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ON THE RELATIONSHIP BETWEEN METAPHOR AND TECHNOLOGY: A COMPARATIVE STUDY ON NANOTECHNOLOGY

DISSERTATION

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Declaration of Authorship

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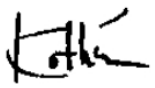
In Prague, August 2019 Pavel Kotlík



Abstract

At the turn of the millennium, the most developed countries began to take interest in nanotechnology, that is, technologies defined by their precise nanometer-level functionality, but also by their substantial, realised, or anticipated changes in industry and medicine. At the European policy level, nanotechnology has become part of the pan-national governance principle, accompanied however by low public awareness of the benefits and risks. Nanotechnology engenders gradual, albeit very controversial transformations where actors adopt various communication strategies.

The dissertation presents an analysis of the relationship between metaphor and nanotechnology. Neither metaphor nor nanotechnology is a neutral resource to be freely exploited, but both have significant implications for the strategic efforts of actors who use them. The study has the objective of exploring the social representations of nanotechnology in the various local (cultural) contexts of their medialisation and investigating the isomorphism which exists between metaphorical structures and the evolution of nanotechnology controversies.

The theoretical part considers the role of metaphors in constructing social representations of nanotechnology and in translating between *there and then* and *here and now*. These representations and transformations depend on multiple contexts—social, political, cultural, and epistemic—where both actors (agents) and structures must to be taken into consideration to give an account of particular events and trajectories of mattering. Metaphors affect, in particular, imaginaries of the nanoscale and future expectations of benefits and risks, and they also provide a semantic link to narrative elements and storytelling. They have proved to be both supportive and restrictive to the development of nanotechnology.

The data used in this study ranges between the years 1999 and 2015, using approx. two thousand articles from Web of Science, the European Commission (CORDIS), and Czech, French, and British national (print) media. By integrating two analytical approaches, metaphor-in-discourse (Charteris-Black 2004, Semino 2008) and the 'actantial' model of narrative (Greimas 1987, Cooren 2001), the analysis focuses on matters of concern and related metaphorical patterns and structures. Accordingly, the study is followed by a critical approach to the implications of metaphor use and related transformations linked to the dynamic of discourse and nanotechnology development.

My contribution falls into four areas. (1) In the study of the Web of Science corpus, I show how scientific laws extend to society through numerous translations of *creative evolution* (Moore's law being an example). It is argued that Moore's law is a metaphor which yields tremendous imaginaries of the nanoworld and implies a sociotechnical convergence. As such, creative evolution

is also restrictive of certain development options. (2) The analysis of the science policy (CORDIS) corpus demonstrates that metaphors of locations, events (past and future), and actors are representations of power on the cultural-cognitive level (a discursive formation which I term *nano-Orientalism*). Addressing how policymakers embrace metaphors and related narratives as true representations of reality reveals how they initiate actions in terms of qualifying roles, collaboration models, mobilisation of resources, grant eligibility conditions, and so on. (3) The dissertation assembles unique profiles of nanotechnology controversies from the Czech, French, and UK mass media, which make it possible to see how metaphors intervene differently into various *dispositives of nanotechnology acceptance*. (4) The case studies reveal that metaphors have three capacities: activating, generative, and organisational. These are based on metaphorical concepts linked to narrative structures and discursive formations. In conclusion, the relationship between metaphor and nanotechnology is made of paradox. Metaphors create *protected spaces* for technology development, but they also represent a genuine resource to be exploited by inserting *ambiguity as objectivity* in reporting. This major media strategy creates conditions which ensure the multiplicity of socially available narratives and interpretations. The metaphor capacities and biases, sociotechnical convergence, and the plurality of ontological regimes are fundamental challenges for the assessment of nanotechnology.

Résumé (en français)

De nombreux pays développés ont commencé à s'intéresser aux nanotechnologies au tournant du millénaire. Ces technologies sont définies par leurs fonctions précises au niveau nanométrique et par les changements substantiels, concrétisés ou anticipés, dans l'industrie et la médecine. Les nanotechnologies sont devenues partie intégrante du principe de gouvernance pan-national de la politique européenne s'accompagnant en outre d'une faible sensibilisation du public aux opportunités et aux risques. Les nanotechnologies engendrent des transformations graduelles qui restent néanmoins controversées et diverses stratégies de communication sont mises en place.

Cette thèse porte sur l'analyse de la relation entre la nanotechnologie et la métaphore. Toutes les deux ne sont pas des ressources neutres et sont impliquées dans les efforts stratégiques des acteurs qui les utilisent. L'étude a pour objective d'explorer les représentations sociales de la nanotechnologie dans divers contextes culturels et locaux et d'analyser l'isomorphisme existant entre les structures métaphoriques et l'évolution des controverses relatives à la nanotechnologie.

La partie théorique examine le rôle des métaphores dans la construction des représentations sociales de la nanotechnologie et dans la traduction entre « là-bas et en ce temps-là » et « ici et maintenant ». Les représentations et transformations dépendent de contextes multiples; social, politique, culturel et épistémique tandis que les acteurs et structures doivent être considérer en tenant compte des

événements concrets et des trajectoires d'importance (c'est-à-dire *les sujets de préoccupation)*. Les métaphores affectent notamment les imaginaires à l'échelle nanométrique, les attentes futures des bénéfices et risques, et fournissent un lien sémantique aux éléments narratifs d'un récit. Ils se sont avérés être à la fois favorables et restrictifs au développement de la nanotechnologie.

Les données utilisées dans cette étude s'étalent de 1999 à 2015, soit environ 2000 articles de « Web of Science », du service d'information sur la recherche et le développement de l'Union Européenne (CORDIS) et de journaux grand public tchèques, français et britanniques. En intégrant l'approche « métaphore dans le discours » (Charteris-Black 2004, Semino 2008) et le modèle « actantiel » (Greimas 1987, Cooren 2001), l'analyse visait à identifier les sujets de controverses et les structures métaphoriques correspondantes. En conclusion, l'étude emploie une approche critique des implications de l'utilisation de la métaphore et transformations liées à la dynamique du discours.

Les contributions principales de cette thèse proviennent de quatre domaines. (1) L'étude du corpus « Web of Science » a démontré comment les lois scientifiques s'étendent à la société par de nombreuses traductions de « l'évolution créatrice » (exemple de la loi de Moore). La loi de Moore est une métaphore qui produit des imaginaires étendus du nanomonde et implique la convergence sociotechnique. En tant que telle, l'évolution créative est également restrictive pour certaines options de développement. (2) L'analyse du corpus de CORDIS a révélé les métaphores des lieux, des événements (passés et futurs) et des acteurs eux-mêmes comme représentations du pouvoir au niveau culturel et cognitif (formation de discours que je nomme 'nano-Orientalisme'). Cette analyse a mise en évidence comment les décideurs politiques interprètent les métaphores et les récits associés comme représentations fidèles de la réalité, pour initier des actions en termes de rôles qualifiants, de modèles de collaboration, de mobilisation de ressources et de conditions d'éligibilité aux subventions. (3) La thèse rassemble des profils de controverses sur les nanotechnologies provenant des médias tchèques, français et britanniques, et montre comment les métaphores interviennent dans les dispositifs d'acceptation des nanotechnologies. (4) Enfin, les études de cas présentées révèlent que les métaphores possèdent trois capacités de transformation: initiatique, générative et organisationnelle. Ces capacités sont basées sur les concepts métaphoriques, liées aux structures narratives et les formations discursives. En conclusion, la relation entre la métaphore et la nanotechnologie est une relation paradoxale. Les métaphores créent des « espaces protégés » et représentent également un instrument à exploiter en ajoutant « l'ambiguïté en tant qu'objectivité » dans les rapports. Cette stratégie médiatique majeure est destinée à créer les conditions garantissant la multiplicité des récits et interprétations socialement disponibles. Les capacités et biais de métaphores, la convergence sociotechnique et la pluralité des régimes ontologiques sont des défis fondamentaux pour l'évaluation de la nanotechnologie.

This dissertation is dedicated to my family: my mother, Libuše Kotlíková; my father, Tomáš Kotlík; and my partner, Amandine Verlande, who have always believed in me. Thank you for all of your loving support along the way.

Preface

I have always been fascinated by the human ability to master different intellectual and material resources, by emerging technologies they produce, and also by society's ability to be subdued by the disruptive powers of these technologies and their surroundings. Technology's unprecedented powers, both old and new, and their social context have swayed me many times between accounts of social and technological determinism without recognising them as alternatives of looking at the very same thing. This fascination with technology and my drive to understand it as a social researcher previously drew me to reflections on technological myths, not as something fictional (false) or old, but as something very present in our modern surroundings. My master's thesis, entitled *Promethean Technology* (2010), taught me a valuable lesson, which I have attempted to incorporate into my subsequent research. Technology has always been as much about mastery as it has been about promise (expectations). Right there, in all the accounting, appears one constant: Technology has always been about figures. Think of technical images as graphs, or no less complex and determined figures of future achievements. Any technology is about *figuring out*, technically, economically, historically, socially, and ethically simply all that there is about the world transformed by (with) technology. The previous argument should not force an idea that technology, especially technology use and its implications, is always reflected. The quest for more reflexivity and increased awareness of these issues then represents the purpose of my study.

While, from a democratic point of view, it is crucial that we, citizens or our representatives, be involved in decisions concerning the development of technology development, to make responsible decisions, we should strive to develop the ability to analyse and evaluate ideas offered to us by those who exclude us from more balanced positions of power; without this there can be no democratisation of technology (or democracy resp.) because there is no choice. Hence, the struggle or conflict lies in our ability to negotiate or determine our chances of influencing ideological or hegemonic meanings being imparted by science (industry), policymakers, or media. The public reaction to genetically modified organisms (GMOs) may have distorted their regulations beyond repair but also proved that even the public could enforce meanings which may have altered development. With future technology development in mind, such as nanotechnology, all participants and stakeholders should have the power themselves to exercise interpretive freedom

and resistance to being normalised into some dominant discourses. Such is also my responsibility as a social researcher, reaching to continually establish the field of *nanoethics* so as to provide a better ground for more informed discussion on nanotechnology. Nanoethics might seem a neologism. However, it develops along with anything which contributes meaningfully to an ethical discussion on nanosciences and nanotechnologies. Many of the issues discussed in this thesis could have also been placed elsewhere—in bioethics, the ethics of surveillance, ethics and public policy, and so on. This dissertation thus responds to the challenge of finding the context for issues pertaining to nanotechnology (cf. *Nanoethics* 2012: 153). The discussion is relevant and timely, provided emerging technology, despite not standing on its own, can be considered something moving ahead of social relations.

In my perspective, nanotechnology is perceived as discourse or a communicative event rather than mere material technology. As a consequence, the study of nanotechnology's implications is moving to the background, and the focus is now on the processes and practices of constant renegotiating and re-figuring all these realities. The study seeks to improve understanding of the relationship between the language used and nanotechnology development at the media interface between science, policy, and the public. It aims to gain insight into the controversies being enabled and constrained within this interface, and which is, as I argue, a place of ongoing *metaphorisations* (or *carrying over*) of various matters of concern. In this sense, it should contribute to metaphor studies while accentuating the sociological approach to metaphor, that is, considering reality *outside* of the language—what reality language precedes and proceeds from. It should also contribute to science and technology studies (STS), the study of the relationships between scientific and technological innovations and society, and media studies, two invaluable frameworks used to gain insight into nanotechnology discourse.

Designing and compiling a corpus from various sources, conducting transdisciplinary research, and writing this dissertation has been a great challenge with ever-increasing involvement in the learning process. I hope the presented study achieves its goal of imparting more knowledge and insight of the problem and provides interesting content in return, what I believe will therefore be a rewarding experience for the reader's investment in this text.

Pavel Kotlík, August 2019

Acknowledgements

I am grateful for the generous and helpful suggestions made by the anonymous readers during my endeavours of going public with the first results. The chapters were presented at international conferences—in particular, Non-human in Social Science (2012) in Prague, S.NET (2014) in Karlsruhe, the ESA (2015) conference in Prague, and EuroNanoForum (2017) in Valetta. I presented the first drafts of the dissertation, or its parts, at the IRIST 40th Anniversary Conference (2013) in Strasbourg, and at the Faculty of Social Science Doctoral Conference (2015) in Prague. Doctoral seminars of the Institute of Sociological Studies (Charles University) and at the Augustin Cournot Doctoral School (Université de Strasbourg) were a great vehicle to share knowledge and expertise between researchers and their different backgrounds. I profited immensely from the spirited discussions on each of these occasions. I would like to thank colleagues at both universities, in Prague and Strasbourg, whose limitless passion for science and technology studies and its linguistic aspects has supported my enthusiasm to write this dissertation. Working with Simon Smith and members of the Narrating Crisis research team has been an invaluable experience and provided an environment which was both exciting and challenging.

I would like to express my thanks to both directors, Martin Hájek and Matthias Dörries, for their suggestions of improvement to earlier drafts of this work, for their guidance, patience and support. I would also like to thank the following institutions which have been invaluable in providing sources of knowledge for this dissertation: Charles University in Prague (Faculty of Social Sciences Library) and the University of Strasbourg (Bibliothèque Nationale et Universitaire).

Style and Semantic Conventions

As has become accepted practice in cognitive linguistic approaches (see Charteris-Black 2004, Semino 2008), the upper case is reserved to represent the abstract thoughts underlying metaphors (usually known as conceptual metaphors). Words or phrases selected for the focus of discussion are placed in single speech marks; once they are definitively classified as metaphors, they are shown in italics.

Example:

‘I am at a *crossroads* in my life’

LIFE IS A JOURNEY

Except where ambiguity might arise, references to the corpora are by acronym and year, without the name of the article; WoS is used to cite the Web of Science; CORDIS stands for the Community Research and Development Information Service; and CMC, BMC, and FMC are reserved for the Czech, British, and French media corpora, respectively. These specialised corpora were compiled ad hoc from various media archives and, as a media reference to nanotechnology, should not be confused with non-specialised collections of natural language use, such as the British National Corpus which uses the acronym BNC. Czech and French texts were translated except for a few technical notes or special expressions which demanded more detailed attention (e.g. in the footnotes). Finally, there are a few words and concepts which figure prominently in my discussion and which have no single translation that adequately encompasses their thematic usage in the dissertation. I gloss or explain the thematic significance of these terms when they first appear in the text and later use them from time to time without translating them.

List of Abbreviations

ACS	American Chemical Society
AMO	Atomically modified organism
CEA	Alternative Energies and Atomic Energy Commission; preceding agency Atomic Energy Commission (Commissariat à l'Energie Atomique)
CM	Conceptual Metaphor (Abstraction Level)
CMT	Conceptual Metaphor Theory
CNRS	National Centre for Scientific Research (Centre national de la recherche scientifique)
CNDP	National Commission for Public Debate (Commission Nationale du Débat Public)
CTEKS	Converging Technologies for the European Knowledge Society
CZ	Czech / Czech Republic
DAM	Defence and Military
EN/UK	English / United Kingdom
EC	European Commission
EN/UK	English / United Kingdom
EU	European Union
EIT	European Institute of Innovation and Technology
ELSA	Ethical, legal, and social aspects
ERA	European Research Area
ESFRI	European Strategy Forum on Research Infrastructures
ETC	Erosion, Technology and Concentration (action group)
FP	Framework Programme
FR	French / France
GIANT	Grenoble, Isére, Alpes, Nanotechnologies
GMOs	Genetically Modified Organisms
INPG	Institut polytechnique de Grenoble
INRA	National Institute of Agricultural Research
JTI	Joint European Technology Initiative(s)
LETI	Laboratory of Electronics, Technology and Instrumentation (CEA-Leti)
LM	Linguistic Metaphor (Surface Level)
MIP	Metaphor Identification Procedure
NBIC	Nanotechnology, Biotechnology, Information Technology, and Cognitive science
NNI	National Nanotechnology Initiative (United States federal government programme)
NM	National Media
N3M	Nanofibers for the 3rd Millennium
nm	Nanometre = 10^{-9} metre
OMC	Open method of coordination
OECD	Organization for Economic Cooperation and Development
PMO	Pièces et Main d'Oeuvre (activist group)
REACH	Registration, Evaluation and Authorisation of Chemical Substances
RCN	Record number
RFID	Radio-Frequency Identification Technology
RRI	Responsible Research and Innovation

S.NET	Society for Studies of New and Emerging Technologies
STS	Science and Technology Studies
STM	Scanning Tunneling Microscope
TA	Technology Assessment
TCCAS	Technology Centre of the Czech Academy of Sciences
TUL	Technical University of Liberec

Corpora

WoS	Corpus of articles compiled from the Web of Science database
CORDIS	Texts and press releases from the Community Research and Development Information Service (CORDIS) database
NM	National media archive
CMC	Czech Media Corpus; media articles compiled from the Newton Media database
FMC	French Media Corpus; media articles compiled from the Europresse database
BMC	British Media Corpus; media articles compiled from the Factiva database

Contents

Introduction

Nanotechnology is the art and science of manipulating and rearranging individual atoms and molecules to create useful materials, devices, and systems. Through this manipulation, products are designed to have fewer imperfections and more durability, drugs to be more efficient and have fewer side effects, and energy sources to be cleaner and more cost effective. While its potential is at the same time presented as obvious and exciting and the risks as challenging, there is much about nanotechnology which we do not understand. One of the early Eurobarometer surveys targeted at emerging technologies indicated a trend that Europeans are generally unaware of nanotechnology, do not have a solid overview of its benefits, and are not excessively alarmed about its risks (Eurobarometer 2010). This lack of public awareness contrasts with the research being done in thousands of private laboratories all around the world, each racing to secure the next valuable patent in a competitive environment. Nanotechnology applications are well under way, yet they require considerable funding to retain the high level of excellence, to remain competitive in the valorisation of research, and to persuade others of its importance. The world of the laboratory is thus never isolated from the outside world and, somewhat peculiarly, nanotechnology has been defined from the outset as a 'conquest of the nanoworld' at nanoscale and in the future (cf. Nordmann 2004a: 49). Designing futures for whole societies to be rebuilt 'atom by atom' has been introduced as another metaphor by the various regulatory bodies which, during the past decade or so, have launched ambitious nanotechnology strategies (cf. Amato 1999, Nordmann 2007a). These visions are arguably not mere rhetoric but have been transformed into real initiatives, collaboration models, resource mobilisation, and communication strategies.

In the European Union, nanotechnology is a multibillion and all-currency encompassing phenomenon, with ambitious programmes aimed at Converging Technologies for the European Knowledge Society (CTEKS; Commission 2005a). 'Convergence' has become a common metaphor to represent (future) interactions between scientific disciplines and technological fields, sometimes under the acronym NBIC, that is, the convergence between nanotechnology, biotechnology, information technology, and cognitive sciences. Science and technology studies (STS) scholars go so far as to relate this process to new normative regimes of postmodern science and post-academic scientific research (cf. Roco and Bainbridge 2003). Among these new regimes, nanotechnology

convergence has been the subject of a debate concerning tendencies of increasing emphasis on commercialisation and market forces in modern universities—fundamentally at odds with core academic principles (Moriarty 2008). Yet, the convergence has become more than an overlap of traditional disciplines and commercialisation. For the European Commission (EC), which supports nanotechnology as the largest public institution in the world, the convergence becomes a carrying structure for identity politics. It is a metaphor aligned with strategic policies which incorporate nanotechnology into identity-building projects, seeking to reimagine what a nation or community represent (cf. Jasanoff 2005). Many of the European communities integrate this pan-European approach while developing their specific nanotechnology programmes. As Sheila Jasanoff noted: 'Cultural specificity survives with astonishing resilience in the face of the leveling forces of modernity. Not only the sameness but also the diversity of contemporary cultures derive, it seems, from specific, contingent accommodations that societies make with their scientific and technological capabilities' (Jasanoff 2004: 14). Nanotechnology has therefore distinctive local features and convergence is here a meaningful concept also because it is positioned against fragmentation and resistance of local (also epistemic) cultures.

In Europe, and countries such as the Czech Republic, France, and the United Kingdom, nanotechnology has been brought to the public through media hype over its risks and benefits, and in some cases, public debates were organised by governments in collaboration with industry and academia (cf. Nano for the 3rd Millenium in the Czech Republic, Débat Public in France, or NanoJury in the United Kingdom). Being often presented as deliberative meetings around 'round tables', these debates themselves worked as metaphors that created further expectations. They were successful to the various degree. They came relatively late, after decisions already being taken, and in the aftermath of previous controversies, such as GMOs, asbestos, and nuclear. These former experiences with emerging technologies have influenced the acceptance, refusal and judgement of nanotechnology as they 'carried over' the images and strategies of the public (local) authorities, activists groups, and the media (cf. Kearnes et al. 2006, Scheufele et al. 2009, Laurent 2007, Doubleyday 2007, Vinck 2009, Toumey 2011). Nanotechnology has been represented by various metaphors, has been assigned the hyperbolic expectations and related threat of a 'public backlash', altogether setting in motion an interesting discourse dynamic at the interface between science, policy, and the public.

I.1 Nanotechnology Development and Metaphors: Transformation Thesis

This dissertation places its analytical focus at the interface between science, policy, and the public as it is essential for understanding nanotechnology development dynamics. It corresponds with recent discussions about the limitations of two-dimensional, or otherwise uni-directional science-

policy-public models for analysing nanotechnology (cf. Rip 2006, Toumey 2006, Doubleday 2007, Laurent 2007, Ruivenkamp and Rip 2011, Chateauraynaud 2009, Vinck 2009 and 2011, Vernant 2014). According to these models, nanotechnology development is a result of transformation dependent on the mutual reinforcement of technoscientific possibilities, policy mandates, and societal objectives, as well as on their ongoing contestation and resistance. To date, however, there has been a little reflection on the ethical, legal, social, and political implications of metaphors in these models of transformations.

This is surprising as the role of metaphors in the framing of scientific advances as well as their impact on patterns of public acceptance and rejection, trust and scepticism may be significant (cf. Hamilton 2003). When the conventional and relatively *closed* metaphors used by scientists are *opened up* in the public domain, there is also danger that they will be used in ways that go beyond, and even against, the scientist's original intentions (cf. Nerlich et al. 2000, Knudsen 2003, Weigman 2004). Media attention to nanotechnology's potential benefits or risks appear to rely on alerts voiced by scientists, and policymakers (Pidgeon, Harthorn, and Satterfield 2011), but media counts on readership and thus has its own logic. Media processes the 'passage of nano' in a way not always aligned with the general interests of science, policy, or the public (cf. Vinck 2009). Authors or groups can be marginalised and subject to caricature and denunciations (fear, syndromes). Furthermore, the public is often assumed to not fully understand the messages about the supposed impact of nanotechnology, for example, because these messages may be ambiguous, contradictory, and confused (Satterfield et al. 2009). The metaphors may thus become strategic tools designed to create and overcome contestation. It is another way of reinforcing positions or, conversely, to subvert them. This is important, as science communication includes scientists and scientific advisers, often with deep connections in politics and industry, who can run effective campaigns to mislead the public and deny informed decisions (cf. Oreskes and Conway 2010, Joly and Kaufmann 2008).

The situation then demands from social sciences not only that symmetry be recovered but also that we are returned to how nanotechnology, expertise, and even the public are defined as homogenous entities. In a meta-analysis of twenty-two studies made worldwide between 2004 and 2009 concerning the public perception of nanotechnologies, Satterfield and his colleagues (2009) found that more than fifty-one percent of participants reported knowing 'nothing at all' about nanotechnology. Similar results were found in a representative European sample (Eurobarometer 2010). The general lack of information on the matter suggests the amount of space for nanotechnology social representations can be filled by framing effects and communication agendas. However, these studies often overlook how science, policy, and the public as such is represented and constructed. In short, an analysis of how the actor's role is attributed and translated in and by

the media is called for. There is always danger that the active influence of metaphors on technology development could be overrated, and non-dialogical, material factors should not be underestimated. After all, nanotechnology is a case of technoscience, where the 'matrix of materiality' cannot be neglected (cf. Ihde and Selinger 2003). Nevertheless, this does not prevent us from questioning nanotechnology development as a 'metaphorisation' of technoscientific possibilities, policy mandates, and societal objectives, and hence their materialisation within these complex relationships.

The role of metaphor in the mechanism of transformation is arguably essential. Rather than representing merely a rhetorical strategy, a metaphor is considered an inter-discursive device which translates technical (scientific) objects and images to political and social images, and vice versa (cf. Hellsten 2002, Knudsen 2003, Nerlich and Dingwall 2003, Low 2005). The translation concerns how the invisible nanoscale is made intelligible to various actors by using more familiar vocabulary and concepts. From the images of 'landscapes' of the nanoscale, socio-technical 'convergence', to images of 'nano as (the next) GMO', metaphor forces the actors involved—whether scientists, policymakers, or the public—into specific frameworks of value, meaning, and action. Nanotechnology discourse provides an environment in which metaphors can thrive, but metaphors may also change the environment. The previous sociological discussions should be more readily intelligible in this perspective. The agency-structure, in particular, directs us to important questions concerning (social) transformation: What are, in a given context, the relevant actors and metaphorical structures? How much freedom do agents have in doing what they do as they are both enabled and constrained by metaphorical structures? How does metaphorical structure (with its distinctive agent-structure relationships) move to a different type of agency-structure relationship (i.e. from a words and syntagmatics to discourse)?[1] The idea is not to separate the agent and the structure—that is, for example, the actors and the policy—but to consider discourse as an ontological link between both. The question of stability and change at the interface does not disappear but is recomposed.

Based on the above arguments and considerations, my thesis research involves seeing the relationship between metaphor and nanotechnology neither exclusively regarding their *agentic* properties nor in their essential *structural* properties, but rather in terms of *capacities* (cf. Nerlich 2003), making sense of even the unintended forms of patterns and consequences. In this sense, we should consider that metaphors can stabilise, reinforce, or conversely, leave the interface unstable while opening or constraining the other transformations. The focus of my research lies in examining

[1] The relationship is characterised by a certain state of communication, always provisional, historically, between different elements and levels (cf. Elias 1983; Chateauraynaud 2003: 226). At the same time, it is a transformative patterning of social relations where rules and resources drawn upon in the production and reproduction of social action are also the means of system reproduction (cf. duality of structure in Giddens 1984: 16-18).

metaphors (figures) moving from *conventional* places, where secure, closed, and fixed knowledge is communicated, to places which increasingly engage with *dynamic* metaphors, supportive of multilayered controversies and multi-stakeholder debates on nanotechnology. More specifically, I am asking the following questions:

1. How are metaphors tied to specific social representations of nanoscience (nanotechnology)? Can any particular systematic nanoscience (nanotechnology) metaphor(s) be identified in light of the current diversity of the field?

2. How are metaphors linked to European nanotechnology policy, in particular, exploring the antagonism, consensus, competition, and indifference of various actors? Are there any consequences of the particular metaphor uses?

3. Which conceptual patterns are common in the representations of nanotechnology controversies in the (local) cultural contexts? Can any particular structures (meta-structures describing types of relations between actors and concepts) be identified? How are matters of concern in nanotechnology discourse tackled by media?

The above questions aim to explore metaphorical patterns and structures in various scientific disciplines (and epistemic cultures), policies, and public debates and hence there is a challenge of studying metaphors within and between discourses. Still, even when their unique contexts are considered, there is a space opening before us for a *comparative study*: to explore the differences between those locally grounded (cultural) concepts and meanings, narratives (counter-narratives), and discourses; not to commend one and discredit the other, but to identify their value for such a comparative analysis (cf. Toumey 2006). The epistemic cultures may have various normative regimes of engagement with nanotechnology, while being bound to representations of the 'nanoworld' (scale/future). Nanotechnology is here not only about the 'engineer's way of being in science' but also a 'place oriented' endeavour (cf. Nordmann 2004b, 2007a and 2008, Bensaude-Vincent 2009, Maestrutti 2011). Nanoworld becomes a key concept (and a 'keyword') that could unlock answer to the first research question and even scrutinise the 'convergence' as a metaphor. The second question aims to investigate how nanotechnology is grounded in the political and economic climate of the European Union and which has been shaped by the challenge of the European Commission with meta-coordination of various actors. The particular role in this challenge play 'technology roadmaps', that spread across policy discourse and through the Community Research and Development Information Service (CORDIS) database. The term 'database' might be here misleading. The consensus about nanotechnology in CORDIS, is as much result of the moderation of various actors, and is here taken as a reference for studying science

policy discourse (Åm 2013). Metaphor analysis at the local (cultural) level, addressed in the third question, should then allow to identify country-specific patterns of nanotechnology mediation and deliver additional input for the comparative study.

As mentioned earlier, nanotechnology has been developed under a low public awareness, and has received increased attention of the media in Europe (as the rest of the world). The aftermath of previous controversies (GMO, Nuclear, BSE), cultural meanings and local experiences have not only permeated media messages about nanotechnology but they have also become a strong predictor to acceptance of nanotechnology (cf. Scheufele et al. 2009, Laurent 2007, Doubleyday 2007, Vinck 2009, Kahan et al. 2009, Toumey 2011). At the same time, it was mentioned media processed the 'passage of nano' in a way not always aligned with the general interests of science or the public (cf. Vinck 2009, Pidgeon, Harthorn, and Satterfield 2011). It is thus considered as appropriate research strategy to focus on the *media practices* as such. With this additional objective, the scope of the comparative study is extended to research on actor's (also media) strategies.

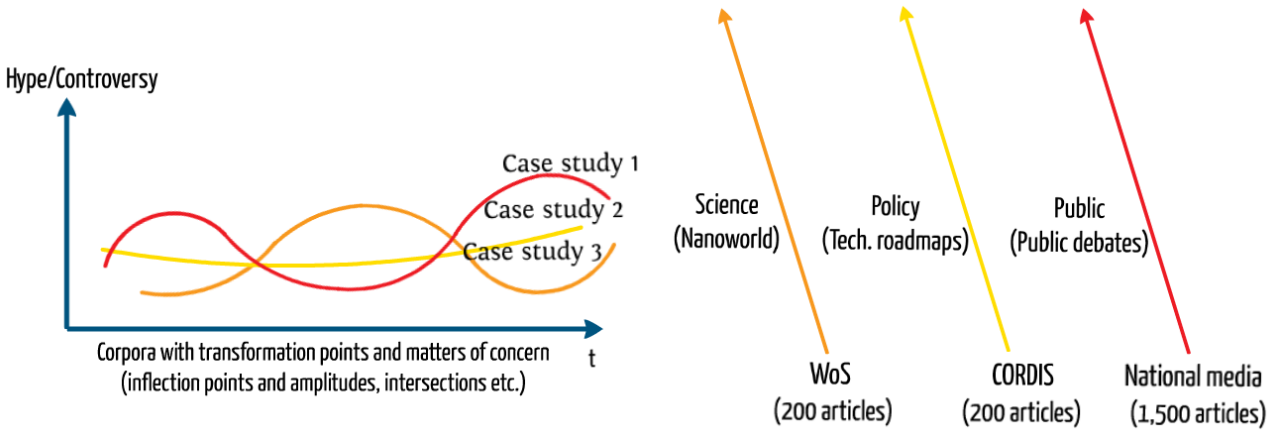


Figure I.2 Data overview and outline of corpora compiled from Web of Science (WoS), Community Research and Development Information Service (CORDIS) and the Czech, French and the United Kingdom (Newton Media, Europresse, Factiva) media databases.

In order to model the science-policy-public interface, I chose a period between 1999 and 2015, with approximately two thousand articles on nanotechnology. The rationale behind this choice was, with the research questions being considered, the studied period should exceed a particular discovery, framework programme, regulatory issue, or public debate. Data for this study was constructed as an ad hoc compiled corpus of texts and images from various sources using Web of Science, CORDIS, and media databases (also in Figure I.2). The media has undergone a transformation over the years, and nanotechnology, also, has been framed within the growing influence of electronic and, particularly, social media (Runge et al. 2013). However, the periodisation of research, starting at the turn of the millennium, as well as feasibility of the study, influenced my choice of traditional (broadsheet printed) media over electronic and social media.

The study of the relationship between metaphor and nanotechnology is outlined as an

integrated methodology: a systematic corpus-based approach which sharpens its analytical focus on 'matters of concern' (Cooren et al. 2015), related variations in metaphorical 'concepts' (Lakoff 1993), and narrative 'actantial' model (Greimas 1983, and 1987). By combining the analytical models of *metaphor in discourse*, as topological or narrative variation, I argue how these can be used to study various controversies (cCooren 2001), and how metaphors can further make manifest the discursive formation (Foucault 1972). The above methodologies have been brought together for getting a grip on complexity and contingency and to explain the reasons behind the amount of discursive (and political) coordination. Just like systematic metaphors, narratives connect actors, events (locations) and experiences which were disconnected, allowing them to become interconnected and planned, displaying coherence, integrity, fullness, and closure (Gottweis 1998: 33–37). Nanotechnology discourse develops as much through sudden irruptions, transformations, contradictions, and differences as it does through constancy or regularity. Wherever regularities of dispersion can be found, we say there is a 'discursive formation' (Foucault 1972). This concept is useful to investigate in more detail within the relationship between metaphor and nanotechnology to show (in ref. to Foucault 1972: 31-44): how any particular object of nanotechnology discourse finds in it its place and law of emergence; how regularities in models of governance (technocratic) become aligned with models of governmentality (knowledge and power); and finally, how public debates are not fully regulated by subjects nor by recourse to a psychological subjectivity as other rules and regulation of its enunciations can be identified.

The following section summarises how the research design was constructed into the dissertation's structure: the theoretical perspective on nanotechnology and metaphor, methodology as an integrated approach to metaphors-in-discourse analysis, data collection and case study contextualisation, instances of research and discussions which unfold in their respective analytical chapters, and finally, the synthesis and conclusion. An outline of the thesis is first and necessarily a rough overview which can guide the structure of the argument, and it is followed by the contributions of the presented thesis.

I.2 The Structure of the Dissertation (Outline of the Thesis)

This dissertation is divided into six parts: the theoretical setting for nanotechnology (**Part I**) and metaphor (**Part II**), methodologies (**Part III**) and data (**Part IV**), findings with case studies (**Part V**), a discussion of the synthesis of the findings (**Part VI**), and lastly, the conclusion (**Part VII**). I provide introductions and summaries throughout the analytical parts to facilitate the workflow and arguments as they unfold.

The first chapter (**Part I**) provides a discussion of what can be considered nanotechnology discourse, as well as a discussion on the current status of nanotechnology as an issue for the social

sciences. The chapter provides information about the larger context in which technological development occurs. This is achieved through a presentation of the diverse body of theoretical perspectives which follow the organisation (and morphology) of modernity, (new) production of scientific knowledge, the sociology of expectations, critical sociology, and last but not least, media studies. The first section aims to provide more clarity over how definitions are established. The recognition of ambiguity in definitions and background language games is an essential part of the social research agenda, as is the figurative language which entails hype and hyperbole, especially language oriented towards scales, past and futures. Nanotechnology has an undoubtedly material dimension while also being a kind of language in action which contains expectations and uncertainties related to potential benefits and risks. A specific debate targets how *resource mobilisation* influences organisation of the emerging fields alongside framing effects, narrativisation, and discursive formation. Although metaphor theory has its own place in the next chapter, the first lines of the argument emerge over its potential to open a door to the strategies of relating and translating discourses where there was previously relative autonomy. This is an important feature in a pragmatic of discourse that allows the concept of intertextuality and interdiscursivity to be expanded into tracking systematic metaphors and discursive formation(s).

The second chapter (**Part II**) starts with an outline of metaphor theories and their philosophical traditions. The overview of theories and traditions is essential for introducing the social theory of metaphor applicable to nanotechnology discourse. The opening of this chapter consists of subsections, dedicated to authors who brought some original perspective to metaphor, in particular, M. Black, G. Lakoff, M. Johnson, and P. Ricoeur. These authors and their critique is important in understanding assumptions about the nature of metaphor, especially (the introduction of) the cognitive regime of metaphor, reflecting the phenomenon of language and thought, or (readable in) the distinction between linguistic and conceptual levels. Each author is also discussed in the context of implications for understanding metaphor in a social milieu (transformation thesis). In addition, the described mechanism of metaphorical *translation* is especially helpful in conceiving figuration within a controversial dynamic such as the functional shifting between *there and then* and *here and now*. This altogether allows a narrowing down of the multilayered and controversial settings delineating contexts which must be taken into consideration and for methodology. The last section discusses the research questions (Q1–Q3).

Part III offers a thorough presentation of the strategies employed in this thesis and which are indispensable to metaphor analysis. Controversies, its indicators, and the problems related to its measurement, have been adduced in this section as well as phases of research, which follow trends in studying metaphor in discourse. Section 1 starts with a discussion of some of the methodological problems related to metaphor research: occurrence, structure, and interpretation of metaphors. The

type of register, frequency, genre of discourse, and context is argued to be an important threshold for *metaphoricity* so that metaphor identification can be fitted for specific tasks and datasets. These issues find correspondence in the methodology—presented in Section 2 as *lexis*, *semio-narrative*, and *discourse* level, and as the corpus-based metaphor analysis. There are different resources for metaphor analysis available even though studies of metaphor in discourse increasingly rely on corpus-based approaches. The corpus-based approaches are ideally suited to investigate the use of metaphorical expressions, and particularly, their systematicity and structures. However, a close reading of text passages is necessary for determining the metaphoricity and setting several limitations on corpus annotation and its validity, as well as on the feasible size of the corpus.

In the first section of **Part IV**, information about the material is given. Its first subsection presents the background for the collection and corpus compilation, while the second subsection presents a general overview of the material. In order to create a platform through which the sciences, politics, and the public intersect, the prepared data comprises an ad hoc compiled, specialised corpora from (1) the Web of Science corpus (science); (2) the CORDIS database (policy) corpus; and (3) additional corpora extracted from national newspaper archives (NA) in the Czech Republic, France, and the United Kingdom (public), with approx. 2,000 articles altogether. The initial semi-quantitative pilot content analysis becomes paramount in light of the data chapter, where the relative strength of transformation points and ranking appear. Nevertheless, the quantitative overview is used only for the purposes of opening the chapter's case studies. The overall research design of the thesis follows a qualitative setting which can better answer the methodological issues related to metaphor studies. Additional methodological specifications (contextual requirements) and case study introduction are then bound to particular sub-chapters.

Partial arguments are developed in **Part V** through subsections which present relevant aspects of nanotechnology discourse and the metaphors which were discovered during the analysis. Taken together, all the analytical subsections are intended to be substantial contributions to the interpretation of sociolinguistic data and to scrutiny of the transformation thesis. The thesis describes mechanisms through which metaphor intervenes at the interface of science, politics, and the public (media), but also how it emerges from different cultural and material conditions (different nanotechnology profiles). Case studies are presented on the normative regimes of the *nanoworld* (WoS), the nanotechnology roadmaps of the European Commission (CORDIS), and nanotechnology controversies (national media). These studies represent systematic metaphoricity which unfolds in parallel with different issues related to nanotechnology development (actors, identities, values, attitudes, and actions). For example, (a) the nanoworld case study follows metaphorical aspects of different laws which circulate within and between scientific domains (scientifications), but they also extend to society. The example of Moore's law then serves to

describe how the social and technical effects essentially merge with each other, albeit as the discursive formation of *creative evolution* translated to different scales. The technology roadmaps case study (b) considers metaphors as strategic tools used by the EC to consolidate the science policy model of governance. The metaphors are here being followed as a narrative of an innovation journey to the nanoworld, and also critically examined as an institutionalised practice and discursive formation (*nano-Orientalism*). The final section on (c) nanotechnology controversies then builds on previous case studies of public debates and focuses on the position of metaphor in culture (community), here delimited by three data sets from national media (printed newspaper): Nanospider technology (CZ), the Grenoble model (FR), and nano-GMO (UK) metaphors. These are each discussed in their own chapters focusing on the critical processes at the global (European) level while evincing the often highly country-specific forms of nanotechnology appropriation, expressed by the forms and contents of the debate and regulation at the local (national) level. The case studies help in understanding that we are not dealing with a single system of relations and transformations.

The conclusions from these case studies are the major contributors to the discussion in **Part VI** on the relationship between metaphor and nanotechnology development. The study here considers three types of metaphor capacities: *activating*, *generative*, and *organisational*, all applicable in explaining the mechanism of transformations. All case studies serve as evidence of a model nanotechnology development through intensive narrativisation. The nanotechnology discourse dynamic is then critically examined against identified discursive formations (and their root/master metaphors), reaching beyond the domains of science, policy, and public (media)—in particular, creative evolution (Moore's law), nano-Orientalism (roadmap), and risk/fear controversy (ambiguity as objectivity), respectively. These formations capture the multiplicity of socially available narratives and interpretations and where metaphors even work to create *protected spaces* for technology development. In principle, media are involved in activities which contribute to the social embedding of science and technology; their role, however, is not exclusively to defend science or policies. The metaphor capacities and biases, socio-technical convergence and the plurality of ontological regimes are fundamental challenges for nanotechnology assessment.

The last part (**VII**) offers some final remarks on the study while engaging with the complex pragmatics of transformations, and also, with nanoethics. Subsections discuss a summary of the findings, the limitations of the study, and provide suggestions for future research. I address the multiple ontologies that emerge from the relationship between technology *and* metaphor, and related challenges. It is argued that future studies should pay attention to the differences existing between cultural spaces and should make sense of the varieties of ways in which representations circulate in society. Further development of (critical) social research is suggested as a shift to

transformative learning, aware of the potential metaphor (and narrative) capacities and biases. These issues, which tend to receive attention only separately, require developing further our theoretical sensibility concerning different methodological applications and support in the empirical material. The final word follows the broader context of social science studies, especially with regard to responsible research and innovation.

I.3 Contributions to Understanding Nanotechnology Development

The transformation thesis is presented as a main argument on metaphors which can stabilise, reinforce, or conversely, leave the space between science-policy-public unstable while opening or constraining the nanotechnology development (see later argument on metaphor capacities, protected spaces and ambiguity; T1-T2-T3 / T1'-T2'-T3' in Figure I.1). Based on my empirical findings, I found metaphor not merely represents (for) something in terms of something else, not simply a new mirror to the representation of reality; it represents and intervenes at the same time; representation and intervention are entangled.

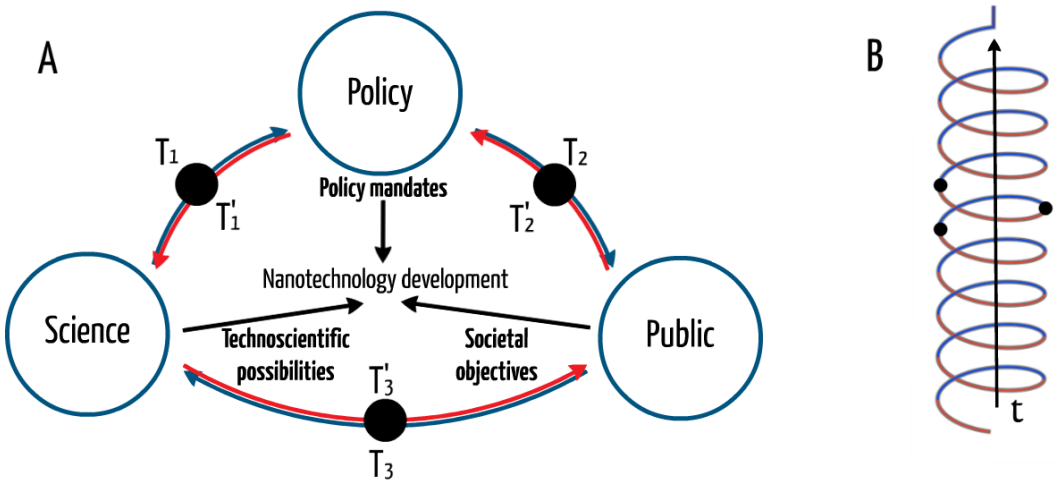


Figure I.1 Nanotechnology development falls within the nexus between policy mandates, technoscientific possibilities, and societal objectives. *A* is a top-down perspective, whereas *B* is diachronic.

All in all, for our understanding of metaphor and related transformations, there are arguably three capacities to consider: *activating*, *generative*, and *organisational* capacity (cf. 'metaphors-in-practice' in Yanow 2005; 'generative metaphors' in Schön 1993, or 'flexible words' in Edelman 1977; 'ideographs' in McGee 1980). The capacities increase with the metaphorical systematicity, whereas dynamics are at their peak when a new metaphor is introduced; capacities may be weak in dead or sedimented metaphors, but this is a rather temporary situation, based on the actor who can use old metaphor creatively (e.g. the Frankenstein myth translated from biotechnology to nanotechnology discourse). The essence of the metaphor's activating capacity is based on context-dependent novelty. This novelty includes a situation when a particular metaphor is embedded in a counter-narrativisation or counter-argumentation (cf. Mordini 2007a), providing space to new strategic actors (activist discourse, for example, translating images of Big Science into Big Brother). Generative capacity can shape strategies which trigger matters of concern, translating between definitions of issues and their (lack of) solutions. Organisational capacity is given by the size and quality of a network and then also by metaphors embedded in narratives which assign various

characters and their roles, such as, the aware and unaware, brave and fearful, well-informed and uninformed, but also in terms of responsibility and legitimacy. Even though the capacities of metaphors are placed in ideal-typical categories, this does not mean their functions are not mutually implicated and may not be entirely consistent between actors, topics, and genres, nor that they cannot lose their capacities if not (regularly) used. The three capacities are arguably all applicable to the relationship between metaphor and nanotechnology, with a concomitant shift between the metaphor *of* nanotechnology (composition) to a metaphor *for* nanotechnology (repertoire).

The first case study takes a challenging look at the regions of language use which have systematically pursued literal expression as a norm—the language of science (and law). The way the language of science is being purified of ambiguities and interpretive freedom (against bending laws), it often marginalises metaphors to commentary and heuristic, or 'gestalt' psychology (cf. Carnap 1959, Hempel 1965). Nevertheless, metaphors have been considered important methodological tools in both the construction and critique of legal and scientific theory—ranging from persuasive writing to scientific models (cf. Black 1962, Hesse 1966, Knorr Cetina 1981, Nerlich and Hellsten 2007, Gentner and Jeziorski 1993). In line with these authors and a position favouring a perspective wider than 'ornamental', science may be challenged and even counterfeited by figures (metaphors) which compete in degree of predictability and guide researchers and engineers as if they represented laws and theories. The dissertation, moreover, uses a normative regime concept to point to the integrity of nanotechnology discourse. It shows how the figures which circulate within scientific domains extend to society (uncovering human perspective) through numerous translations and formation of discourse (cf. Foucault 1972). It is argued *creative evolution* is a discursive formation that yields tremendous imaginaries and is scalable to every dimension it reaches through the root metaphor of the Moore's law (as a worldview, and rational civilisation model, cf. Eisenstadt 1973, Arnason 2010). The creative evolution through its metaphors carries specific visions, attitudes, and actions that are hereafter argued as being more than cognitive or image schematic.

The second contribution is in policy analysis and the study of nanotechnology governance, highlighting the role of technology roadmaps in policymaking; also understanding the emergence of a specific power regime of governmentality (Foucault). STS scholars contributed significantly to characterising technology roadmaps as generative metaphors (Rip 2012), consensus building narratives (Berker and Throndsen 2017), and forceful fictions (van Lente 2000). They did not however fully explain how nanotechnology roadmaps are established in the policy discourse dynamic. My analysis necessarily complements their work by addressing how the regulatory regime emerges as an alignment between the nanoworld, the narrative of an innovation journey, and the discursive formation of *nano-Orientalism* (cf. Said 1978, or Harley 1989). This can also explain

how policymakers take metaphors and related stories as figuratively 'true' as the alignment establishes qualifying roles, collaboration models, resource mobilisation, grant eligibility conditions, etc. By deconstructing metaphors, narratives, and discourses together, I demonstrate that the cartographic representation of locations, events (in the future), and actors are not a neutral or innocent form of knowledge, but representations of power in their deeper cultural-cognitive setting.

In national media, I show how various actors metaphorise matters of concern, introducing an important dynamic in the evolution of nanotechnology controversies. Metaphors create a link between individual agency, local experience and more durable images, imaginaries, and collective archetypes—becoming integral part of the various *dispositives of nanotechnology acceptance*. This includes the relationships of animal-machines, institutions, or public debate on genetically modified organisms (GMOs) with deeper cultural knowledge of progress and crisis. The thesis here subscribes to the social theory of metaphor and its meaning-generating mechanism, which nevertheless produces ambiguous terms that actors use to fulfil agendas and that can later resurface as conflicting. In that case, translations become treasons for some actors (Cooren 2001: 197). For media, however, this represents a genuine resource. Debates over sensationalism, up-to-dateness, and unequivocal clearness tend to dominate discussions of scientific controversies in the media (cf. Weingart et al. 2000, Furedi 1997). But these debates also seem to obscure the important issue of *strategic ambiguity*. In other words, maintaining the ambiguity is a major media strategy in creating conditions which ensure the multiplicity of socially available narratives and interpretations.

I provide evidence that the metaphorical perspective is essential in closing the distance even between incongruent positions which extend the nanotechnology discourse and which can work towards creating *protected spaces* for technology development (cf. van Lente 1993, Rip 2011). In this sense, religious discourse is not juxtaposed as a techno-critique either (cf. Toumey 2011, Scheufele et al. 2009) but extends its symbolism to advance visions of science, technology, and society. Metaphors also represent a genuine resource to be exploited by inserting *ambiguity as objectivity* in reporting (cf. Eisenberg 1984, van Dijk 1997, Oreskes and Conway 2010), and therefore intervene differently into public debates. The dissertation concludes that metaphor is not a neutral resource to be freely exploited, but rather it has significant social, ethical, and legal implications for the actors who use it. The metaphor *capacities* and *biases*, *sociotechnical convergence*, and the *plurality of ontological regimes* are fundamental challenges for the assessment of nanotechnology. Being aware of it, we should work towards unmasking the social fabric of both their purposeful and unintentional use as well as wherever they emerge. Rather than disorienting the agent, the capacities of metaphor should be mobilised for transformative learning and increased reflexivity in future dialogues over emerging technology.

Part I Nanotechnology Discourse

Chapter 1. Nanotechnology Definitions, Organisations, and Resources

We are powerfully imprisoned in these dark ages simply by the terms in which we have been conditioned to think.
Cosmography (1992) by Buckminster Fuller

In 2007, an article published in *Le Figaro* speculated about the impossibility of a new Nobel Prize category for nanotechnology.[2] The article did not debate to whom the Nobel Prizes should be given. The author considered instead what in the nature of discoveries would qualify as nanotechnology when related research is traditionally awarded in chemistry, physics, and medicine. A decade later, a 2016 prize was awarded for 'the design and synthesis of molecular machines' to Jean-Pierre Sauvage, Fraser Stoddart, and Bernard Feringa in chemistry. In the language of the Nobel Prize, nanomachines do but nanotechnology (nanoscience) itself does not exist. Is nanotechnology the same, even partially, as physics or chemistry? The answer to that question depends on one's perspective. According to Bernadette Bensaude-Vincent (2009), nanotechnology is a 'technoscience' as it embodies the ambitions of both the scientist and the engineer, and as Nobel laureate and chemist Richard Smalley claims, 'nanotechnology is the builder's final frontier' (cited in NSTC 1999: 1, also in López 2004: 133). The claim from traditional science disciplines is particularly strong, as Philip Ball (2003), a science writer for *Nature*, noted, 'The debate about the ultimate scope and possibilities of nanotech revolves around questions of basic chemistry.' Similarly, scientist Nicolas J. Goddard argues that people seem to 'have missed a point about nanotechnology. We chemists have been doing this stuff for years. It is only since physicists started muscling in that the subject had to have a fancier name' (Sainsbury et al. 2003). Hence, the technoscience perspective thrives as not only chemists but also physicists and even (physical) biologists reclaim their identity through various achievements: 'DNA and proteins have dimensions of nanometres and, as molecular biologists can manipulate these molecules, they can surely call themselves nanotechnologists, should they wish to do so' (Broers 2005)[3]. However, it is exactly the

[2] 'Le Nobel de nanotechnologies n'existera pas' (Nobel prize in nanotechnology won't exist) in *Le Figaro*, October 2007.
[3] Biologists can address their identification with nanotechnology in attempts to mimic feats of nature where molecular 'machines' drive our muscles and transport cargo around cells, among other things, says Paul Rothemund, a research

same technological feat that makes nanotechnologists (and nanoscientists) distance themselves from chemists and biologists (cf. Munchi 2007: 434). For example, 'we can look at how substances fit together and see in reality what chemists had known before only in theory', writes science journalist Fiona Harvey, 'and by shaping how things are formed at a fundamental level, scientists [nanotechnologists] can create a whole new class of substance: nanomaterials' (Harvey 2001). Everyone is drawn in as the figures nanotechnologists evoke (like machines and DNA) cover all the classical natural science and engineering disciplines. This has one significant consequence which points to the emergence of a nanotechnology discourse.

We enter nanotechnology discourse before we even find agreement on what and if nanotechnology is. Nanotechnology discourse has been built on various technology myths and established its own myths of origin long before it left the laboratory—in Foucauldian terms, it has its own historicity. For example, Richard Feynman's 1959 talk, 'There's Plenty of Room at the Bottom', is often considered to be the origin story (a *pourquoi* story) of nanotechnology: 'The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big.' This vision preceded events like the invention of the scanning tunnelling microscope. And even if we cannot be utterly sure Feynman inspired scientists to do things they would not have done otherwise, his talk has been retroactively read into the history of nanotechnology. Taking the example of the father of modern genetics, Gregor Mendel, Foucault showed that inconsistencies occurred. Mendel spoke the truth, but he was not in the truth of the *biological discourse* of the time—biological objects and concepts were formed by other rules (cf. Foucault 1990/1992: 24). Similarly, Richard Feynman spoke the truth, but he was not in *nanotechnology discourse* yet—nanoscale objects and concepts were constructed by other rules, and in particular, they were formed by the electron and scan tunnelling microscope. As in the case of Mendel, a whole new sort of objects in nanoscience had to be developed in order to allow Feynman to enter the truth and his statements be proved (to a great extent) correct.

In the following part, I will attempt to maximise the scope in which nanotechnology discourse expands through definitions and mobilises material and rhetorical resources into various organisational structures. The definition of nanotechnology as such is a subject of controversy due to the lack of clarity or understanding of what it *is* and which surpasses the domains of science and engineering. As nanotechnology develops at the interface between science, policy, and the public, it accomodates accompanying language games. Technoscientists, leaders of business and industry, policymakers, fiction writers, political activists, the general public, and, last but not least, social

professor at the California Institute of Technology, in Pasadena: 'A biologist might use DNA "origami" to take proteins that occur separately in nature and organise them into a multi-enzyme factory that hands a chemical product from one enzyme machine to the next in the manner of an assembly line.' (Highfield 2006)

scientists all draw boundaries on issues relating to nanotechnology, which effects the definition of the field. Nanotechnology development within these boundaries of discourse is dependent on the mobilisation of various resources, ranging from material to rhetorical. It has organisational aspects which correspond to expectations, projects of modernity, but also to techno-critique and multilayered controversy enframed by media practices. These symptoms and morphologies, inseparable from nanotechnology discourse, will be investigated through various sociological theories and instances of social science research. Thus, the following excursions may seem stranded from metaphor studies at first. However, establishing theoretical framework for nanotechnology and pointing out their inter-relationships should prepare ground for the social theory of metaphor.

1.1 Nominal, Real, Teleological, and Metaphorical Definition of Nanotechnology

It should be made more clear that social sciences are not outside definition-making practices, nor can they can be held responsible for ensuring there are clear definitions of nanotechnology. However, they should provide more clarity over how definitions are established. In doing so, I will follow nanotechnology definitions in a critical way and review the often conflicting interests in definitions. The recognition of ambiguity in definitions and background language games is therefore an essential part of my agenda, as is the figurative language which entails hype and hyperbole, especially language oriented to scales, past and future. This is as important since a specific debate should target how *definition-making* influences reconfigurations of the emerging fields alongside these dimensions. Only then can we have a meaningful discussion about nanotechnology development and relate to questions aimed at the transparency and openness of uncertainties as well as claims about the potential benefits and risks.

Nanotechnology emerges, as I want to argue, in the context of three definitional approaches. It first arises through a normative definition characterised by dictionary formula; second, the labelling of particular material and practical instances we find in reality, that is, real examples or occurrences; and last, by (trying) answering a teleological question: What are the emerging technologies (nanotechnology) for? Such an approach allows the investigation of multiple aspects of the phenomena. It is, nevertheless, equally problematic and these definitions raise specific questions of their own. The multitude of boundaries drawn by definitions often leads to contrasting perspectives on the content and no single definition can encompass the complex research disciplines, policy, and public realms which nanotechnology signifies (cf. Woodhouse 2004). By stretching definitions too wide, social sciences have raised awareness of claims that nanotechnology is not a specific technology, but an *empty signifier* without any real content (cf. Wullweber 2008). This perspective is controversial but also allows even the most radical social constructivist perspectives. Far from liberating us from the unquestionable existence of different material realities

and social practices, the argument on *signification* permits the positioning of the metaphorical definition.

1.1.1 Nominal Definition: Implications for Nanotechnology as a Legal Field

In a traditional sense, *nano*, the Greek word for dwarf, refers to the size of a nanometre, one billionth of a meter. It would seem the reference to the scale provides the necessary and sufficient conditions which technology must meet to be called nanotechnology. For example, 'at least one dimension of a nanoparticle or the relevant length scale of an exploited phenomenon must lie between 1 and 100 nanometres (nm) long' (NNI 2014). While nanotechnology was initially defined by this scale, there has been little consensus on a universally accepted *nominal* definition of nanotechnology. All in all, there have been at least five characteristics central to the question of the nominal definition (Hodge et al. 2007: 10):

1. Size—from around 100 nm down to less than 0.1 nm.
2. A range of technologies—imaging, measuring, modelling and manipulating matter.
3. Multidisciplinarity—physical, chemical, biological, etc., with each being purposefully 'engineered'.
4. Size-dependent novel properties and functions.
5. The control and purposeful manipulation of matter at the atomic scale.

All these nominal definitions create space for normative regimes of nanotechnologies in the sense of various legal fields, such as the ethics concerned with duties and rights (deontology), technical standards, or any other more or less structured standards. This includes the laws which consecrate nano as a legal term, such as patent law, but also in terms of the obligation to declare any substance in 'a nanoparticle state' (Lacour 2011 and 2013). The nominal definitions have historically created a perimeter around nanotechnology as a legal field which has also expanded into various 'codes of conduct' (cf. NanoCode or NanoNorma). The codes of conduct were among the first nano-specific EU legal measures and have aimed at overcoming the limitations of defining nanotechnology (and nanomaterials), such as in REACH.[4] Other measures have been initiated and developed within policy frameworks such as the European research project Nanosafe (2003–8), led by the CEA (former Atomic Energy Commission). The European Commission, in particular, has funded a set of projects on nano-security, coordinated in the EU NanoSafety Cluster under the

[4] Regulation (EC) n 1907/2006 concerning registration, evaluation, and authorisation of chemical substances (REACH), and restrictions applicable to these substances as a regulatory directive for chemical substances sought to establish a high level of protection for human health and environment while ensuring the free circulation of nanomaterials within the common market. However, the implementation of nanomaterials as any chemical substance (within REACH) has been alarmingly criticised due to the fact that size of nanoparticles as well as their shapes matter in assessing the properties of nanomaterials (such as toxicity).

Seventh Framework Programme for Research and Technological Development and the Horizon 2020 programme. In these nanotechnology regulations, the *precautionary principle* remains a fundamental argument for the absence of any additional regulation.

There are several points of interest for social science. Measurement has a crucial role as it involves the assessment of geometrical features of size, shape, and roughness at the nanoscale—the study of which is a field called nanometrology with devices requiring a high degree of accuracy and reliability in nanomanufacturing becoming the backbone for nominal definition. These devices, however, also serve as inscription techniques which construct nanomaterials as a phenomena (cf. Bachelard 1953 and his concept of *phenomenotechnique*). The nominal definition then not only concerns the characterisation of new sample structures and characteristics but it is also mobilised to provide objective status for the definition of nanotechnology as a field. Moreover, the nominal definition has become prevalent in public discourse because it is easier for scientists and engineers to communicate to a broader public without much scientific literacy, and it avoids explicit discourse about the norms and values of the technology (cf. Schummer 2009: 268, Bassett 2017: 4). The social sciences follow the nominal definition in terms of its implications for (legal) agenda setting as it creates obligations for different social actors such as patent examiners, policy and lawmakers, fund contractors, etc. (cf. Lacour 2011) The patent examiners, in particular, are confronted with the nominal definition and its limits and may lack vocabulary when it comes to emerging technologies. The nominal definition is here responsible for the tendency towards the use of *neologisms* coined with the nano- prefix for different kinds of research, sometimes of former micro-technologies, which now fall under nanotechnology (cf. Bassett 2017).[5] It also means that this research is, from that point on, funded as nanotechnology. As the term gains currency, more companies want to use it, making it difficult to discern whether there is real nanotechnology content or just companies eager to leap aboard a bandwagon (and put 'nano' as a prefix on their work). Such a social practice is rather underexplored in social science research but points at the essential strategic interest of various actors in nominal definition. In other words, the nominal definition delimits the space of social practices which, as such, become an object of ongoing controversy regarding the boundary work within and between related social fields, not limited to scientific disciplines but more generally all actors being involved with their collective agendas.

1.1.2 Real Definition: Latent, Evolutionary, and Revolutionary Nanotechnology

The real or substantive definition refers to a list of specific research topics which usually appear under the umbrella term nanotechnology in research centres, governmental research programmes, nanotechnology conferences, but also nanotechnology journals, media, and policy documents. Or

[5] Improvements and advances in current R&D are sometimes attributed to nanotechnology just because size-reduction techniques have brought one, two, or all three length dimensions into the neighbourhood of 100nm.

put differently, nanotechnology is *what people do* when they engage in practices together with other people and their instruments, in specific places and at a specific time, ranging from nanoelectronics to nanomedicine, and so on. The variability of practices and the profile of nanotechnology actually differs in time and space (communities and countries).

Historically, nanotechnology has already made it onto the market and is suddenly everywhere in technoscientific circles. This is, in most cases, so-called *incremental* (also latent) nanotechnology which has fuelled much hype and continues to do so (Munshi et al. 2007). It involves improving the properties of many existing materials by controlling their nanoscale structure, size, and shape—incremental thus means simply making substances very small, for example, the ultrafine clays and oil particles used in cosmetics for better skin, plastic materials reinforced with carbon nanofibers that are stronger and lightweight, better lithographic techniques fit for the development of integrated chips, and so forth. These represent significant improvements on what has been done before; however, they do not really represent a decisive break from the past (Jones 2004). If one sticks to incremental nanotechnology, one will not perceive any new ethical issues because there is nothing new about nanotechnology other than the name. Nanotechnology is 'hidden' behind gradual changes in technology. The companies making significant investments in nanotechnology are ones that already have vast experience in the technology sector, such as BASF, Dow Chemical, DuPont, General Electric, Hewlett-Packard, IBM, L'Oréal, and many others. Incremental nanotechnology as an innovative activity is difficult to measure, especially on the consumer side, and hence is practically invisible.

Evolutionary nanotechnology has features which cannot be explained merely by size-reduction (Munshi et al. 2007). With evolutionary nanotechnology, we move beyond simple materials which have been redesigned at the nanoscale to actual nanoscale devices that do something interesting, for instance, a new generation of biomimetic, smart, or otherwise functional materials. Such devices can, for example, sense the environment, process information, or convert energy from one form to another. These include nanoscale sensors, which exploit the huge surface area of carbon nanotubes and other nano-structured materials to detect environmental contaminants or biochemicals, or a new generation of organic and polymer-based solar cells. Other products of evolutionary nanotechnology are semiconductor nanostructures, such as quantum dots and quantum wells, which are being used to build better solid-state lasers. Scientists are also developing ever more sophisticated ways of encapsulating molecules and delivering them on demand for targeted drug delivery (Jones 2004). Although evolutionary nanotechnology is highly based on the projections of laboratory experiments and still awaits commercialisation, it invites the development of realistic scenarios for future markets. Evolutionary nanotechnology, however, represents a small fraction of what many see as the substantial longer-term economic and societal promise of

nanotechnology (Sargent 2011). As Clayton Christensen writes in *The Innovator's Dilemma* (1990), sustaining technologies improve existing products and disruptive technologies replace them.

With *radical* (also revolutionary) nanotechnology we experience an almost surreal gap between what technology is believed to promise and what it actually delivers (Jones 2004). It represents the most extreme visions of nanotechnology, some of which continue to be inspired by Richard Feynam's (1959) vision of 'manipulating and controlling things on a small scale'. Eric Drexler, an MIT engineer, adopted this vision into the concept of molecular manufacturing, which is considered the ultimate goal of nanotechnology among certain groups of technoscientists (Drexler 1992). Twenty-seven years later, Drexler, in his report *Radical Abundance: How a Revolution in Nanotechnology Will Change Civilisation* (2013), presents us an updated version of his vision, the central theme of which is to take pre-emptive action. At the international level, we have to prepare for the disruptions, that is, 'falling demand for conventional labor, resources, and capital in physical production, with the potential for cascading disruptive effects throughout the global economy', as well as 'disruptions in supply chains, trade, dependence, and the revaluation of assets, e.g. mineral resources and large industrial facilities, for example, which will lose much of their value' (also in Pamlin and Armstrong 2015: 118). Technoscience scholars envision radical nanotechnology as one which evokes the wildest of dreams, comparable to 'modern alchemy', even returning us to the 'world of fantasy and magic' (cf. Nordmann 2007a, Maestrutti 2011, Bensaude-Vincent 2009 and 2014).

The *real* definition finds its counterpart in social research, perhaps the most developed in the social sciences, ranging from scientometrics, surveys, interviews, to ethnography. It is dealing with measurement and the analysis of growth and trends (Braun et al. 1997), nanotechnology interdisciplinarity, patterns of collaboration, publications (Meyer and Persson 1998, Schummer 2004, Shapira et al. 2010), actor networks (Selin 2006), patent scientometrics (Hullmann and Meyer 2003), innovation landscapes (Sampat 2004),[6] and ethnographic investigations of laboratories and other specific sites of scientific activity (Fogelberg and Glimell 2003). A specific brand of social research focuses on 'real' practitioners of nanotechnology, where researchers and engineers must navigate between different regimes of communication, complex mental representations, and dynamic social interactions (cf. Ball 2002). Ethnographies can look at how speech, gesture, and objects are used to construct meaningful activities and identities. For example, the ethnographic study of Fogelberg and Glimell (2003) focused on a group of nanophysicists and how they organise and represent themselves when coping with a never-ending transition or *flux*, where the making of

[6] Economic reports and surveys are made on a regular basis, such as those published by Lux Research, Inc., looking at the valorisations of research and global government spending on nanotechnology (cf. Lux Research 2013). Similarly, Merrill Lynch, a major financial company, published the Nanotech Index to help investors keep track of companies dealing with nanotechnologies.

identity seems to violate as much as obey institutional bonds and affiliations (Fogelberg and Glimell 2003: 10–12 and 115–37). In contrast to many claims and hopes, the lack of particular interdisciplinary collaboration between various research fields indicates it might indeed be appropriate to speak of nanotechnolog*ies* (plural) rather than of one nanotechnology field. This may have consequences on measuring perceptions, attitudes, and actions such as government support and (local) resistance (cf. Schummer 2007: 3). As I intend to show in this thesis, however, the singular nanotechnology is equal in reference to discourse. Whereas the plurality becomes an exact point of departure for technological and even social convergence and the objective of identity politics, when speaking of nanotechnology in the singular, the speaker forces together the accompanying and often incongruent historical developments as well as evokes future scenarios and expectations of development.

1.1.3 Teleological Definition: Imag(in)ing Nanotechnology's Past, Present, and Futures

Nanotechnology is not only defined by the nanoscale or scientific and engineering practice that show past and present achievements, but also visions of what it may become, in an entanglement of imaging and imagining (cf. 'non-presentism' in Mody 2004, also Schummer and Baird 2006, Toumey 2008, Ruivenkamp and Rip 2011).[7] Nanotechnology is here defined according to declared ends, purposes, and prospective goals (from the Greek word *telos*). For example, nanotechnology has been named alongside nuclear war, ecological catastrophe, and super-volcano eruptions as 'risks that threaten human civilisation' (see a report from the Global Challenges Foundation in Pamlin and Armstrong 2015: 114–19). Another belief about nanotechnology is that it can boost innovation and whole economies, providing a unique industrial opportunity.[8] It permeates all areas of life and concerns all branches of industry: medical and pharmaceutical systems, agricultural and food production, transportation as well as building trade, and last but not least the military (Schwarz 2004: 203). It thus emerges as a specific language from tensions around boundaries between reality and fiction (hyperreal): in and out of control, development and disaster, human and post-trans-human, and so on. Various groups reinforce these tensions, including futurologists, software engineers, investment consultants, religious groups, non-governmental organisations, governmental agencies, and the like. As such, nanotechnology discourse spreads across different genres, from origin myths and political speeches, to conference proceedings, fiction literature, computer games, films, etcetera. Altogether, these form around nanotechnology a distinct configuration(s)

[7] Nanotechnology, in contrast to, for example, physics and chemistry, 'seems decidedly non-presentist' and that 'nanotechnologists work as much in this future world as in the present' (Mody 2004: 108).

[8] cf. 'Science and Technology Policy: Nanotechnology' by the Organisation for Economic Cooperation and Development (OECD 2015), website at www.oecd.org/sti/nano; or 'Vision, Goals and Objectives: NNI Strategic Plan 2014', by United States National Nanotechnology Initiative (NNI 2015), website at http://www.nano.gov/; or 'Research and Innovation: Key Enabling Technologies', by the European Commission Directorate General (ECDG 2015), website at http://ec.europa.eu/research/industrial_technologies/policy_en.html

represented by values, like health, wealth, and security as well as relative attributes, like smaller, faster, harder, cheaper, and so on. The teleological definition thus relies on symbols and references to pasts, presents, and futures in terms of what nanotechnology means socially, politically, and culturally.

The teleological definition should not give the impression that it is centred around the rhetorical dimension or separated from material practices. It revolves around imaginaries as well as specific technology projects (cf. sociotechnical imaginaries as specific projects in Jasanoff et al. 2008). These are not merely visions, but imaginaries materialised in government-funded initiatives. For example, the *technology convergence* or the NBIC (nano-bio-info-cogno) acronym here represents research practices which leave their traditional disciplines and also a metaphor for the popular belief that nanotechnology will make nearly anything possible (cf. Kurzweil 2006). It can be understood not only as an evolutionary stage but agenda-setting, advanced by the National Science Foundation in the United States (Roco and Bainbridge 2001) and CTEKS in Europe. As a strategic policy, convergence becomes incorporated into identity-building projects which seek to reimagine what a nation or community represents (cf. Jasanoff 2005, and a later chapter in this thesis on nanotechnology policy). Developed countries especially invest in keeping a competitive nanotechnology portfolio state of the art, from catching up with others to leading whole sectors. This can hold true, yet in some cases, technologies can also undermine economies and entire industries. Introducing new technology can make raw material supply from developing countries obsolete or it can suddenly change the demand for materials (e.g. replacing precious metals, natural dyes, plastics, etc.). The teleological definition of nanotechnology should thus be understood as introducing metaphors for convergence as well as a new societal gap between developed and developing, between aware and not aware, supporting and opposing (cf. Stiglitz and Greenwald 2014)—this scenario has been described as a 'nano-divide' (Schummer 2007a). Far from liberating us, modern technology is envisioned in conservative not revolutionary forces (Edgerton 2006: 159, see also Horkheimer and Adorno 1972, Horkheimer 1974). This has consequences for social sciences as old power relations are transmitted through new technology, even the most 'radical' ones. The teleologies not only strongly colour the definition of nanotechnology but also social science research.

The response of social sciences to various teleologies has been shaped by the transdisciplinary initiatives of social scientists and professionals from the related fields, such as the Society for the Studies of New and Emerging Technologies (S.NET), formed by STS scholars from across the United States and Europe, and the emergent academic journal *NanoEthics*, devoted to the topic since its founding in 2007. Nanoethics, or the study of nanotechnology's ethical, legal, and social aspects (ELSA), is an emerging field of research which takes into account various issues (cf.

Moor and Weckert 2004, Lin and Allhoff 2007). The legitimate subject matter extends to anything that can meaningfully contribute to the discussion (cf. the editorial section in the journal *NanoEthics* by Weckert 2012: 153). For example, the social sciences began to notice nanotechnology, in its trans- and multi-disciplinarity as well as in its cultural landscapes (such as between developed and developing countries), poses a problem of adaptation to cultural diversity and represents a challenge of ethical relativism (cf. Schummer 2009: 278). Still, the ethical and social dimensions remain under-researched in the social sciences due to scientific and technological complexity, and also in the sense that there is necessarily a time gap between the development of a field and participation by social scientists, and funding limitations (cf. Bennett and Sarewitz 2006). Related to that, there are limitations in the policy models for nanotechnology which capture the complex interactions between various actors (cf. Rip 2006, Toumey 2006, Doubleday 2007, Laurent 2007, Ruivenkamp and Rip 2011, Chateauraynaud 2009, Vinck 2009 and 2011, Vernant 2014). Finally, it should be more evident that focus on teleologies must make it possible to transcend the boundary between real (i.e. existing) and fictional accounts, and therefore, to consider structural elements such as narratives and metaphors. Next, I will focus on how the definition of nanotechnology relies on metaphorical elements and include, in particular, scenarios and narratives of crisis. I will point out how the *metaphorical definition* expands the previous definitional approaches, especially reflecting the particular regime of times and modes, including actors and various social representations of nanotechnology.

1.1.4 Metaphorical Definition(s) of Nanotechnology: *There and Then* and *Here and Now*

Incremental, *evolutionary*, and *radical* nanotechnology, as a heuristic introduced by Wood et al. (2003), may be useful for investigating the transition between existing and expected nanotechnology but also in indicating a range of visibility. On one hand, nanotechnology has been recognised in past and present scientific and engineering achievements. On the other, nanotechnology is a latent unestablished practice—at least with the exception of imaginations of futures and past experiences as a practice. The above definitions are thus useful ideal types because they reflect what is *already here* and what is *expected*, capturing different levels of the interiorisation of past and future and the elaboration of technoscientific projects. The further in time we move forward with the projections, the more revolutionary nanotechnology emerges. An additional perspective on definitions could yet strive for more symmetry and place on an equal footing these various practices of materiality and imagination, that is, 'prophecy', 'dream' and 'sober reality' (cf. Chateauraynaud 2009: 27 and 2012: 100). In the following part, I will attempt to argue how metaphorical definition achieves this, and how it even allows repositioning of nominal, real, and teleological dimensions.

It has been noted that the nominal definition has become prevalent in public discourse

because it is easier to communicate to a broader public without much scientific literacy, and it avoids explicit discourse about the norms and values of technology (Schummer 2009: 268). However, the nominal definition is not more comprehensible for the sheer reference to the nanometre scale alone but the figurative language that is attached to it, such as analogies to 'smaller than the width of a human hair' as well as metaphors of 'landscapes' and 'little people' (cf. Nordmann 2007a Mordini 2007a). These truly enable the communication of nanotechnology and replace the need for scientific literacy. Here also, studying the nominal definition should be sensitive to the potential influence of metaphors (and analogies) to the implementation of nanotechnology norms (also laws) and policies. The metaphorical definitions related to scales not only translate information on the invisible but arguably also the benefits and risks of nanoscale or the nanoworld.

The real definition is no less permeated by figurative language as is the identity of practitioners and the various objects. The real definition and the related debate on the metaphor of 'technological convergence' however captures how nanotechnology is covering almost all modern technologies and becomes perhaps too all-encompassing to be meaningful (cf. Wullweber 2008). Analysing nanotechnology as an object of identity politics here marks the most challenging moment for social science research. Assigning the identity and boundary work which happens through common boundary objects and related disciplines can have multiple effects, however. Moreover, as researchers establish various sociotechnical imaginaries (incl. projects) and draw boundaries, it is essential to study the identity of the objects and the actors themselves. The mechanisms of metaphorical transference here reach the construction of nanoscientist identities, but also *pro-* and *anti*-nano movements, policymakers, and the public.

Finally, social science research approaches teleologies to indicate a certain state of *non-presentism* which can even hinder us from assessing technologies effectively or discounting the based decisions as illegitimate. This is more pressing as we get familiar with the speakers presenting nanotechnology development as inevitable 'fact'. In other words, nanotechnology will be (or is already) here (cf. *pas encore là* and *déjà là* as temporal modalities in nanotechnology discourse in Chateauraynaud 2006, 2009, 2011 and 2012: 98–99)—everywhere in our society. We must deal with the omnipresence economically, socially, and culturally. We cannot deny it, delay it, or ignore it as it is already happening—a *matter of fact* shifts into the *matter of concern* (cf. Cooren 2000). What *should* be done becomes as important as imagining what *could* be done. In particular, the *principles of precaution* and *anticipation* themselves work as metaphors that shift into various modes of temporality (Chauteauraynaud 2012: 100). If 'manufactured nanoparticles, measuring just billionths of a metre across, should be treated as if they were new substances' (Sample 2005), a *case by case* scenario then represents the feasibility issue of keeping up with innovation before

regulation. Similarly, labelling nanotechnology on behalf of *previous controversies* marks metaphorical mechanisms. For example, many people believe that GMO is a technical term which carries a large significance for interpreting the safety of food. However, translating GMO and nano into the metaphor of 'nano as (the next) GMO' or 'Frankenstein nanofood' may be an oversight of the common frame. Mihail Roco, a scientist, advisor at the National Science Foundation in the United States, and proponent of nanotechnology, responded to the transferential techno-critique of nanofood: 'If you say nano-structures are dangerous, then you can't eat anything' (Cressey 2013). Physicist Frans Kampers also argues that 'food is naturally a nanostructured material' (Lang and Kampers 2013).

In sum, how we define nanotechnology metaphorically is never truly separated from modalities of time and space, that is, shifting between the *there and then* and *here and now* of various locations, events (actors), and structures. The metaphorical dimension should be recognised as inseparable from vision of scales, past controversies, and future prospects as well as all the socio-ethical challenges which nanotechnology could engender as the transference of images within and between discourses. To outline the mechanism with its possible implications, we can review a few additional examples of metaphorical definitions which target nanotechnology.

1. *The next Big Thing* (Uldrich 2003, or Drexler 2013)

Many believe that nanotechnology is the next big thing. 'We believe nanotechnology could be the next growth innovation', said Steven Milunovich, Merrill Lynch's global technology strategist. Depending on whom you ask or interpret, however, nanotechnology might be the next big thing, but also the next Big Brother (as compared to Big Science), the next asbestos, or the next GMO. Scientists and policymakers are rather desperate to avoid nanotechnology becoming the stage for the next big showdown between science and society. These are all relevant meanings of the next big thing metaphor.

2. *The Janus face of nanotechnology* (Adam 2012)

The chair of nanomedicine at the University of London, professor Kostas Kostarelos, looks to ancient Rome to make a modern point: 'Like Janus, the Roman god with two faces who looked simultaneously forwards and backwards, scientists working on nanotechnology, and society more broadly, need to consider the "dichotomy" of the technology . . . . Nanotechnology could be seen as a scientific marvel or a health hazard . . . it could offer the dream of tiny "machines" to fix individual cells, or the nightmare of asbestos-like particles stuck in the lungs. "We need to understand there are these dichotomies . . . . And we must avoid hype, both positive and negative', he said to a science correspondent during *The Guardian* (media) panel.

3. *Nanotechnology is necrotechnology* (Alberganti 2006)

When nanotechnology got branded by activist discourse as necrotechnology, it refers to nanotechnologies that originate in the 'laboratory [to impose] artificialisation of the world—vampirism of technical system on ecosystem' (le Hir and Cabret 2005). The term 'necrotechnologies' was coined by Jean-Pierre Berlan, an economist at the National Institute of Agricultural Research (INRA) and an anti-GMO activist, to pinpoint what he considers the true identity of biotechnologies. French opposition to nanotechnology has then taken up this neologism to name a set of new technologies including nanotechnologies (Joly and Kaufmann 2008).

4. *Nanotechnology is an empty (floating) signifier* (Wullweber 2008).

The empty signifier is intimately connected with the argument that the term nanotechnology is too broad to be meaningful (Wullweber 2008). An empty signifier is a hybrid of universality and particularity. Social forces struggle to launch such signifiers and to fill their content (Laclau 1996). The metaphor is used to denote that nanotechnology is a signifier without referents and is a word that does not point to any actual object and has no universal, agreed upon meaning.

5. *Nanotechnology is noumenal technology* (Nordmann 2005).

Noumenal technology, as Alfred Nordmann uses the term, appears to be a contradiction: 'Technology is a human creation that involves human knowledge and serves human needs; this firmly roots it in phenomena and it appears absurd to speak of technology that exists beyond human perception and experience among the things-in-themselves . . . Noumena are distinct from phenomena. While the latter are the things as they appear to us and as we experience them, the noumena are the philosophically infamous and mysterious things-in-themselves' (Nordmann 2005: 1–6).[9] The metaphor here signifies a certain collapse of distance, a world that is not directly accessible to our senses, like atoms or molecules.

The few illustrative examples by no means represent all nuances on the scale of opinions, but effectively show how defining nanotechnology figuratively shifts between neutral, positive, and negative, but also points to the referents and actors who utter them. It captures rather well how metaphorical definitions emerge within various contexts and how metaphorical language constitutes hype, fears, and public backlash, even establishing connections with different controversies. In particular, if we give weight to the empty signifier argument (Wullweber 2008 and 2015), it seems what *nanotechnology is, or is not* must be accounted for in a variety of metaphorical forms that can effectively fill in the 'empty' signified space with signifiers. Derived issues from this stance are

[9] 'The noumenal world is nature uncomprehended, unexperienced, and uncontrolled; it is nature in the sense of uncultivated, uncanny otherness.' (Nordmann 2005: 1) The nanoscale world is retreating from human access, perception, and control, and where the uncanny otherness qualifies as an absence of vision.

how ‘actors’, ‘matters of concern’, and such are themselves defined; how they are determined by nanotechnology as an organised field of practices; and how various material and symbolic resources are involved.

1.2 Nanotechnology Organisation (Composition view)

In this section, I will move beyond nanotechnology definitions to discuss the specific organisation of practices alongside various sociological theories and approaches. A combination of several theoretical backgrounds aims to provide an explanatory model with which to grasp the interplay between science, policy, and public in its complexity. This is achieved through the diverse body of theoretical perspectives which follow the organisation (and morphology) of modernity, the co-production of scientific knowledge, the sociology of expectations, critical sociology, the sociology of controversies, and, last but not least, media studies. Technology development in a knowledge society lies in the hybridisation of elements from university, industry, and government to generate new institutional and social formats for the production, transfer, and application of knowledge (cf. Leydesdorff and Etzkowitz 1996). But that also extends towards the public, opening new spaces for politics marked by persuasions, accusations, and scaremongering, giving media a central role. While there are many possibilities how to study nanotechnology under its current organisational forms—studying media will be argued as convenient and appropriate choice exactly because it allows to focus on the interface between science, policy, and the public.

The sociological theory of modernity brings several arguments which could qualify as symptoms or even having a direct connection or influence on nanotechnology organisation. The modern world, marked by more acute competition, implies a more urgent requirement to push the horizon of competitive action further and further into the future, beyond the gaze of one’s competitors (Giddens 1999: 2–3, also Brown and Michael 2003). To increasingly control the future (e.g. markets that do not yet exist) demands stretching the temporal envelope and being increasingly preoccupied with and generating notions of risk and opportunity (also in Beck et al. 1994). The catastrophic accidents of the 20th century, such as Chernobyl (1986) disaster, prove technologies create as many expectations and uncertainties as they dispel, and these uncertainties cannot be ‘solved’ in any simple way, and neither by further scientific advances. In other words, the progression of science and technology depends on opportunities as well as ‘manufactured risks’ and which are conversely created by the very progression of human development (Giddens 1999). This interferes with other debated symptoms of (post)modern society such as the centrality of information (Bell 1976, van Dijk 2005) or the network as a new social morphology (Castells 2000, van Dijk 1999). Indeed, scientists, engineers, and policymakers are increasingly expected to reach beyond the borders of their own specific fields of expertise and establish relationships with wide

and heterogeneous networks of potential collaborators (Borup et al. 2006: 287). These symptoms are at the heart of the idea of the *knowledge society* emerging from science expertise, policies, and even everyday instruments we devise to create knowledge about present and future and to facilitate its better management. From climate change to the mad cow disease (BSE) crisis and grey goo, from government politics and social movements to lifestyle politics, nanotechnology is an organised field of practices with a specific co-production of knowledge at the interface of science, policy, and the public.

1.2.1 The Socio-logic of Knowledge: Co-production, Trading Zones, and Non-human Networks

Nanotechnology development can be approached as the consolidation of objects and spaces, and the interactions between them which can generate new combinations of knowledge and resources that advance or hinder innovation at the local (national, regional, community) and global level. And further, science and technology have always been social, cultural, political, and economic activities—the relation between science (and technology) and society is not one in which the former affects the latter, but one of recursive co-production (Jasanoff 2004). As much as the production of knowledge is central to any technology development (and its organisation), there are several related concepts and strategies.

'Does the idea of co-production represent anything more than the intuitively obvious point that ideas of nature, no less than ideas of society, are constructed by human endeavour?' (Jasanoff 2004: 17–18) The STS concept of co-production should be used to subject such processes to critical scrutiny, especially when scientific knowledge is considered as something which both embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments, and institutions (Jasanoff 2004: 2–3). We can ask, in particular, what aspects of the role of science and technology in society may most appropriately be addressed in the idiom of co-production; for instance, what sorts of scientific entities or technological arrangements can usefully be regarded as being co-produced with which elements of social order? How do processes of co-production relate to more orthodox accounts of technical or political change? And what methods and approaches are best suited to investigate instances of co-production? (Jasanoff 2004: 19) These investigations have always had a specific normative dimension in the sense that what characterises various levels of co-production is not just an interaction of actors and resources but a context. In fact, the context in which technology develops is a substantial factor in studying co-production.

It has been noted that nanotechnology has a specific interdisciplinary and cultural context. Although having adopted interdisciplinarity, it functions to different degrees under traditional structures inside and outside. If new technologies emerge, they are continuously challenged in their compatibility with these traditional structures and adaptability. Another noteworthy issue is that

when the relationships between different actors are assembled into interfaces between science, policy, and the public, co-production occurs in terms of both cooperation (consensus) and conflict. We can point to the consensual view with the concept of a 'trading zone' (Galison 1997) which sensitises perspective on nanotechnology organisation by key features of *collaborative* interactions. Nanotechnology is then an *innovation system*, defined according to a set of objects, components, relationships, languages, and functions. For example, the history and also the epistemological challenges of technical convergence between nano-, bio-, information, and cognitive technologies can be explained through the concepts of trading zones and interactional expertise (cf. Gorman 2004 and 2010). Physicists, chemists, biologists, and engineers must gradually develop what was effectively a pidgin or creole language involving shared concepts like self-assembly, and which physicists, chemists, and biologists represent symbolically in terms of their theories and practices (engineering). These exchanges across disciplinary boundaries are carried out with the help of boundary objects that act as bonding agents. These agents are both material and symbolic, and STS scholars recognise this shift from the *traditional* concept of agency and identity: 'Identity is particularly germane to co-productionist accounts because, whether human or non-human, individual or collective, it is one of the most potent resources with which people restore sense out of disorder.' (Jasanoff 2004: 39) The critical scrutiny of co-production should allow it to be followed in the sense of 'mutually and at the same time' but not necessarily through 'collaboration' (cf. Nerlich 2015). The co-production idiom should be assessed through various, even conflicting positions. It should be open to investigation in various cultural contexts of conflict.

Finally, scientific knowledge is not only socially coded and historically situated but sustained and made durable by material-symbolic actors and hybrid networks (cf. Ihde and Selinger et al. 2003). In particular, scholarly work on technoscience provides the vocabulary for critical discussion about the translation of ontologies and the implosion of dichotomies (cf. Callon and Latour 1992: 349, Jasanoff 2004: 15, and also, Latour 1996, Haraway 1990, 1997 and 1999). For my purposes, the term 'translation' is deliberately meant to be as vague and generic as possible. For example, Callon (1986: 211) defines translation as the process of 'creating convergences and homologies by relating things that were previously different'. A translation, in other words, is an act of invention that operates by joining previously disparate elements. Actors emerge through translation (Ibid.). Of particular interest are objects as *hybrids* and which emerge against a *discourse of purification*. In this sense, the hybrid ontology should not be understood as an 'argument (out) of moderation'—a false compromise where 'an individual operating within the false compromise fallacy believes that the positions being considered represent extremes of a continuum of opinions and that such extremes are always wrong, and the middle ground is always correct' (Craiutu 2012: 13-14, see also Callon and Latour 1992: 346). The 'middle ground', previously considered a rather

illogical situation, can easily become the new extreme in the continuum of opinions. The technical and social aspects of nanotechnology differ in at least one important respect. As the American physicist Richard Feynman allegedly once said, 'Imagine how much harder physics would be if electrons had feelings.' There is an important difference between the natural and social sciences. In the natural sciences, scientists try to understand and theorise about the way the natural world is structured. The understanding is one-way; that is, while we need to understand the actions of minerals or chemicals, chemicals and minerals do not seek to develop an understanding of us (Feynman ref. in Tucker 1998: 59). That being said, to admit that sometimes it might be appropriate to accept moderation and symmetry depends on what it opposes. There is no clear-cut edge or border between social and technical *systems* to the extent our *practices* are concerned. Sociotechnical may refer to the interrelatedness of *social* and *technical* aspects of an organisation or the society as a whole. Additionally, non-human elements emerge in nanotechnology discourse at the outset of various rhetorical strategies, notably naturalising nanotechnology ('We do what nature does'); *bio*-mimetism, however, can be understood beyond the rhetorical strategy. Nanotechnology research is just as bound to the discovery of truth known from poetics. Its development has many aspects, all of which affect and essentially create each other, albeit with respect to different variables operating at different scales.

The middle ground position is more than a sensibility. We should recognise social and technical as not separate but intrinsically influencing each other. More importantly, it is the task of the social sciences to investigate that which is not immediately discernible at any given moment, that is, the practices of separating reality into contingent networks forming extremes and that are embedded in scientific methods (cf. 'purifying practices' in Latour 1993). Here, we can turn to Latour's (2007) idea that all dichotomies and their logical separators should go in the air! The author, in his actor-network-theory (ideally conceived without separators), focuses on the topology of actors and world positioning and which breaks, for example, the science laboratory into the 'dissolution of inside/outside' while 'playing havoc with differences of scale'.[10]

With nanotechnology, it might be argued that all former distinctions cease to exist in pure form: social and technical, cultural and natural, individual and institutional actors, and also, we might add, literal and metaphorical! This is probably even amplified by the so-called collapse of distance that Alfred Nordmann uses to describe the lack of critical awareness regarding reality and the limits of knowledge or control in nanotechnology (Nordmann 2006: 4). Yet, we should not see the uncertainty outside the politics of technoscience or even strategic ambiguity. Studying the

[10] On a related note, it might be argued that a similar effect to that of the scientific method is produced by metaphor analysis, one which creates oppositions between literal and figurative language. Those cognitive linguists who have established a link between linguistic forms and semantic structures of the mind (cognition) are especially familiar with creating contingent networks—the formations of a hidden meaning (cf. Lakoff and Johnson 1980, Fauconnier and Turner 2002).

history of nanoscience and nanotechnology offers an interesting case of showing how science and engineering interact on the basis of ambiguity and the hybridisation of elements, but also, where purifying practices may shape the content of the debate on scientific knowledge. For example, when Eric Drexler (engineer) debated with Richard Smalley (chemist) on molecular assemblers, both described their incongruent positions on the issue as threatening the future of nanotechnology. Drexler, an engineer turned to metaphor for molecular robots as features already present in nature as 'ribosomes', a metaphor which was mobilised to defend the feasibility and discussion of 'the question of what nanotechnology can ultimately achieve'.[11] Smalley, a chemist, argued that any attempt to make molecular robots is unlikely to solve the problem of 'fat/sticky fingers', moreover, it 'scares our children' with unlikely scenarios (see also articles and open letters from both authors published in *Scientific American* and *Chemical and Engineering News* between 2001 and 2003).[12] Both Drexler and Smalley turned to metaphors in order to replace statements of facts and theories with matters of concerns. In his book *The Singularity Is Near* (2005), Ray Kurzweil defended Drexler's ideas, calling Smalley's responses 'short on specific citations and current research and long on imprecise metaphors'. On the deconstruction level of the still highly hypothetical scenario, these metaphors were never objective descriptions but have been nevertheless part of the regime of co-production and thus were potentially performative in influencing future discussion.

1.2.2 Sociology of Expectations: Forceful Fictions, Scenarios, and Prophecies

Another theoretical tradition which provides an alternative perspective of the regime of co-production and organisation of nanotechnology is a *sociology of expectations*. The earliest considerations of the role of expectations dates back to Robert K. Merton (1948: 195), who dealt with self-fulfilling prophecies. The self-fulfilling prophecy is from the outset, according to Merton, a false definition of the situation evoking a behaviour which makes the original false conception come true. An action is influenced by expectations and the results explain the past course of events. The sociology of expectations has, since Merton, developed into a relatively coherent theory within STS, focusing on how actors become bound to expectations in emerging technologies (cf. van Lente 1993, van Lente and Rip 1998, Brown and Michael 2003, Selin 2007 and 2008). Harro van Lente (1993) construes expectations as 'forceful fictions' and shows how expectations are implicated in the innovation processes and crucial for agenda building. The sociology of expectations, especially in the constructivist tradition, speaks for multiple transitions of images and the identity of actors, not restricting it to any fixed position in a controversy but rather a fluent process and procedure. According to this view, experts (including sociologists) and the public are categories which are

[11] Drexler, Eric (2 July 2003). 'Toward closure'. Foresight Institute. Retrieved 5 July 2019.
[12] In 'Nanotechnology: Drexler and Smalley make the case for and against "molecular assemblers"'. *Chemical & Engineering News*. 81 (48): 37–42. 1 December 2003.

themselves constructed through discourses and practices *during* the debates, thus becoming part of the discourse dynamic (Laurent 2007: 351). In other words, how actors frame the nature and range of issues associated with emergent technologies is highly significant since it has the potential to legitimise certain definitions over and above others (Anderson et al. 2005). Moreover, this extends to the definitions of actors themselves. The individual or collective actors which influence collective expectations are themselves subject to the influence of collective expectations (Konrad 2006: 431–32).

Sociology has a wide range of materials to study expectations, for instance, reproductive technologies (Bloomfield and Vurdubakis 1995), pharmaceuticals (Hedgecoe and Martin 2003), lab-on-a-chip technologies (van Merkerk and van Lente 2005), and nanotechnology (Selin 2007). What these studies have in common is they show us there is a plurality of temporal patterns at the interface between science, policy, and the public, whether voicing emergency, anticipation, prediction, or foresight, or even science fiction. In fact, 'taking seriously the processes by which scenarios and visions of the future develop in contemporary societies is an essential task for a sociology devoted to monitoring critical processes over the long term' (Chateauraynaud 2009 and 2011). In other words, taking even the most fictional accounts seriously means to not overlook substantial discourse dynamics. For sociologist Francis Chateauraynaud, representations of nanotechnology within the scope of public debates comprise the contrasting temporal figurations—'there will be a day', and 'besides there is already' (*déjà là*) and 'already there' and 'not there yet' (*pas encore là*). Not only do these constantly move the horizon of expectations but they also portray delays in regulation and other anticipatory regimes which insensibly slide into the use of time and modes (cf. Chateauraynaud 2006: 5–17). Whether the expectations are based on an attitude of 'already here', 'wait-and-see', 'prediction', 'promise', or 'prophecy', these are all crucial sources of action and judgement. The expectations scholars who have theorised about future have shown that expectations are useful, not only in creating momentum but also different resources are used to create protective niches or protected spaces (Geels and Smit 2000, Rip 2011, also in Selin 2008: 88). These protected spaces work as collective representations and should be studied as such.

Emerging technology is being appreciated or feared not only because of the scientific merits or inherent properties of technology but also because of strategic alliances and their pre-existing extra-scientific values and beliefs. In reality, there always is a variation in expectations between different kinds of actors—basic researchers, entrepreneurs, potential end users, and so on (Brown and Michael 2003). Technology development can thus be understood in the sense of developing consensus, even authority over heterogeneous actors. It is open-ended, rather unruly, and in that sense, always threatened with going out of control. Expectations are among functional resources for collective mobilisations. In building alliances and strategic relationships to marginalise competing

fields and activities, ideas are how networks between research, industry, and political structures emerge. Technology development is then better described by quasi-objects which can be conceived as a stabilised human and non-human collective (cf. Latour 2007). In this sense, development becomes a relevant actor-constellation, connecting data, people, ideas, question givers, and solution providers. Under manifold translations and numerous delegations, its contested character, its topology, becomes ever more complex (cf. collective narratives in Berker and Throndsen 2017). The expectations have temporality of a narrative but also durability of the most ancient myths that speak to us about the opportunities and risks. These ontological and temporal patterns, as specific formations of discourse, are arguably critical to our understanding of nanotechnology development.

In particular, studies which have focused on grasping the attitudes toward nanotechnology or public debates in local (national) contexts are challenged by the multidisciplinary character of nanotechnology as well as by expectations which are emergent within these cultural contexts (cf. Doubleday 2007, Laurent 2007, Vernant 2014). The actors articulate expectations in their own terms, experience, cultural knowledge (values), and so on. The public understanding of science, however, is not necessarily anchored in science as understood by scientists. On the contrary, public understanding in a scientific controversy is largely shaped by the rhetorical strategies of the competing parties, with the result that pseudo-scientific positions look much the same as scientific conclusions (see also 'understanding of science' and 'public understanding of science' in Locke 1994, 1999a, ref. in Schummer and Baird 2006: 405). Here, a translation of science and public images is not merely a way of interacting with external constituencies, it affects the way scientists themselves perceive their realities: In fact, an analogy or metaphor created for the purpose of public communication can, perversely, spring back and affect the thinking of its creators as well (O'Shaughnessy 2004: 87).

In my thesis, I take on the challenging task of showing how figurative language provides images of futures and metaphorical forms of expectations. Moreover, in these expectations, all actors involved are being assigned an identity in stories of nanotechnology. The narratives in particular play a central role in the discursive assessment of a controversy and which should be investigated as isomorphism between narrative and a structure of controversy (see also Cooren 2001). Studying expectations can serve as critical to the discussion as does studying *techno-critique* as a specific configuration of contrasting expectations and counter-narrativisation. As with promises and expectations, we should consider how techno-critique as such becomes an organised field of social practices.

1.2.4 Critical Sociology: From Techno-Critique to Horizons of Acceptability

Critical inquiry of technology was pioneered by the Frankfurt School of critical sociology. The key idea of the Frankfurt School is that technologies play an important role in defining the human

condition, that technology is not neutral, and that its use involves taking a valuative stance. Horkheimer and Adorno (1969[1947]), Marcuse (1964), and Habermas (1970), as well as Heidegger (1977) and Ellul (1964), each in their own way, 'questioned' technology, arguing why we should challenge its instrumentality and to what ends. The proponents of emerging technologies, such as nanotechnology convergence, promise abundance and a better quality of life, while others alert about challenges of its instrumentality which have ethical, legal, and social aspects. Nanotechnology and its expected future omnipresence, however, removes ever more intensively what the critique of technology usually ended with, a retreat from the technical sphere into art, religion, or nature.[13] With nanotechnology convergence, it is argued, one sphere merges into another (Nordmann 2007a). Nature (phenomenal) and culture are here a prerequisite to understanding the politics of technoscience rather than offering a clear-cut vision of ideological struggle: 'Visions that are rooted perhaps in different ideologies, in historical progress over time vs. global expansion in space, in conceptions of individualism, notions of religion and technology. It [convergence] also orients the attention of engineers as well as scientists (whose problems and interests prove to be closely coupled in nanospace)' (Nordmann 2007a: 8). It is true that the traditional ideological model of controversy has information value. As governments launch additional support for nanotechnology, activist groups continue to denounce the convergence of technologies as a new 'totalitarianism' and even act to derail their development (cf. a repeated argument of the Pièces et Main d'Oeuvre [PMO] activist group in France). For these reasons alone, the conflicts must be taken seriously, especially when different instances of nanotechnology are found in Europe (as in the rest of the world) and are being associated with conflicting promises and expectations. But even though we can acknowledge the actors are 'critical' in their own right, we must also be reflexive to this criticism alone (cf. Boltanski 1990). It is necessary to point out how my investigations overlap with such critical stances as another organisational feature of nanotechnology development.

Critical sociology that can serve the above objective has since the Frankfurt School mobilised fine-grained theoretical stances, and in particular, under the influence of Foucault and constructivism (cf. Bijker et al. 1989). It took a fresh look towards techno-critical discourses to unveil what previously seemed to mask political interests, irrational fears, obsolete conservatism, and even reactionary positions. Techno-critique has been related to the mechanisms which produce power and (social) control, and democratising nanotechnology only ideally means expanding technological design to include alternative interests and values (Pidgeon and Rogers-Hayden 2007), or in Habermasian terms, the requirement for mutual engagement in critical (public) debate. From

[13] In 'Technology and Science as "Ideology"' (1970), Habermas denounces the 'secret hopes' of a whole generation of social thinkers—Benjamin, Adorno, Bloch, Marcuse—whose implicit ideal was the restoration of the harmony of man and nature. He attacks the very idea of new science and technology as a romantic myth (in Feenberg 1996: 48).

relatively large public debates organised by governments to more local *café scientifiques* (science cafes), there are many examples of co-ordinated exchanges at the interface between science, policy, and the public, sometimes organised even by social researchers themselves (cf. the study of risk perceptions and attitudes of Dutch science café participants, by Dijkstra and Critchley 2016. In this thesis see also *The Guardian* panel in the UK, Vivagora in France, or Česko je Nano [Czech is Nano] in the Czech Republic). These 'debates' are formed as well as forced, and actors are always threatened with losing themselves in hegemonic (or dominant) representations. We should not yet lose critical focus on these exchanges, especially in circumstances where a particular debate always emerges at the centre of various policy strategies and cultural contexts.

Technologies have, according to Andrew Feenberg, 'social meanings' and a 'cultural horizon' (Feenberg 1992 and 1995). The social meanings have symbolic content attached to them by various social actors or stakeholders. There is also a cultural horizon of technology, a horizon of technology acceptability which works towards the social shaping of technology. The two concepts provide Feenberg the positioning for his critique of technological determinism (and scientific-technical rationality), and they leave open the determinate possibility of social intervention. He calls this possibility 'subversive rationalisation' (Feenberg 1995: 3–22). It is here that Feenberg sees a possible role for organised social movements in the redefinition of the language codes of public debates and for challenging the language code of technocratic policy posed by organisations (and state institutions). We may find, for example, that planned policies on nanotechnology in the European Commission, as well as the related debates concerning a 'moratorium', are enframed in criticism over the 'best' laws and practices, in themselves constructing the criticism of anti-technology movements as 'anti-progress' movements. How to grasp, in particular, nanotechnology critique as such, being in itself a contested field of social practices? How to reach beyond any particular social meanings and cultural horizons? The social movements are neither neutral nor innocent. Their language codes intervene and resonate with the technical codes, and even become subversive codes; that is, they establish horizons of acceptability—or, translated into the language of sociology and discourse analysis, they also become elements in discursive formations with different dispositives of acceptance. The research on dispositives of acceptance, embedded within technoscientific possibilities, policy strategies, and culturally conditioned visions and goals, however, should not shift our focus from cultural diversity to ethical relativism (cf. Schummer 2009: 278). It should allow for scrutinization of the systematic forms of construction which are behind actors' arguments when they describe their motives for actions, or of the others, while considering them part of the discursive formations (Foucault 1972: 208-209). The critical aspect then means looking at the controversies from different angles, deconstructing how consensus and conflict are established. Critical sociology is an important theoretical resource which may bring the

organisation of nanotechnology, its objects/places/futures into much sharper focus under a strong, determined, and determining manner. In this sense, nanotechnology is a regime of knowledge and power (cf. Foucault's works on 'governmentality').[14] It produces ontology and historicity, forms of subjectivity and otherness/alterity (Nordmann and Schwarz 2010). It is exactly in the above context that the critical discussion on nanotechnology is timely.

1.2.4 Sociology of Controversies: Actors, Alliances, Trials, and Matters of Concern

Controversy is also an organisational layout. Scientific controversies in particular often have profound social, political, and economic implications, and more and more often they feature public disagreements among scientific, technical, or medical experts (Martin and Richards 1995: 506). This is sometimes circumvented by considering there may actually be two controversies: a cognitive controversy (a controversy over knowledge) and a social controversy (a controversy over non-scientific issues) (Engelhardt and Caplan 1987). There are many reasons to take an interest in *controversies* [as they] *involve scientists in new policy positions as advisers to citizen groups, interveners in public hearings, and participants in review boards and special commissions* (Engelhardt and Caplan 1987: 290). The various actors and their roles are being assigned at official (media) and officers fora (conferences of consensus). There, actors may become allies as well as enemies. The *consensus is fundamentally fragile; many controversies come to an end without having been resolved by evidence alone, and stable scientific fields always contain malcontents who attribute the consensus to pure social conformism*' (Bourdieu 2004: 19, in ref. to Barnes 1974). The social aspects may be not completely acknowledged by experts in natural science themselves—for them, it may be *facts* rather than their *representation* which should open or close a controversy (Gross and Levitt 1997). From a social constructivist perspective of controversies, however, truths are accepted, controversies are resolved, and knowledge is created not on its own through a logically rigorous scientific method but also by social factors (Collins and Pinch 1993: 144–45).[15] We may recall the Drexler versus Smalley debate on molecular machines to see how facts are inseparable from their representation and from the actors who speak on their behalf. Depending on the perspective, different actors may be the focus of an analyst's attention. The actors are typically government, corporations, and community (or activist) groups. Their conflicting claims may be inevitable as different individuals might have different rankings of importance for social (or rather

[14] For Foucault, it is governmentalised space, tactics, and strategies—not laws—which are what is important to observe in relations of power that produce/organise governed identities (Foucault 1975 [1977]). This issue, related with the organisation of nanotechnology, is tackled in the presented thesis; for instance, in a chapter studying the normative regimes of nanotechnology and where among the most attractive features of governmentality is (its) creativity (cf. Rose et al. 2006), or in a chapter on cartographic mapping as a key strategy of governmentality (cf. Harley 1989).

[15] Collins and Pinch (1993: 144-145) provide convincing evidence to show that 'scientists at the research front cannot settle their disagreements through better experimentation, more knowledge, more advanced theories, or clearer thinking'.

sociotechnical) factors.

We should, which cannot be repeated enough, stretch the focus to different definitions of actors which would provide new insight into the historical or structural composition of a controversy, but also more variable resource mobilisation. Non-human elements, such as scientific (public) reports, may elicit criticism and other reactions as well (e.g. the 2004 Royal Society report on nanotechnology in this thesis). Human actors (individual, group) are able to mobilise a range of resources, carrying scientific authority, political power, and public supporters, but also as various symbolic and belief systems (cf. Jenkins 1983). They set up via matters of concern, they expose alliances, and they also have the character of knowledge claims which *justify*, *accuse*, or *denounce*, simply changing the frame of situations (Chateauraynaud 2009: 42–43, also in Boltanski a Thevenot 2006). For all actors involved, controversies are 'tests' and they can be perceived as an organised narrative or series of 'episodes' or trials (cf. Cooren 2001: 182). Overall, controversies are valuable sites for carrying out research into all kinds of co-production regimes. Nonetheless, controversies are, exactly for these reasons, useful as an informal way of assessing technology, enabling social learning without immediately seeking consensus (Rip 1987). All aspects of the assessment—scientific, political, and social—are always interrelated. They should be considered together, and their relationship enframed as *multilayered controversy*.

Nanotechnology is a good example of the intertwinement of multiple layers of controversy. Whether the confrontations occur over the control of toxicity and the regulation of nanomaterials; over the implications of lab-on-a-chip technology, such as radio-frequency identification (RFID) used as a population surveillance method; or over molecular machines which can take over the world (the grey goo scenario), the implications of particular discoveries become controversial across the domains of science, policy, and the public. The 2009-10 National Debate on nanotechnology in France, for example, demonstrated that controversy can develop quickly at the local and national level, from local scientific groups and media organisations to political institutions and activism. Here, actions which had been following policy plans over the years—to improve the regional development of the institutions in Grenoble as well as the overall national standing of France in innovation—and regarded as accepted (local and national strategy) matters, were suddenly exposed and denounced (cf. Laurent 2010, Vernant 2014). Although experts were involved, it was still hard to determine or discount the implications through scientists alone; the communication setting, seemingly more a 'presentation of facts' rather than dialogue with stakeholders, also contributed (cf. Vinck et al. 2009, Guston 2010). We must, thus, readjust the positivist view of the controversy (as if resolved by facts and separated from social factors) as scholars have begun to notice there are obvious limitations to expert knowledge in resolving issues of public controversy (cf. Doubleday 2007, Laurent 2007). Any nanotechnology controversy has

also never been completely isolated in a sense that it has, sooner or later, become a reference to previous 'regulatory failures' (Grove-White et al. 2004, Sandler and Kay 2006, Bowman and Hodge 2009). Examples such as the outbreak of GMOs, asbestos, nuclear technology, and even debates over climate change have all been associated with nanotechnology in the context of opportunities (sustainability options) and threats (toxicity risks), and thus, formative of public policy and regulatory concerns. Using such a metaphorical transference (and analogical reasoning) of otherwise historically separated events may pinpoint the role of GMOs in the public backlash against nanotechnology. However, it redefines the roles of science, policy, and the public (reasons for their engagement) in nanoscience research and its development, application, commercialisation, and regulatory processes (Sandler and Kay 2006). Precisely, there is not only a problem of finding a common language for the debates but also questions in regard to the role of the previous experiences and the model arrangement of the communication platform for debating these issues.

Studying controversies should be an effort to reconstitute the symmetry of perspectives but not avoid the distinction/separation of the literal and figurative level of representation without strictly privileging one over the other. This results in shifting the status of scientific and lay knowledge to be alternative accounts. There is no justification for assigning the cognitive level to science and the social level to the public (cf. Engelhardt and Caplan 1987); all actors of a controversy use the figurative repertoire of conceptual tools.[16] Moreover, the cognitive and social level is a feature of each of the links between science, policy, and the public. Thus, the figurative model of controversy should allow for the integration of several aspects of development mechanics—especially, when there is overt controversy over a seemingly non-controversial topic. The role of media in the dynamic of controversies will be considered next.

1.2.5 Media Studies and Science Journalism: Platforms, Bridges, and Arenas

The development of controversy gives media a central role. The controversy within which scientists and media operate entails implicit criteria for information selection which deviates only superficially (not substantially) from power structures in particular media and policy contexts. After all, media is an interface where dominant ideas (or ideologies) and beliefs are constantly reproduced by relying on the information of those who define the dominant ideology (Hall et al. 1978). Media can amplify the perceived threat to the existing social order, and the authorities and courts then act to eliminate the threat. Similarly, Schudson (2003: 2) argues that by selecting, framing, and shaping the news, experts (and also journalists) create a reality to which the public responds. Claims made by certain actors, especially those who enjoy high-status positions in society, can be processed by

[16] The requirement to treat even the conflicting claims of all actors symmetrically or impartially is fundamental to the sociology of scientific knowledge (cf. Bloor 1976[1991], Barnes 1974[2008], Gilbert and Mulkay 1984[2003], Callon and Latour 1992, Latour 1996, among others) and which here extends to literal and figurative accounts.

media in a manner which allows them to become the 'primary definers' (Hall et al. 1978: 57). Media in the globalised world has an influence on what we consider important and in whom we trust (Katz and Lazarsfeld 1955, Giddens 1990).

Media is sometimes mobilised explicitly under a specific project to act as a *bridge* between scientists and the non-scientific public. *The Guardian* panel or the NanoJury on nanotechnology in the UK context, Vivagora in France, or Česko je Nano in the Czech context are historical examples of such mobilisations of influencers. Therefore, media is undoubtedly a place of scientific *legitimisation* which can be quite co-operative and peaceful, provided that, while scientists come to media to reach for higher symbolic status, credibility, or economic rewards, media align their own interests in selling their message to the audiences. In other words, media is effective not only in science and public communication but also in shaping scientific and technology policies aimed at defining and eliminating uncertainties and disagreements (Nisbet et al., 2003). And even though journalism is an important 'watchdog', holding others to account, it is also a 'scandal machine' which selects information and can inflate the importance of trivial accounts—it has a contradictory status (in Allern and Sikorski 2018: 1). This means media does not necessarily carry a positive regard for science—that is, media is not a protected space of science. Rather, it creates a space where arguments backfire and inspires the opposite reactions too (Toumey 2005). Toumey sees this relationship in the *figurative* level of controversy to be the case of a drama between good and evil, hope versus fear, or fairness versus unfairness (Ibid.). Similarly, Kearnes and Wynne (2007) interpret public ambivalence on nanotechnology as a nested set of enthusiasms and anxieties. These figurative accounts can be used to see the public in a different light in terms of having influence on alternating hype-disappointment cycles (Brown and Michael 2003, Geels and Smit 2000). Experts are also directly or indirectly involved in these 'hot' and 'cool' phases (Callon 1998). They correspond to the content of media *hype*, a media form often used in public debates as a kind of self-inflating media coverage (Vasterman 2005). The idea that controversies are, among other things, *hyperbole*-driven suggests metaphorical resources should be rethought, utilising their ambivalence as a creative resource rather than as *the* problem. Moreover, it gives the public a role that is not marginal.

Given such a wide array of discourse dynamics (and practices), media can no longer be conceptualised as a communication *platform* in which journalists generate news content related to technology by moving scientific advances onto its agenda. They also put forward reactions against technology development by involving rising voices from the public and other stakeholders. These can have different logics of action, can have different registers of language use (especially with regard to technical language), and can even come up with incompatible perspectives on issues (Hellsten 2002). Modern societies thus must cope not only with environmental risks but also with

risks inherent in communication (cf. Weingart et al. 2000). It is increasingly difficult, however, to discern who counts as an expert and what counts as valid expertise. In the case of the complex character of nanotechnology (different fields under one umbrella term), there is a danger that a journalist will become a caricature of the expert, and to revive popular quote: 'someone who knows less and less about more and more until he knows absolutely everything about nothing'.[17] If there is a notion of the need for a journalist who is well-qualified with solid subject specific as well as *transversal competencies*, that need is even more urgently translated into our society's need for a well-informed and qualified public. If we were to look at the number of journalists reporting on nano (as represented in the data for this thesis), we could conclude nanotechnology is crafted by a relatively small population of experts, but where public reactions to nanotechnology are the work of many that are unaware (cf. Eurobarometer 2010). We should then consider that nanotechnology discourse has a relatively large number of producers and an even larger number of audiences-receivers who, combined, give birth to a relatively new disciplinary rhetoric within which actors engage in the asymmetry described by power-knowledge relations. The media involves the voices of these participants, incorporating their agenda and frames, and leading to the balancing of positives and negatives, channelling the ambivalence and polarisation.

To summarise and connect with the previous sections, science, politics, and (mass) media are not only considered particular social fields but also cultural inscriptions of knowledge (van Dijck 1998). It is an area where knowledge is co-produced, expectations are becoming collective, and techno-critique emerges. This altogether gives nanotechnology development an organisational form which cannot be neglected especially if we consider the relationship between metaphor and nanotechnology. One of the challenges is to render very detailed, specific, and often jargon-laden information produced by scientists into a form which non-scientists can understand and appreciate. Media, which prepares content that informs about the benefits and risks of science and technology, is, according to Stephens (2005), related to a special field of expertise: *science journalism*. Scientists can become trained journalists, or conversely, journalists trained scientists, with a common mechanism to reformulate much of the scientific register into simplified words. If we return to our concept of hype, it is not only a set of hyperboles (Wullweber 2008) but fairy-tales, paranoid narratives, or crisis scenarios (Mordini 2007a) which also bridge these social fields. The figurative accounts play their part in popularising and dramatising issues, making them more engaging. Such practices can from the perspectives of metaphors be assumed as dynamic tools of communication, a condition for different groups to understand each other, support each other, and act in a certain way and be influenced, normalised, and contested.

[17] A saying that has since 1920's been assigned several authorships (among them Nicholas Murray Butler [1862-1947], the president of Columbia University) has also become one the Murphy's technology laws that applies to any pursuit of becoming an expert.

1.3 Nanotechnology Resources (Repertoire View)

When technologies are developed, not only does materiality change but so too does interpretative and design flexibility. Technology allows the physical world to be enhanced or modified, yet conversely, it also requires considerable resources which have both material and rhetorical (or material-semiotic) aspects. For example, research teams get together the moment they agree on a common vision of the future, not just when they gather material support. Their consensual approach to common objects cannot be limited to material settings (people, instruments, materials, institutions, etc.) but must include the way they develop (common) language and common narratives (Berker and Throndsen 2017) and establish complex 'trading zones' in both co-operative and coerced settings (cf. Collins et al. 2007, Gorman 2004). In other words, technology development can be characterised by a mobilisation of material and symbolic resources. The 'matrix for materiality' (in reference to Ihde and Selinger 2003) has, in this sense, a corresponding symbolic interface which roughly features cooperation and conflict, or put differently, it has a controversial dynamic with various interpretive (action) frames, narratives, and discourses.

If there were not many different resources, material or symbolic, would this not alter the dynamics within technology development? And would not technologies be irrelevant if they did not mobilise certain frames and narratives that resonate in (between) various discourses? As much as these enable us, considering the intelligibility and what is assumed relevant, they must have a privileged position as they carry functions over into various contexts. In line with this mechanism, I want to prepare the ground for arguing metaphors are relevant resources as well as a complementary dimension which reassembles these various levels. Considering various resources should thus prove useful in informing how metaphor can be processed further in theorising about technology development.

1.3.1 Material Resources and (or) Sociotechnical Imaginaries

Materiality must be considered since nanotechnology has always been about engineering a way of being in science—that is, the technological design of devices (Nordmann 2008: 218). At the same time, it is exactly nanotechnology which proves materiality of the nanoscale is no less accessible and determined than constructions of the mind. Because nanotechnology objects are material by design, in this sense 'mind controls the matter' (Bensaude-Vincent 2009: 96). In other words, materiality of the nanoscale is not given once and for all and we shouldn't understand it as a single regime of technoscience. An alternative to problematise status of materiality is within narratives. For Donna Haraway, understanding material objects is living inside stories, or also, 'objects are frozen stories' (Haraway with Goodeve 2000: 107). Even if we do not fully subscribe to this thesis,

it should alert us that materiality is no more clear than symbolic aspects.

Technology is a matter of state, military, and politics, or, a matter of concern. In *Do Artifacts Have Politics?* (1999), Langdon Winner argues technology development involves technical arrangements as well as social order from the outset; it is a profoundly cultural activity. That is, the invention, design, or arrangement of artefacts or the larger system becomes a mechanism for settling the affairs of a community. The idea that 'artefacts have politics'—the notion that technical things have political qualities and embody specific forms of power and authority (Winner 1999: 121)—is perhaps still provocative as it contextualises something we typically perceive as separated strands.[18] Technological determinism—the belief that technology shapes society rather than being a product of it—is a view that we should neither fall into but that should enable us to look at nanotechnology development from different angle. One way of thinking about this is to extrapolate what would happen if a specific technology, such as microscope, was removed. What would be the residual changes in society? Materiality plays a subtle and deep role in our ways of moving about in the world, inseparable from science as practice and culture (cf. Ihde and Selinger 2003).[19] It is sustained by a relatively stable structure and its segments, which include objects, situations, events, and experiences. The stability is relative, and retrospectively, we can even see it as an achievement (cf. Munshi et al. 2007, Mody 2012). This achievement can be described in terms of material resources, such as instruments, which set up networks, narratives, and discourses. Once one network of people (defined by their common connection to an organisation, a discipline, or an instrument) adopts some element of nanotechnology discourse, other nearby or connected networks emerge (Mody 2012: 165). For example, using a microscope spreads nanotechnology discourse to a variety of disciplines, microscopists are themselves positioned as interdisciplinary and inter-organisational mediators (Ibid., 166). This view corresponds especially to the post-phenomenological theories of technology which focus on the role of technological mediation: 'Instead of understanding technologies as formations of formal rules, we should aim to understand the way in which their materiality shapes our experiences of the world' (Ihde 2009). Technologies such as the scanning tunnelling microscope constitute 'embodied' experience in the sense that they make our objects of experience 'present in a specific way' (Verbeek 2005: 141).

However, this form of embodiment should not be separate but complementary to the form of embodiment experience incited by language and symbolic mediators (cf. the extreme form of

[18] Social sciences go so far as to argue that we should remove separation between *technical* (also material) and *political* (also social)—between 'social context or technical content' (Latour 1990: 116; or 'quasi-objects' in Serres 1987).

[19] The question of materiality is particularly sound in technoscience scholarly work which focuses at 'matrix of materiality' as something within or from which something else originates, develops, or takes form (Ihde and Selinger 2003: 9). This is inspirational and provocative in forcing us to rethink our notions of symbolic interfaces, in rendering thematically explicit how the *nonhumans* (atoms and molecules, for instance), who cannot speak for themselves, are embedded, which is to say, socially, politically, and culturally structured.

embodied experience in Lakoff and Johnson 1980 introduced in the next chapter)—something that post-phenomenological theories often neglect. For example, policymakers make us believe that the 'path' to nanotechnology has been characterised by growing commitment among a variety of organisations, disciplines, and instrumental communities and the design for this geographical symbolism is their own instruments: technology roadmaps (cf. Commission 2006 and 2010a). Not only proponents but also opponents do their best to mediate through symbolism and language while forcing various objects and meanings into a formation of categories and topology. Take for example the anti-nano movement in Grenoble (cf. Laurent 2010). The PMO activists, sometimes called neo-Luddites, launched slogans and leaflets into the debate on nanotechnology, images and imaginaries which are dispersed as certain objects, actively pursuing the categories of issues and their boundaries. This connects well with Sheilla Jasanoff's concept of the sociotechnical imaginary as a collectively held repertoire of narratives embedded in 'shared forms of life and social order' (Jasanoff 2015: 3) but also embodied in the instrument, such as a microscope, a solar power plant, or object, such as activist leaflet. Placing sociotechnical imaginaries into the category of material resources instead of symbolic could yet seem like a basic misunderstanding. Their independence from materiality is nevertheless relative. Sociotechnical imaginaries, such as explicit projects, are arguably becoming stable because they also integrate certain beliefs (images) implicitly as well as larger systems of language and thought. The imaginaries are, for Jasanoff, the 'active exercises of (state) power', for example, the allocation of funds, the suppression of dissent, investment in infrastructure (Jasanoff and Kim 2009). The sociotechnical imaginaries of emerging technologies can be abstracted from intentionality as they, like discourses, do not belong to anyone in particular. Sheila Jasanoff (2015: 29–31) writes, 'Discourse shares with imaginaries the properties of being collective and systemic (e.g., Hajer 1995), but it usually focuses on language and is less directly associated with action and performance or with materialisation through technology.'

One of the most important advances is to start relating to imaginaries not as mere illusions or fantasies, but rather to work with the concept as one would with a cultural resource, potentially used by social actors (with other supporting practices) to negotiate social order. Arjun Appadurai (1996), who follows the French philosophical tradition, argues imaginary (*imaginaire*) is a constructed landscape of collective aspirations, which is no more and no less real than the collective representations of Émile Durkheim (1912), now mediated through the complex prism of modern media (cf. Ezrahi 2012). It is argued that 'the imagination is now central to all forms of agency, is itself a social fact, and is the key component of the new global order' (Appadurai 1996: 31).[20] Imaginaries are a useful concept for studying interactions of science, technology, and the public

[20] 'The imagination has become an organised field of social practices, a form of work (both in the sense of labor and of culturally organised practice) and a form of negotiation between sites of agency ("individuals") and globally defined fields of possibility' (Appadurai 1996: 31).

within cross-cultural or national variations. For example, nations are imagined political communities (Anderson 1983) or imagined geographies (Said 1978), but so too are nanotechnology(-ies). They are 'collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects' (Jasanoff and Kim 2009: 120). Imaginaries always have technoscientific dimensions—technoscientific imaginaries are also simultaneously social imaginaries (Marcus 1995) whereas imagination is an organised field of social practices (Taylor 2004). Here also, the discourses and social practices (such as imagination) are dialectically related (cf. Harvey 1996, Fairclough 2001). The sociotechnical imaginaries which bring about some of the emerging materialities are, in this sense, characterised by a patterning of metaphorical expressions, narratives, and discursive formations. That is to say, they are different elements but not discrete or fully separate. There is a sense in which each internalises the others without being reducible to them.

1.3.2 Interpretation and Action Frames

Following the works of Goffman, we come to a notion of frames as a 'filtering process through which societal level values and principles of conduct are transformed and refocused so as to apply to the situation at hand' (Gumperz 2001: 217). Frames function to organise experience and guide action by enabling individuals 'to locate, perceive, identify, and label a seemingly infinite number of concrete occurrences defined in its terms' (Goffman 1974: 21). Frames have an action-oriented face that orient individuals. Goffman further suggests that frames imply a correspondence or isomorphism between the individual's perception and the organisation (1974: 26). Moreover, they are culturally determined, familiar activities which are independent of any single individual: 'Frames are a central part of a culture and are institutionalised in various ways.' (Goffman 1974, 1981: 63). Although interpretations, attitudes, and actions likely result from a variety of factors, there has been an increased interest in media frames (as type of frames) regarding emerging technologies.

Nisbet and Huge (2006), who studied the media discourse of biotechnology and stem cell research, found frames focusing on new research and novel discoveries dominated early coverage. However, as media attention increased, policy frames and frames highlighting the ethical and moral components of these issues were more likely to occur. Other studies of emerging technologies, such as nanotechnology, suggest strategy and conflict frames were most common when news media coverage reached its peak (cf. Cacciatore et al. 2012: 3). Importantly, shifting between frames might be a more long-term feature of the media, giving greater weight to a particular moment of controversy. Frames are thus an integral part of the 'issue-attention cycle' in the sense of a cyclical pattern (Brossard et al. 2004, Shih et al. 2008, Cacciatore et al. 2012) and which may require a longer timespan to study them effectively.

In particular, frames are used as a theoretical concept in social science research to study the mobilisation of social movements and organisations (cf. framing theory in Entman 1993, orders of worth in Boltanski and Thevenot 2006, or collective frames in Lakoff and Ferguson 2006). According to Norman Fairclough, frames are internalised assumptions and expectations, part of the interpretations of 'members resources' (Fairclough 1989: 78). By these resources, Fairclough means schemes, frameworks, and scripts, internalised representations of particular activities ('activity type') or models of social behaviour (Fairclough 1989: 158). One of the important transformative functions of frames is the interpretive work of they perform via focusing and the articulation of functions which, for example, activate adherents, transform bystanders into supporters, exact concessions from targets, demobilise antagonists, and problematise and challenge authoritative views (Snow and Soule 2011: 385, see also the argument on narratives in Cooren 2001: 188, following Greimas schema in this thesis).[21] Metaphorical frames fall into this scheme and the sociological framework because they are not only cognitive but also collective.

This distinct sociological version of framing is useful in explaining how the making of meaning exhibits regularity, despite Turner's (2001: 145) argument that frames have proved 'nearly useless for explaining how a new schema can arise before it is manifest in our regular experience'. In other words, uncovering how particular contexts for interaction are established is not the same as uncovering how frames are established as such. The metaphor mechanism, especially the creation of novel metaphors, as I want to argue, may bring more clarity to such a transformation. Frameworks are formed as well as formative representations of anything which might *figure* as a topic, for example, a subject, thing, process, or abstract concept. A frame has a subjective context which can be represented as an assembly of items joined together. *Metaphorical frames* are then relationships of entities which connect with or bridge categories of understanding. This resembles concepts of metaphorical frames as systematic cross-categorical comparisons which reduce uncertainty and support further inferences (cf. Lakoff 1993). It is also another reason why the analysis of frames should take interest in metaphors as specific entities or groups of entities.

In the case of nanotechnology, an important communicative function of frames has been pointed out in the contextualisation of quite abstract issues by offering patterns of interpretation through influence of authority figures, stories, and pre-existing attitudes (Priest and Greenhalgh 2012). For example, genetically modified foods have often been problematised through use of the label 'Frankenfoods' (Nerlich et al. 2000). In techno-critique discourse, the story of nanotechnology sometimes has the following interpretative framework: The mad scientist creates a Frankenstein-

[21] 'If one decides that an actor is the hero of the story, then she, he, or it becomes the subject and her, his, or its main opponent becomes the antisubject. The tension created by these two opposing desires provides, a priori, the frame to the story. As we will see, everything that happened after can be included narratively in these two schemas' (Cooren 2001: 188).

like monster which can no longer be restrained, thus unleashing an uncontrollable menace upon society. Without getting ahead of the analysis and results presented in this thesis, this metaphorical frame shows interesting complexity. We may find various interpretations of the 'mad scientist' are presented around a particular issue of relevance (a recent discovery, for example), and these frames sometimes also combine into unprecedented effects. A specific type of situation becomes the presence of ambiguity—in other words, when two or more contrasting frames are integrated under a single media frame of *reporting objectively*. This also allows media to transit from the initial position of a 'watchdog' to an *arbiter* role. In this sense, media frames act as organising storylines for news issues, suggesting to audiences what is relevant about an issue and what can be ignored (cf. Nisbet and Huge 2006: 3).

Altogether, nanotechnology development can be studied as a maintenance and contestation of multiple frames, not only limited to the lobbying activities of strategic actors but also corresponding to journalistic needs or reflecting the meta-level composition across various policy and sociocultural environments. In any given text, media, or discourse, the pattern of media coverage can be critically examined from a perspective more nuanced than just the balancing of positive and negative. The pattern as well as the content can likely differ in science, policy, or various national media offering interesting comparative lines. However, the idea that frames can be derived through metaphor analysis and that these can be related to attitudes and actions (i.e. action frames) still remains to be established.

1.3.3 Narratives (and Networks), Success Stories, and Crisis Scenarios

Narratives are an integral part of frames and are resources of the various policies, state regulations (also laws), industrial strategies, or activists' interests. An agentic perspective allows the narrative to be grasped in a sense that people use stories to create, convince, or counter others and their collective agendas. Narratives are related to the expectations and negotiations of various actors, individual or collective. Through 'rival stories' people create, organise, and sustain coalitions during social controversies (Fisher 1984: 14). In *Governing Molecules. The Discursive Politics of Genetic Engineering in Europe and the United States* (1998), Herbert Gottweis emphasises the crucial role that narratives constructed around molecular genetics and biotechnology play in the processes of policymaking and the emergence of actors and institutions. For example, a new 'high technology' industry has become part of a policy myth and an expression of identity politics (Gottweis 1998, see also Jasanoff 2005). As a form of legitimation, stories and narratives are a means of stratifying values and identities throughout organisations (cf. Czarniawska 1997, or Cooren 2001). Narratives may still have analytical bias as they can force reality into a very rough and temporally determinate blueprint of a controversy which may yet never find ending (closure)—such as the case of nuclear technology, GMOs, artificial intelligence, etc. Actors such as social

movements—industry, science, and the public can also be considered additional actors—can always enter a discursive field to produce and maintain counter-narratives or even (de)stabilise discourses.

Technology development should thus be examined as the maintenance of frameworks which extend to outcomes of competing narratives. Multiple stories are, in fact, at the heart of the analysis of controversies as the plurality of accounts (stories) has been the starting point for studying nanotechnology origins, policies, and public perceptions (cf. Milburn 2002, Fogelberg and Glimell 2003, López 2004, Macnaghten et al. 2005, Kaiser 2006, Kurzweil 2006, Mordini 2007a, Toumey 2005 and 2008, Rip 2012, among others). There are many stories of nanotechnology successes and cover stories, histories and tragedies, but also techno-myths, science fictions, and fairy tales (cf. a comprehensive overview in Mordini 2007a: 19–20). More fundamentally, nanotechnology is permeated by narratives through and through to the extent that *time* and *space* become an intelligible experience as they are when articulated in a narrative way (cf. Ricoeur 1985: 94). What should not escape our attention is not only the *infinitely small* (nanometre) nanoscale, or retrospective establishment of the origins of technology, but the nature of the debates about places in the future and the possible risks and benefits of nanotechnology. The presence of narratives suggests strong sociocultural (including the sociopolitical) dimension of nanotechnology, from the founding myths of institutions in Grenoble (France), for example, to the Frankenstein myth or warnings of a nearing Malthusian catastrophe, which for some experts nanotechnology can resolve. Another example, Michael Crichton's novel *Prey* (2002), which in succession with other events led to the release of the Royal Society and Royal Academy of Engineering's report on nanotechnology (2004), gives relevance to fiction which provided a rationale for further actions. Being representations of issues, providing historical continuity, and evincing the coherence of various accounts, narratives have here, just like frames, an action-oriented face.

According to François Cooren (2001), however, the challenge does not consist of analysing narratives as resources but operationalising the idea that any organisational form (including controversies) is ultimately structured as a narrative. Controversies themselves are organisational activities which can be understood retrospectively as a meta-narrative.[22] Cooren's approach is largely based on Greimas's semio-narrative theory (Greimas 1976) which views narrative as a structure found at any level of controversy analysis, from the tiniest episodes to the largest systems of coalitions: 'Our own concern . . . has been to extend as much as possible the area of application of the analysis of narrative . . . a fundamental semantics and grammar' (Greimas 1976: 63). In his study of the Great Whale River controversy (2001), Cooren uses Greimas's model of very precise

[22] The *meta-narrative* here does not strictly mean a form of reliance on some universal truth (as in Lyotard 1979), or not as such. The term is used to describe *translation* (or carrying over), referring to an operation that consists of *standing for something else* which amounts to (a) 'inserting someone or something into a given narrative schema' (Cooren 2001: 184), or (b) a metaphorisation of actors, events, and places, which will be further used in my analysis.

terminology to analyse the organisation of different narrative episodes (events), objectives, and trials (quests) and their multiple actors (actants) into what he calls narrative schemas. The basic assumption underlying the study of controversy through this model is that the narrative has a polemic or agonistic dimension. Moreover, the structure of the narrative shifts to multi-level as each actor is a main character in the story in some regard. Like the narrative, the sub- or anti-narratives have their own organisation and can be analysed accordingly (cf. Cooren 2000: 64). Similar to STS scholars such as Ghimn and Shields (2014), Cooren also noticed there is a particular use of Greimas's model for studying science controversies as the transition of equilibrium from conflict to consensus. In line with the Greimasian schema, the nanotechnology controversy passes through *conflict* (between helper and opponent) and *consensus* (between sender and receiver). Cooren finds coalitions organised by different competence phases (Greimas's vocabulary)—narrative subschemas—which consist of getting as many helpers as possible while eliminating, avoiding, or sometimes transforming into helpers as many opponents and obstacles as possible in order to complete the main objective (Cooren 2001: 183–84). Cooren's perspective is useful as it allows the study of any segment of the nanotechnology discourse and finds fragments of stories told about actors, heroes who pass a series of trials and (or) accomplish great deeds, or just small stories about actors realising something (cf. Rip 2012: 160). We may understand these as emplotments in different narrative phases, key moments stretched between opening and closure, corresponding to a narrative which has a beginning and an end. In other words, scientific controversies have sequences in narrative time as passages from equilibrium through disequilibrium to re-establishing equilibrium (Cooren 2000: 71–74). Disequilibrium is created by labelling a situation as a problem, a matter of concern; by identifying victims; designating causes; and predicting an apocalyptic or promising future. On the other hand, re-establishing equilibrium involves labelling solutions, identifying their consequences and beneficiaries, coupling solutions with problems to resolve, and integrating them in a broad complex of public policy and a referential framework (cf. Zittoun 2014, Cooren 2000: 71–74, also Boltanski et al. 1984). This approach allows the transformation of success stories and crisis scenarios into a more complex overview of a controversy. It can be used to shift our attention to the 'narrativity' of nanotechnology, here included of the normative regimes (such as Moore's law, for instance).

To conclude this excursion into the narrative dimension, narratives in this thesis are worked with in a double sense. My investigations concern interpretations and narratives *about* nanotechnology as resources which are part of a collective repertoire of actors and organisations. Nonetheless, I do not merely want to ask how different interpretations and ontological narratives about nanotechnology emerge. By looking at the composition of controversies from a more structuralist perspective, we can enrich our understanding of how the technology controversy itself

in turn becomes narrative—in other words, the narrative *of* nanotechnology. The first form of narrative is told by participants, while the second form of narrative is constructed through the researcher's method—the 'storying of stories' (cf. ontological and epistemological narrative in McCormack 2004). The metaphorical model of Greimas (and adapted by Cooren) will be at the forefront of improving the understanding of the various dimensions of nanotechnology discourse.

1.3.4 Inter-discursivity and Meta-pragmatic Discourse

Discourse represents 'a specific ensemble of ideas, concepts, and categorisations that are reproduced, and transformed in a particular set of social practices and through which meaning is given to physical and social realities' (Hajer 1995: 44). Discourses are neither objects nor closed systems or social structures and placing them into resources might seem a basic misunderstanding of their relative autonomy from subjects and their 'discursive constitution' in the Foucauldian sense (cf. 'docile bodies' in Foucault 1975 [1995]: 138). Still, discourses exist as ordering attempts only through subjects and their articulation; discourses cannot be seen as separated from action (Sedlačko and Staroňová 2015). Discourses, together with material arrangements, help to construct and renegotiate the somewhat durable realities which make particular actions more sensible or probable than others (Ibid.). This outlines the important reason why discourse appears in the setting of resources.

As Fairclough (1992: 102, or 1993: 137) contends, discourses spread across texts and are inherently intertextual. By that he means that texts are constituted elements of other texts. Each text contains an articulation of multiple texts and voices. They are also inter-discursive, articulating different discourses and genres (Phillips and Jorgensen 2002: 73). Texts indicate social practice and institutional settings, including, for example, the establishment of public debates on nanotechnology (actions), the publication of news about nanotechnology, demonstrations, political meetings, and the like. These are discourse practices concerning the distribution, marginalisation, and even the establishment of the sociotechnical imagination, for instance, maintaining and formatting a specific image of public debates and grand technoscientific projects. Every so often, proponents of nanotechnology construe the (imaginary) public as irrational and fearful, and the more active public can also advance images of a scientist with an unending will to change the world for better or for worse (as in previous reference to 'mad scientist'). In short, whereas technology development is bound to the most subtle sociotechnical imagination, it also becomes the structure of a discursive formation. Nanotechnology discourse, in this sense, includes imaginaries of various objects, events, and the projects of various actors that constitute controversies. However, nanotechnology controversies are not bound to any particular discourse, or not as such. Instead, the identity (what *is*) nanotechnology here depends on larger units of discourse than words/phrases and narratives, as well as interaction between various discourses.

For example, *nanotechnology discourse* interacts with *policy discourse*; their relationship is not strictly a subordination of one over the other. Instead, both contain arguments on *assessing risks* and *responsible research and innovation* (cf. Commission 2004). Other scholars have also noticed that interdiscursivity is an important feature since the driving factor behind public attitudes are various forms of heuristics or cognitive shortcuts which audiences use to make sense of technology, especially in the absence of information (cf. Scheufele and Lewenstein 2005, Scheufele 2006, Brossard and Nisbet 2007). Chris Toumey, in particular, has dedicated a large interest in the interdiscursivity of nanotechnology regarding *national discourse* on democratising nanotechnology (Toumey 2006) and *religious discourse* regarding critical reactions to nanotechnology (Toumey 2011). In the latter study, he argues that engaging religious audiences on nanotechnology can be a complex issue and fills the gaps when the public lacks any particular knowledge or vocabulary. Thus, *public discourse* interacts with that of science and policy (Toumey 2011: 251–52). Interdiscursivity may also be responsible for difficulties in assessing technology based on various shifts in risk perception and divergence, including discourses related to various disciplines such as nanomedicine, nanoelectronics, among others, which influence the perception level of various 'health, environmental, [and] societal' concerns that nanotechnology might represent (Priest et al. 2010). Conflicting perceptions may arise if nanotechnology promotes a healthy environment or leads to the conduct of detrimental activities. Therefore, interdiscursivity may pose a problem to *translate/transform* information to various audiences, use resources for effective transference between various experiences (such as GMOs, climate change, asbestos), and so forth.

The role of metaphors, as I will show in the next chapter, is indispensable in such a discourse dynamic. As Ricoeur (1975) would have it, a metaphor is the inner fabric of discourse, yet this extends in a particularly important function. Metaphors are intra-discursive and inter-discursive tools (Bono 1990: 71–72). They display interdiscursivity precisely because 'their different input spaces are linked to different discourses' (Koller 2004: 19). In other words, they have the capacity to translate and relate various discourse (such as between GMOs and nano). Therefore, they have the potential to open a way to the strategies of relating and translating discourses where there was previously relative autonomy. Metaphors (and narratives) here serve to make an equivalence of sense between images (and stories), functioning metasemantically and metapragmatically. This is an important feature in a pragmatic of discourse which allows the concept of intertextuality and interdiscursivity to be expanded into tracking the systematic metaphors and their capacities but also larger formations of discourse.

Part II Metaphor in Discourse

Chapter 2. Theories of Metaphor

… eu metaphérein
[to metaphorise well]
Aristotle, in *Poetics* (1459a)

3.1 What metaphor is and what it does (Introduction)

Most people have some understanding of what a metaphor is. Many have encountered them in literature and poetry, and most of us also know that, even when we talk casually, we may take advantage of figurative language, perhaps especially when there is some evasive, hard-to-grasp emotion or thought which we want to communicate (Johansen 2007: 11). Since Aristotle, the metaphor has been perceived as a human capacity, and contemporary theories that build on philosophy of language and studies of rhetoric advance the idea of identifiable metaphorical structure (cf. Richards 1936, Black 1962, Ortony 1979, Eco 1984). Metaphor is a universal human faculty and as such it provides the opportunity for systematic analysis of everyday language to highly specialised scientific fields (e.g. in scientific modelling in Black 1962, Hesse 1966, Kuhn 1979, Gentner and Jeziorski 1993, Brown 2003; or political discourse in Chilton and Ilyin 1993, Chilton and Schäffner 2002, Hellsten 2002, Charteris-Black 2004, Semino 2008).

Metaphor theories hold in common the general definition of metaphor as *expressing something in terms of something else*, for example, life in terms of a journey. Things get complicated, however, as we acknowledge metaphor as a phenomenon of language *and* thought (Black 1962). While most scholars agree that metaphor has some cognitive import, there is much disagreement about the nature of that import and how it is generated. In such a hypothetical situation we can go even further, to another extreme of uncertainty. There is no 'correct' understanding of metaphors outside context. That means metaphor, especially the creative or novel metaphor, is a product of the author's, the writer's, or the poet's imagination at work; they invented it with or without a description of incidents or episodes; and they conjured it up with stories and within a particular discourse. And the opposite view also comes to be true. It is also the reader who brings the metaphor to life, supplying its characters and stories. This is not as much an act of

improvisation but re-figuration (cf. Ricoeur 1975: 114-115, or 'mimesis' concept in his later volumes of *Time and Narrative*). Because of the nature of this standpoint, it is inevitable that some conflict of thinking around metaphor exists, especially concerning its limitations as a research method. This is notably influenced by the epistemological tensions between realism and relativism, positivism and social constructivism, and particularly in conceptions of the relationship between language and reality.

My objective, however, is not to revise different philosophical traditions. Instead, my intention is to extend the debate over metaphor from what metaphor *is* to what metaphor *does*. Metaphor is delineated as an element of language and thought, with an identifiable structure, a context-dependent *event* in the discourse dynamic, which is invaluable for studying the active influence of metaphors on our perceptions and attitudes but also our potential (in)actions. I explore the distinction between linguistic utterances (textual and image representations) and the conceptual level of metaphor. The position of conceptual and systematic metaphors in networks and narratives has a practical use for metaphor analysis as metaphor can be associated with the formation of discourse. It is argued that by considering various levels of metaphor and more broad dynamics of translation, we can observe how it is positioned at different interfaces and how it circulates between science, policy, and the public. This chapter thus points out the role of metaphor in the complex pragmatics of transformation which aims to bring together perspectives of agents as well as a grander vision of discourse dynamics.

2.1 Classical and Contemporary Theories of Metaphor (after Aristotle)

The generally accepted definition of metaphor, straightforwardly put as discussing something in terms of something else, dates back to the philosophical tradition of Aristotle. In *Poetics*, Aristotle introduces a metaphor which means 'carry(-ing) over' (*meta-pherein* in Greek). To master metaphor (to be metaphorical [*metaphorikon enai*]), is to metaphorise well (*eu metapherein*), which is to see or perceive resemblances by observing sameness (*to homoion theôrein*) in dissimilars (ref. from Ricoeur 1975: 33, in *Poetics*, 1459 a3–8, and *Rhetoric* 1412 a10). [23] A little may have remained from Aristotle's *classical* metaphor theory. As Umberto Eco notes though: 'of the thousands and thousands of pages written about metaphor, few add anything of substance to the first two or three fundamental concepts stated by Aristotle' (Eco 1984: 88). These fundamental concepts of classical theory are as follows: (1) metaphor is a trope, that is, a figure of speech to be found on

[23] Paul Ricoeur, who dedicates the first chapter of his *The Rule of Metaphor (La métaphore vive*) to Aristotle (1975: 13-61), draws attention to the paradox that Aristotle defines a metaphor by means of another metaphor, namely metaphors of transference. At the same time, Ricoeur's own perspective becomes part of this paradox when the metaphor is described in terms of vision: 'seeing as'. The paradox is quite common among other authors (cf. 'resonance' in Black 1962).

the level of single words (*lexis*); (2) metaphor is the transposition of meaning from one word to another; (3) metaphor is a deviant and thereby an improper use of words; and (4) metaphor simply replaces some equivalent literal expression and has thus just an ornamental function in discourse. In *contemporary* theories of metaphor, however, we notice various shifts, even contradictions: (1) metaphor is not a lexical but a discursive phenomenon, and it relies on co-text and context necessary to accompany metaphor identification and interpretation; (2) metaphor is a phenomenon of words and thought—it has a processual character; (3) the general metaphoricity of language is against the postulate of the improper use of words; and (4) metaphor is no longer a decorative ornament which can be substituted by a literal expression and is said to have a proper cognitive function in language (comparison reprised from Buss and Jost 2003: 2). The latest contribution is the social theory of metaphor. And even though it is generally accepted that metaphor has an action-oriented face, there is an epistemological tension between either revealing existing similarities or, conversely, creating them (cf. Indurkhya, 1992: 1–5, also the 'politics of metaphor' in Hellsten 2002: 16). In this sense, the social theory of metaphor emerges in a pragmatic setting aimed at author-versus-reader initiated strategies of communication and action.

The most sound questioning of the metaphor after Aristotle has historically targeted the basic assumption of its cognitive import. American philosopher Donald H. Davidson, in 'What Metaphors Mean' (1978) argues:

> [Metaphor is] the dreamwork of language and, like all dreamwork, its interpretation reflects as much on the interpreter as on the originator. The interpretation of dreams requires collaboration between a dreamer and a waker, even if they be the same person; and the act of interpretation is itself a work of the imagination. So too understanding a metaphor is as much a creative endeavour as making a metaphor, and as little guided by rules. (Davidson 1978: 31)

Davidson has raised several points which go against cognitive (also semantic) theories of metaphor, arguing: (1) metaphors, or metaphorical expressions, do not say anything beyond the literal meanings of their words, nor do metaphor makers say anything beyond the literal meanings of the words they use; (2) metaphors do not have a special, second, or figurative meaning; (3) metaphors do not convey ideas or have cognitive content (beyond that expressed by the literal meanings of the words used); and (4) there are no rules for making or interpreting metaphors.[24] This

[24] Similarly, in his overview 'Metaphor in the Philosophical Tradition' (1981), Mark Johnson interprets Thomas Hobbes's theory as the expression of a 'literal-truth paradigm', which is built on three assumptions, namely (1) that 'the human conceptual system is essentially literal'; (2) that metaphor is 'a deviant use of words in other than their proper senses, which accounts for its tendency to confuse and to deceive'; and (3) that 'the meaning and truth claims of metaphor (if there are any) are just those of literal paraphrase' (1981: 12). Philosopher Thomas Hobbes advocated

perspective becomes probably the most frustrating for metaphor methodologists, literary critics, and especially psychoanalysts when we consider they are working with metaphors as a part of the therapeutic discourse while searching for truth values in metaphors, for example, in those extracted from dreams. Here, even emotion-related vocabulary makes metaphor part of a larger group of emotional terms than simple words like anger, fear, love, and joy (cf. Kövecses 2000: 20–22). Where Davidson argues that metaphors have no cognitive content whatsoever beyond that of their literal meanings, he means to say that there is nothing beyond their literal meanings 'that the interpreter must grasp if he is to get the message' (Davidson 1978: 448). If there ever was a special metaphorical meaning, this meaning should disappear when the metaphor dies and becomes merely a literal language (Ibid., 447). This goes against authors who touch upon cognitive theory, such as Black (1962), Lakoff and Johnson (1980), and Paul Ricoeur (1975), and the distinction between novel and dead (sedimented) metaphors. After all, Ricoeur's now classical work, *The Rule of Metaphor* (1977; *La métaphore vive* [1975]), argues that the novelty of metaphor is the very life force of language which renews itself upon it. Davidson also turns against another distinction—the difference between a simile and a metaphor—arguing that all similes are trivially true because anything is *like* anything else in infinitely many respects, whereas most metaphors are patently false, because, for example, no person *is* a pig, or wolf, or an island, or a sun (Ibid., 445). There is no such thing as special simile meaning; consequently, Davidson concludes, there is no such thing as special metaphorical meaning. The failure of paraphrasing metaphor arguably proves there is no meanings beyond the merely literal (Davidson 1978: 253–55, also in Miller 1979). Davidson's position is more in line with the positivist substitution view stuck on the problem of interpreting metaphor and even finding a right non-metaphorical paraphrase. Finding a correct non-metaphorical paraphrase is yet a cornerstone of theories which aim to overcome the issue by reference to metaphor as a system of associations (Max Black), conceptual domains (George Lakoff and Mark Johnson), or image-schema of 'seeing as' (Paul Ricoeur).

The idea of non-literal discourse also appears in the philosophy of Friedrich Nietzsche, who once wrote: 'Those who would like to seem profound to the crowd strive for obscurity. For the crowd believes that if it cannot see to the bottom of something it must be profound' (Nietzsche 1882, Section 173, also in Williams 2001: 136). What if reality is fundamentally unclear? What if access to truth was not paved by the literal? For Nietzsche, the truth is a combat-decorated veteran in what he calls the 'mobile army of metaphors, metonymies and anthropomorphisms' which we use of to make sense of the world (cf. Erskine and Lebow 2012). The philosophy of language of

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excluding metaphors from rational discourse because they 'openly profess deceit' (1651 [2008], chapter 8), while John Locke (1690 [1998] Book 3, chapter 10) claimed that figurative language serves only 'to insinuate wrong ideas, move the passions, and thereby mislead the judgment; and so indeed are perfect cheats'. Later, logical positivists like Carnap and Hempel assumed that metaphors involve category mistakes; they have no real meaning or verification conditions for rational discourse.

Donald Davidson thus contrasts in claiming metaphors 'mean what the words, in their most literal interpretation, mean, and nothing more' (Davidson 1978: 32), where it is a fallacy of the analyst to interpret them as they would mean more and have more than just a literal meaning. Davidson's theory of 'no separate meaning' may have missed the mark, yet Nietzsche, with an 'everything is metaphor' seems to go too far. The social theories of metaphor incline towards the second position, where it is argued the literal language is seemingly unfit for articulating experience or that our literal language cannot give us truths (or all the truth). This is particularly sound criticism if we consider the nanoworld at the nanoscale as well as the future as an ever-escaping objective reality. The examples from nanoscience are numerous as there are expectations from nanotechnology which exceed our wildest dreams. My intention is not to go against these oppositions or argue for reference, but to follow re-figurations (cf. Ricoeur 1988) as alterations of our experience and which not only have influence on the public debate over nanotechnology but also its development.

2.1.1 Interaction Theory and the Grammar of Metaphor (Black)

In *Models and Metaphors* (1962), Max Black gave the first systematic treatment of metaphor within analytic philosophy which extended beyond the earlier claims of positivists that metaphor could (and should) be dismissed from investigations as an obtrusive or unimportant ornamental feature of natural languages.[25] Metaphor here is not a mere ornament with a literal equivalent in language, but it is treated as irreducible to literal explanation. Black begins by defining metaphor as 'a sentence or another expression in which some words are used metaphorically while the remainder are used non-metaphorically . . . [it] creates similarity and acts as a filter through which something is viewed (Black 1962: 27). The phenomenon is hinging on a word while simultaneously being dependent on the whole sentence. Advancing from the studies of rhetoric by Ivor A. Richards (1936), Black introduces the terms *focus* and *frame* in order to name the metaphorical word in a sentence and the rest of the sentence, respectively (Black 1955: 276). Metaphor is the whole of these parts all together and dependent on the interaction between the two parts. Based on this view, he speaks of an *interaction theory* and a *grammar* of metaphor.

The grammar of metaphor should ideally allow us to assess how to ascertain that metaphor occurred and to provide opportunities for the analysis in a larger system of language. The metaphor resonates more in a degree of metaphoricity when there are more connections across domains belonging to metaphorical parts (Black 1979: 27–28). To explain the concept with the help of the language of physics, Black introduces *resonance* as a response in a viewer, hearer, or reader of the metaphor: It is when two things are linked in some way or somehow touching, and then one taps,

[25] 'Analytic philosophers operate under the principle that "whereof one can speak only metaphorically, thereof one ought not to speak at all' (Black 1962: 25). Especially the philosophers of logical positivism and empiricism assume metaphor should be banned from science to secure objectivity in scientific theories and explanations (cf. Carnap 1959, Hempel 1965).

vibrates, or oscillates and the other responds at that same frequency. To approximate the concept to Ricoeur's perspective here, resonance is forced as much as it becomes the force (see 'living metaphor' in Ricoeur). It is not a mere word which resonates with one another but a 'an interaction between two "systems", grounded in analogies of structure (partly created, partly discovered)' (Black 1979: 39, also in Figure 2.2).

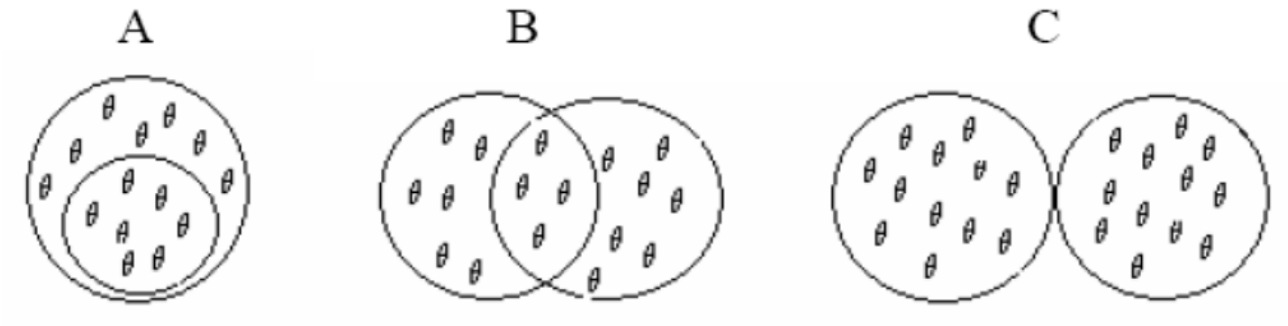


Figure 2.2 Semantic domains and resonance (adapted from Moreno 2004: 308).

For example, associations with nanotechnology can be represented by emphasis, such as 'nanotechnology is a disruptive technology', or metaphorically, such as 'nano is (the next) GMO'; the latter case is based on the resonance evoked between the two previously (temporally/chronologically) separate cases of technology controversies. Yet, the association does not stem from the words alone but their semantic domains (above images). The metaphor is not simple *emphasis* (A), but a resonance between previously separated domains (C). For example, both nano and GMO can be associated with a risk through emphasis (A), but nano and GMO resonates metaphorically (B or C) as they share association depending on contextual meaning. In our case, a nano is GMO. Under contextual conditions of public debate about the future of nanomaterials, for instance, these two elements can resonate. Black (1979: 26) assumes resonance requires the receiver's (reader's) cooperation in perceiving what lies *behind* the words used whereas interpretative response will depend upon the complexity and power of the metaphor. In our case, the small dots in Figure 2.2 might be considered as complexity that lies behind resonances and is effectively put to work through discourse: nano is the domain of atomic substances, nanoengineers, opportunities, and risks; GMO is the domain of living substances, bioengineers, opportunities, and risks. This perspective is useful in discussing how metaphor capacities involve creation of the protected spaces or notion of ambiguity concealed in metaphors (discussed later in this thesis).

In order to fully grasp the grammar of metaphor, Black places a distinction between metaphor, analogy, and simile. Concerning metaphor and analogy, he creates a conception which postulates an interaction between two systems grounded in analogies of structure—partly created, partly discovered (Black 1979: 39). The analogy has qualities similar to a model of reality with somewhat controlled correspondences. Yet for metaphor, there is no infallible test for resolving its

ambiguity, a necessary by-product of its suggestiveness. Analogical reasoning, however, is still part of metaphor. Additionally, the true-false values are not direct criteria for metaphorical statements. For example, the metaphorical utterance, 'nano is *not* a GMO', is as metaphorical as the opposite (or positive) statement. The falsity/truth of a literal reading of metaphor thus cannot be the criteria for assessing that a metaphor has occurred. Analogy, such as the globe model of Earth or the planetary (Rutherford's) model of the atom on the other hand, is accessible to such direct criteria that it also exhausts its usefulness. What simile makes explicit, metaphor states implicitly. By claiming 'nano is *like* a GMO' (simile) in terms of dangers, toxicity, or public backlash, we not only give up on the above criteria but also give up on some of the metaphor's open suggestiveness, characteristic of poetry (poiesis). In other words, a 'good' metaphor possesses significant cognitive content reaching beyond even the best literal paraphrase, which 'inevitably says too much—and with the wrong emphasis' (Black 1962: 46). Compared to analogy and simile, a 'metaphorical statement is not a substitute for a formal comparison or any other kind of literal statement, but has its own distinctive capacities and achievements' (Black 1962: 37). The claim about metaphor's own distinctive capacities and achievements is a challenging hypothesis for social science studies of metaphor (cf. Nerlich 2003). The concept of a capacity is still relatively vague in metaphor theory however, and Black is widely appreciated by methodologists.

Interaction theory (and the grammar of metaphor) seems to offer the researcher stable ground for treating any particular case of metaphor, textual or pictorial, yet it has many important methodological requirements and consequences. It relies on pre-requisites for identification and interpretation, and it also means metaphor cannot be explained exhaustively in plain (literal) language. Any effort to explain metaphor exhaustively has to deal with interpretative ambiguity. What elements of a 'system of associated common-places' come into play is also dependent on the various predispositions of the reader, depending on which community of speakers they are a member. Black sees the importance of cultural knowledge for interpreting metaphor. And while the role of context is emphasised, he suggests understanding metaphor use through ad hoc 'associated commonplaces' (Black 1962: 43). This is an important but often overlooked aspect of Black's theory. The associated commonplaces must be taken into consideration as both, reader- and author-initiated strategies. And there is an important consequence. Metaphor evinces a certain degree of pragmatism. In my view, associated commonplaces—represented as concepts in conceptual metaphor theory (CMT)—conflate what is potentially a resource as well as an invocation of desired or protected spaces. The social theory of metaphor should then shift between a sphere of interpretation (associated commonplaces) to a range of actions (their isomorphisms). Black's theory offers more than vocabulary from which coherent (action) frames can be identified. Frame analysis is a rather micro-analytical method, even though frames would always be part of a discourse.

Understanding metaphor use requires a macro-analytical level.

2.1.2 Hermeneutic Theory and 'Living' Metaphor (Ricoeur)

For Paul Ricoeur, the figurative language consists of 'seeing as', where any idea can be freely presented under the image ('gestalt') of seeing as another. Ricoeur, like rhetoricians, sees in metaphor a figurative presentation which is animated and treated in the same context as brevity, surprise, concealment, enigma, antithesis. Like all these processes, the trait of mind is at the service of the same end: to persuade the listener/reader (Ricoeur 1975: 50–51).[26] This also gives the metaphor a global vision. A metaphor is a rhetorical device; however, that is not its only feature. Metaphor is not exclusively an oratory device, and its aim is not to be persuasive—the author-initiated strategy is only secondary. It is not grounded exclusively in argumentation but in representation and meaning. Here Ricoeur's theory is in direct dialogue with Aristotle's *Poetics* in terms of placing metaphor at the heart of mimesis, not as the mere imitation of something, accidental or otherwise, but the deliberate creation of something in order to represent something else. The core idea of the hermeneutic approach explores the relationship of the metaphor to the environment from all aspects, to approach repeatedly, to think, to contemplate, to circle from the whole to parts and from parts to the whole, to constantly take into account the contexts, experience, and meaning (Ricoeur 1983: 104). The metaphors (and the world's) interpretation always requires new efforts from each participating consciousness. Ricoeur's theory of metaphor thus represents a subjectivist view, unlike the objectivist perspective which aims for a more interpersonal approach to understanding metaphor. Any language can be metaphorical of anything—that is the freedom that metaphor opens up. 'There is no non-metaphorical standpoint from which one could look upon metaphor, and all other figures for that matter, as if they were a game played before one's eyes', writes Ricoeur, 'In many respects, the continuation of this study will be a prolonged battle with this paradox' (in *The Rule of Metaphor* [*La métaphore vive*]1975: 25 [2004: 19];).

Just as in interaction theory, the metaphor is a 'synthesis of heterogeneous elements'—an act of grasping together, which converges the metaphor with the plot of the story (Ricoeur 1983: 9/127 and 1990: 21). As Ricoeur (1975: 57) notes, the subordination of the *lexis* (word) to the *muthos* (sentence/emplotment) already places the metaphor in the service of 'saying', but, in turn, the subordination of the muthos to the mimesis gives metaphor a more global aim. This is an interesting paradox which places metaphor in service of narrative and discourse. The two structures are also dependent on metaphor. In order to understand and interpret metaphor, we have to move away from the analysis of the word, to the analysis of a sentence and then of *discourse*. Here I see

[26] Similarly, M. Black (1962: 34) argues, '[The] reader is taken to enjoy problem-solving—or to delight in the author's skill of half-concealing, half-revealing his meaning. Or metaphors provide a shock of agreeable surprise.' It is also in this capacity that metaphor (as *catachresis*) holds a peculiar cognitive value: it helps to orient in/frame experiences (of pleasure, of pain) which cannot be easily expressed.

Ricoeur's important contribution to the methodology. It is the sentence that is the unit of metaphorical meaning and as such not reducible to the sum of its parts (as compared to I.A. Richards and M. Black's grammar of metaphor) and the meaning of a sentence (and metaphor) is a relationship between contexts. Ricoeur here offers a strong *contextual* theory, where the meaning of a word must be 'guessed' by a reader or listener each time the word appears according to the context in which it is being used.[27] Meaning comes from the interplay of words with one another in the sentence and the context of discourse. Thus, the understanding of metaphors cannot be secured by consulting dictionaries or even encyclopaedic knowledge. Metaphor analysis must include, but not be limited to the study of lexis.

If we come back to the structure of metaphor (also 'grammar' in Black 1979) on the level of lexis, a metaphor is not the tenor (resp. focus) or the vehicle (resp. frame) but the sum of both. Once the metaphor, such as 'man is a wolf', is established, not only do we never see man in the same way again, but we also never see wolves in the same way again either: 'The wolf appears more human at the same moment that by calling a man a wolf one places the man in a special light' (Ricoeur 1975: 115 [2004: 102], see also Black 1962: 44).[28] Ricoeur here draws close to the theoretical stance elaborated by Fauconnier and Turner (2002) as conceptual (mental) blending. What is important about metaphor is not the 'semantic violation' or juxtaposition of two meanings (the literal and the figurative) itself, but 'the solution to the enigma' which it presents for the listener or reader (Ricoeur 1975: 246 [2004: 229]). This work of interpretation is itself an intrinsic part of the metaphorical process. In order to understand metaphor, and in contrast to creating some instruction, Ricoeur, in his own way, rehabilitates intuition and imagination. This also advocates a methodology which is qualitative and extends to Ricoeur's centrality of a 'living' metaphor. A metaphor for his own theory, Ricoeur introduces a 'living' metaphor that 'forces conceptual thought to think more' (Ricoeur 1975: 384 [2004: 358]): 'Metaphor is living not only to the extent that it vivifies a constituted language. Metaphor is living by virtue of the fact that it introduces the spark of imagination into a "thinking more" at the conceptual level. This struggle to "think more", guided by the "vivifying principle", is the "soul" of interpretation.' Figures convey meaning in a more vivid manner than literal utterances, making the language more effective. To give colour, to astonish, and to surprise through new and unexpected combinations, they breathe force and energy into discourse (cf. Ricoeur 1975: 85–86 [2004: 73]). Metaphors, then, are not deceptive. The metaphor is most

[27] Just in line with phenomenology, Ricoeur's strong contextual theory extends on all figurations. For Merleau-Ponty, the figure is the simplest sensation we can have – it's 'the very definition of a perceptual phenomenon'. Perceptive 'something' is always in the middle of something else, always part of some 'field'. The specificity of perception is that it admits the ambiguity, the trembling that it has to be contextualised (transl. from Merleau-Ponty 1945: 10 [1999]).

[28] 'If to call a man a wolf is to put him in a special light, we must not forget that the metaphor makes the wolf seem more human than he otherwise would' (Black 1962: 44). This is also the moment in the hermeneutic arch (a mimesis) when it becomes a full circle—previous experience is the basis for its revitalisation. Similarly, the 'Nano is (the next) GMO' metaphor here implies how these two controversies essentially merge into each other.

powerful at the intersection of the world of the author, text, and reader (listener) so that not only does it irresistibly compel attention and interest, but it also revitalises the language.

For the purposes of my study, it is important for Ricoeur to remind us that the capacity of a metaphor is essential to the revitalisation of language within new emerging experience (technology, nanoscale, future, etc.). Language absorbs new experience by intrinsically running beyond the literal, and this new experience cannot exist without metaphor (hence, the 'living' metaphor). As cognitive linguists would have argued, these are metaphors 'we live by'; our most essential mental concepts (e.g. time and space) are inherently based on metaphorical descriptions (cf. Lakoff and Johnson 1980)—this also appears explicitly in Ricoeur's *Time and Narrative*, *Volume 3*. It requires us to rethink our epistemologies and even the basic ontogenetic problems with the nanoworld—in other words, how our consciousness and knowledge of the scale and future grows (e.g. the 'nanoworld as an ever-escaping space/reality' grounded in images, cf. collapse of distance in Nordmann 2005).

Yet the capacity to transfer meaning from one thing to another is conditioned by a phenomenon where some meaning is used and some is not (cf. Ricoeur 1975: 112–13). Metaphor in nanotechnology discourse should be understood through its achievements as much as recognising that it forces us into selective blindness. There are other uses of Ricoeur's theory—extensions and intersections. The mechanism of metaphor as 'seeing as' in a global vision can extend to the concept of the *root metaphor*. Introduced by American philosopher Stephen C. Pepper in *World Hypotheses* (1942), root metaphor is 'an area of empirical observation which is the point of origin for a world hypothesis'. A root metaphor, says Earl MacCormac (in *Metaphor and Myth in Science and Religion*, 1976), is 'the most basic assumption about the nature of the world or experience that we can make when we try to give a description of it'. A root metaphor can be an image, a narrative, or a fact which shapes an individual's perception of the world and interpretation of reality (Brown 2003). In fact, Theodore Brown's root metaphors/models are at the core of what Thomas Kuhn described as 'paradigms' in *The Structure of Scientific Revolutions* (1962). It is also interchanged with a *master metaphor,* or less commonly a *myth*. The root metaphor is a worldview, a shaping perception potentially transmitting to all relations, attitudes, and actions. Another extension of Ricoeur's (hermeneutic) theory can be considered in the *therapeutic metaphor*, used by a therapist to assist a client in the process of personal transformation. The resemblance is functional for the patient as it allows one to see reality differently, inherently changing one's attitude to the world. This particular role of metaphor may seem far from the functionalities in nanotechnology discourse, yet therapeutic metaphor can not only be responsive to dealing with the unknown or be considered within the requirement of a more informed discussion on nanotechnology, but also a response to policy frustration (see the discussion on EC policy in this thesis).

2.1.3 Conceptual Metaphor Theory and Systematic Metaphor (Lakoff and Johnson)

In *Metaphors We Live By* (1980) George Lakoff and Mark Johnson suggested that metaphors not only make our thoughts more vivid and interesting but that they actually structure our perceptions and understanding. The authors even go so far as to say that 'perhaps the most important thing to understand about conceptual metaphors is that they are used to reason with' (Ibid., 65). Conceptual metaphor theory (CMT) focuses on the structure of inferences inherent in metaphor. These inferences are the basis for making evaluations and decisions, drawing conclusions, and responding accordingly, as reasoning in terms of a metaphor translates into actually experiencing everyday life, indeed *living* in terms of metaphor: 'The full import of [metaphor] for our lives arises through its entailments. Those entailments are consequences of our commonplace cultural knowledge' (Lakoff and Johnson 1999). When people find themselves at a 'crossroads' in their decisions, according to cognitive linguistics this might signal the metaphorical concept for 'life' in terms of a JOURNEY. Similar imagery, this time a collective journey, can be the interpretation of the sentence 'European Governments are determined not to miss the boat on the next "nano" revolution' (CORDIS, 2005a). CMT is used for an analysis which focuses on cross-domain mapping in the conceptual system. This way, any metaphorical expression splits into a *linguistic expression* (a word, a phrase, or a sentence) and that which stands submerged below 'the surface realisation of a cross-domain mapping' (Lakoff 1993: 203). So, for example, utterances such as 'I am at a crossroads in my decisions' or 'I took a wrong turn somewhere at an early age' are considered metaphorical expressions which realise the mapping LIFE IS A JOURNEY (traditionally marked in capital letters). While on the linguistic level of words we observe semantic tension, at the conceptual level, this gets resolved by mapping one idea onto the other. Life is understood in terms of a journey, or in Black's terms from before, life resonates with journey. Conceptual metaphors are in this sense 'systems of associated commonplaces', which are behind any linguistic metaphor uttered in a given context.

According to cognitive linguists, it is possible for different languages and cultures to conceptualise certain phenomena in similar ways because of the universal aspects of the human body (cf. Kövecsesc 2002: 171). Concepts such as UP IS MORE (good) then DOWN (bad), expressed as 'my mood was rising', TIME IS A MOVING OBJECT in 'time flies', or RESOURCE in 'I don't have enough time left' are taken as evidence that individuals (and cultures) derive similar ideas from their (bodily) experiences and seem to see themselves undergoing the same physiological processes in given situations. When a metaphorical concept has such an experiential basis, it can be said to be 'embodied'. This is sometimes termed as *experientialism*, a much criticised moment in the theory which grounds conceptual structure in certain patterns of our experience and where human language is a mere derivation from bodily experience; any complex

language relies on the body, on our perceptual system, the biology of our brains, and how our bodies function in the environment we live in.[29] Since the foundation of the theory in the 1980s, doubts have been expressed about the legitimacy of extrapolating too readily from language to cognitive structure. As Rakova (2002) argues in her article, certain parts of this very elegant picture are difficult to accept. The idea of embodied structuring of concepts depends crucially on accepting a kind of extreme empiricism which is unlikely to be true (Rakova 2002). Similarly, Anna Wierzbicka, in her essay 'Metaphors Linguists Live By' (1986), argues it is 'an illusion to think that spatial and otherwise physical notions are inherently clearer to us that frankly mental ones . . . it is an illusion to think that the external is more accessible to us, and more familiar to us than our inner world' (Wierzbicka 1986: 296). This problem concerns precisely the assembling of arguments concerning the relationship between language and thought and the *social interactions* which characterise all scales of the outside world, including nanotechnology development. But the significance of conceptual metaphor theory can be derived from the debate, surpassing its arguments on the embodied nature of concepts.

The social sciences have already taken up the challenge, studying conceptual domains (using CMT) to draw comparative lines among seemingly disparate metaphorical expressions, texts, corpora, and even discourses, seeking the notion of social dynamics (change) in and from metaphors (cf. conceptual metaphors in political discourse Chilton 2004, Charteris-Black 2004; in scientific discourse Hellsten 2002, Semino 2008). The conceptual metaphor here has taken a pragmatic coat, that is, a visible part of the discourse which can influence concepts and salient structures of discourse mutually and vice versa—not only unintentional and pervasive but also intentional and persuasive use (Charteris-Black 2004 and 2005, Hart 2007). Thinking systematically about nanotechnology development as a 'journey', as in the above example, may lead one to a set of expectations, whereas thinking of it as 'new social contract', 'a religious sacrament', or a 'masquerade', 'an irreconcilable gap' or a 'war' could arguably carry a different sets of expectations. When a government document describes the public as 'uninformed' or 'fearful' it does not take them as serious threats, but if they are 'pawns' in the hands of activists branded as 'neo-Luddites', they are considered a historical threat—as 'machine-breakers'. In other words, the uninformed public does not immediately relate to (dangerous) activism whereas neo-Luddism does (cf. the chapter in this thesis on images of the public during the public debate on nanotechnology in France). This leads to a recognition of how conceptual metaphors not only shape our view but create the images of actors or expectations which determine actions. The priority of concepts

[29] CMT has a tradition of a structured field of inquiry which expanded from the early forerunners (Lakoff and Johnson) to the theory of mental spaces (cf. Fauconnier and Turner 1998, 2000 and 2002), accentuating the universal influence of bodily experience on language. In other words, our physical bodies and their embeddedness in the environment influence mind structures; language concepts are hardwired to brain structures.

(cognitive) to linguistic (surface) expressions, however, always remains a challenge for researchers focused on metaphor in discourse. Studying metaphor in discourse requires focusing on inferences or adjustments of concepts and is precisely what links conceptual metaphors as a part of a system that shapes everyday experience and actions.

For the purposes of my dissertation, my focus is on the conceptual rather than the linguistic level of metaphor analysis; that is to say, it is similar to the frame analysis which seeks structures under which additional thought revolves. The prerequisite for the theory may seem like a step towards a level of abstraction which is hardly congruent with positivism or empiricism that excludes any metaphysical speculations. However, as Lakoff and Johnson (1980) would have it, the question was never to get away from facts but to get closer to them, not fighting empiricism but, on the contrary, renewing empiricism. This is visible in both the contemporary version of the theory, which focuses on concepts within pragmatic sociology, as well as its systematic integration into networks and narrative structures.

2.1.4 Theory of Visual Metaphor (Forceville)

The pictorial (or visual) metaphor as a phenomenon covers all previously discussed theories. In most theories there is no rupture between metaphors as texts and/or images. Scholars who in particular understand metaphor as 'a matter of thought and action, and only derivatively a matter of language' developed an interest in non-verbal and multi-modal manifestations of metaphor (cf. Lakoff and Johnson 1980: 153, Semino 2008: 155–57). The metaphor is traditionally understood as a figure of speech, but this extends to other modalities of 'seeing'. Imagery is central to any metaphor, or in Ricoeur's terms, we depart from 'seeing as' (cf. Ricoeur 1975). Yet, the approach to visual or pictorial metaphors requires a certain theoretical twist which relates ever more intensively to a wide range of disciplines: aesthetics, poetics, semiotic theory, the history of culture, anthropology, and media studies. This range of social fields should by no means hinder us from understanding visual metaphors within sociological theory. We should consider the extent to which visual metaphors are among the principal meaning generators in political as well as science and popularisation discourse, such as technology planning, theory-constitutive schemas, advertising, or techno-critique, among others. Images can be used to promote certain views and values, even elicit 'correct' emotional responses from the observers. Visual metaphors, also, are image-schematic, they arguably have the capacity to introduce coherent worldviews and story-like scenarios. This should not be confused with the fact that images contain groups of signs which are often scattered in the view. The author of an image can be actively involved in such a showcasing, 'setting the stage' and positioning the image (cf. Ruivenkamp and Rip 2011). The reader contributes to the setting as well by interpreting it and framing the situation. It is essential to understand these images are representations which are designed to be read and re-read, to arouse interest, emotions, even

actions.

How to approach visual metaphor in these modes is a delicate task. In my thesis, I find particularly useful the theoretical model for visual metaphors proposed by Charles Forceville, which translates images and imaginaries into the grammar of metaphor (cf. Black) and even allows for the study of metaphorical concepts (cf. Lakoff and Johnson) or their integration in discourse (cf. Ricoeur). Forceville distinguishes figurative regimes or modes based on elements of spoken language, written language, visuals, gestures, music, sounds, smells, taste, touch, and others in which 'monomodal metaphors' are 'metaphors whose target and source are exclusively or predominantly rendered in one mode' (Forceville 2006: 383), and their combination would be a so-called 'multimodal metaphor'; that is, a metaphor 'whose target and source are each represented exclusively or predominantly in different modes' (Forceville 2006: 384). Multimodal metaphors are also images accompanying texts, which brings into question how text and image (and even sound) interact. How do we construct meaning in these multimodal formats? And how do we analyse their interaction? For visual metaphors as well, the analyst needs explicit criteria for the analysis. For this purpose, Forceville (1996) distinguished three types of visual metaphor which he labels *contextual metaphor*, *hybrid metaphor*, and *alignment metaphor* (also *simile*), depending on whether it is the visual context which metaphorises an object (contextual metaphor), whether the target and source are physically conflated (hybrid metaphor), or whether they are juxtaposed/aligned (simile). The following schema captures Forceville's typology of visual metaphors (see Figure 2.3 below).

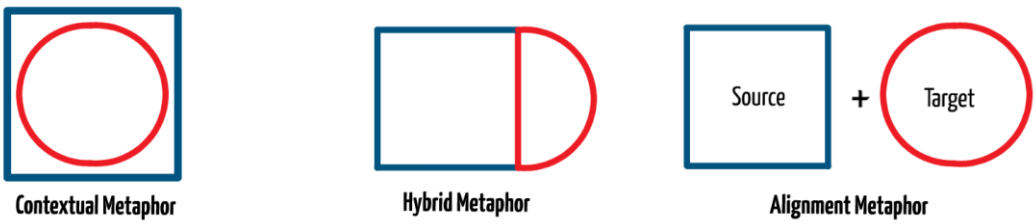


Figure 2.3 Three types of visual metaphors; the circle represents the metaphorical target and the square represents a metaphorical source.

There are several examples from nanotechnology discourse which can demonstrate these different juxtapositions between the source and the target domain of a visual metaphor (Figure 2.4–2.6). For example, images of 'nanomachines' have been circulating in popular-scientific texts to translate the achievements of programming miniature 'nanosubmarines in our arteries' (2.4a, left) or 'weapons for killing cancer' (2.4b right), which in Forceville's schema corresponds to metaphor of the contextual variety: NANOMACHINE IS (BLOOD) AGENT (left), NANOPARTICLE IS (HEATED) BULLET (right). The set of images in Figure 2.5 was obtained from a scientific article presenting the technical design of nanotechnology and its applications in Nanomedicine. The so-

called ‘Nanospider technology’ is the electro-spinning method for creating nanofiber scaffolds, used for ‘trapping viruses’, or ‘growing stem-cell’ cultures. The metaphorical parts, such as a spider’s spinneret is mechanic, whereas webs can be organic polymers. We can consider it metaphor of the (animal) hybrid variety: NANOMACHINE IS SPIDER. In the last set of images (Figure 2.6a and 2.6b), we see someone is ‘hiding their head in the sand, like an ostrich’, ignoring their problem while hoping it will magically vanish. Here, the technology critic sets a frame which evaluates the shortcomings of safety tests. In the right image, the author visualised the argument of how regulators should not only think about ‘catching euros’ but also think about the ‘precautionary principle as a sanitary web’. These are metaphors of the alignment (simile) variety: RESEARCHER IS (LIKE) AN OSTRICH (left) and EUROS ARE (LIKE) NANOPARTICLES. The alignment type is particularly interesting as it shows how two (or more) images conflate concepts, narratives, and discourses, and which suggests a pragmatic aim. It should also be more evident how visual metaphors extend from technical images to different social images, or the applications and implications of nanotechnology. Visual metaphors are of interest as they become complex imaginaries in nanotechnology discourse, images of the scales, or imaginaries of futures (cf. Maestrutti 2011: 41–78, and visual metaphors of ‘seeing and manipulating the invisible’). They show the intellectual prowess of research, skilful engineering, and also artistic rendition. This is because even the colour impression added to images of nanoscale is something which was imparted by the author rather than being readily visible at the nanoscale. The nanoscale is partly beyond the wavelength and its images are no less determined than the foresight of nanotechnology futures. Visual metaphors thus depend on the instrumentation as much as choice.

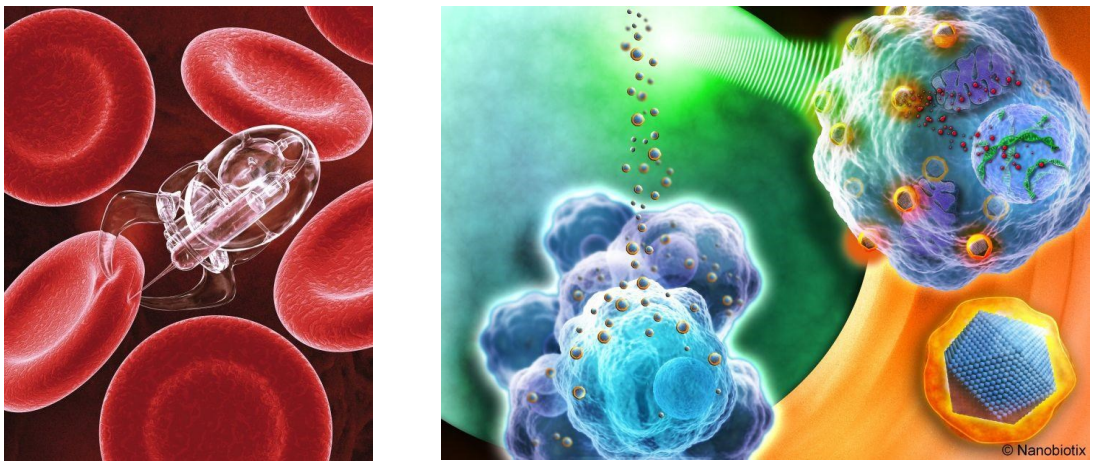


Figure 2.4a *Left*, Metaphor of the contextual variety: NANOMACHINE IS (BLOOD) AGENT.
Figure 2.4b *Right*, NANOPARTICLE IS (HEATED) BULLET.
Source: Ottino 2003 (2.4a), Le Monde 2011/Les Echos 2013 (2.4b)

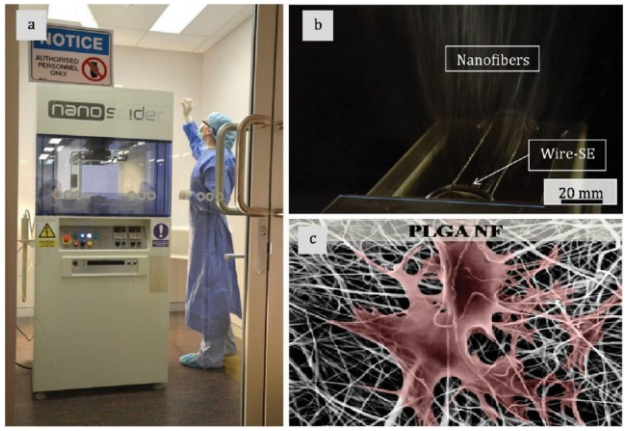


Figure 2.5 Metaphor of the (animal) hybrid variety: NANOMACHINE IS SPIDER
Source: Elmarco INDEX, 2013

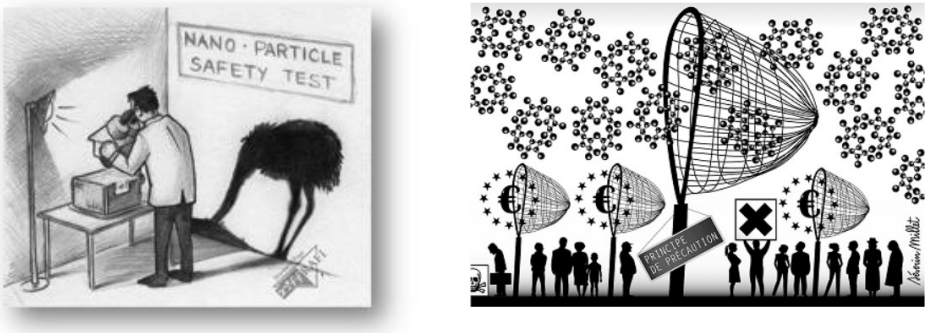


Figure 2.6a Left, Pictorial metaphor of the alignment (simile) variety: RESEARCHER IS (LIKE) OSTRICH. **Figure 2.6b** *Right*, EUROS ARE (LIKE) NANOPARTICLES. Source: ETC-Group, 2012 (2.6a), Le Monde 2012a (2.6b)

2.2 Social Theory of Metaphor and Science and Technology Studies (STS)

In a paper titled 'Why Metaphors are Necessary and Not Just Nice' (1975), Andrew Ortony argues there are important social functions of metaphor, such as the compact way of conveying a great deal of information, a metaphor being more vivid than a literal expression, and also, conveying the inexpressible, or the more dynamic, continuous aspect of our experience. This is an essential aspect which follows cognitive linguistics but not the entire scope of the social theory of metaphor. In a parallel to the philosophy of language and study of rhetoric, the social theory of metaphor follows a long tradition of social science, resonating with Bronisław Malinowski's (1923) argument on language as a mode of behaviour, George H. Mead's (1934) symbolic interactionism, and the social

construction of reality through language (Berger and Luckmann 1990), among others. By nature, all communication is in some sense social—without any social interaction, we innately have no language ability or expression. Since the *linguistic turn* (originating in Wittgenstein's *Philosophical Investigations*, 1953), however, some scholars went as far as to argue that reality (for example, past, present, and future) does not exist outside our textual representations of it, and that these representations cannot be separated from the ideological aspects that people bring to them. As such, language, with its symbols and meanings, 'permeates both the forms and the contents of all other cultural activities' (Dewey 1938: 45). The social theory here shifts to the *performative thesis*, which was historically outlined by Searle (1989) as the ability of some descriptions to bring about described situations in reality, or, in line with J. L. Austin's (1962) hypothesis, that apart from reporting about the world, language also serves to do things and change the world somehow.

But instead of presenting strong philosophical and aesthetic convictions on metaphor and language, the kind of discussion I would like to bring in is to look at metaphors *doing something interesting*. Metaphors should be acknowledged as social tools beyond (but not separated from) cognition, not so much because it allows us to understand the matter better but primarily for its capacities, such as the potentiality for a new way of organising things (cf. Yanow 2005). Science and technology studies (STS) in particular allow for the capture of the magnitude of metaphor as a phenomenon at the interface between science, policy, and the public. The corresponding discussion on how metaphors matter can then be transmitted to the research questions which open instances of research on matters of concern in nanotechnology discourse (see later). By taking into account metaphors, concepts, their systematicity, and the capacities of metaphors, we can explore various contexts and even unintended consequences of metaphor use.

The role of metaphor in science to introduce and control change has been historically contested (cf. Pylyshyn 1979), though nowadays the contemporary trend of researchers and historians of science is to trace its significant influence. Metaphor and analogical reasoning have a place in scientific discovery, theory building, and didactic purposes (cf. Black 1962, Hesse 1966, Boyd 1979, Green 1979, Gentner and Jeziorski 1993, Ziman 2002, Brown 2003). The consideration of metaphor has led some researchers to even argue for a shift in Western science—a historical change in metaphor shifted to models using analogy (cf. Gentner and Jeziorski 1993: 447 who compared alchemy as driven by metaphors and modern science as a shift to the development of analogical models). The change has also been described on the basis of replacing conventional gestalts and puzzle-solving which no longer serve to maintain normal science (cf. Kuhn 1979, see also Kuhn 1970: 11). When a metaphor becomes established, it is argued, it may be difficult to abandon and can lead a field astray for years, even decades (until former metaphors become 'broken symbols', cf. Tillich 1957).

For instance, Moore's law becomes a metaphor for 'technologies presented as the next generation . . . [and which is] self-justifying because the notion of next generation is widely accepted' (van Lente and Rip 1998: 222–23). The metaphor concealed in the law inevitably reached beyond science, to industry policy and public discourse. Emphasising the role of metaphors in science should thus be followed by further reflexivity which does not underestimate interactions at the interface between science, policy, and the public. In *Making Truth* (2003) Theodore Brown shows that not all associations to the 'greenhouse effect' metaphor are useful in understanding some aspects of 'climate change' (e.g. the warm environment of a greenhouse) but have consequences on public perceptions. Similarly, 'DNA as a book of life' carries functional associations within science, such as methods of 'reading, transcription, inscription', and so forth, but it is also an ideological dogma of a written truth (cf. Nerlich and Dingwall 2003, Nerlich et al. 2002). Elsewhere, in *Illness as Metaphor* (1978), Susan Sontag argues how metaphors for diseases described via warfare scenarios carry a stigma and superstition to the patients—a disease is an enemy and a killer, and patients are victims, thus contrasting therapeutic metaphors. A 'battle against cancer' or 'war on cancer' may hurt (some) prevention intentions (in Hauser and Schwarz 2015). Sontag went so far as to argue for the elimination of metaphor from discourses surrounding illness. However, even the shifts which some researchers observe, for example, in nanomedicine from metaphors of 'war' to 'ecological' metaphors (cf. Bensaude-Vincent and Loeve 2013), suggest metaphors are practically an unavoidable part of scientific and public (or therapeutic) discourse. In other words, metaphors work for the maintenance of scientific discourse, but also the policies and institutions that go with it, such as the pharmaceutical industry or media. Brigitte Nerlich and her colleagues (2002) approach metaphor in a similar fashion. They show how the language used during press conferences on genetic research (esp. Human Genome Project in 2000) was largely successful in influencing subsequent UK media reports, which often echoed the same positive metaphors so as to emphasise the magnitude of the achievement and simultaneously reassure the public about the positive outcomes (the treatment of currently incurable illnesses).[30] Just as the in case of Moore's law, metaphorical articulations were represented and defended rhetorically, and they created 'protected spaces' (cf. van Lente 1993). To show how these 'spaces' are established, being themselves epistemological but also protected (i.e. researchers) metaphors, is an important task for social science research.

For example, expectations of how some members of the public would react to

[30] In studies of scientific controversy in biotechnology, Elena Semino (2008) and Knudsen (2003) found the general public, scientists, as well as politicians, used the 'closed' metaphors of expert discourse as 'open' metaphors in achieving their rhetorical goals. Even the explicit identification and criticism of the metaphors can serve as a tactical move in public discourse, both in posing as speaking the plain truth or parodying the opponent's positions (cf. Musolff 2004). The metaphorical concepts used in these situations involve not only the transfer of semantic structures but also of emotive and evaluative aspects as integral parts of seemingly self-evident conclusions (Musolff 2004).

nanotechnology in the same way many reacted to GMOs places metaphor and analogical reasoning in a strategic position that requires careful consideration by scientists, policymakers (also regulators), and the public. The actors who enforced a change of general opinion towards the negative direction represented by 'nano is (the next) GMO' place a serious obstacle for the further development of nanotechnology (cf. Rip 2006: 358, and fear of a public backlash). The sudden change of opinion in which technology's potential has become tainted by discourses of risk, fear, danger, and threat can be called stigmatisation (Wilkinson et al. 2007). But the rhetorical figure became problematic exactly because particular relationships were projected, whereas others may have been systematically marginalised, such as the unquestionable achievements of nanomedicine. The metaphor not only opened but also constrained actors in their interpretations, attitudes, and actions (as in Figure 2.7). It allowed particular actors (social groups or individuals) to enter discourse and exchange experience in debate; to understand, express, interpret, and constitute social relations; and to evoke relationships between discourses of biotechnology and nanotechnology.

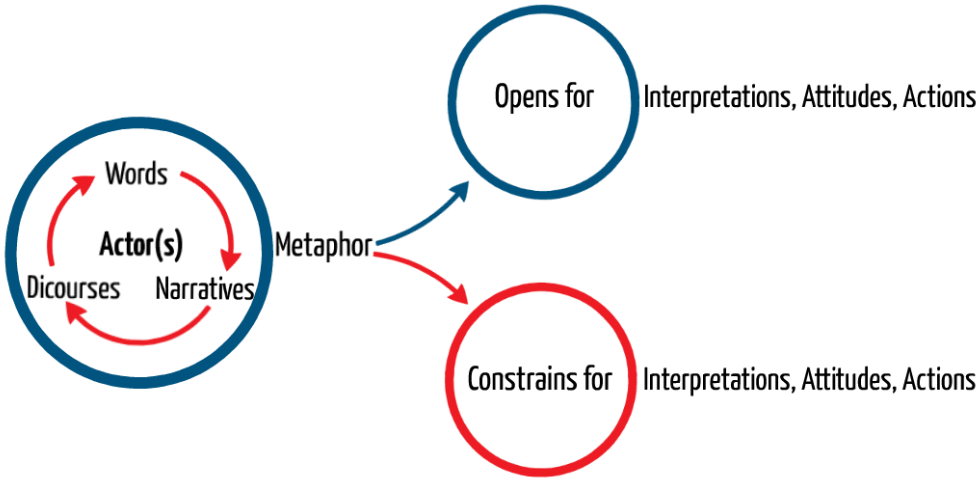


Figure 2.7 Metaphor has an enabling and constraining role at the science, policy, public interface. These roles are related to interpretations, (dis-)empowerment, and the strategic decisions of different actors, traceable in the relationship to systematic metaphors, narrative structures, and discourses.

In this sense, I find particularly useful the concept of a metaphor *capacity* because it represents both an agent- and structure-centric view and provides a link to even unintended consequences tied to particular metaphors. As Brigitte Nerlich has suggested, the notion of capacity could help conceptualise metaphors themselves in 'ecological terms' that would 'study the "structural coupling" between a metaphor and the environment . . . Over and above its intrinsic semantics [and where the metaphor] therefore has a "pragmatic", dynamic, action-oriented face' (Nerlich 2003: 136). Of the previously discussed capacities was how nanotechnology becomes characterised by an inter-discursive role of metaphors as tools of exchange within and between discourses. It is exactly the interface between science, policy, and the public that is the environment of metaphors (cf. Hellsten 2002: 24, also Bono 1990: 71–72, or 'messengers of meaning' in Maasen

and Weingart 1995). If we assume that metaphors have capacities, depending on their environment or interfaces, then nanotechnology discourse is not only an environment for metaphors (as stated above) but also that metaphors themselves transform that environment. While the first perspective acknowledges nanotechnology is an environment that brings about metaphor (its compositional element), the second implies that nanotechnology discourse is co-constituted by metaphor (its resource).

The previous chapters can be tied together to model nanotechnology development and the historical emergence in the aftermath of previous controversies, to suggest a wider process of transference, interdiscursivity, and *narrativisation*. By considering the relative stability of social representations, there is supposedly a certain trajectory of mattering (cf. mattering has history, in Cooren et al. 2015). Repetition cannot be the only good measure of the strength or stability of the mattering (Cooren et al. 2015: 11), like when various actors serialise mattering by reassembling previous problems (e.g. GMO, asbestos, nuclear technology, etc.). Cooren offers an interesting perspective on how narrative structures become tied to matters of concern and how these structures evince 'isomorphism' with the evolution of a controversy, especially 'organization of coalitions' (Cooren 2001: 183). In line with his approach, we can advance this modelisation of controversy further as it involves *metaphorisation of the matters of concern*, as a certain invocation, evocation, and convocation of technoscientific possibilities, policies, and societal objectives: 'Matters of concern . . . are matters of interests, by definition, what is supposed to animate the actors when they defend or evaluate a position, account for or disalign from an action, or justify or oppose an objective . . . . They invoke, convoke in their talks and writings to explain, justify, legitimize or account for their positions or actions and that of others' (Cooren et al. 2015: 10–11).

Metaphor theory has also provided perspective on representations which can only be partly accessed through the semantic domains of words, or words transference and the resonance of their semantic domains. The narratives also provide an opportunity to study the sociocultural variations where a similar or variant concept does not always represent the same matter of concern. But these are not sufficient conditions. The next analytical level should correspond to systematic uses of the metaphors and *discursive formation*. They can together indicate how and to what extent the representations translate within and between discourses. The reasons behind the metaphors' use and their systematicity are then considered from a specific perspective on the meta-pragmatic level of discourse as well as the deeper relationship between knowledge and power.

2.3 Research Objectives and Questions

My main research objective is to study the relationship between metaphor and nanotechnology regarding actor strategies, as well as their (actor's) embedding in narrative structures and discursive formations. Following the trend in STS studies, the presented research was conducted during

selected periods of controversy and in particular contexts where actors and their conflicts emerged over definitions. This is important as the rhetoric is expected to be most visible at these key moments when social groups or individuals attempt to define or redefine reality (cf. Oreskes and Conway 2010). Each such case study requires an introduction to the context and an adjustment of the methodology and data sampling. Studying the relationship between metaphor and nanotechnology was focused on a specific initial content—*matter(s) of concern* (cf. Latour 2004 and 2008, Cooren 2015), a thing, a topic, a subject, or an issue being presented, discussed, questioned and/or accepted in order to decide collectively how to go about nanotechnology. Social theory of metaphor (the above considerations) was applied to frame discourse dynamics concealed in the novel, conventional, and systematic metaphors. I had the following objectives:

- investigating metaphorical capacities and biases; and which also required …
- studying the narrativisation of nanotechnology, shifting from agentic to structural (topological and temporal) properties of nanotechnology controversies; and
- providing insight into discursive formations that can characterise entire nanotechnology discourse across science, policy and public interface.

The above objectives that cover several analytical levels within both the *synchronic* and *diachronic* dimension of controversies were expected to allow drawing comparative lines across the science-policy-public interface; to scrutinize the origins and progression of public debates as well as to point out the existing problem associated with discursive and argumentative technology assessment. Concerning the relationship between metaphor and nanotechnology, the study of the implications of nanotechnology as such moved into the background, and the focus became on the *processes* and *practices* of constant renegotiating and re-figuring of social representations. The structure of the empirical analysis has been outlined by the following research questions:

1. How are metaphors tied to specific social representations of nanoscience (nanotechnology)? Can any particular systematic metaphor(s) of nanoscience (nanotechnology) be identified in light of the current diversity of the field?
2. How are metaphors linked to European nanotechnology policy, in particular, exploring the antagonism, consensus, competition, and indifference of various actors? Are there any consequences for their particular use?
3. Which conceptual patterns are (most) common in the representations of nanotechnology controversies in (local) cultural contexts? Can any particular structures (meta-structures describing types of relations between actors and concepts) be identified? How are matters of concern in nanotechnology discourse tackled by media?

Part III Methodology

Chapter 3. Metaphors in Texts and Society

> A successful metaphor is *realised* in discourse, is embodied in the given text, and need not be treated as a riddle.
>
> Max Black, in *More About Metaphor* (1979: 23)

3.1 Metaphor Studies (Introduction)

The previous chapter on metaphor theory discussed metaphor as a systematic projection of language, imagery, and inferential structure between conceptual domains, but it also pointed to the strategic use of various actors and their individual or collective representations. Nanotechnology is a real practice in laboratories, conference rooms, in movies and sci-fi literature, and in public debates, among others. In this sense, it concerns the interpretations and attitudes of 'individuals and actions belonging to an "imaginary or 'possible'" world' (Eco 1979: 12). There is therefore no single 'best' methodology, and the necessary or convenient choices should not signify that methodology can uncover everything or not estrange us from the actual experience of the real practitioners.

The methodological challenge is to develop a model in which to describe the controversies sensitive to the theoretical framework. The methodology should reveal more about the metaphorical concepts, narrative structures, and discursive formations, sometimes only revealing partly visible traces of discourse. These are valid analytical levels with their own achievements in studying nanotechnology discourse. Furthermore, there are studies which follow metaphors as hyperbolic language used by practitioners and policymakers (Berube 2005, Wullweber 2008 and 2015). Following the narrative dimension has also been among the methods of analysis—even central to studying nanotechnology with regard to various expectations, success stories, and narratives of crisis (cf. López 2004, Toumey 2005 and 2008, Mordini 2007a). In addition, the studies have been conducted with a macro-analytical focus on interactions between various discourses (Toumey 2011). By studying metaphors *across* these various analytical levels, however, many ideas about the discourse, actors, and their strategies may arise.

The aim of this chapter is to outline how metaphor analysis can enrich the study of discourse

dynamics and contribute to a more systematic and integrative assessment of metaphor methodology in studying nanotechnology discourse. The principal objective of this chapter is to demonstrate how the study of a metaphor in discourse can be integrated at the methodological level between cognitive linguistics (metaphor analysis), narratology (narrative analysis), and social linguistics (discourse analysis). To achieve this, I first review some of the common methodological problems. The boundary concerning the figurative and literal parts of the discourse as well as the various metaphorical structures is addressed as a problem of metaphor occurrence, form, and interpretation. I further investigate how to avoid methodological issues inherent in the declared competencies of the various analytical levels, especially if treated as separate methods. In this sense, the subchapters on lexis, narrative, and discourse provide important *validation checks* for the proposed research design. The conceptual metaphor studies have a practical value in the proposed corpus-based metaphor analysis as they can be used with a social science methodology and inform about typical metaphor patterns in different types (or genres) of discourses (cf. Semino 2008), even critically examining various discourse strategies (Charteris-Black 2004). Similarly, combining metaphor analysis and the study of narrative grammar, inspired by the studies of Greimas (1976) and Cooren (2001), is done so in order to provide essential guidelines for research on narrative structures and discursive formations. It is argued that corpus-based metaphor analysis not only expands our intuition about metaphors, but it also enables systematic exploration of the uses of metaphor(s) in their natural contexts (cf. Deignan 2005: 95): 'The advantage of size and the inclusion of a wide range of texts is that the corpus has greater potential for making claims about language' (Charteris-Black 2004: 31). Nevertheless, studies on metaphor are often limited to a list of the most frequent metaphors in a specific discourse (cf. Charteris-Black 2004 and 2005). This is quite understandable and also the safest way to argue for proof that certain metaphors are characteristic of the discourse under study. I find it therefore appropriate to examine metaphors moving from conventional places, where secure, closed, and fixed knowledge is communicated, to places which increasingly engage with dynamic metaphors supportive of controversies and multi-stakeholder (public) debates on nanotechnologies.

3.2 Metaphor Studies and its Challenges: Occurrence, Form, and Interpretation

The previous chapter on theory suggested metaphors, like other social representations in general, are flexible enough to allow for several uses and interpretations. At the same time, they are robust enough to maintain a certain identifiable structure. The ability to exploit context in order to determine the meaning and resolve potential ambiguities is not a uniquely linguistic ability, but it is dramatically illustrated in the ease with which native speakers are able to identify the intended meanings of common polysemous words (Miller 1999). The sociocultural context is important in

assessing thresholds for *metaphoricity* so that metaphor identification can be fitted for specific tasks and datasets, for example, metaphors versus technical or political terms. Still, even the human mind can be burdened by particular cultural contexts and personal aesthetic or not fully comprehend metaphors which are achieved via additional technical knowledge. In both directions, there are always metaphors which pass unnoticed when the text is read (conventional and dead metaphors). Assessing their *systematic use* also requires suppressing some of their context (we semantically isolate rich and ideally endless inferences). The research design is never free from these constraints, but it is exactly the combination of semi-quantitative (corpus-based)/semi-qualitative (discourse analysis) approach that can be turned into an advantage.

Even after the dilemma between the two analytical approaches is reformed into a combination of methods, there are additional important decisions to make. Metaphor studies differ with respect to what should be focused on in metaphor—whether words or thought, a scale of co-text and context, are necessary to accompany metaphor occurrence, form, and interpretation. For Paul Ricoeur (1975), to understand and interpret metaphor requires moving away from word analysis to an analysis of the sentence and then of the larger discourse. It is the sentence which is the unit of metaphorical meaning and, as such, not reducible to the sum of its parts. The sentence is not enough for Ricoeur as he offers a contextual theory whereby the meaning of a word must be 'guessed' by a reader or listener each time the word appears according to the context in which it is being used. It has been noted that metaphor is a phenomenon which thrives in discourse as its natural environment (Maasen and Weingart 2000). For cognitive linguists, however, the mind is the environment (Lakoff and Johnson 1980). This dual embedding, thus, poses a problem if the analyst seeks to recover and semantically 'isolate' metaphor for further processing based on theoretical models, cultural (and common) knowledge, or personal experience.

For these reasons, researchers are never really free from uncertainty in metaphor use even if the context is considered (Ritchie 2003). After all, the uncertainty arises not only on the part of the reader but the writer himself is also facing a kind of dilemma when forced to decide what and how a particular metaphor he intends to use is expressed. Even authors of texts themselves are generally unaware of all the meanings their texts convey. This would make any metaphor analysis hopeless if the scepticism was not well balanced, arguing that if the author is able to write a comprehensible text for themself, so too should the reader be able to read (and understand) it. The reader does not read randomly, and thus, the analyst can proceed systematically without the paranoia of 'subjectivity' (cf. Eco 1979: 7, Bortolussi and Dixon 2003). The basic philosophical stance behind this argument might be described as a mode of inference called *abduction*, or 'inference to the best

explanation' (cf. Hobbs et al. 1993, but also Eco 1990: 59).[31] In other words, whereas theory describes metaphor as a rule violation or a semantic resonance, the analyst must provide the best explanation as to why and where metaphor (words or sentences) interpretation resonates and does not create semantic dissonance, that is to say, a lack of agreement in meaning or a lack of consistency in language. To relate the above argument differently, text can be characterised by its 'openness', the way it lends itself to a double level of interpretation (naive and critical), thus presenting a distinct self-referential and self-reflexive element. In the following sections, I will attempt to bring these two strands closer to my proposed methodology.

3.2.1 The Boundary between Literal and Metaphorical: A Problem of Occurrence

Instances of some metaphors can be identified rather reliably. Markers such as using inverted commas in some case become good but not sufficient indicators of metaphoricity. There are other metaphorical signals or tuning devices in a text, such as 'as it were' or 'literally' (Semino 2008: 199). Other cases of metaphors are yet fuzzy or not clear-cut because we are dealing with conventional metaphors (Semino 2008: 14). Such is also the case for some technical terms. There are many situations where the metaphoricity of a word or phrase is not straightforward, which suggest resonance is a matter of degree and the occurrence of metaphor is essentially uncountable in comparative or absolute numbers (Semino et al. 2004, see also Goatly 1997:14). As the uses of metaphors follow particular contexts, it is thus appropriate to pay close attention to concepts related to systematicity and how context is established.

First, it seems that metaphorical uses should not be too frequent as 'frequency breeds literalness' (Hanks 2006: 21). Note that the reference here is to absolute frequency, not to a comparative frequency within the uses of the word or concept in question. For the purposes of comparative studies, researchers can focus on the frequent and relevant metaphorical expressions, which Charteris-Black (2004) calls 'metaphor keys'. These are expressions or concepts which the researcher finds to be of interest and frequent in the manual analysis of a particular set of data, so they are subsequently searched or concordanced in a larger corpus (also in Semino 2008: 198). In my study, I adjust this approach by focusing on the metaphoricity of particular expressions or concepts which unlock special meanings of nanotechnology (e.g. so called 'Nanospider' technology), represent social actors (e.g. activists as 'tricksters'), or even places (e.g. research institutions as 'temples' of nanotechnology); all of these can be characterised by metaphor keys

[31] The term 'abduction' was coined by Charles Sanders Peirce in his work on the logic of science where it has its proper place in the context of discovery. Eco connected abduction to model reader. Texts are never completely self-referential. They create a 'model reader', capable of actualising the various meaning-contents in order to decode/fill the gaps of the possible worlds (cf. Eco 1990 and 1979). In my view, the abduction has correspondence also to Black (1979: 23-28): 'A successful metaphor is *realised* in discourse, is embodied in the given text, and need not be treated as a riddle . . . metaphorical statement as a verbal action essentially demanding uptake, a creative response from a competent reader' (emphasis in italics added).

which ‘unlock’ meanings in a particular context of controversy.

Second, important cases of systematicity and contextual uses are technical terms. Since the presented study is focused on nanotechnology and related science policy discourse, technical terms occur at a high rate, some of which have metaphorical origins. Low and Todd (2006) argue that a technical term may have little metaphoric impact on the technical reader but be treated consistently as metaphoric by the non-technical one. Therefore, we must decide on a policy with respect to technical terms which matches our own needs as analysts. It may be that words normally used in a highly technical register are rarely used metaphorically, but that does not mean they did not originate in ‘living’ metaphors (e.g. ‘electric current’, ‘social stratification’). Metaphors, beyond rhetorical function, serve specific situations or a genre of discourse, such as a lecture, scientific report, theory building, an so forth, which does not prevent the conventional metaphor or technical term from becoming a novel and dynamic representation once it extends beyond or between the scientific fields.

Third, from the perspective of the classification between novel (‘living’) and conventional (‘dead’) metaphors, we can assume that recognising metaphoricity is to a large extent a subjective exercise, dependent upon context. If we have little information about the context, metaphorical-literal identification can become very problematic; the expression ‘European Governments are determined not to miss the boat on the next “nano” revolution’ (CORDIS 2005e), for example, very likely has a metaphorical meaning of a ‘boat’ and also a ‘“nano” revolution’, even carrying quotation marks as an indicator of metaphor focus. It happens that ‘boat’ in a science policy journal may alert us to metaphorical use, while in a marine research journal, it could be a literal expression. Another example, the expression ‘Rottweiler behind the bar’ (cf. Steen 1999) in a short anecdote, requires assessing contextually (included recognising humour or even tonality of voice) as to whether there is a person behind the bar to ascertain the expression as either literal or metaphorical. In both cases we must rely on contextual knowledge.

Finally, there are descriptions which seem to become metaphorical when they are near a very abstract, vague, poorly understood term (such as landscape metaphors for the ‘nanoworld’) and where even the ambiguity of images can be functional. In turbulent times, such as during scientific controversies, deliberately ambiguous and vague metaphors seem to be a powerful tool designed for change (cf. Maestrutti 2011: 76). However, the puzzle-solving activities which employ conventional metaphors as technical terms are an important research activity that maintains ‘normal science’ (cf. Kuhn 1962, Gentner and Jeziorski 1993, Brown 2003). Not only can researchers convey abstract and/or novel concepts to students by using more concrete and/or familiar concepts as source domains, but researchers themselves and the public can also be invited to consider a familiar concept from an unfamiliar and/or scientific perspective. For example, there are specific metaphors

aimed at describing the 'assembly' of atoms and molecules within the concepts of 'buildings', 'landscapes', or described in terms of molecular 'robots'. These concepts function as deliberate metaphors which can have suggestive metaphorical entailments: 'A metaphor is used deliberately when it is expressly meant to change the addressee's perspective on the referent or topic that is the target of the metaphor, by making the addressee look at it from a different conceptual domain or space, which functions as a conceptual source' (Steen 2008: 222). Elsewhere, Steen (2011: 17) argues that although novel metaphors and direct metaphors are typically deliberate, deliberate metaphors can also be conventional and indirect. It is thus unclear how we can identify deliberateness. Instances of direct metaphor (e.g. a word put between quotation marks) and novel metaphor always seem to be cases of deliberate metaphor. Once the researcher identifies an (in)direct or conventional metaphor, the issue of the metaphor's interpretation is only partly resolved.

3.2.2 Micro- and Macro-structural Composition: A Problem of Form and Interpretation

The interpretation of metaphor by the reader is not necessarily identical with that intended by the writer, but simply one which enables the reader to make sense using the information available to them at the time. Although the process is from the beginning complex, indeterminate, and unstable (Semino et al. 2004; Steen 1999), researchers can employ different methods to verify the context and measure systematicity against the default associations to concepts, as well as the strength of the connection to particular narratives and discourses. This is represented at multiple levels: *dictionary aid* (associations with lexis), *semio-narrative dimension* (networks and narratives), and *discourse analysis* (associations with actors and their arguments). These three analytic layers suggest a complex hierarchy for investigating metaphors at three different levels: words, (macro)structures, and discourse(s).

3.2.2.1 Dictionary Aid (Lexis)

All words are to a varying degree polysemous and, for Lakoff (1993: 205), polysemy is one of the main pieces of evidence for 'a system of conventional conceptual metaphors in a language'. Put differently, words apply to a range of other entities metaphorically because the system of associations related to words allows doing so. In 'European Governments are determined not to miss the boat on the next "nano" revolution', 'boat' has qualities and characteristics which can resonate as a metaphor. To find independent evidence that metaphor occurred, we can consult a dictionary or even extract concordances from the larger policy corpus to see if the concept of a BOAT/SHIP is used systematically. In a 2013 Council of Europe report, nanotechnology regulations were said to 'have struggled to keep up with the pace of scientific innovation'. The expression 'keep up with the pace' or 'struggle' are candidates for metaphor. Regulations do not

struggle and do not keep up with the pace, they do so only figuratively. The Merriam-Webster Online Dictionary defines 'to keep up' as 'adequately informed or up-to-date' and 'to maintain contact or relations with'. The expression appears as a rather conventional metaphor (as much so as the word 'struggle'). With its use in the policy document, however, the author may have been trying to convey a situation whereby policy (regulation) moves at a distance with technological development in a manner that is difficult to maintain. The sentence thus creates a particular metaphorical projection with additional metaphorical entailments. As with the previous example, we can consider a larger systematic metaphoricity where the actors and means represent metaphors. The nano-revolution is a place and governments are the crew. This could generate a code for analysis which represents another concept—MOVEMENT/JOURNEY (boat/keeping up the pace)—or allows for the creation of a list of expressions for the given semantic domain(s).

The research of metaphors should inspect characteristic vocabulary used in texts and discourse in order to identify candidates for metaphors. Dictionaries are useful tools for they contain basic *co-text* and *context* information on the usage of words. Yet, consulting dictionaries or reference corpora cannot replace a researcher's intuition as such—at the very practical end of our work with metaphorical expressions, metaphor analysis can never be fully automatic. A metaphorical statement involves a rule violation and 'there can be no rules for "creatively" violating rules' (Black 1979: 24). Which is why there can be no dictionary of metaphors, even though lists of codes resemble them. Or put another way, we cannot construct a machine (an *automaton*) capable of generating and understanding metaphors (cf. Eco 1979: 69; and the work of Julia Kristeva on 'signification'; or O'Grady 2004). If such a machine were possible, it would have to operate beyond words. It would understand and become author to metaphors like the human mind; it would probably become creative and (artificially) intelligent. It would also understand stories and work within the narrative dimension as additional consolidation of meaning. Humans have a specific attitude towards and within narratives as they can replace narrative fiction for reality; narratives which may be 'more real than the truth, that it can inspire a sense of identification with and perception of historical phenomena, that it can create new ways of feeling' (cf. Eco 2017: 259). Any identification procedure must engage with *fiction*, such as allegory and irony, to become poetic (or *mimetic*)—a creative storyteller.

3.2.2.2 The Semio-narrative Dimension

Further interpretational rigour can be achieved by relating metaphorical expressions to narrative structures. Metaphors do not occur isolated from one another. They can interact with one another both in *paradigmatic* and *syntagmatic* fashion. While the first can be described by complex topologies of different levels of abstraction between expressions, their concepts, and their semantic

distance, the second is the domain of narrative plot (cf. paradigmatic and syntagmatic order in Ricoeur 1990). A metaphor is closely related to paradigmatic order: Things are similar in some way, and yet they are not identical. For example, the 'Nanospider' metaphor for electro-spinning technology of nanomaterials is based on the semantic co-presence of two (at least) ontological entities: spider and machine. At the same time, the metaphor is never isolated from the syntagmatic order as it is an elementary constituent of a phrase, sentence, text, or larger narrative structure. Metaphor can be integrated into the complex allegory of a 'nanospider wrapping nanowebs around the whole of planet Earth' (see also the analytical chapter in this thesis). In another example, the 'boat' metaphor may be a semantic link to a story/imagery of a race, or conquest, or journey as a fundamental part of a modern Odyssey. Placing metaphors into narratives and understanding them is then a sign of a certain semiotic competence related to taxonomic and syntagmatic structures broadened by a dimension of semantics and discourse (cf. Greimas and Courtés 1982: 83) and cultural knowledge. Discourse semantics means metaphors can expand into narrative correspondences (allegories), spread across different texts (meta-narratives), reaching different temporalities (myths), and even incorporating cultural archetypes.

The relationship between metaphor and narratives which I want to establish in my thesis is Greimas's (1983) actantial model. Greimas considers a narrative to be built on a system of modalities which relate to actants (figures), their degree of competence in *wanting, being able, and/or knowing how to do* performance as the realisation of action and the sanctions or rewards which the performing subject has incurred (Greimas 1976: 109). The actantial model is traditionally applied to a detailed and even quantitative analysis of verbs (modal). However, it should be viewed in a larger context and a more general schema of metaphorical signification. The whole actantial scheme allows for the study of relationships between actors who are themselves metaphorical: 'The overdetermination of actants according to this category of being and seeming accounts for the extraordinary game of disguises (jeu de masques), which includes confrontations between heroes who might be hidden, unrecognised, or recognised and disguised traitors who are unmasked and punished' (Greimas 1976: 111). Such an analysis permits the recovering of a narrative structure as an allegory, in other words, by means of symbolic fictional figures and actions—finding a story within the story. This encompasses metaphorical forms as well as the temporal patterning of the actor's actions in relation to those of other objects or events, past or future. In this sense, narratives constructed on the basis of metaphors can be identified at the interface of science, policy, and public discourse: 'Some in fairy tales defeat the ugliest seven-headed dragons or against all odds they save the king's daughter; others inside laboratories resist precipitation or they triumph over bismuth' (Latour 1987: 89). Latour's adaption of Gremais's model in particular has analytically adopted one important aspect of the symmetrical perspective on *actants*, defined as actors who accomplish some

action and who may be both *human* and *non-human* (cf. Greimas and Courtés 1982: 5). This extends the perspective on what makes a hero but also an opponent or helper, an applicable nanotechnology stakeholder whether expert, advisor, politician, or the public as well as competition, nanomaterials, nanomachines, etc. In any given narrative or its subschema, actors are someone's opponents and helpers (in Callon's [1991] terms 'intermediaries'), opening multitudes of perspectives on narrativity. Even when one of these actors takes centre stage, the relationship between an opponent and helper is particularly important in what Latour describes as a 'trial of strength' or a 'test' (cf. Latour 1987: 78–79; adapted from Ghimn and Shields 2014).[32] This is arguably an important aspect of the evolution of the narrative in which multitudes of entities are assembled, translated, transformed.

Nano-technoscientists, policymakers, the public, but also other actors become meta-characters, becoming themselves a semantic link to narrative elements. Extending Greimas's approach, Cooren (2001) presented an analytical framework which explains how social controversies exhibit organising properties similar to those described by Greimas's (actantial) model. Using the model allows different narrative episodes to be scrutinised in the analysis of controversies. Any controversy begins with a *manipulation* phase which corresponds to a breach in (social) order: 'A controversy, like any narrative, always starts because at least one party feels that an order has been jeopardised in one way or another' (Cooren 2001: 183). For example, we can identify a controversy beginning and initiating a narrative, for instance, 'being late to the nano-revolution'. Cooren (2001) perhaps less explicitly suggests the initial phase (where the story begins and who is hero) is arbitrary but still essential in triggering the episodes of the story because a series of sequences will now be enacted. If we start with disorder, episodes unfold in order to restore the threatened order as a response phase (cf. 'denunciation' in Boltanski et al. 1984, Boltanski 2012, ch. 3). In the manipulation phase, a subject wants or must restore a specific order, the economy, for instance—in other words, different 'orders of worth' (cf. Boltanski and Thevenot 2006). This will constitute an objective but also an object of desire or what Greimas called a mission or quest (Cooren 2001: 182, also in Greimas 1983: 204). The subject, being an individual or collective actor, must mobilise a series of helpers, confront opponents, and overcome obstacles. Based on our chosen perspective, some helpers become 'simple' intermediaries (Callon 1991) of full-fledged actors, such as when public opinion refuses to be mobilised by the groups' campaign (cf. Cooren 2001: 184). This is an important situation in the analysis of nanotechnology controversy—also

[32] The semio-narrative approach (thus) enables the researcher to consider all the different helpers and opponents as genuine actors, even the non-human, as we will see in the case study of Moore's law or Nanospider technology (in both cases there is a strong anthropomorphism): 'It is not only words that are now lined up to confront the dissenter, not only graphs to support the words and references to support the whole assembly of allies, not only instruments to generate endless numbers of newer and clearer inscriptions, but behind the instruments, new objects are lined up which are defined by their resistance to trials' (Latour 1987: 79).

known as a 'public backlash' (cf. Rip 2006). The public, previously more or less amorphous, emerges as a specific actor. Each actor, including the public, has its *competence* phase as a sequence of sub-ordinations, sub-missions, and sub-quests necessary to complete the *performance* phase. The final episode in the narrative schema is the *sanction/reward* phase where a subject is blamed or rewarded for his success(es) or failure(s).

All communication exchanges can be studied as iterations of these four phases. The model can be applied to single lines of modalities between a subject (e.g. EU governments) and objects (e.g. Nano-revolution), whether individual or collective, fulfilling different roles of senders on a mission, subjects-heroes, helpers, opponents, and receivers (see also Figure 3.1 below). We should be able to find a model of narrativity in any text, especially with regard to different controversies, success stories, narratives of crisis in policy, and regulatory failures with different actors, and, thus, compare them, their topologies, and temporalities.

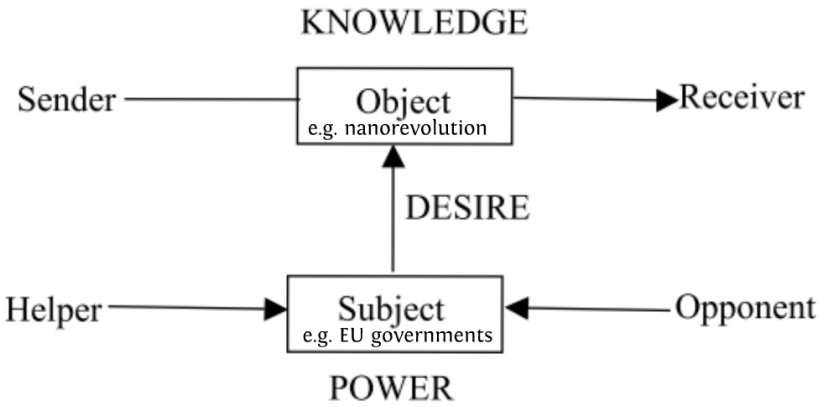


Figure 3.1 The actantial model, adapted from Greimas (1983) as diagrammed by Kwiat (2008: 44).

Use of the Greimasian model in social science studies is based on the assumption that we can use isomorphism which exists between the general structure of a narrative and the evolution of controversy (Cooren 2001: 181). Authors themselves may have created a kind of metaphorical *topos* that can support the lines of argumentation and coherent views—which narrative schema is thus corresponding to both author- and reader-initiated strategies. We can assume actors introduce stories (success and crisis) in which the elementary metaphors and even actions themselves would make sense. This will be explored later in the example of the 'technology roadmap' trope and which particularly integrates the coherent scenario of a 'journey'. Narratives are hence more than a means of exploration with identifiable structures, they are discursive strategies which can indicate a pragmatic aim. Yet, the analysis of narratives into which metaphors engage must go beyond, by means of discourse analysis, and scrutinise discursive formation in a given genre of discourse or between various discourses (composition view).

3.2.2.3 Discourse Analysis: Between Author- and Reader-initiated Strategies

It was noted in the theoretical chapter that metaphor has a positive (formative) connotation with the discourse in question (cf. Black 1962, Ricoeur 1975, Lakoff and Johnson 1980). In a discourse, structural properties of language—words, concepts, ideas, categorisations, and such—are transformed into intelligible relationships (*énoncé* and *ordre du discours* in Foucault 1970). There are certain things that will be said and certain topics which will emerge, such as questions over development, sustainability, and the role of the public; these topics are spread across scientific studies, policy (political) declarations, personal (or local) stories, artful images, laws, arguments, and so forth. Metaphors too are utterances, or meaningful speech acts which make propositions and are tied to discourses (type, genres) and their formations. They will depend precisely on the discursive field(s) where debates happen. Discursive fields, evolving over the course of discussion and debate—sometimes but not always contested—about relevant events and issues, and encompassing cultural materials are constitutive of the contestation and alliances between actors as well as their concepts (Snow 2013). Discursive fields are thus inter-discursive as they inherently contain resonance between various discourses.

At the level of discourse, the analysis is concerned with the orientation of communication to particular arguments within texts where metaphors occur. Metaphors may be smaller, but they are not less flexible units. Typically embedded in arguments, metaphors may directly serve the creation of an argument but also, in a less straightforward predictable fashion, as frames and schemes (Schön and Rein 1994, Kövecses 2005).[33] Among the *discourse functions* which researchers recognise as powerful are: 'framing of a topic, highlighting and hiding, emotionalising and attentional functions, as well as creating and compacting inferences' (Goatly 1997). What these functions of metaphor share in common, they contribute to *organising* the discourse; however, they also invite us to oscillate the view of a metaphor between author and reader-initiated strategies—beyond the intentionality of a speaker as a member of a particular community or institution. As Caballero (2006: 231–32) noted, 'Metaphor is, then, both a conceptual and a socialisation tool, and one that is partly acquired and effectively put to work through discourse interaction.' While explicitly formulated arguments are considered by the researcher, leaving aside metaphors risks leaving out a part of other discourse activity (cf. Semino 2008). In this regard, analyses of metaphors have been used not only to characterise single lines of an argument but also to discover 'systems of metaphor', which may structure or characterise an entire text (Ortony 1993: 4). Nevertheless, even after such systematicity has been found, it is a challenging task to scrutinise a

[33] It is argued that metaphor provides rich inferences also by activating commonsensical frames from everyday life (cf. Kövecses 2005). Metaphors may provide further conceptual twists, e.g. in the 'boat' metaphor, *excitement*, *reward*, or *adventure* could appear singularly or together, thus eliciting knowledge in a way literal discourse cannot.

certain metaphor so as to establish the relationship to the discourse of interest.

Accordingly, it is imperative for sociological purposes to analyse the implications of a metaphor's use. Metaphors filter some meanings, interests, and practices over others, thereby excluding other interpretive alternatives. The study of metaphors should thus be balanced with (critical) discourse approaches and comparative study. The critical and comparative aspect of metaphor analysis in discourse targets arguments when the analyst asks: *Who articulates them as arguments? Whose metaphors are presented? Who wins and who loses if one particular metaphor is dominating the discourse? Who is marginalised by a particular metaphor?* With these questions, we tackle issues of *critical* metaphor-in-discourse analysis (cf. Charteris-Black 2004 and 2005). While discourse analysis focuses on the moment a particular metaphor develops (supporting) a particular argument, the (critical) discourse analysis moment goes on to identify what aspects of the discourse are conceptualised by which metaphors, by whom and for what purposes, and to what effects. Connecting a basic level of corpus linguistics with metaphor analysis and discourse analysis should thus provide evidence about a metaphor's relatedness to actors (individual or group), even regarding their ideological associations to particular institutional settings. This should yet be distinguished from investigating systematic metaphors (or their root metaphors) as integral parts of discursive formations. The formation is not exclusively a particular discourse. It can indicate how and to what extent the representations translate within and between discourses (Bono 1990, Koller 2004). The reasons behind metaphor use and the meta-pragmatic level of discourse are extended to a more profound relationship that relates the local functionality of metaphor to global structures of knowledge and power (Foucault 1972). Foucault does not provide straightforward methodology to study formations and also the relationship to metaphor has to be derived from his theory. As Foucault (1972: 62) writes:

> 'One does not pose the question at the level of discourse itself which is not external translation, but the locus of emergence of concepts; one does not attach the constants of discourse to the ideal structures of the concept, but one describes the conceptual network on the basis of the intrinsic regularities of discourse; one does not subject the multiplicity of statements to the coherence of concepts, and this coherence to the silent recollection of a meta-historical ideality; one establishes the inverse series: one replaces the pure aims of non-contradiction in a complex network of conceptual compatibility and incompatibility; and one relates this complexity to the rules that characterize a particular discursive practice.'

A metaphorical concept is here related to an order of discourse (*métaphore d'ordre*) and regularity, it appears in texts by a whole set of relations that are peculiar to the discursive level. To metaphorical utterances, a particular discursive formation is regularity which shapes what is likely

and possible to be said (*enoncé*), felt, and thought, but then also, what is considered socially, economically, and politically (un)acceptable. It is a system or formation of matters, objects, modalities (also narrative), concepts, and strategies, it is a formation of knowledge (and power).

3.3 Metaphor Analysis of the Nanotechnology Discourse (Integrated Approach)

The metaphor analysis has been outlined in three layers: words (concepts), narratives, and discourse(s) formations. These are different layers in the order of nanotechnology discourse which are represented through interrelated *phases of research.* The main focus is on metaphors used for representing and intervening in matters of concern—in other words, metaphors are studied as they are used to open, re-formulate, or close issues, promoting, maintaining and criticising them. This metaphor use, it is argued, is interrelated to narrative and discursive levels in a way (transformative) that is non-reducible to either of these. Methodologically, this means examining the corpora in segments (also cultural) which are fluid and constantly shifting, searching for their inflexion points, amplitudes, and any relative intersections of metaphors, narratives, and discourses.

- In the first phase and pilot content analysis, I read the corpus of texts to gain insight into discussed matters (things, events, locations, etc.) so as to identifying their content and the more durable controversies—what these texts share in common. Following the traces of discourse where possible, I focus on the novelty/conventionality of the different uses of metaphor, and in some cases, whether they are supportive or critical of the issue. This means I pay attention to the representation as well as the user of the metaphor (scientists, journalist, etc.). The reading then focused on metaphorical expressions, or metaphor keys (see also Charteris-Black 2004, Semino 2008: 191–216)[34] considered capable of unlocking specific meaning related to controversies. For each studied case, I assumed there was a particular trajectory of mattering with certain inflexion points (cf. 'mattering has history', in Cooren et al. 2015). The matters of concern (also in Latour 2004 and 2008) are a thing, a topic, a subject, or issue being presented, discussed, questioned and/or accepted in order to decide collectively how to go about nanotechnology(-ies). Matters of concern are 'matters of interests, by definition, what is supposed to animate the actors when they defend or evaluate a position, account for or disalign from an action, or justify or oppose an objective . . . . They invoke, convoke in their talks and writings to explain, justify, legitimise or account for their positions or actions and that of others' (Cooren et al. 2015: 10–11). Repetition can be a

[34] The metaphor analysis here follows the Greek etymology of the word 'metaphor': to transfer or bear, in this case, meaning from one context to another. Conceptual metaphors involve the transfer of a set of correspondence between semantic domains (Semino 2008: 226). Metaphor keys are metaphorical expressions which the researcher finds of interest and frequent in a manual analysis of a particular data set so that they can be subsequently searched/concordanced in a larger corpus (Semino 2008: 198).

good measure of the strength or stability of the mattering (Cooren et al. 2015: 11), as when various actors make something relevant, they 'serialise' representations by creating sequences between/of various problems (e.g. GMO, asbestos, nuclear, etc.). In my view, matters of concern include establishing this relationship as a certain invocation, evocation, and convocation which corresponds to metaphorisations.

- The aim of the coding phase is aimed at generating a family of codes and typology within the relatively large sample of discourse in question. The analysis was here inspired by the metaphor identification procedure (MIP, developed by the Pragglejaz 2007 group, also in Semino 2008: 11–16), which does however incline too much towards lexical units of discourse. In the first phase of the analysis, I conducted open coding for metaphorical candidates to obtain the *conceptual* metaphors and their variations. Just like linguistic metaphors, conceptual metaphors involve the transfer of a set of correspondences between semantic domains (Semino 2008: 226). Hence, I used axial coding of the conceptual metaphors to obtain their dimensions within and between these domains. In all phases, the coding process was assisted by Atlas.ti, software used for qualitative analyses. This enabled the generation of topology within the relatively large sample of discourse in question. Next, I advanced to an analysis of the narrative structures which would correspond to the particular model of these relations.
- At the *story level*, metaphors can create a particular scenario about what did, can, or should happen to emergent technologies. Similar to systematic metaphors, narratives connect events and experiences which were disconnected, becoming interconnected and planned, displaying coherence, integrity, fullness, and closure (Gottweis 1998: 33–37). It was assumed that by probing into the locations, events, actors, and related structures of signification, metaphors could reinforce the structure of representation (cf. Greimas and Courtés 1982: 247–49). Greimas's actantial model was also used in the analysis of controversies to identify its actors and phases of a controversy. In particular, Greimas's actantial model, applied by François Cooren in his analysis of the Great Whale River case (2001) controversy, here inspired the model relations between actors as well as the phases/series of tests/trials. In principle, Greimas's narrative schema is usually obtained through modalisations in *being* and *doing*. For my purposes, however, it was adjusted to the notion of the *metaphorisations* of actors, events, locations (and their variations) as if controversies were allegories, chains of significations, and networks of elementary metaphors.
- Within the perspective of Foucault's (1972) analysis of knowledge, next step was studying metaphors as a discourse/discursive formation that created typologies/topologies within which even the characters of a story were distributed and governed. At the *discursive*

formation level of analysis, the assumptions of the critical metaphor analysis were therefore applied above the considered rhetorical strategies or ideological convictions of the particular actors. Instead, I was seeking to find the regularities that characterize a discursive formation, that is, formation of objects, formation of the subjective positions, formation of concepts, formation of strategic choices, and not the grammatical level of sentences, or the logical level of propositions, or the psychological level of formulation (Foucault 1972: 116). In this sense, the metaphor was studied to *do* more than a linguistic category, it became part of a discursive formation with its historicity, cognitive schemas, and order of discourse.

- By following the above analytical levels, the *comparative* level of study sought to explore the differences between actor's strategies and make a synthesis of those locally grounded concepts, narratives, and discourses; not to commend one and discredit the other, but to identify their value for such a comparative analysis (cf. Toumey 2006). The comparative study was conducted as a comparison across three analytical levels: concepts (measuring systematic use of a concept), narratives (and identifying counter-narratives), and discourses (interdiscursivity and pragmatics of discourse). The final stage considered how these could altogether explain the relationship between metaphor and nanotechnology. This became more apparent in analytical chapters on public debates, but also in common discussion (Chapter 10) on metaphor capacities and biases, and various ontological regimes.

3.4 Atlas.ti: The Analytical Tool Used

It is a common practice that those who aspire to have a comprehensive, context-informed, and relatively data-driven study decide on software for qualitative analyses such as Atlas.ti, Alceste, Nvivo, Ethnograph, among many others. As far as they assist in finding functional types through code co-occurrences, these tools can, to some extent, keep a researcher from the tendency to get lost in over-generalisations. On the other hand, like any other instrument or program, codes can create an illusion of factuality and scientism. Through the addition of different levels of codes and processing, these codes via basic transformations can be a treacherous enterprise; even measuring co-occurrences can backfire by adding uncontrollable synergy to subjectivity. Responsibility for these kinds of transformations is, as with the inputs and outputs, therefore always attributed to the analyst. In order to obtain context-dependent interpretations, the programme was used with *memo notes* which can be used as filters for codes and various analytical levels, in my case, some of which are expanded upon in writing within the analytical chapters.

The analysis of the data for this thesis is assisted by the state-of-the-art software Atlas.ti. One of the advantages of this program is the opportunity to conduct qualitative textual analysis while integrating some quantitative features in research design. It brings clear advantages to how

data is stored, processed, and presented. There are however methodological challenges which emanate from various features of this approach. The common operation is the practice of adding interpretative linguistic information to a collection of data (Leech 2005). It is also among the most debated ones. There is a never-ending conflict of perspectives as to whether a text with codes (or 'tags') brings 'value added' (Leech 2005) and an objective record of analysis (McEnery 2003), or conversely, adding the information is a 'perilous activity' where text loses its integrity and context (Sinclair 2004: 191). As an effect, the analysis is not only challenged but protected by interpretative information, such as codes and annotation (morphological, syntactic, semantic). For example, a large corpus can be observed through these codes, yet information beyond can also be missed (the previously discussed dilemma between systematicity and context thus transmits into this analytical tool). The rich statements which have been initially condensed into categories risk the possibility of failing to discover important nuances (Sinclair 2004: 191). The statements do not actually form precise categories, and the same applies to perceived metaphoricity, which depends to a large degree on intuition and context (Ritchie 2003: 125–38). At any given moment, the categorisation process employs subjective judgements based on the coder's own mental schemas, which may entail an understanding not shared by other readers.

An important characteristic of the technology advancement is the corpus size and how it can be worked with. The volume of textual data presented in various fields has increased significantly due to the development of new means of communication as well as numerous databases of published materials. The analytic tools have improved so they can be used in all the phases of research: coding, categorisation, and the interpretation of the data. They allow different functional codes to be gone through at different levels of abstraction, enabling the creation of networks of codes, memos, text units, and other annotation items, modelling situations and finding correlations. While this maintains focus on the relatively larger size of the corpora, it can considerably improve workflow. The interpretations often result from the identification of two entities within each other so that their common properties (resonance) only need to be assumed once. Yet the computer-assisted study not only allows for each conceptual overlap between the target and the source domain to be treated as a new entity, it is also possible to keep and reorganise the source and target domains into entirely new categories (or families) of codes. The software program allows the researcher to proceed by segmenting the corpus into relevant units of significance and by achieving a multidimensional categorisation in accordance with the metaphor analysis specific to each case study. This clearly has a large impact on working with narratological model and discursive formations. These two 'structures' are constructed through reasoning with manually coded concepts and operate both in the source and target domains. For example, a researcher can take linguistic expressions which are representations of a small discourse fragment input and model different

relationships as codes of *synonyms*, *taxonomies*, *analogies* (and metaphors), making their synthesis. Finding a systematicity establishes links between the codes, such as target and source domains, but also other levels of social representations (cf. Moscovici 1998). One particular type of social representation is the insertion of metaphors in 'actantial' model of narratives which would allow a compositional overview of the controversy. Finding a narrative structure with metaphorical operators (e.g. coded according to the Greimasian model) is then an additional tool for linking parts of the discourse and uncovering discourse coherence. This means identifying who acts 'metaphorically' as a subject, object, helper, opponent, etcetera and how particular formation emerges between various discourses.

It has been noted that in applied conceptual metaphor theory semantic domains become more important for analysis than linguistic expressions. Still, linguistic expressions as lexical items are important as they trigger conceptual domains and mapping between source and target. Essentially, every word (or phrase) of content could be encoded as knowledge of the link between source and target. Regarding metaphor, words as well as phrases can be included as single entries representing individual manifestations. For example, the metaphorical expression 'European Governments are determined not to miss the boat on the next "nano" revolution' can be coded as a conceptual metaphorical mapping of INNOVATION IS JOURNEY as well as GOVERNMENTS ARE TRAVELLERS/PASSENGERS, NANO-REVOLUTION IS A PLACE/LOCATION, among others. The complete/coupled conceptual setting had to be considered in many cases with the corresponding theoretical model (such as the Greimasian or Lakoffian Location-Event-Strcuture models, see also analytical chapters). Atlas.ti was especially used to code and create meta-relationships within and between conceptual domains, that is, to study vocabulary associated with specific source domains (such as JOURNEY) and to capture these inter-textually and across the interface of science, policy, and the public discourse on nanotechnology. This was considered a meaningful strategy for analysing phenomena as complex as 'technology roadmaps', for instance. These are, and quite paradoxically, not merely surface expressions of the particular conceptual domain of a given context but an entire conceptual system of metaphors.

Part IV Data

Chapter 4. Corpus Compilation and Case (Re)Construction

Specialised corpora do not grow on trees.
Routledge Handbook of Corpus Linguistics, 2010

4.1 Corpus Compilation (Introduction)

As John Sinclair, pioneer of corpus linguistics, pointed out, we should not expect a general reference corpus like the British National Corpus (BNC) to document specialised genres and domains adequately (Sinclair 1991: 24). For this, we need specialised corpora, containing reasonably parallel texts, as they are more likely to document the conventions of the genre and the concepts and terms of the domain. Compiling a *specialised* corpus of nanotechnology discourse has one important feature. There is no previously available collection of the discourse type in question. In particular, nanotechnology as a research practice or even as a policy (e.g. regulations) is not a single unified field. It would be wrong to rely on single source material (Stubbs 2000): 'It is unwise to rely on a single corpus, however large or well designed it might be: all corpora have in-built biases, and findings should therefore be checked in different independent corpora.' The relationship between nanotechnology and metaphor in a specific genre of discourse such as scientific, policy, or the public (broadsheet) media seems more appropriate for specialised and multiple corpora. Multiple corpora should allow insight into nanotechnology discourse and possible transformations at the science-policy-public interface. Moreover, it corresponds well to a choice of design in which to implement a qualitative study in various local (national) contexts, that is, studying particular cases. How does one proceed in the construction of the interface and the reconstruction of particular case studies while maintaining feasability? The main challenge of this chapter is how to reduce the enormous discourse which nanotechnology represents while maintaining the plurality and complexities, the values, and the attitudes of representations (not only metaphorical) in their social contexts.

In the next section, I will focus on all the corpora used in this thesis, how they were assembled/compiled ad hoc to further increase the analytical insight into the discourse dynamics in specific contexts. The chapter presents the three data sets, assembled to mirror the science-politics-

public interface in the following databases: Web of Science (WoS), Community Research and Development Information Service (CORDIS), and national media (NM), such as Europresse, Factiva, and Newton Media. The construction of the specialised corpora and a basic overview of specific characteristics of theirs, which may be appropriate to take into consideration, are included in a series of tables and graphs. The corpora compilations and descriptions, and especially in regard to the process of generalisations, are argued as a first step in the qualitative study. These descriptions may all seem of little relevance, yet assessing the general context of the articles and their collections proved to be a continuous endeavour, even directly interfering with the coding procedure. To reconstruct known and unknown characteristics of nanotechnology discourse was also believed to be achieved by randomising and maintaining a relatively large sample over a long period of time (1999–2015). Constructing the material for the qualitative study yet proved to be something of a continuous process, and several strategies were applied in piecing it together. Also, all databases from which the corpora were obtained are in digitised form but differ in respect to their free availability to the public, such as publicly accessible sources and databases accessible only under special licences like Web of Science and the Factiva, Europresse, Newton Media, among others.[35] Finally, a particular feature of these specialised corpora is a multi-modal regime of texts and images and a multilingual variety of three different languages: Czech, English, and French. Translations were applied only for the material presented in the thesis document.

4.1.1 Web of Science Corpus

The first corpus, compiled from the Web of Science (WoS) database, focused on modelling nanotechnology discourse resourced from different scientific disciplines (fields). Web of Science represents the visible world of nanoscience (and nanotechnology)—and though regulated by peer-reviews and journal editors—can serve as a reference to nanotechnology discourse. But instead of searching 'nanoscience/nanotechnology' keyword in the database, or using a database search category that was introduced only later, I decided to assemble the discourse through common reference to nanoworld. Nanotechnology discourse has been previously described as scale and future oriented. It has also been defined through contestation between experts from traditional disciplines and who in that regard can question their affiliation to the field (see discussion back on pages 30-31). These debates have always been part of the nanotechnology discourse, nevertheless. The issue with adherence to a category or label can arguably be resolved by the common reference to nanoworld. There are some interesting choices, like scan 'tunneling microscope' as common boundary object, for instance, but delimiting the discourse this way would remove social sciences. 'Nanoworld' as a keyword is arguably the next best choice that can relate to various sciences

[35] For this type of material, I used licences from Charles University, Library of the Faculty of Social Sciences and the University of Strasbourg, Bibliothèque nationale et universitaire de Strasbourg.

operating physically, legally, philosophically, and so on, at the nanoscale and which in their reference to the nanoworld become part of nanotechnology discourse.

The construction followed the usage of the word 'nanoworld' (keyword) in the title of an article or body of its abstract between the years 1990–2015. An issue for studying the corpus any further was how to deal with metaphors and technical terms. Nanoscience discourse has been bound to a specific scientific language register or scientific field, there were always utterances which qualified as barely or not metaphorical. We find technical terms for 'chaotic quantum *dots*' (quantum laws), 'radiative *lifetimes*' (conservation law), '*wave*lengths' (power law), 'nano*machines*' (scaling laws), '*tunneling* effect' (logarithmic law), or sociological terms for '*precautionary principle*' (regulation/workplace law), '*folk historiography*' (Moore's law), or '*progress*' (law of virtue/moral imperative), etc.; all of these are sedimented (dead) metaphors in various registers. Additional strategy concerned exploring corpus subcategories (WoS offers some queries in this regard), and which entailed the possibility of reaching a special sub-population. Nevertheless, my aim was not to quantify the empirical data in categories for some historical purpose or quantitative measures.

4.1.2 European Commission CORDIS Corpus

The second corpus was compiled for a study of the European Commission (EC) nanotechnology policy. The articles were selected between the years 1999–2015 using the keyword 'nanotechnology' in the CORDIS database, the primary information repository of the EC. The corpus has a specific value in targeting nanotechnology discourse in the European Union's institutional setting. The database complies with the guidelines of the Publications Office of the European Union on behalf of the European Commission's research Directorates-General and Agencies. It contains data from different actors on EU-funded projects being executed. Furthermore, science editors and journalists prepare the content by writing research reports, news, or making interviews for the sake of maintaining different storylines. CORDIS is therefore not only a repository for research projects, it is also a science policy medium with a specific editorial and political agenda, a representation of specific goals, desires, and interests. Even when actors submit information about projects (contracts were signed), it is a form of ideological compliance: 'The project leaders justify their focus referring to the European Commission's articulated demands' (Åm 2013: 13). The consensus about nanotechnology development in CORDIS, emerging from the interaction between researcher (engineer), policymaker, and journalist (editor), is thus taken as a reference for science policy discourse. Other databases could indeed capture the additional nuances of the EC policy; however, following all these would create a corpus with thousands of entries and thus is beyond the scope of this study. Also, CORDIS generally contains information about projects which are being executed or have already been completed. These are filed when contracts are

signed and when CORDIS receives the data from the Commission.

The specialised corpus for this case study was compiled by searching for texts on nanotechnology (keyword) in the *news* section of the CORDIS database. This was believed a viable strategy to explore the matters of concern, in addition to collecting *reports* on projects and policies in the selected time period. There was no further specification in the request, such as specific policies or instruments ('technology roadmap') as the discourse is wider than a topic. Other criteria included a search which would span over the years 1999–2015, exceeding the period of a particular framework programme. As the initial corpus was considerably large, randomising the sample reduced its size to approximately two hundred articles. Each article in CORDIS has a 'record number' or RCN, thus it can be traced back (see also the last section of this report). Bearing in mind that the CORDIS database may explicitly represent limited categories of issues, it still provides a good and broad range of information with which to look at EC nanotechnology policy. In particular, it also allows for a combination of analysis at the European level with national data (corpora) in order to confront country-specific patterns of nanotechnology mediation and deliver additional input on the translation processes between science, EU policy, and national contexts.

4.1.3 National Media Corpora

The third corpus (or corpora) was compiled as a national media collection (NM), using pan-European databases such as Factiva, Europresse, and Newton Media to obtain material for an analysis of daily broadsheet newspaper articles from the Czech Republic, France, and the United Kingdom. All the national corpora consist of different daily newspapers (and several magazines), the aim of which is to factor out some of the unknown variables such as the political background of a newspaper, if applicable. In the Czech Republic, these are *Mladá fronta Dnes*, *Lidové noviny*, *Právo*, *Hospodářské noviny*, *Profit*, and *E15*; in France, *L'Express*, *Liberation*, *Le Figaro*, *Le Monde*, *Les Echos*, *La Tribune*, *L'Humanité*, *La Croix*, and *Le Nouvel Observateur*; and in the United Kingdom, *The Daily Telegraph*, *The Sunday Telegraph*, *The Times, The Financial Times*, *The Guardian*, *The Independent*, and *The Observer*. The articles in these subsets were selected between the years 1999–2015. Next, I will focus on the reasoning behind the compilation of the national corpus. Different strategies were applied to explore and become better acquainted with the size and scope of media activity during the last fifteen years.

Despite having already given up on a quantitative study per se, my search in the database was aimed at a larger collection of data and targeted articles so as to be selected on the basis of references to 'nano-' in their titles and subtitles. Following the headlines instead of searching for 'nano' anywhere else in the body of the text was a decision made to reduce the enormous discourse, as oppose to filtering articles where nano is either the main or side argument. Both would provide informed discussion on media content and practices. Also, using a simple prefix was expected to

maintain the possibility of finding extensive variability—in other words, representativeness for a larger set of issues and following all the forms of nano hype. An important step was to exclude those texts from nanotechnology discourse containing the nano- prefix yet used in another cultural-linguistic context. These non-nanotechnological, and thus, irrelevant news items or reports had to be eliminated. As such, we find nano- occurring as a preposition in the Czech verb '*nano*sit' (to carry in) and as a universal relation to names, such as '*Nano*ok' (member of Inuit tribe), or a former Albanian prime minister 'Fatos *Nano*'. Special cases where nano- was excluded during the construction of my corpora is the music gadget called Ipod *Nano* and the Indian car Tata *Nano*. These two technologies belong to technology hype but do not figure in my research as such, or at least not above the statement that the nano- prefix proliferates in society and the market economy. Our creative society is breeding nano- figures which cannot enter my analysis in any greater detail.

One of the important choices made and which preceded the compilation of the national media corpus was deciding to focus on traditional over electronic media. The media has undergone a transformation over the years, especially due to the growing influence of electronic and, particularly, social media like tweets (cf. Runge et al. 2013). In a social science article for the journal *Science*, Brossard and Scheufele (2013) found that nine out of ten people in the United States turn to search engines to find information, and sixty percent of the US public lists the internet as their primary source of information about specific scientific issues. The conclusion of this research carries implications for science journalism and attention should be paid to these trends in communicating science. Similarly, the study 'Coverage of emerging technologies: A comparison between print and online media' (Cacciatore et al. 2012) explored differences in the volume of coverage and thematic content between US print news and online media coverage for nanotechnology. The authors found that while American print news media coverage of this emerging technology has peaked and started to decline, internet (Google Blog Search) coverage of nanotechnology is still growing (also in Figure 4.1). Additionally, their data show discrepancies in the thematic content of online and print news coverage—online users are more likely to encounter environmentally themed content relating to nanotechnology. The authors of the study further suggest that public discourse on related issues will be shaped, in part, by media consumers' preferred information platform.

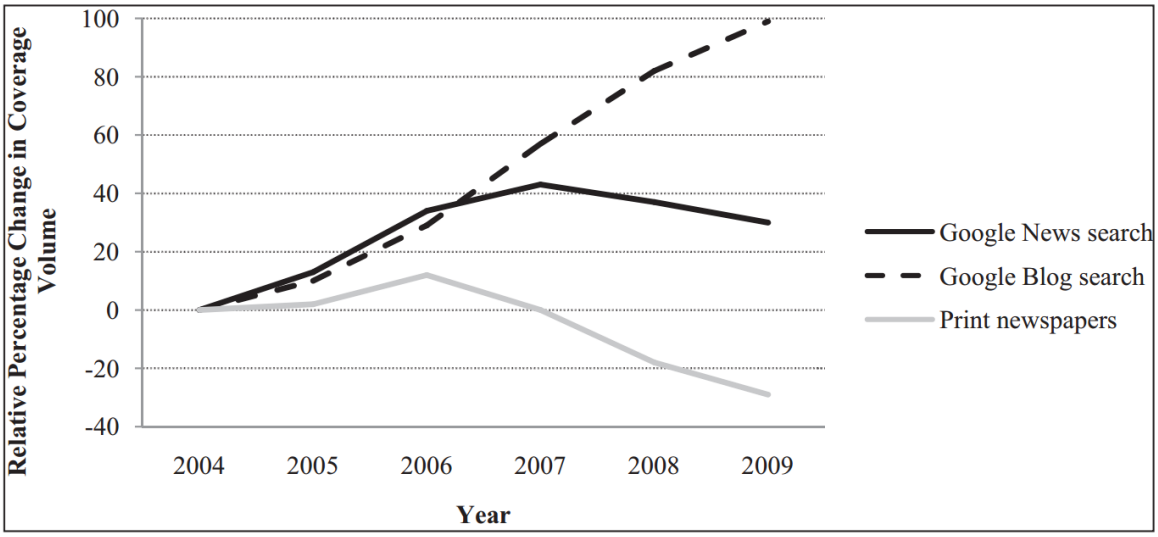


Figure 4.1 A comparison of coverage volume trends of nanotechnology stories in print and online media from 2004 to 2009. The study of print and online news coverage on nanotechnology yielded that blogs in particular are likely to devote continuous attention to a certain news topic, even after its disappearance from the traditional news agenda. The authors concluded 'that the cyclical pattern of news in traditional media formats may not be a necessity online' (Cacciatore et al. 2012). Source: Cacciatore et al. 2012: 11

A phenomenon, and one which is closely related to these changes in the media, is the 'personalisation of news' (Geens et al. 2007), where a reader has the possibility to choose sources and types of messages which interest them and can follow up on these through searched patterns (e.g. alert messaging). This trend may lead, however, to certain media isolation from certain types of messages as the reader is not directly influenced by messages they decided to ignore (cf. Sunstein 2001, Iyengar and Hahn 2009). In other words, despite being exposed to a variety of content and opinions, people tend to be selectively exposed to content which is congruent with their own viewpoint (cf. Cacciatore et al. 2012: 15).[36] Also, the transformation of electronic media is connected to the possibility for readers to use discussion as their opinion platform, commenting or blogging about a topic in online media and in this way engaging or influencing the public debate. In this sense, journalists lose their monopoly—bloggers are sometimes more informed than authors as they may become direct observers and reporters of events and participants in those debates (citizen journalism).

The public can now use multiple media formats for science news, whereas at the beginning of the century the opposite was true. A decision to focus on traditional media was also influenced by electronic media's characterisation as the 'noise' of the internet; its 'openness' may also be its biggest weakness—the 'shallow waters of click-throughs' (Murphy 2014: 56) as when clicks and screen swipes become a starting point for opinion formation and argumentation. This by no means should imply that traditional media are void of ambiguities and contrasts of opinion or borrowed,

[36] For example, nanotechnology appears regularly in certain periodicals, including *Scientific American*, *Wired*, *Technology Review*, *Nanowerk* (US/UK), *Science et Avenir* (France), or *Technet* (Czech Republic), among others. These, however, presuppose already certain interest in technologies.

repeated, and recycled conversations. In the case of traditional media, such as newspaper, people always expect, according to Umberto Eco (in 'Numero Zero' 2015), something more—commentaries and analysis—yet, this content demands more space and more money. In some cases, nanotechnology initiatives directly used the traditional media (such as *The Guardian* or *Le Monde*) as their communication platform in voicing their views. Finally, a large number of people encounter nanotechnology while reading science (or policy and economy) pages. At the same time, an even larger number do not read them, nor do they read newspapers, magazines, or websites which report on nanotechnology. In all cases, the information which proliferates in traditional and electronic media is not opinionless space, leaving available all kinds of strategies and forms of public reactions to nanotechnology.

4.2 Case (Re)Construction

Having all the data sets assembled, it was expected that the initial pilot observations would allow for the identification of ongoing controversies, providing good candidates for studying matters of concern. A data overview suggests that the amount of articles published every year on nanotechnology has been growing. This corresponds to other studies which suggest nanotechnology has been making it rather continuously into the media headlines without losing its sensationalist character—the term nanotechnology media *hype* might be quite useful here (cf. Berube 2005, Cacciatore et al. 2012). By looking however at the structure of nanotechnology media coverage more closely, it was assumed that each cultural context has its own hot and cool phases of in coverage (controversy), measured in absolute numbers (and frequencies) as well as the general context of discussed issues. The process of amplification and magnification during these media-generated news cycles is captured in graphs as dramatic transitions, turning points, and skewness (cf. Vasterman 2005). These attention cycles should also correspond to certain frames and narrative structures (cf. Nisbet and Huge 2006).

Returning to previous studies for comparison, it was found that all the analysed traditional media devoted continuous attention to nanotechnology. Yet, each context showed a certain news topic which emerged and started to disappear from the traditional news agenda, always with a different duration. Sometimes, issues re-emerged. This would suggest that there may be a cyclical pattern of news in traditional media or that the term 'media-hype' can be used in the nanotechnology debate, representing a kind of self-inflating media coverage. The obtained graphs arguably have interpretative value for the specific discourse dynamic in different contexts: controversy opening, closure, and the like. The relative frequency of articles with specific topic occurrence published over the selected period of time thus becomes an essential part of the controversy indicators.

4.2.1 Data Overview and 'Hype' Identification

In Table 4.1 (below), we see an increase in articles over the subsequent years indicating how the 'nanoworld' became a conventional figure and, related to that, fifty years after Feynman, the period in which nanoscience/nanotechnology might have been established as a discourse.

Table 4.1 Articles obtained from the Web of Science database (using the keyword 'nanoworld') in total and relative numbers over five consequent periods.

Years	1990–94	1995–99	2000–4	2005–9	2010–15	Total
Articles per period	3	14	40	68	41	166
Relative no. (%)	1.8	8.5	24	41	24.7	100

The structure of nanoworld (nanotechnology) corpus regarding various disciplines is quite variable. The compiled corpus consists of approximately two hundred articles from several different research areas. Adopting the WoS analytics, these are chemistry (65), physics (49), material science (57), engineering (31) and other topics (64). Although some articles cover more than one research area, their topical inclination to natural sciences (and engineering) met the expectation of finding a majority of issues in physics, chemistry, and material science (cf. Fogelberg and Glimell 2003, Ball 2003, Munchi 2007, Bensaude-Vincent 2009). Social sciences are represented but rather scarcely (cf. Shapira et al. 2010). In several cases, WoS proved to be quite erroneous in placing articles in clear-cut categories, such as when 'A Legal Version of the Nanoworld' (WoS 2011a), an article discussing the matter from the legal fields (law discipline) perspective, was placed in the physics research area. As for the document types, the WoS corpus features articles (101), proceedings papers (46), editorial material (27), reviews (21), or news items (19). The statistics from 2010–15 are not conclusive as some articles were not available in a given year under university licence.

And what has been found as the matter of concern for metaphor analysis? The prevalent point all along the spectrum is that (legal) scientists and regulators must face the indeterminate character of the nanoworld. It is argued that phenomena at each scale are governed by identifiable laws but by different (sometimes very drastically different) constitutive relations (WoS 2008a: 92). One of the first entries in the WoS corpora concerns the nanoworld opening before us with breakthroughs in electron microscopy, which 'opened the doors/gateways' and 'built bridges' to the nanoworld (1991, 1994), allowing for the manipulation of atoms and molecules. The initial testing procedure (keyword) was designed as a pilot content analysis that started with tagging the explicit nanoworld 'laws'. This involved excluding words which were not considered for the analysis, for example, words such as 'flaws' (not in law), 'lawn' (e.g. 'a lawn of single-stranded DNA molecules'), author names like 'Lawrence', or places such as 'Wroclaw'. Other words were

partially considered but not fully integrated, such as 'outlaw'. Also, 'copyright law' in the article's *footnotes* (i.e. author's disclaimer) has been considered marginal, although we could imagine a certain relevance, especially if it appears in the main body of the text. There are, for example, regulatory regimes of the nanoworld which extend to the author of this thesis himself—the *production* practices of articles as exercised according to the 'law'. This study does not imply, even in the absence of a specific statement, that there are no other codes relevant to laws and regulations. The regulatory regimes which are considered are not a perfectly closed area. The study aimed specifically at metaphors for and in laws and that extended beyond the capacities of the automatic search.

The articles for the second corpus were obtained from the news section of CORDIS, including two categories of reports/news: (a) reports on EU-funded research projects from the experts who provided them or from science editors (based on each report summary), and (b) news written by journalists on current research and innovation activities, including project interviews, trending science news, reporting on events, and funding opportunities. As we can see in Table 4.2, nanotechnology reporting in the database reached its highest peak between 2007–13, with steep acceleration after 2002 (in 2004 for absolute numbers).[37] The statistic is also influenced by the periodisation of different Framework Programmes (FPs) (in Table 4.2). Data beyond 2007 was affected by the transition to the new FP (the seventh) where nanotechnology had become one of 'key enabling technologies'. This was complemented by CORDIS transforming its structure of reporting and creating a special nanotechnology section within the database. The last period of the corpus record (2014–15) in the table below shows only a fraction of the eighth FP (Horizon 2020), but we can roughly extrapolate to receive results comparable to the previous seventh FP. What Table 4.2 cannot show is the absence of negative nanotechnology images in the CORDIS corpus. This should by no means be taken to mean the absence of controversy as the topic is clearly represented as a crisis of nanotechnology governance (see the later case study). Also, even with the amount of positive bias, the obtained corpus can always serve as a comparative study relative to various contexts where a conflict of perspectives on nanotechnology exists (see the later national media corpora).

The corpus was compiled to cover the European Commission's science policy discourse and shifted to a case study of 'technology roadmaps' since these were identified among the dominant policy metaphors. For example, the 'European paradox' (or 'valley of death') and the 'European research area' (ERA) were among the frequent metaphors, suggesting metaphors of a landscape

[37] In 2004, the European Commission held a public consultation on the future of nanotechnology in Europe, following its communication 'Towards a European Strategy for Nanotechnology' (May 2004). Soon after, it launched a newly revamped information service on nanotechnology within CORDIS, bringing together news and information from diverse sources.

potentially mixed with other systematic use of metaphorical language.[38] As it shall be argued in the corresponding case study, not only did the amount of references to metaphors of landscape and its governance dramatically increase with the reporting on nanotechnology, these images have been spreading to other categories such as research projects, networks, report summaries, or programmes, among others. The reason for this 'dispersion' has specific explanation in sociology.

Table 4.2 Articles obtained from the CORDIS database (using the keyword 'nanotechnology') in total and relative numbers per consequent periods of the EC Framework Programmes (FP7–FP8).

Years	1999–2001 (~5th FP)	2002–6 (6th FP)	2007–13 (7th FP)	2014–15 (~8th FP)	Total
Articles per period	5	90	124	29	248
Relative no. (%)	2	36.3	50	11.7	100

Against the background of a gradual increase in the number of articles concerning scientific research in WoS and best policy practices in CORDIS, journalists in the national media have been concerned about the disruptive technology since the early years. The opportunities and risks of nanotechnology were addressed in all media (and countries) studied, while being channelled from different resources and different technology areas, therefore, assembling unique nanotechnology controversy profiles. A particular feature of the Czech Republic is that the media gave particularly large attention to the opportunities that nanofiber technology developments might have in medicine (health) and concerning the environment (ecology). The risks, which are regularly raised at the international level (and also in the French and British context), were only rarely addressed in the Czech media examined. This was a surprising initial finding, which led to additional considerations of the comparative study that must reach beyond literal and explicit content of the controversies (and public debates).

Table 4.3 offers a perspective, in absolute and relative numbers, of the articles from the Czech, French, and the British national media (NM). If we compare the absolute numbers in the three countries in a graphic format, we can observe the mediascapes differ in regard to size and timing. This also anticipates how likely they correspond with various content (see later). The relative strength in the occurrence of articles across national media reporting on nanotechnology

[38] The 'European paradox' was introduced in the *European Commission Green Paper on Innovation* (1995), reintroduced with the latest Horizon 2020 Framework Programme (2014–20) and particularly, with the European Institute of Innovation and Technology (EIT) initiative. As with the 'Lisbon Strategy (Agenda)' (2000), the paradox belongs to myriads of figures tailored for nanotechnology development and strategic planning. The ERA is an area in which scholars do not bias the choice of collaborators on grounds of geographical proximity or national borders (Frenken et al. 2007) and is therefore another strategic metaphor for future adjustments. Yet, if there is any distinguishable discourse (language use), it is much broader and arguably vaguer than that arising out of the mid-term revisions and re-launches of Lisbon or the ERA.

allows for the identification of inflexion points and themes for further analysis. The mix of indicators suggests the common *hype* in the media—measurable in graphical skewness and inflexion points.

Table 4.3 Number of articles in broadsheet print media (selected via the keyword 'nano' in titles and subtitles). The table is constructed in absolute/relative numbers for the Czech Republic (CZ), France (FR), and the United Kingdom (UK).

Years	1999	2000–3	2004–7	2008–11	2012–15	Total
Articles per period (CZ)	1	15	115	152	101	384
Articles per period (FR)	13	75	231	228	94	641
Articles per period (UK)	4	110	116	64	60	354
Relative no. in CZ (%)	0.3	3.9	29.9	39.6	26.3	100
Relative no. in FR (%)	2	11.7	36	35.6	14.7	100
Relative no. in UK (%)	1.1	31.1	32.8	18.1	16.9	100

*The articles from the corpus could not have been categorised evenly (17 years represent a prime number); thus, the year 1999 has a separate statistic. The table was constructed for comparative measures between selected countries.

Despite their differences in absolute numbers, however, the three national media corpora arguably manifest a similar controversy evolution/dynamic: After a controversy around nanotechnology begins—it can be a technical object, place, or process—what often follows is the emergence of some form of public debate (the debate is followed further by a decline in media coverage). The content is partly visible in Figure 4.1 below. It shows how both France and the United Kingdom engaged early in the nanotechnology debate and, at some point, the start of an abandonment of nanotechnology in the headlines. The media coverage of nanotechnology in the Czech Republic is somehow offset. Nevertheless, it appears that all three countries mirror the development of controversies with a similar progression and structure.

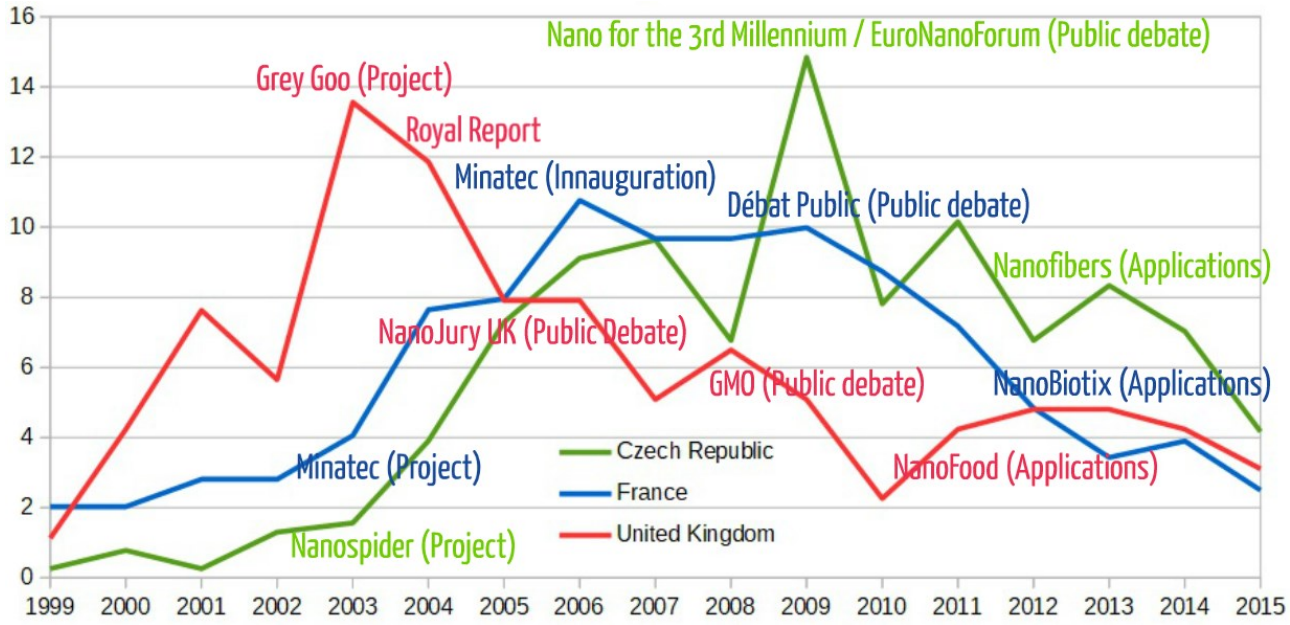


Figure 4.1 The character of the media coverage in the Czech Republic, France, and the United Kingdom in relative numbers (period 1999–2015).

By looking at the above nanotechnology publications (in relative numbers), we may presume that each cultural context had its own hot and cool phases of nanotechnology emergence, reaching their maximum peak at different times and scales. These fluctuations are not random (as if it was the arbitrariness of the media) but arguably correspond to actual events to which the media respond, amplify, polarise, and update the public (cf. Weingart et al. 2000). Moreover, it is among the principal objectives of this thesis to show how metaphors may play a role as powerful catalysts of these phases which represent matters of concern (Latour 2004 and 2008, Cooren et al. 2015).

Taking a closer look at the general content of these matters (measured as the relative strength of the peaks in media coverage), I observed that in the Czech Republic, the media has paid most attention to nanoscience projects from the city of Liberec and the so-called Nanospider technology. Media-generated news accelerated with steady progress between 2004 and 2009 (with a small decline in 2008). In the case of France, the media amplitudes correlate with the announcement of new nanotechnology projects at Minatec (in 2003), a research institute in Grenoble and the principle protagonist in a new wave of public debate over nanotechnology's risks and benefits. In the United Kingdom, much of the media hype occurred as a response to the 2004 Royal Society's report and was triggered by images of self-replicating nanomachines (also known as the grey goo scenario)—a controversy which inflated the media coverage during the years 2003 and 2004. Another strong concern was that nanotechnology might be the 'next GMO'. Altogether, these issues seem to stand out above others in the multitude of texts produced in recent years on nanotechnology and provide a fairly solid basis for the opening of case studies.

The initial quantitative overview suggests the data provides a solid basis for comparative study, although the quantitative research is, due to the character of metaphor, better suited to a

statistical overview of non-metaphorical units of discourse. In terms of the quantities of articles, with 'nano-' we can confirm that nanotechnologies get considerable attention across all corpora. Here, the amount of articles since the beginning of the millennium has been increasing, although in the long run, there have been occasional reversals where 'nano' appeared less in the headlines. This should not be confused with the amount of articles not featuring nanotechnologies as the main argument, but their increasing number was confirmed in other studies (cf. Shapira et al., 2010). For example, 'nanoworld' has gained importance over time as the technical instruments for its exploration have been introduced. Nowadays, we find a large number of articles which extend from technical to social contexts of nanotechnology. Elsewhere, the CORDIS database reflects increasing EC reporting on nanotechnology, issues related to regulations, its sociopolitical issues, and economic worth.

4.3 Corpora Limitations and the Problem of Generalisation

Corpus construction influences our ability to answer research questions in an important way. Since the aim of this study is to understand how metaphors are used and what they do, and not how often these metaphors are applied, the exact density of articles (and metaphors) is not essential. A total sum of approximately two thousand articles is relatively large. One may seize upon a range of examples of metaphor use—in science, policy, and the public (media)—and try to draw universal implications from a sample which is also perhaps too small to carry the weight placed upon it. Rather than a quantitative analysis, the focus is on the case studies and, within these, analysing novel and conventional metaphors in the text and within the context.

The corpora were compiled to cover the period between 1999–2015, that is, over fifteen years of conversation at the interface of science, policy, and the public. The appearance of nanotechnology in the media (and thus the public) was scarce at the beginning of a millennium. However, it should not be confused with the fact that most of the metaphors in this thesis may have already been known. As a result, this allows for the focus to be on figurations linked to more recent storylines and where, in some cases, older figures expand into new networks. The corpus-based metaphor study should thus take advantage of both *synchronic* and *diachronic* characteristics outside the quantitative measures. The temporality is important but in the exact sense that it is a necessary condition for the emergence of controversy (events). Even though the selected texts cover part of the discourse on nanotechnology over the fifteen-year period, the thesis does not aspire to be a historical analysis. It is a metaphor analysis which matters for the purposes of sociological analysis.

Some of the texts are genuine scientific texts intended for an expert audience (in WoS), while others introduce popular scientific images of experiments (in national newspaper archives) or

policies (CORDIS) corresponding to a particular field. The shifts which occur are an integral part of the research, policy, and public media texts—in other words, they are inter-discursive. In this sense, the border between the science, policy, the public is fluent. Media integrates expert knowledge reviewing articles published in distinguished scientific journals such as *Science* and *Nature* with clearly established sociopolitical contexts. The articles are sometimes written by authors who have a former professional background in the natural sciences but reflect on wider societal contexts when communicating nanotechnology. A significant amount of information is generated from authors mixing different knowledge sources, regimes, as well as genres. Related to that, we find texts mixing present with future—again, this confirms the initial argument of nanotechnology discourse: its symptomatic orientation towards the future as well as the blurring of *current* concerns and *potential* implications. The limitations of reviewing reality/fiction are not a concern of this thesis. The articles are excellent material for this purpose. However, they do not allow an embrace of the interactional contexts within which these relationships take place, as would ethnographic material and interviews. These would have been a great addition to the analysed data yet posed limits in regard to feasibility.

Part V Findings and Case Studies

Chapter 5. Normative Regimes of the Nanoworld in the Web of Science Database: From Moore's Law to Creative Evolution

Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution.
Albert Einstein, in *Cosmic Religion* (1931)

Give me a laboratory and I will raise the world.
Bruno Latour, 1983

5.1 Identifying the Problem/Matter of Concern: Normative Regimes

In a traditional sense, the 'nanoworld' refers to the universe at the nanoscale, a world infinitely small, populated by atoms and molecules, and extremely different to the macroworld with which we are all familiar. A world at the nanoscale is constantly in motion—analogous to an infinitely large and distant cosmos. Yet, according to science philosopher Alfred Nordmann, it is no different from the world of our minds and concepts. Nordmann has aptly noted this qualitative change in the way our minds relate to objects and processes at the nanoscale as a 'collapse of distance' (Nordmann 2006). The distance, we might argue, collapses in both space and time. The absurdity to speak of a world which exists beyond human perception and experience finds another referent in the world which represents a future society transformed by nanotechnology. In line with the theoretical chapter on nanotechnology discourse, expectations delimit the nanoworld in its symptomatic orientation towards the future, making the 'future present' in different social images (cf. Schummer 2007), just as there is the immediate 'scale presence' in its variety of technical images. These two orientations (or vectors) of the nanoworld are worth our further attention.

The way we look at the world always depends on the instruments we use to acquire knowledge about it (cf. 'Becoming-Media: Galileo's Telescope' by Joseph Vogl, 2007). Seeing through a microscope includes staining slides, enhancing photographs with computers or using colour filters and focusing instruments before, in theory, adjusting them until something recognisable comes into view, all by way of forcing instruments to accommodate how our eyes function (Pitt 2004: 158–60). All that we know about the nanoworld is collectively learned, shared, and formatted, and the sociotechnical dimension is present in all our practices from the very

beginning. The fact is, it may take more than one person in order to 'see the nanoscale' and, further, the seeing is beyond the ability and any measure of a naked eye. A similar accommodation though occurs while looking at the past and the future through transformations of technical into social images, reaching outside the laboratory ('seeing a future nano-society' or relating to past previous experiences). In other words, the world is not built only in the laboratory (cf. Latour 1983), it adjusts to the industrial world, marketing logic, the agenda settings of (science/media) policies, and users (cf. Akrich 1995, and the laboratory as the 'world's creative hub') —it is so much more.

The nanoworld should be understood not only as something that *is*, but also as something which has a purpose as a place to live. Put another way, when turning towards reality, a scientist or layperson is, in a fact, moved by a strong presupposition that the world is organised somehow (Bloor 1976 [1991]: 36), correct to the extent that the human world is structured as a product of human activity. The nanoworld applies to all kinds of activities, taking the form of (social) representation in the sense of its structure and organisation, its implications, and also our possible or allowed actions. By considering its different orders concerning things that *are*, *will*, or even *should b*e, we are engaging with the different normative regimes of the nanoworld. The normative regimes, such as laws, are a characteristic feature of the nanoworld since 'there is no society without law' either (Pospíšil 1971: 107). Laws (and norms) figure as factual boundaries of social life (Giddens 1984: 4). The nanoworld should thus be fully accessible to analysis, which follows the trends in contemporary social studies of law, summarised by American anthropologist Sally Engle Merry as (1) having a large interest in how *actors* and institutions produce *meanings*, the impact of these meanings on surrounding social relationships, and the influence of *cultural context* on the substance of legal procedures; (2) moving to the *national* and *transnational* context; (3) having renewed interest in legal *pluralism* and how *multiple legal systems* interconnect; and (4) having a growing interest in *power*, including the ways in which the law constructs and deconstructs power relations (cf. Merry 1988, in Soukup 2004: 582). And further, the normative regimes should not be understood only as means of (social) control but as a constitutive system which creates the concept of (social) order and as a form of ideology which contributes to the cultural construction of the world. The attention to the 'narrativity' of the law (cf. Brooks 2006) can open to thought some of the unthought assumptions about nanotechnology discourse. Similarly, the imagination, viewed as 'an organised field of social practices', here serves as another key ingredient in making social order (Appadurai 1996, Taylor 2004, Jasanoff and Kim 2009: 122) and should be given larger attention

My major concern is to ask what are the normative regimes (laws) of the nanoworld, particularly with regard to scale (spaces) and society (futures). This should allow addressing the first research question of this thesis, i.e. how are metaphors tied to specific social representations of nanoscience (nanotechnology)? Normative regimes are examined as systematic metaphor(s) of

nanoscience (nanotechnology) and narratives that can shed a different light on the current diversity of the field. A related objective is to learn what the implications of some of the leading metaphors (figures) are and what options and constraints these represent. Rather than attempting to extract each and every one of these diverse accounts, I found a relatively stable conceptual representations of laws and which circulate within scientific domains but also show how they extend to society (the unfolding human perspective) through narrativisation and discursive formation. It is argued the *creative evolution* is a leading (root) metaphor of the nanoworld which yields tremendous imaginaries and is scalable to every dimension it reaches through the root metaphor of Moore's law. As much as the nanoworld normative regimes are interpreted and perceived through this figuration, science and technology development is subjected to economic and sociopolitical ends which delimit our choices but also our responsibility to society.

5.1.1 Studying Nanoworld in Science Discourse

It is a challenging task to demonstrate how we can get a better understanding of the nanoworld not by emphasising the literal but by looking to the figurative level, arguably revealing more overt aspects of the nanotechnology discourse. Normative regimes have been found on many occasions to reflect emerging technologies and institutions, and it has become an increasingly complex issue for nanotechnology and its multidisciplinary character (cf. Bowman and Gilligan 2007, Lacour 2011). There are many different normative regimes applicable to nanotechnology, such as hard and soft laws, rules, as well as accompanying social rules, such as ethics, deontology, technical standards, or any other legal standards. Moreover, the process by which new normative regimes are put in place or existing regulations (such as the REACH directive on chemical substances) are altered is the subject of national politics, intense lobbying by industry, societal challenges, and shifting public sentiments, all of which affect technology development.[39] Analysis at the figurative level may thus be mobilised to find some common ground. One the major theoretical positions of the previous chapters was to consider metaphors an important methodological tools in both the construction and critique of legal and scientific theory, ranging from persuasive writing to scientific models (cf. Black 1962, Hesse 1966, Knorr Cetina 1981, Nerlich and Hellsten 2007, Gentner and Jeziorski 1993). At a position favouring a wider than just 'ornamental' perspective, laws may be challenged, and even counterfeited by figures (metaphors) which compete in their degree of predictability and guide the researchers and engineers as if they represented the laws and theories. This approach can be differentiated into the analysis of metaphors *in* law and the metaphor *of* law in so far as metaphor is taken not just as a rhetorical trope which helps make a legal or scientific point persuasive but as a constitutive element of the law (cf. Murray 1984).

[39] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

The metaphor analysis, as elaborated in the methodological section, is outlined in two phases. The first was a directed approach to identify specific/explicit laws as *matters of concern* in the Web of Science (WoS) database as it contains rich information about concerns over the validity and utility of nanoworld laws in different nanoscience and nanotechnology fields. The compiled corpus covers a vast area of research, involving articles ranging from 1999 to 2015; however, the study did not seek to identify all the explicitly present laws. In the second phase, it aimed to identify some of the major (imaginary) extremes/boundaries of law, such as natural (science) and social (community) laws and their hybrid forms (Moore's law) as an alternative extreme. I did not extract each and every metaphor but focused on identifying conceptual metaphors associated along these imaginary boundaries. Following metaphor-in-discourse analysis design, even though corpus-based, the study focused on particular law-figures and had both textual and graphical (pictorial) formations (as figures altogether). Finally, the analysis included uncovering the narrative dimension based on elementary metaphors and structures identified as the discursive formation. Discussion and conclusions from this chapter would then inform the final review and synthesis in Chapter 10.

5.2 Nanoworld: Between Nature and Society (Results)

Initially, approximately two hundred articles were identified in WoS (keyword 'nanoworld'). A total of roughly 100 different articles were regarded as containing relevant information about 'law'. This ratio (approx. 1:2) suggests that explicit 'laws' have a role to play in articles about the nanoworld. The content analysis conducted in the corpus revealed a model variability of the different laws ranging from, for example, laws of thermodynamics, mechanics, optics, and so on, to social aspects such as community, competition, patent, workers laws, and other such regimes. The initial overview of the laws is captured in Figure 5.1. Here, the natural sciences' articles far outweigh the social sciences. Whereas we find the articles from natural scientists in abundance, social scientists are scarcely represented.[40] This could suggest that the regimes of the nanoworld were not initially framed as a problem for social science (cf. bibliometric analysis of social science literature on nanotechnology in Shapira et al. 2008). However, this asymmetry disappears as we advance towards the metaphorical level.

As it was already pointed out in data section, the prevalent argument all along the spectrum is that (legal) scientists and regulators must face the indeterminate character of the nanoworld. It is argued that phenomena at each scale are governed by identifiable laws but by different (sometimes

[40] The corpus contains articles from authors such as H. Röhrer (IBM), the inventor of the Scan Tunnelling Microscope (STM) or other Nobel Prize holders and nominees. There are articles written by researchers from many different universities and institutions from all around the world (IBM, Max Planck Society, NATO), but also science and technology writers and editors from the magazines *Nature*, *Science*, etc. The texts which could qualify as social science contain articles on science education as well as articles from science and technology studies. There are long editorial books as well as short communications.

very drastically different) constitutive relations (WoS 2008a: 92). Moreover, laws translate, support, and counter each other, and their categories are not so clear, for example, physical laws (nature) and laws of physics (discipline). Although measuring science (here a variability of laws) may thus be effective for some purpose of scientometric measures, these alone cannot explain the flexibility and variability of certain figures. The 'law(s) of nature' (WoS 1999a) and the 'spirit of the law' (WoS 2011a) are arguably two laws located among numerous normative regimes of the nanoworld (in Figure 5.1, at the bottom left and right). Their semantic domains, 'nature' and 'spirit', are best described as the figurative edges of the spectrum. They each point to a resource on a physical, normative, or legal basis. In other words, the laws we design or discover about the nanoworld take into account both the 'nature' and 'spirit' (culture) as their referents or a border with the out-of-law. At the same time, they are metaphors and sources and targets of metaphoricity. Nature, although a contested term which means different things to different people, here applies to a universal law or reality which may or may not include humans.[41] In Figure 5.1, the laws of nature are statements concerning the uniformities or regularities of the nanoworld; they are descriptions of the way the nanoworld *is*, an underlying order based on approximations and generalisations: physics, chemistry, biology, for instance. The spirit of the law is placed on the opposite side of the spectrum. It refers to opinions and beliefs of a group of people, community customs, or culture; it reaches in the continuum of space to where there *is (not)* no law (explicit or legally binding document) representing scholarly inquiry into legal history, philosophy, economic analysis, and sociology.[42] The regimes of the existing nanoworld laws thus not only correspond to the contents and characteristics of nature but also to the customs and traditions of a community:

- Humans are subdued by natural laws, they remain—in spite of all their technological power—a tiny part or a powerless particle within the cosmos at large. (WoS 2008b: 212)
- The Spirit of Law remodels the reality . . . by forcing objects from other worlds to fit into the logic of its categories and associated topographies. (WoS 2011a: 694)

[41] 'For natural philosophy everything perceived is in nature. We may not pick up and choose. For us the red glow of the sunset should be as much part of nature as are the molecules and electric waves by which men of science would explain the phenomenon' (Whitehead 1920: 28–29). It should be noted though, there is a more nuanced distinction between 'laws of nature' and 'natural laws', as invoked in legal or ethical theories.

[42] Even and exactly when there is no explicit law, past and future behaviour can be subjected to the spirit of the law. The spirit of the law can be violated, but it still applies to legal relations, such as a constitution, tax obligations, patent law, etc, but it is also used in unregulated phenomena.

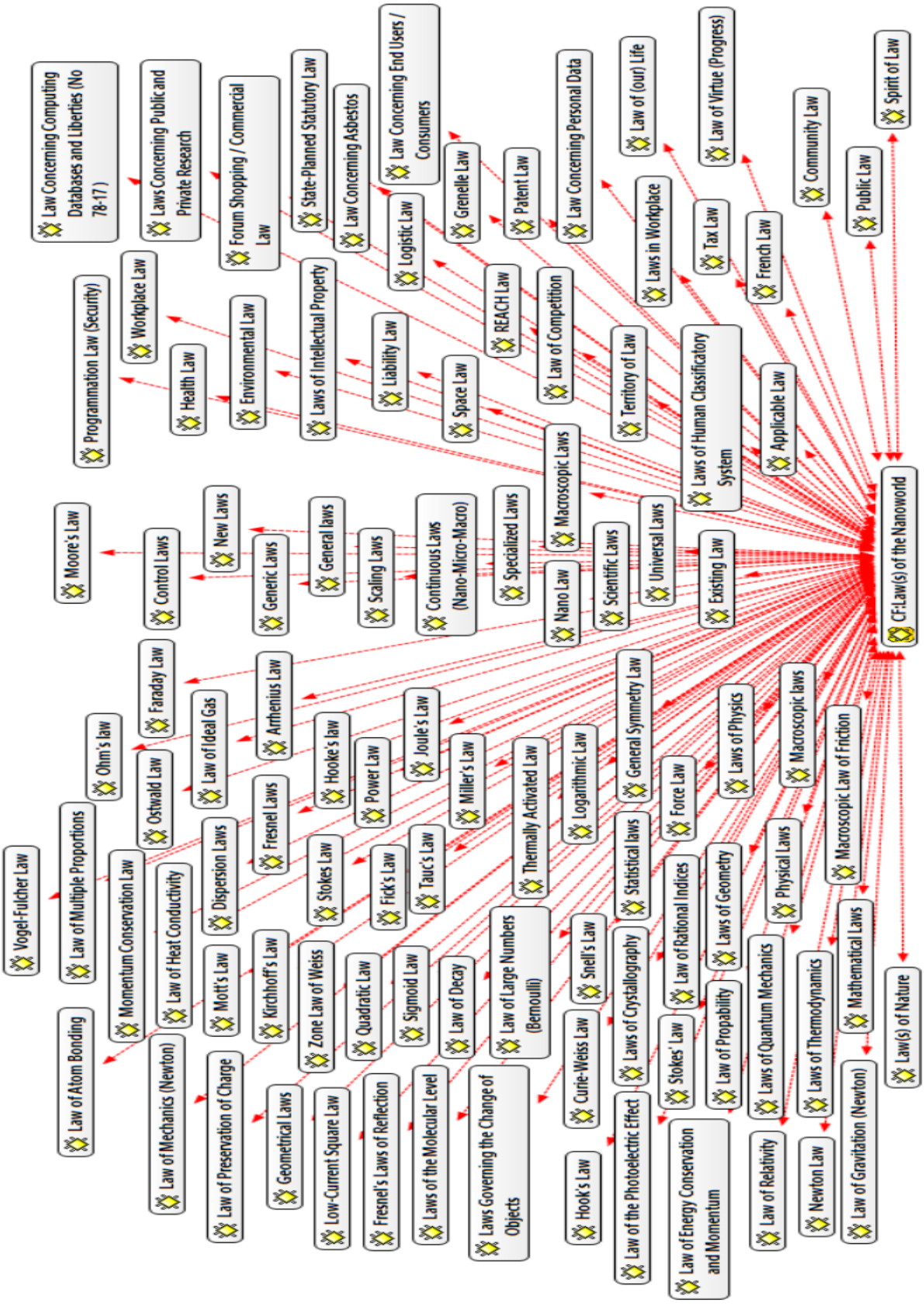


Figure 5.1 Laws of the nanoworld and their divergence between nature and culture (community) or the unity of science and the tree of knowledge (matter-culture-mind).

In the middle range, between technical and social aspects of the nanoworld, Moore's law is situated. This result is as trivial as it is illuminating. It is trivial in the sense that no one has

seriously been arguing that Moore's law would be a deterministic natural law.[43] The simplified version of this law states that 'processor speeds or overall processing power for computers will double every two years' (WoS 2001e: 76). It is also 'a price-performance variable' (WoS 2005d: 5), a 'rule of thumb' (WoS 1998a), or a 'roadmap' (WoS 2001a) for the electronics industry which has been guiding semiconductor technology development. The result, however, is also far from trivial if we consider the numerous transitions and translations of Moore's law into other laws and figures to the point that it is permeating into *all* science-society relations (see later). In the following section, we will investigate the metaphoricity of nature, spirit (culture), and Moore's law in more detail.

5.2.1 Nature as a Resource, Self-Assembly, and Evolution in the Nanoworld

In 'Using DNA to Power the Nanoworld' (WoS 2007a), the author appeals to researchers to 'harness the power of in vitro evolution for making synthetic polymers with a specific function'. The title is rhetorical shorthand for what nanoscientists and engineers have been doing: looking to nature for ideas—not only for natural products but for all sorts of new materials. It might be argued that a point is made through concepts such as of DNA IS ENERGY and NATURE IS RESOURCE, or together occurring in the context of the wider concept NATURE IS A STORE OF VALUABLES. In the article 'Evolution in the Nanoworld' (WoS 2007b), it is argued that 'the automatic molecular assembly and selection steps exhibited by the molecules, which start as random mixtures, demonstrates a fundamental step in the evolution of life' and that these 'hold great promise as an efficient avenue to new catalysts, nanotechnologies, and surface applications'. Because DNA so readily makes and breaks chemical bonds, reconnecting and modifying materials at the atomic level, engineers believe that studying it may reveal ways to make molecule-size machines called 'assemblers'. SELF-ASSEMBLY corresponds to what nature does and what is characteristic of the mechanisms of nature, but it also becomes a resource for researchers and engineers: 'What are the possibilities of working in nature's way? Infinite. There are so many tasks that nature performs in a much more elegant, efficient, and successful way than we can do or attempt to do' (1998b). Self-assembly as such becomes metaphorical, whereas the small, regularly shaped structure of LEGO BLOCKS lend themselves well to demonstrations of spontaneous mesoscale and directed assembly (WoS 1999b, WoS 2011b). Research focuses on the self-assembly of biological molecules and their applications in biosensors, photovoltaics, medical imaging, tissue engineering, genetic engineering, and cancer research (WoS 2011c, WoS 2012). Self-assembly and self-organisation, as the evolution of mesoscopic devices, also appears in nanolithography and the

[43] In 'Gordon Moore: The Man Whose Name Means Progress. The visionary engineer reflects on 50 years of Moore's Law' (interview by Rachel Courtland, 2015), Gordon Moore himself said repeatedly that '[i]t's not a law in any real respect': 'It was an observation and a projection.'

semiconductor industry—aimed at developing molecular SPECIES[44] and new GENERATIONS of transistors (WoS 2001b, WoS 2004a, WoS 2008c). In all these and similar cases, evolution is a worldview, a way of seeing the nanoworld and extracting meaning from it (Figure 5.2a/2b/2c).

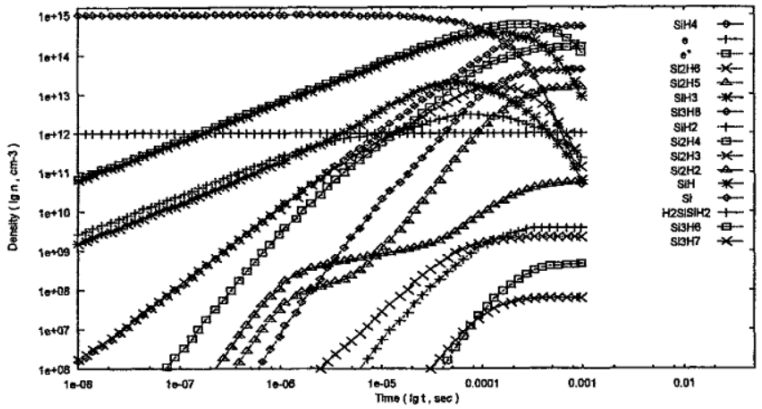
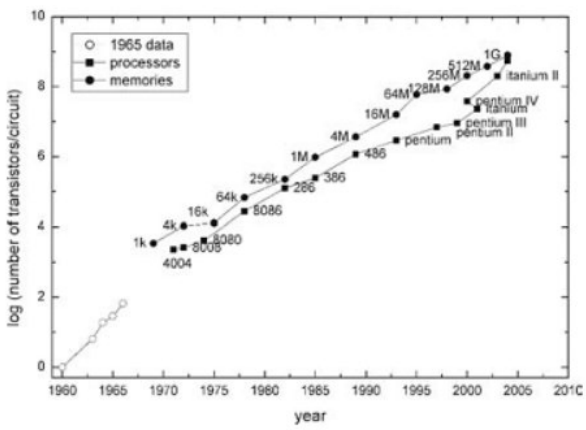


Figure 5.2a 'Evolution of species in SiH4 discharge' (2001b)



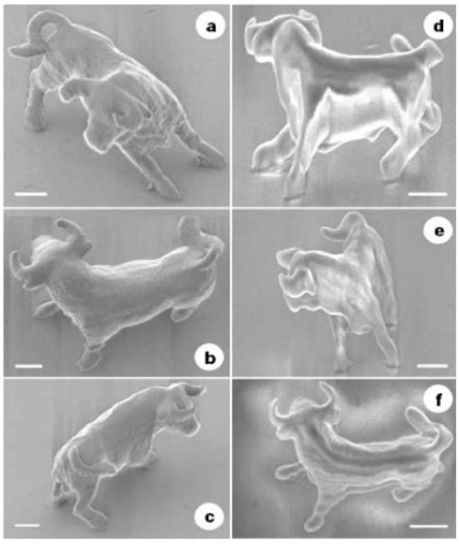


Figure 5.2b *Left*, Moore's law and the evolution of integrated circuit complexity (WoS 2005a). **Figure 5.2c** *Right,* Fabrication of a bull sculpture in 'Projecting the Nanoworld: Concepts, results and perspectives of molecular electronics', reprinted from Kawata et al., *Nature* 2001 (WoS 2004a).

5.2.2 Culture as Convergence, Second Nature: NanoAge and Journey to the Nanoworld

The scientific disciplines themselves should be understood figuratively and beyond their collections/accumulation of explicit laws. In 'Chemistry at a Historic Crossroads' (WoS 2009), the author maintains the imaginary of scientific endeavour as a progressive JOURNEY leading to novel areas (Figure 5.3): 'The crossroads of physics and biology through chemistry—Physical Biology—is an example of the emerging new fields.' The ultimate goal is then 'to understand the function from knowledge of structure and dynamics, and for phenomena of collective behavior, such as self-assembly, phase transitions, macromolecular folding, interfacial organisation, emergence, and others'.

[44] *Chemical species* represent supramolecular structures of atoms, molecules, ions, etc., and is a conventional metaphor.

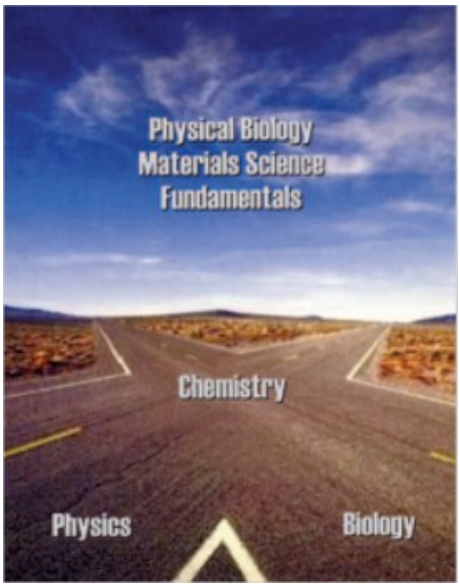


Figure 5.3 'Chemistry at a Historic Crossroads' (WoS 2009)

The scientific fields not only must reassess their goals but themselves evolve as (epistemic) cultures in a non-classical way, as a new type of configuration. The authors of 'Nanotechnoscience' (WoS 2008b) place this in the context of reaching the nanoworld through a CONVERGENCE of different technological fields or communities, harnessing 'nanoscale laws, biological principles, information technology and knowledge of integration' (Ibid., in Figure 5.4). With the resulting 'evolutionary' system creation, we move beyond simple materials which have been redesigned at the nanoscale to actual nano-devices that do something interesting, including the new generation of 'bio-mimetic', 'smart', or otherwise functional materials.

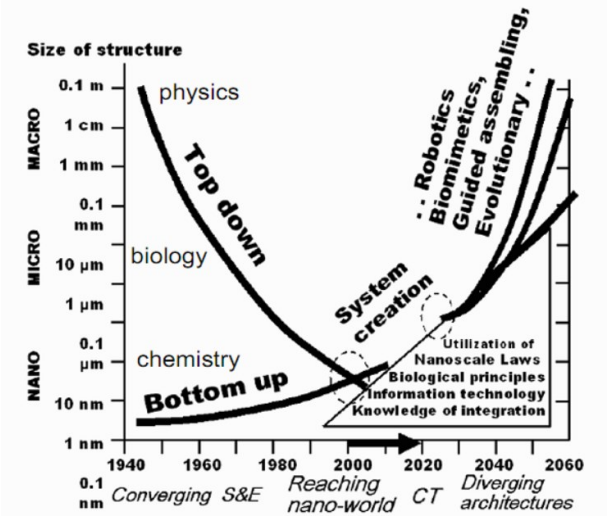


Figure 5.4 Reaching the nanoworld (ca. 2000) and NBIC methods for systems creation from the nanoscale (2000–2020) (WoS 2008b: 202).

The authors further argue that at that time in history progress became a 'law': 'The first and the main task that theory of progress sets itself is to show that History has sense and the historical

process is not only evolution but progress as well. This task is too heavy for empirical science as it has a metaphysical character. The absolute law of Virtue that should become the law of our life when applied to historical development tells us to mean well in history and do our best to promote the realisation of Virtue, tells us, in other words, to mean progress. Progress is, from this point of view, a moral task, not existence, but the absolute imperative'. (WoS 2008c: 218) Therefore, PROGRESS IS LAW. New methods for regulations, based on the understanding of natural processes and, to some degree, on the 'management' of such processes, are required as incorrect 'prioritizing of objectives can skew the evolution of our civilisation in a way that will be difficult to fix in the future' (WoS 2008d).

The concept of progressing/evolving CIVILISATION appears in the nanoworld (WoS) in many metaphorical meanings. First, the meaning of 'civilisation' characterises a specific type of society which arises at a specific stage in historical development. A transition occurs from the primitive state to more advanced states: 'The mastery of a new material is so fundamental to mankind that historic ages are defined by the state-of-the-art material, hence the "Stone Age" or "Bronze Age" and further, are "characterised by the newfound ability to convert energy into mechanical work, based, for example, on the invention of the steam engine, which powered the industrial revolution"' (WoS 2007c: 367).[45] The author then asks whether the NANOAGE, or the 'mastery' of nanotechnology (nanomaterials, nanodevices), revolutionise how we employ biological and synthetic nanoscale machines to convert energy from one form into the other.

In 'Nanotechnology: Perspective for Future and Nanorisks' (WoS 2008e), the concept of civilisation and evolution merge as 'civilisational achievements are primarily understood as an evolution, systemic complication and expansion of the "second nature", to wit, the world of man-made objects and processes, which directly surrounds man and secures his survival in nature' (WoS 2008e: 250). Civilisation as SECOND NATURE here extends/expands from biological evolution, complexity, and a challenge to its survival. This metaphor is interesting also in the sense that nature had been constantly discussed in terms of something outside of human culture; the metaphor exploits this resonance at a higher order of abstraction (conceptual level).

Finally, civilisation spans technological and technical inventions, as well as the fundamental values and states of man's spiritual world. While we can say that civilisation and culture as man's spiritual development do not concur or may even be opposites, we find quite a paradoxical situation with nanotechnology. In his books *The Age of Spiritual Machines* (1999) and *Singularity is Near* (2005), Ray Kurzweil, an engineer and futurist, gives a perspective of the nanoworld through his vision of a technological SINGULARITY—'the point at which our technologies become the

[45] This was also the sense in which Arnold Toynbee used the term 'civilisation' while identifying different types of civilisations in the history of mankind—driven by 'creative minorities'.

driving force in human evolution' (WoS 2006b). Kurzweil argues that as nanotechnologies will continue to develop at an 'exponential' pace, in twenty to thirty years, maybe sooner if we create quantum computers, we will come to the 'age of spiritual machines'. The nanoscientists further describe this as an evolution of the (post)modern/(post)human condition to the NOOSPHERE,[46] a sphere of a human thought/spirit: 'When the intellectual activity of mankind becomes the determining factor of development. This state was named the "noosphere". Now we can consider that the technosphere is the intermediate modern stage between the biosphere and the noosphere. The evolution of biosphere follows the following scheme' (WoS 2008f: 277):

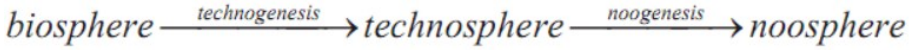


Figure 5.5 'Man is becoming the main geological force' (WoS 2008f).

In Figure 5.5, the modern process of transformation of the technosphere to the noosphere has been named nooGENESIS. The analogy to 'phylogenesis' here returns us to evolution (the semantic domain of the theory of evolution) as a worldview, a carrying structure to extract meaning from the nanoworld (culture). The noogenesis means everything which we can do to amplify our powers and the powers of the things we make—a union of genes, culture, technology. And if so, where is it taking us?

5.2.3 Actions 'Following Roadmaps' and/or 'Chasing Rainbows'

Contrary to what we might have expected about science media, the figurative language of the nanoworld stretches the agency of nanoscientists and engineers to genres of drama, mystery, sci-fi, and fantasy. In 'Building Bridges to the Nanoworld' (WoS 1994) researchers from the California Institute of Technology (Caltech) report of reaching a new physical domain, the 'nanoworld' as TERRA INCOGNITA (WoS 1994), and join numerous speculations on how it could solve complex problems, such as 'sustainable development' (WoS 1996). The nanoworld is represented as a world of 'wonders', 'sources', and 'treasures' which can be exploited by scientists for our wellbeing—a 'wonderland of miniature marvels' (WoS 2006b).

There is always space for scepticism. In 'Chasing rainbows in the Nanoworld?' (WoS 2006a), the author retakes the commentary of the 1998 Nobel prize laureate in Physics, Robert B. Laughlin, from *A Different Universe: Reinventing Physics from the Bottom Down* (2005), arguing that we should not be 'chasing rainbows in the nanoworld, spending money on silly science' caused by our misunderstanding of (quantum) laws. That part of the metaphor, at least we may assume, is apropos of the author's critical stance to some nanotechnology projects which attempt to 'bend nature bottom-up' (WoS 2006). The author is retelling us an old fairy tale set in our modern world.

[46] The word derives from the Greek νοῦς/*nous* (mind) and σφαῖρα/sphaira (sphere).

In ancient mythology BRIDGES to PARADISE represented navigation MAPS as if they were rainbows.[47] Our 'crossing' to the nanoworld are actions (events) required in order to develop 'dream-come-true' technology or access the 'treasures' of the nanoworld. The metaphor 'chasing rainbows' is partly submerged in an argument: 'Rainbows are not constructed and operated by man, but by nature. And one that chases the rainbow to find its end is chasing an illusory goal, for its very difficult to pin down the end of a rainbow. The end of the rainbow keeps moving, resetting itself' (Keller 2004). The literal interpretation though would have done nothing to provide the insight and wisdom it imparts through metaphor. The truth hurts; even when taken metaphorically, it is possible there is no pot of gold at the end of the rainbow. Any nanotechnology activity could also represent this naive 'rainbow chase', a (utopian) 'reaching for the exponential world' while facing obstacles when 'physics breakdown at quantum levels' (WoS 2006a). So too could chasing rainbows represent a law of exponential progress (concealed in Moore's law, for instance), a QUEST for unlocking solutions that will positively change the future.

The focus on finding a way into the messy nanoworld can also be represented by H. Röhrer, co-inventor of the Scanning Tunneling Microscope (STM). In the science article 'Nanoengineering beyond Nanoelectronics' (WoS 1998b), he makes a metaphorical conclusion: 'We went through a development in which, in a metaphorical sense, we have lost the wisdom in knowledge, lost the knowledge in information (T.S. Eliot), lost the information in bits. Nanoengineering beyond might be a road back.' Reaching the nanoworld is reflected in the efforts of nanoscientists and engineers who transform into a fairy tale of searching for 'lost wisdom'. Similarly, other success stories include a metaphor of a JOURNEY (or odyssey) with detailed technology ROADMAPS which uncover EVOLUTIONARY PATHWAYS, in other words, 'learning trajectories' through 'obstacles', past identified 'milestones', and over 'knowledge gaps' (cf. WoS 2001c, WoS 2004b, WoS 2005b, WoS 2006b).

5.2.4 Moore's law: 'Trickster', 'Good' King, or 'Evil' Dictator?

Moore's law is the prediction of a 'doubling of processing power on a chip' (in Figure 5.2b and WoS 2005a), and it has been widely accepted and integrated as a TECHNOLOGY ROADMAP (Intel, NASA, etc.).[48] Furthermore, it has been translated into law for an evolution of 'society accelerating exponentially' (Kurzweil 2001, also in WoS 2005e).[49] Whereas Moore's original

[47] In Norse mythology, Bifröst is a burning rainbow which reaches between Midgard (the World) and Asgard, the realm of the gods (cf. *Poetic Edda* in Anderson 2003)

[48] For example, 'A road map of the organometallic chemistry of semiconductor surfaces: Toward a chemical interface with the nanoworld' (WoS 2003a) and the 'International Technology Roadmap for Semiconductors (ITRS)', prepared by the Semiconductor Industry Association, are materialisations of metaphor guiding whole industries.

[49] When Ray Kurzweil refers to Moore's Law in the social context, he is referring to the continuous application/propagation of the law of accelerating returns across society as a whole: 'Evolution applies positive feedback in that the more capable methods resulting from one stage of evolutionary progress are used to create the next

formulations only counted components, the revised versions have implicit theories about their use in different technological fields. The third extension adds the assumption that society evolves at an accelerated pace. It extends Moore's law to include imaginaries which comprise multiple different technologies, as well as social orderings.

Gordon Moore, the originator of the law, has reformulated or updated the original extrapolation from 1965 several times (notably Moore's 1975, 1979 revisions), and there have been other updated figures, all of which transform Moore's law into different, yet related storylines. The debate about Moore's law coming to its limits has all the features of a multilayered controversy (cf. Iika Tuomi vs Ray Kurzweil, in 2002–3). The speed of computers and their storage capacity over the last fifty years has increased but slowly begins to run into physical limitations (WoS 1998b, WoS 2004a). A combination of reasons—fundamental physics and technology costs, it is believed—will be responsible for the eventual breakdown of Moore's law. It has guided the semiconductor industry through impressive decades of exponential growth, but there is, as one scientists remarked, and 'end of Moore's law' (Krishnan 2014: 42): 'The two basic problems are heat [melting chips] and leakage [you do not know where the electron is anymore]. That's the reason why the age of silicon will eventually come to an end. No one knows when, but we now can see the slowing down of Moore's Law, and in ten years it could flatten out completely' (cf. WoS 2003b, WoS 2005f). It is contested whether and how long can Moore's law will remain valid, and in line with the evolutionary setting of the scene, a question of whether the fabled transistor ever 'dies' comes in succession (in Figure 5.6 below). After all, being 'born as a discrete device, the transistor's true power and technology leverage [develops] at a pace that is elegantly summarised by Moore's law' (WOS 2005c).

stage. As a result, the rate of progress of an evolutionary process increases exponentially over time' (Kurzweil 2001).

Figure 5.6 Moore's Law is dead. Long live Moore's Law (WOS, 2015b).

When metaphor goes 'Moore's Law is dead. Long live Moore's Law' (also in Figure 5.6), it means the old king is dead, a new a king should live; here, referring to Moore's law 2.0, unless there is a law 3.0, or 4.0, etc. For example, it is more like 'Silicone is dead. Long live gallium nitride', but the context is only true if constrained by adherence to Moore's law, that is 'Moore's law with Si is dead. Long live Moore's law with GaN'. It is true that the trope is so old, and we have read it many times. The experts have been arguing over Moore's law merely passing through a series of paradigm shifts; the next expected shift and one which might re-incarnate the law is a transition to a '3D architecture of transistors' (WoS 2001d). There have been a number of proposals: 'protein', 'DNA', 'optical', 'quantum', 'molecular computers' or tweaking technology by 'parallel processing' (WoS 2004a).[50] Here, Moore's law does not die but 'lives multiple lives' (WoS, 2015c, also in Figure 5.7 below).

[50] It is argued that, whereas previous lithography techniques were using a 'top down' approach in 'carving' transistors and chips, the new nano lithography makes use of the 'self-assembly' of crystalline or molecular structures, in other words, 'bottom-up' approaches. Quantum computing does not use classical transistors anymore. Instead of zeroes and ones, it works with spins, their superposition, entanglement, or interference—these are (developed with / to work with) assembly languages. Nature is at the same time an inspiration for these computers as much as it is believed to improve modelling nature, i.e. cancer, weather (global warming), intelligence, etc.

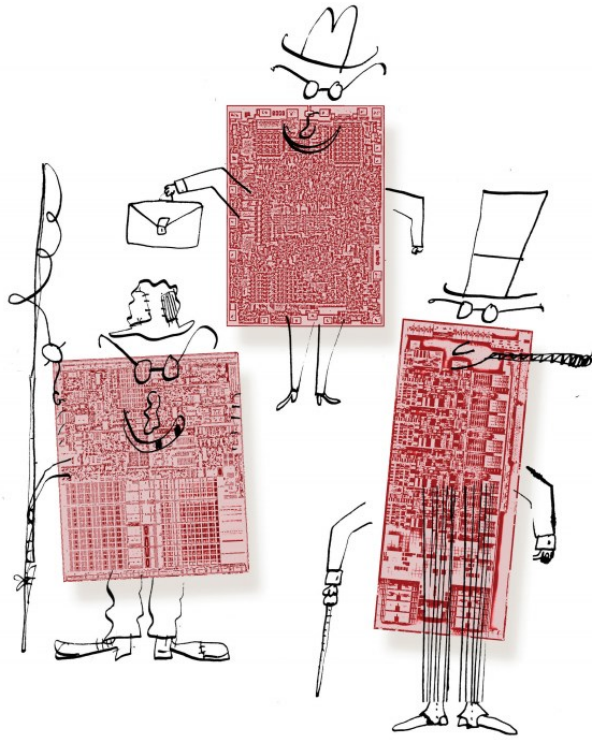


Figure 5.7 'The Multiple Lives of Moore's Law' (WoS, 2015c).

In the article 'The Multiple Lives of Moore's Law' (2015c), published on the fiftieth anniversary of Moore's law, a story was presented with three characters: a gentleman with a walking stick and a cigar, an elderly man with a fishing pole and some missing teeth as well as patches on his hat suggesting he is not in his prime, and then there is a cheerful man with a suitcase, almost as if ready to do business. Personification is a particularly pervasive type of metaphor since it involves the use of our experience and knowledge of human beings as its source domain (Kövecses 2002: 49–50). These ontological metaphors are also effective rhetorical devices to provide technology with criticism. In 2001, a *Scientific American* article starts by saying: 'When Gordon Moore, one of the founders of Intel, plotted a growth curve in 1965 that showed the number of transistors on a microchip doubling every 18 months, no one had any idea that his speculations would not just prove prescient but would become a dictate—the law by which the industry lives or dies' (Stix 2001). The ability of Moore's law to be updated with new materials and transistors, to sustain exponential figures in electronics, to 'disguise' itself as other engineering laws, and 'more', suggests its identity as not only a shape-shifting TRICKSTER but an ever ruling KING and DICTATOR. The author of 'Moore's Law is Dying (and That Could Be Good)' (WoS 2015a; also in Figure 5.8) argues that what has held back the open-source hardware movement is not a lack of business acumen, it has been the rapid evolution of electronic technology (Moore's law):

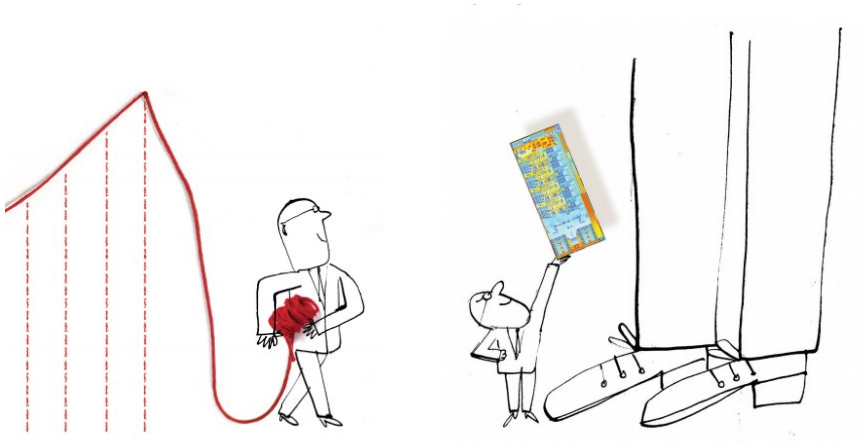


Figure 5.8 'Moore's Law is Dying (and That Could Be Good)' (WoS, 2015a).

'Open-hardware practices need a market window for profiting from innovative improvements made at a pace that the engineers at small businesses can manage' (Ibid.). The scene is set, the author believes, for many kinds of open-hardware 'ecosystems' to blossom. The inevitable slowing of the law may spell trouble for today's 'technology giants', but it also creates an opportunity for the 'fledgling' open-(source) hardware movement to grow into something that could potentially be very big. The return of 'artisan' engineering, where elegance, optimisation, and balance are valued over raw speed and feature 'creep'. Someday in the foreseeable future, the author further argues, we won't be able to buy a better computer next year: 'The idea of heirloom laptop may sound preposterous today, but someday we may perceive our computers as cherished and useful looms to hand down to our children' (Ibid.).

The images of Moore's law which were initially introduced within the conceptual domain of the ANIMAL KINGDOM have now shifted into a FANTASY KINGDOM, where death is not inevitable and heritage is in the hands of a creative scientist, engineer, and policymaker. This shift may be due to the fact that Moore's law exists within different genres of discourse on the nanoworld (such as academic writing, advertising, or policymaking) with a specific configuration of rhetorical figures and narratives. Nevertheless, here also, EVOLUTION remains a worldview to consider.

5.2.5 Creative Evolution in the Nanoworld (Narrative Dimension)

Seeing the nanoworld's normative regimes as they are portrayed in Figure 5.1 is just one way to make sense of what is happening on the more implicit level of the discourse. We can attempt to follow a level of the controversy which refers to alliances at different metaphorical levels, combining actors such as the '(human) spirit', nature, culture, and society, resulting in the meta-narrative structure, but also formation of discourse that I call 'creative evolution' (see later reference to theoretical concept).

On a literal level, a scientist/engineer (or technoscientist) is a subject who is being driven by a desire to fulfil different technoscientific projects, such as developing a (new) transistor, problem-solving based on the convergence of scientific disciplines. The technoscientist is also an intermediary between science, society, policy, industry, nature, culture, etc., and Moore's law (or the transistor) becomes an actor in its own right, while others are its opponents/helpers. Moore's law (materialised in the transistor), according to the broader definition of an actor, here represents a subject that can be integrated into an additional narrative schema. As such, it is being translated by different intermediaries into a multiplicity of roles and sub-quests: of capacities of transistors, chips, memories, or accelerated returns—even singularity. At the common level, the subject-object relationship is characterised by desire to reach the nanoworld and that of sender-receiver through legitimacy provided via the translation of technoscientific possibilities into societal objectives (society as a receiver). The obstacles can be characterised as activities outside an actor's agenda, such as laws of competition, community, or regulatory laws, and so on (also in Figure 5.9 below).

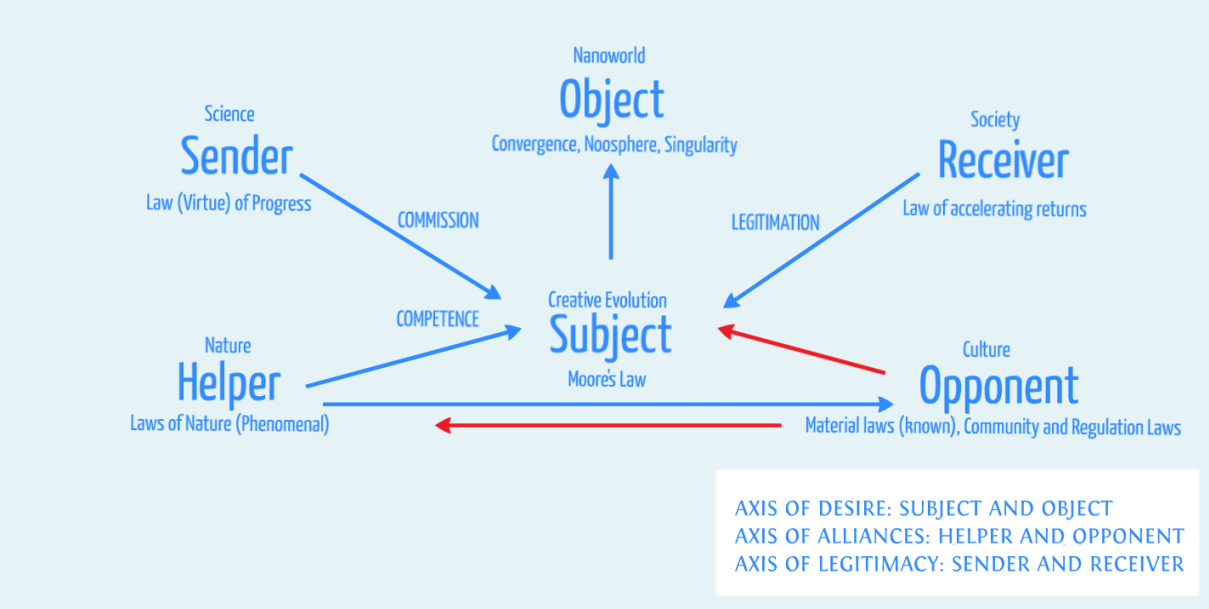


Figure 5.9 The narrative dimension of the Nanoworld (Normative Regimes).

The identification of helpers and opponents can be approached on different levels of abstraction. With regard to the role of natural laws (and laws of nature resp.) and their elementary narrative setting, there are elements which seem to constitute nature as a helper that, in fact, can turn out to be an opponent (e.g. the electron does not cooperate, cannot be located, there is excess heat on the transistor, etc.). The course of nature is not conceived as being merely the fortunes of matter in its adventure through space; nature is an actor with agency that provides new ideas (helper) but also emerges in material laws which set limits (opponent). This is a posteriori sensemaking that shows different alliances, desires, and legitimacy. Moreover, the process of narrativisation shows events and actors are aligned according to a specific order (creative evolution

is a specific discursive formation) and a matter of concern (see next on Moore's law).

The idea of translation is fundamental to understanding the narrative dimension of the nanoworld (and that of normative regimes) because we can see the articulations/relationship between seemingly separated events. Through this articulation, Moore's law is inserted into the narrative schema of other actors. Conversely, we could also say it is actors who are being inserted into Moore's law. The association between scientists and their creativity is also a matter of translation. When scientists perform their tasks, we can say it is nature's creativity performing the task (or even Moore's law) as a common referent: 'Every attempt to mobilize different actors through different strategies can be understood as a narrative translation. Translation is a narrative subschema in which the quest is the effective actor's mobilisation and translation' (Cooren 2001: 185).

Related to that, at least two alliances are involved. One is represented by research teams working on further generations of the transistors, chips, memories, etc. Another group of coalitions is represented by a small industry that does not favour the survival of Moore's law. Other adversaries include various natural laws which control electron location, heat loss, etc.; in other words, they are actants which altogether resist allowing nature to be bent into the exponential form. Culture is taking a figurative role of an opponent in the sense that it represents contemporary knowledge which does not favour the survival/continuation of Moore's law. These two coalitions (axis of alliances) thus try to fulfil a specific quest (their performance), represented by an attempt to implement and complete a specific project or, conversely, to cancel or modify it (also maintaining or deforming the exponential curve).

The main protagonist can be represented by the transistor (the narrative subschema of Moore's law) which must *shape- and material-shift* (his performance phase) to remain in (return to) *exponential* balance (order restoration or maintenance). This mission, however, also translates into the language of industry which represents opposing quests between a *big* industry and an *heirloom* industry (an heirloom industry which ceases to follow the exponential curve, roadmap, or to 'chase the rainbows'). 'Moore's law dies/must die' translates into a narrative of beating the odds of nature, to the shape-shifting trickster, or a ruler who dictates the evolution of industry. Whether order is restored—the law lives—or the order is destroyed—the law dies—a new order nevertheless emerges. There is thus a multiplicity of narrative schemas which view Moore's law, nature, and industry as separate actors in different roles and which refuse to be mobilised (or subdued) by a particular actor's campaign. The final phase is represented by different rewards/sanctions (heirlooms, accelerated returns, or exponential progress) (also in Figure 5.10).

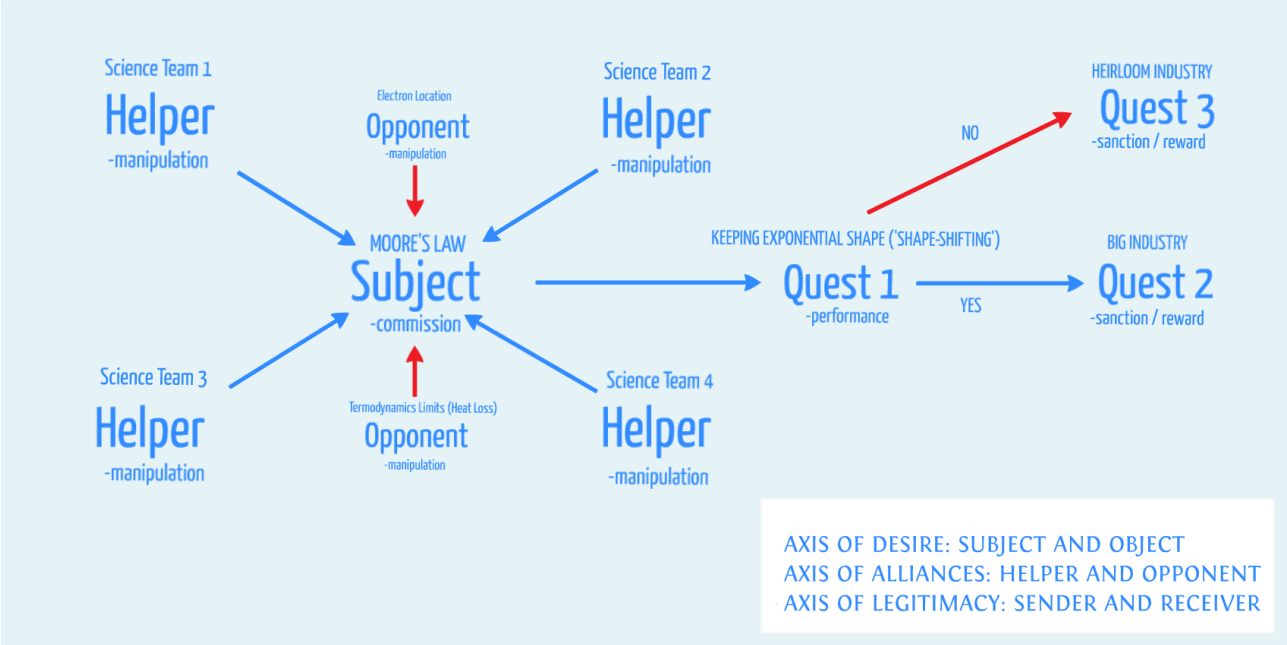


Figure 5.10 The process of narrativisation: a story from the perspective of industry, but also anthropomorphisms in the Moore's law controversy.

Finally, the temporality should not be measured strictly alongside real events, it should be represented by an order which has been jeopardised, for example, exponential growth (i.e. also a specific type of orders of 'economic worth' in Boltanski and Thevenot 2006). There is, then, a (dis)order to be considered at the entrance to the manipulation phase since it implies one of the parties (big industry) wanting to re-establish the previous order. Maintaining or returning to an order can be understood strictly figuratively as a representation in maintaining the exponential curve (Figure 5.2b). If we return to Greimas's schema and a metaphorical event such as noogenesis (in Figure 5.5), a compositional view on creative evolution includes specific global temporality, a meta-narrative structure in terms of three distinct phases: a qualifying event (*épreuve qualifiante*; nano-/bio-sphere), a principle event (*épreuve principale*; technosphere), and a final event (*épreuve glorifiante*; noosphere). These relationships correspond to the temporal envelope of an entire narrative and, as I will argue next, to specific discursive formation.

5.3 Constants, Extensions, and Orderings: Discursive Formation (Discussion)

The initial findings of this study were that the nanoworld and its explicit laws are spread markedly across the current diversity of the field. The nanoworld is inter-discursive to the point that it is modelled through concepts from different science disciplines. The purpose is not to show that the (nano)world is complex and dynamic, but to the contrary, my goal was to also demonstrate that it has constants and orderings—normative regimes which reside beyond explicit laws. And furthermore, the analysis should make more evident that normative regimes are not only represented by metaphors of various laws, norms, and specific projects, they represent various re(con)figurations which reach beyond the metaphorical and semio-narrative dimension of science

discourse. The following discussion will concentrate creative evolution as a discursive formation and on Moore's law as a specific master/root metaphor of this larger formation. The formation not only shows the integrity of nanotechnology discourse (as an answer to my research question) but also resonates and translates technoscientific possibilities into real policies and societal objectives. This finding is essential for the next chapter that will investigate in more detail how the relationship between metaphor and nanotechnology can consolidate models of governance (technocratic) and become aligned with models of governmentality (knowledge and power).

5.3.1 On the Structural Resemblance of Biological and Creative Evolution

The question arises of how fitting creative evolution is as a relevant discursive formation when studying the integrity of the numerous scientific fields (laws) and coherence of the nanotechnology discourse? The structural resemblance between nature and culture (and Moore's law as a guiding metaphor) should be our next focus. In doing so, I will first discuss their resemblance at absolute value (i.e. identity). In the *Selfish Gene* (1976), Richard Dawkins urges us to take the idea of gene (nature) and meme (culture) co-evolution literally. Meme evolution is not just analogous to biological or genetic evolution, nor is it just a process which can be metaphorically described in evolutionary idioms, it is a phenomenon which obeys the laws of natural selection exactly/literally. The theory of evolution by natural selection is neutral regarding the differences between memes and genes. These are just different kinds of replicators evolving in different media and at different rates (cf. Dennett 1995).[51] Here, culture and nature are not opposites in a way which would create metaphorical resonances. Both provide a solid basis for understanding evolution as when organisms are changing over time, and it is because of some need (fr. *besoin* as Lamarck put it) to deal with the environment.

Differences yet may arise if we look into the central metaphors of the evolution concept. In Darwin's *Origins of Species* (1859), the TREE conceptual metaphor is probably his central organising vision of evolution over time. From a single starting point, the genetic changes in different populations send species down different evolutionary paths. Some of these 'branches' survive and split, in turn ending up on new branches. Other branches wither and species become extinct. Over time, the single starting species gives rise to a multitude of different species, some persisting and some passing away. The metaphor of the 'tree of life' is one which Darwin worked on for years and was allegedly never entirely satisfied with, but it is a metaphor that still has a lot of resonance today (e.g. in genealogies as a cultural model of heritage which use 'family trees'). We

[51] Daniel Dennett (1995) supports using the notion of memes to better understand cultural evolution. He also believes that human creativity might operate via the Darwinian mechanism ('Could there be a Darwinian Account of Human Creativity?'). Nanotechnology (and resp. NBIC convergence) implies an evolution which may correspond to this hybrid ontology. According to Jean-Pierre Dupuy (2004), nanoscientists consider all processes at the molecular level and try to identify the 'algorithms' which rule these processes; processes humans are tempted to simulate and then create what, up until now, only nature has been able to achieve (in Laurent and Petit 2006: 252).

have seen how laws of the nanoworld can be organised into a tree metaphor (Figure 5.1). There, Moore's law is a metaphor for ANIMAL/SPECIES that is born and dies with every generation of transistors. As the genealogical *tree* grows, its shape results from endless 'conflict' (another of Darwin's metaphors) with the environment (opponents and helpers). The re(co)figuration of Moore's law, as well as an allegory for creative evolution, is taken as evidence of this mechanism. According to Joly and Kaufmann, microchips operate as connectors (or boundary objects) between heterogeneous worlds: They create links between disciplines, institutions, and practices (Joly and Kaufmann 2008: 8)—the reference to the Moore's law and creative evolution makes them appear as natural as *biological evolution*, as if there was no room for political choice.

With our evidence, however, it is just as fitting to address it as a ROADMAP, where different actors are required to arrive at a *consensus* over the courses of action. There are dead ends as well, and generations of technology end up in blind alleys. However, roadmaps do not grow into such a state via chance (in analogy to random genetic drift), they are driven (metaphor of control)—we draw roadmaps because we do not want to take unnecessary chances. Moreover, when you win the 'lottery (of nature)' no one is likely asking you to justify it, yet when you develop something intentionally, you need to justify the design (actions taken or not taken). As creative evolution contains different concepts and conceptual metaphors for managing evolution, as such, it reconfigures space for legitimisation. It *naturalises* nanotechnology development whether we perceive it through the SPECIES or JOURNEY metaphor. This is ever more remarkable if we consider biological evolution does not escape geographical isolation. The creative evolution of the Moore's law, on the other hand, transmits to all relations and geographies of the nanoworld—it represents the omnipresence of nanotechnology. The project which stands behind creative evolution is here commonly criticised (by Jean-Pierre Dupuy or Michael Sandel) as representing a kind of hyper-agency, the Promethean aspiration to remake nature, including human nature, to serve our purposes and satisfy our desires. It should thus be addressed as a historical, sociological, ethical, and even theological problem (this discussion is left for later synthesis between findings).

As social scientists (and historians, or philosophers) we must ask why the preference exists towards creative evolution. Or, *can it be derailed from its course to a single (singular) outcome?* From a human viewpoint, Darwinian evolution is extremely cruel, but it is also extremely slow. It is not even evident that Darwinian evolution can continue. Effectively, the process of natural selection requires a given environment. By being built according to our economic, political, and cultural constraints, the environment seems to struggle with our detrimental activities (cf. ecological movements). In this context, the paradigms of biological evolution and creative evolution are broken. For one to continue, we would have to return to living in caves and hunting with rocks or radically transform ourselves with nanotechnology, neither of which even the most radical neo-

Luddite would probably want. If our technological environment is leading us to go well beyond nature (to the singularity) and perhaps to a point where we are no longer actively in control of our evolution, it should, however, be responsible evolution.

We do not know what happens beyond the point of our radical CONVERGENCE or SINGULARITY. It is perhaps as abstract as a black hole or an event horizon—the other 'end' of the Big Bang. As physicist Richard Jones (2016) remarks, the singularity metaphor alone, or even when taken together with the Moore's law metaphor (exponential growth, in Kurzweil 2005), is problematic. For example, the real function defined as $f(x) = 1/x$ has singularity at $x = 0$.

> When we talk of the technological singularity [note: finite time singularity] we're using a metaphor, a metaphor borrowed from mathematics and physics. Let's begin by probing the Singularity as a metaphor. A real singularity happens in a mathematical function, where for some value of the argument the result of the function is undefined. So a function like $1/(t\text{-}t0)$, as t [note: t here means time] gets closer and closer to $t0$, takes a larger and larger value until when $t=t0$, the result is infinite. Kurzweil's thinking about technological advance revolves around the idea of exponential growth, as exemplified by Moore's Law, so it's worth making the obvious point that an exponential function doesn't have a singularity. An exponentially growing function—$\exp(t/T)$—certainly gets larger as t gets larger, and indeed the absolute rate of increase goes up too, but this function never becomes infinite for any finite t. (Jones 2016: 5–6)

However, the problem lies not in the validation of metaphor—whether we are ready to be living arithmetically (linear) or exponentially if we are to keep up with technology until machine intelligence surpasses human intelligence and goes into a recursive cycle of self-improvement (Jones 2016: 6).[52] It is instead about the concepts of evolution (progress), creativity, and self. When something is done by self, it implies the location of responsibility. Similarly, creative evolution applied as a norm (or virtue) risks swaying into (social) control of its development options—it naturalises (legitimises) any decisions about the course of technology development. Let's think of the consequences.

The concept of chance and (political) choice raises the essential question of a 'direction' of

[52] This is not meant to deny that difference between living arithmetically (linear) or exponentially is alone an interesting subject for studying history or cognitive science: 'Linear growth we understand intuitively. However, we have no sense of exponential (or percentage) growth. Why is this? Because we didn't need it before. Our ancestors' experiences were mostly of the linear variety. Whoever spent twice the time collecting berries earned double the amount. Whoever hunted two mammoths instead of one could eat twice as long. In the Stone Age, people rarely came across exponential growth' (Dobelli 2013: 106–07).

creative evolution. Unlike one embodied by roadmaps, biological evolution seems to go in the direction of getting *always more complex* and does not follow pre-defined pathways (cf. 'blind evolution' versus evolution of the 'convergence' in Bensaude-Vincent 2009: 73). It has no concept of leadership and transitioning gloriously from one stage to another (as from Stone Age to Bronze Age or Silicon Age to Nano Age). The biological evolution (of Darwin's concept) is chaotic, unforeseeable, and endless, where the inner and outer environment are mutually oriented and vectored. The creative evolution of the Nano Age, on the other hand, is a model of evolution with the notion of directionality, approximating predictions (roadmaps), and even with finality—the singularity/noosphere. In other words, outer and inner environments cease to exist as separate vectors. It is a question whether the concept is necessary or how it adds to the conception of risk that society channels, according to Giddens (1999), towards two finalities: the end of nature and the end of tradition. For Giddens, the end of nature does not mean a world in which the natural environment disappears. It means there are (already) now few, if any, aspects of the physical world untouched by human intervention (see also Jasanoff 2004: 13). For hundreds of years, people worried about what nature could do to us (earthquakes, floods, plagues, bad harvests, and so on). At a certain point, according to Giddens, somewhere over the past fifty years or so, we started worrying more about what we have done to nature. The transition marks a major point of entry to the risk society. It is a society which lives 'after nature'. However, it is also a society which lives 'after tradition'. To live after the end of tradition is essentially to be in a world where life is no longer lived as fate (Giddens 1999: 3).

With these two aspects of being *after*, creative evolution (and its root metaphor of Moore's law) is ever more closer to the concept of NOOGENESIS, a metaphor which blurs the distinction between proper awe for the intricacy and beauty of nature and its nanostructures and an appreciation of the ingenuity of human engineers who try to emulate them. To an extent, this contributes to the opening, maintaining or closing the case for any paranoias about nanotechnology (cf. 'paranoid narratives' in Mordini 2007a). Creative evolution, on the one hand, is a techno-prophecy, announcing the transformation to a radical culture/society of choice in a space which is totally calculable—the human body becoming hybrid in which information freely circulates (cf. Chateauraynaud 2008: 17). On the other hand, it incites fears about irreversibility and accentuates choice (cf. path dependency and lock-in, in Arthur 1989, or in Pierson 2000). It is a challenging task for individuals as much as for neoliberal governmentality. Whether contemporary society, conditioned to be fearful of technology, is to turn to paranoia or optimism remains to be seen. As much as it seems to channel the ambiguity of nanotechnology and capture the attention of the public, creative evolution as a discursive formation has further implications—in a meta-pragmatic discourse, it can become aligned with a policy (and also media) strategy.

5.3.2 There is More to Moore's Law

Moore's law is a fascinating case of how metaphor is manufactured/constructed and how it rapidly propagates in society from scientific articles and engineering labs to policy reports all around the world. It is a root metaphor of creative evolution through which perspective (or worldview) on science, policy, and society unfolds. It is recorded in history that Gordon Moore's original paper was not published in *The New York Times* for public consumption, but in the journal *Electronics*; it was a technical document meant to predict the long-term trend of observed phenomena. But the meaning of 'Moore's law' quickly shifted from a simple statement about costs and density trend lines to one which presented as an overarching trend that governed nearly every aspect of modern society.[53] It has become cultural shorthand for innovation itself. For STS scholars, such as Alfred Nordmann in his 'Design Choices in the Nanoworld' (2007), the law is a folk historiography. It might be studied as modern mythology. No matter what we call it, we now have enough evidence to notice that Moore's law, beyond its validity (or truth value descriptions), is a central component of nanotechnology discourse. There, we find competing narratives in the sciences (such as those contesting the 'death' of Moore's law); scientists are constructing their own persuasive stories, and these can serve as a critique to those of their adversaries. The lesson learned from the presented case study is that Moore's law shifts from literal truth to figurative truth. The point of social sciences (especially in the sociology of expectations) on Moore's law can be directed towards the symptomatic orientation towards future which has the power to transform current practices—a self-fulfilling prophecy (cf. Merton 1948, Merton 1973). Although Gordon Moore was just doing 'wild extrapolation', he also counts among the hero-figures in the development of nanotechnology alongside figures such as Feynman Drexler, a 'prophet of the nanoworld' (WoS 1999a). Moore *is written*, and what is written has power (cf. works of Foucault). The law traditionally expresses both *technological determinism* and *economic determinism*. In other words, if technology development determines new markets and future society, it is also the development of economies which determines the development of technologies. And even as the portrayal of the law has shifted from a truism, its background concepts may still equally entail unquestionable implications. Linking nanoscience, nanotechnology, and society assembles a new status of the *soft law* (a protected space/figure delineated by expectations), thereby promoting adjustment which actors may associate with regulation and high financial, material, and societal costs.

To better understand the normative regime behind Moore's law is to submerge deeper into

[53] Moore's law is traceable in different 'laws of engineering' in science, technology, and society. To name a few engineering laws, I invite the reader to review Rock's, Kryder's, Butter's, Nielsen's, Metcalfe's, and Koomey's laws, among others. In social reality, there are Moore's laws for *practically anything*—from DNA sequencing to our email wasteland (cf. 'Moore's law of Moore's law', in Sanders 2015). Our task is not to assemble evidence as to whether any of these laws are true. Any of these translations might be right or wrong (*reference*)—our interest is the re-figuration of the law.

the metaphorical register, showing its status of generative metaphor (Schön 1993), as well as to relate to a larger discursive formation of creative evolution. In *Singularity is Near* (2005), Kurzweil promises 'we will transcend all of the limitations of our biology, . . . that is what it means to be human—to extend who we are'. Although it is an ambiguous term for a more ambiguous human condition, it became an official societal project when Kurzweil co-founded Singularity University, an institution supported by Google and NASA and which aims to raise the generation that realises singularity. Singularity University claims their 'mission is to educate, inspire and empower leaders to apply exponential technologies to address humanity's grand challenges'—optimism carried over by Moore's law. Altogether, it should be now more clear why Moore's law deserves continuous awareness to its expansion and ethical debate as it has ambition to disguise to mean progress and to transmit to *all* science-society relations. These totalising images always carry with them more troubling scenarios. In *Robot: Mere Machine to Transcendent Mind*, published in 1999, Hans Moravec further considers the implications of exponential technology. Extrapolating the trends from Moore's law, he is yet more pessimistic as he speculates about a coming 'mind fire' of rapidly expanding superintelligence. These are, still, images and imaginaries (also technoscientific projects) that belong to the same discursive formation. They are in reference to the care for the self (soul), the bodies, as well as the 'truth' (or discourses of truth). To philosopher Michel Foucault, this is a central component of discursive formation with regard to the relationship between the inherently connected forces: power, truth, and subjectivity. The Moore's law and creative evolution (discursive formation) will be investigated in more detail in the final discussion. At this point, I will draw the following conclusions.

5.4 Conclusion

The nanoworld is characterised by our experience of the nanoscale (science) and the future (society) at literal and figurative levels, where we must grapple even with the presently inconceivable, with mind-stretching concepts. Here, the metaphor study showed a perspective on the figurative dimension of normative regimes which translate *nature* and *culture* within a specific discursive formation of creative evolution. The formation extracted from WoS brings about a representation of nanotechnology development ranging from nanoscale 'self-assembled' structures, through technology roadmaps, to a 'self-transforming society', and which, among others, shifts and translates between technical and social images. This formation does not simply mirror the (nano)world or its laws (or reality), provided by scientific knowledge, but actively selects which reality to convey. The meta-pragmatic level of creative evolution might induce a corrected attitude of the nanoworld, a kind of suspicion towards figures which in turn may reinforce perspectives,

attitudes, and incite actions. In other words, the endorsement of certain figures as well as their omission may also promote unprecedented development. The problem, however, lies not in validation of whether we are ready to be living arithmetically (linear) or exponentially if we are to keep up with technology. It is rather about the concept of *evolution* (progress), *creativity*, and *self*. When something is done by self, it implies the location of responsibility; similarly, the creative evolution applied as a norm (or virtue) risks swaying into (social) control over development options—it naturalises (legitimises) technology. This should suggest that metaphor analysis can be one of the cornerstones in our understanding of the dynamics of the nanoworld. From a meta-regulation point of view, materialised metaphors of creative evolution, such as technology roadmaps, have potential to resonate with real policies and decisions. Keeping transistors 'alive' consolidates bonds within research projects, especially where it requires interdisciplinarity (DNA chips), an alignment of research with industry, and (public) policy roadmaps. It is appropriate for future investigations to focus on roadmaps in extent and content, especially at the institutional and organisational level.

All in all, creative evolution becomes risk as well as opportunity for our policies. Scientists are continually getting into a better position to confront our nature by understanding the work of a machinist. Similarly, by invoking the repertoire of the field biologist, creative evolution seems open to a position of confrontation with our technological systems. There is much value to be had in looking at nanotechnology development through the metaphorical lens of creative evolution—yet again, however, we should not take its metaphors as identical with the objects and states they represent. In other words, the endorsement of certain figures and their omission embedded in the science articles may also promote unprecedented development, a discussion which will continue in the next analytical chapters.

Chapter 6. Technology Roadmaps, Innovation Journeys, and the Nanoworld: A Spatio-temporal Consolidation of EC Nanotechnology Policy

> *A map is not the territory it represents, but, if correct, it has a similar structure to the territory, which accounts for its usefulness.*
>
> Alfred Korzybski, *Science and Sanity* (1933: 58)

6.1 Identifying the Problem/Matter of Concern: Nanotechnology Policy

It was noted in the introduction to the dissertation that nanotechnology has become incorporated into strategic policies which seek to redefine what a nation or community is and what it stands for (cf. Amato 1999, Nordmann 2007a). In particular, the European Commission (EC) aims to implement nanotechnology as a pan-European research priority and to develop a specifically European approach (Commission 2005). The challenges can be enframed into a model of governance which would coordinate actions at different levels of performance: between research institutes and universities; small to large corporations, suppliers, industry, and trade associations; and nation-states and international bodies. In this sense, the Commission emphasises how the governance of nano ought to be based on collaboration, the best scientific evidence, and available practice (Commission 2010a, see also Schummer 2004, Gilad 2010, Stokes 2013). The EC nanotechnology policy is multi-actor and its long-range strategic planning targets emerging infrastructures ('ESFRI Roadmap') and frameworks for innovation ('Horizon 2020 Roadmap'), and also nanotechnology projects such as 'NanoRoadSME' (2006), 'NanoRoadMap' (2006), 'FramingNano' (2008–10), 'Nanolandscapes' (2011), 'NanoCode and the European Commission Code of Conduct' (2010–12), 'ObservatoryNano' (2012), or 'NANOfutures: Integrated Research and Innovation Roadmap' (2012) among others. These activities not only give an indication as to the general revival of technology roadmaps, used in their traditional form as tools in top-down technology management and now moving in new political contexts. They also show how words, images, and patterns of discourse exhibit their own set of dynamics and have special importance in EC nanotechnology policy. They point to a certain consolidation of 'a strong and unified Europe', which is not, as Sheila Jasanoff (2005: 77–93) argues, merely arbitrary linguistic choice but a strategy. It is a systematic use of language to define problems which European institutions could then position themselves to address in order to legitimise their political existence.

The objective of this chapter is to focus on the character and effects of EC nanotechnology policy consolidation and to determine what information could be obtained through the performance of metaphor analysis within nanotechnology (policy) discourse. In contrast to studies focusing on explicit technology roadmaps (cf. Phaal et al. 2004 and 2009, Kostoff and Schaller 2001, Verbong

and Geels 2010, McDowall 2012), this study deals with roadmapping as a metaphorical pattern and narrative structure (Rip 2012, Berker and Throndsen 2017). I suggest studying roadmapping discourse in the institutional setting, where a relative consensus about nanotechnology has been reached. For this purpose, I assembled an ad hoc corpus (approx. 200 articles) from news and reports on 'nanotechnology' (keyword) development, all from the Community Research and Development Information Service (CORDIS). By combining two analytical models of systematic metaphor, either as a topological or narrative variation, I will argue how these can explain the character and dynamic of the spatio-temporal consolidation of EC nanotechnology policy. The results of the analysis are then confronted with selected policy documents so as to address their embedding in discursive formation that is concealed in the concept of governance but reaches beyond it in terms of the relationship between knowledge and power (see Nano-Orientalism later in this thesis).

6.1.1 Studying Technology Roadmaps in Policy Discourse

Technology roadmaps are commonly used in industry, government, and academia (cf. Barker and Smith 1995, Kostoff and Schaller 2001, Phaal et al. 2004) and have gone through constant evolution (Phaal et al. 2009). Despite their variability reflecting different contexts of use, there is a key gap in the discussion on technology roadmaps in political contexts (Berker and Throndsen 2017). The possibilities to grasp the subject from the perspective of social sciences are endless but instead of exploring all these possibilities, I would like to elaborate on technology roadmaps in a way which extends the theoretical setting of this thesis.

The sociology of expectations has been closing the gap by paying special attention to technology roadmaps as an ideologically anchored notion that technology will continue to offer possibilities for progress (cf. McGee 1980, van Lente 2000). Technology roadmaps emerge as 'protected spaces' and thus are shaped by requirements for protection and some boundary maintenance (van Lente 2000). There is always a variation in expectations between different kinds of actors: basic researchers, entrepreneurs, potential end users, and so on (Brown and Michael 2003). Expectations have been described as a process for developing consensus, even authority over these heterogeneous actors (cf. Kostoff and Schaller 2001, Phaal et al. 2004). If technology roadmaps are to be successful, the same consensual process and boundary maintenance must develop in the European governance context. There, a multitude of heterogeneous actors results in increasing coordination difficulties and which also forces and condenses diverse logics and vocabulary, especially economic incentives and instrumental rationality, with value-oriented responsible development and innovation. A mid-range perspective is provided by Berker and Throndsen (2017), who perceive a roadmap as a product of negotiation of the future, where the resulting 'story' is a compromise between different anticipations. In other words, actors (also

institutions) need to establish at least some rudimentary storyline in order to be able to provide a sense of direction (Berker and Throndsen 2017: 215). This is also where technology roadmaps can open up to metaphor studies. What is usually mapped is not just an innovation landscape but also a series of events which unfold between more or less clearly defined points in time (cf. Phaal et al. 2009). Arie Rip, who studied technology roadmaps as patterns of innovation journeys, sees roadmaps through similar dynamics of innovation and understands them in terms of generative metaphors (cf. Rip 2006: 349–50, Rip 2012: 167), powerful 'frames' which represent a specific problem as well as a solution to this problem (in Schön 1993: 144–47).

We have heard many times from different scholarly sources claiming that *mapping* is only a rhetorical veneer in a given situation, even a replacement for the absence of method. Cognitive linguistics goes more in-depth, describing roadmaps as systems of conceptual metaphors, such as JOURNEY, used across many languages and applied to multitudes of experiences and processes (Lakoff 1993: 219–29). Similarly, the MAP is a wide-scope domain conventionally applied to a very large variety of experiences (Semino 2008: 109–17). The PATH scheme also tends to be used, as Paul Chilton has pointed out, in order to represent 'policies, plans, national history and grand ideas like "progress"' (Chilton 2004: 204). Finding the boundaries of technology roadmapping is something which might prove difficult on these cultural-cognitive grounds. Even so, it is important to get a grip on the complexity and contingency; one must still search and explain the reasons behind the amount of discursive and political coordination. In other words, places and futures grounded in metaphors can offer cues for action and be exploited to perform specific (political) tasks and achieve goals. Their emergence and functionality in nanotechnology discourse should not just be seen as extending empirical evidence to cognitive linguistic theory but also as establishing a connection to the social theory of metaphor. Based on this theoretical background, we can assume technology roadmapping exists more or less implicitly as a metaphorical (narrative) pattern of 'locations', 'events', and 'actors', and discursive formation (Foucault 1972: 31)—and which can altogether have an influence on institutional arrangements. The perspective is reminiscent of Korzybski's much older dictum 'the map is not the territory' (1933) whereby deconstruction goes further in bringing the issue of how language represents place and future into much sharper focus: 'A map is not the territory it represents, but, if correct, it has a similar structure to the territory, which accounts for its usefulness' (Korzybski 1933: 58). Studying technology roadmaps in EC nanotechnology policy discourse should thus address the general question of how metaphors are linked to European nanotechnology policy, exploring in particular the antagonism, consensus, competition, and indifference of different actors, and furthermore, the consequences, if any, for their particular use.

6.1.2 Locations, Events, and Structures: The Political is Physical

There is an important addition to what has been noted on methodology (Chapter 3). Metaphor analysis has been outlined as separating literal utterances (words, sentences) from the conceptual domain level (concepts), traditionally marked in capital letters and searching for their systematicity. In literature focusing on the ROADMAP metaphor, the most frequent are systematic metaphors with background concepts for JOURNEY (cf. Lakoff and Johnson 1980: 44–46, 89–91), PATH (Chilton 2004: 204), and MAP (Semino 2008: 109–17), among others. But there is a rarely used methodology which allows for the study of systematicity between these concepts. Probably the most coherent model is offered by George Lakoff (1993: 206–29), introducing metaphorical *topos* as a systematic transfer from the physical semantic domain (also in Table 6.1).

Table 6.1 Location event-structure model.

POLITICAL	*is* PHYSICAL
Means	*are* paths (for achieving purpose)
Purposes	*are* (desired) destinations
Actions/changes	*are* movements (to or from locations)
Actors	*are* travellers
Inability to act	*is* the inability to move
Difficulties	*are* impediments to motion
External events	*are* (moving) objects
Long-term, purposeful activities	*are* journeys

Source: Adapted from Lakoff (1993: 219–29).

This model is useful also because it does not place constrains in the sense that the list of elementary metaphors is not pre-set or exhaustive. It indicates complex topologies with an internal logic, which can contain richer and more culture-specific knowledge about travellers, vehicles, modes of travel, impediments to travel, and so on (Semino 2008: 92). The events, just as with actors, are conceptual metaphors which can be used further as a link to the according narratological model and to the study of the discursive formation representation. As in the previous case study on the ‘nanoworld’, the metaphors are taken as elements in narrative grammar, and thus, they set in place the various components of the discursive semantics (cf. ‘figurative discourses’ in Greimas and Courtés 1982: 134) and discursive formation. The following section thus presents empirical observations from the CORDIS database which draws on the analytical models outlined in the

methodology. The quotations were selected to show how the CORDIS (EC's) nanotechnology policy metaphors and, in Lakoff (1993) terms, 'locations' and 'events' are used systematically and creatively in order to structure and sustain rich inference patterns. In addition, Greimas's (1983) actantial model is adjusted to uncover 'events-locations' and the actions of different 'actors' in different narrative roles to indicate the pragmatic aim. An overview of the topology, as well as the narrative dimension, is presented at the end of the section, followed by discussion on the discursive formation.

6.1.3 Locations: Lisbon, ERA, and the Nanoworld

References to nanotechnology in the early period involve descriptions of policies and hypothetical development scenarios: After the expert group's foresight report had made six recommendations for 'a research agenda "beyond the Lisbon strategy" . . . to analyse the evolution paths of key technologies', it concluded that 'we need to think beyond Lisbon' (CORDIS 2005a), as if the strategy was a place on a map. The European Commission highlighted the economic and social importance of nanotechnology related to 'an open and diverse European Research Area [ERA] . . . crucial in the quest to minimise and eliminate the various barriers and disincentives to researcher mobility that currently exist in Europe' (CORDIS 2000a). The above utterances or statements relied on some fairly conventional mappings of the (geographical) AREA source domain to represent purposeful, goal-oriented activity and where there are 'barriers' as impediments to research and development. Years later, the twenty-second thematic supplement was published by the Commission, entitled *Exploring the nano-world—Leading EU research in nanosciences and nanotechnologies* (2006), defining the nanoworld as 'a vibrant new research area linked to the convergence of existing scientific disciplines' (CORDIS 2006a). The document established a connection between 'convergence' and 'nanoworld', representing (future) DESTINATION.

Altogether, the Lisbon Agenda (Strategy), the ERA, and the nanoworld are LOCATIONS in a state of mutual endorsement. Their relationship is addressed through so-called 'nano-enabled social, economic, and value chains' (CORDIS 2013a), which represent metaphors for the common work of transforming the multitudes of futures into connected PATHWAYS. Nanotechnology development should enable 'countries to move towards energy self-sufficiency' and when 'the benefits of economic growth will become that much more accessible' (CORDIS 2005b). The pathways are also established when the European Technology Platforms set as their objective achieving MILESTONES, for example, in a sustainable and competitive construction sector by 2030, where 'a pathway to each of the ultimate objectives for 2030 is included in the document, with stepping stone goals for 2010 and 2020' (CORDIS 2004d). Examples like these are not separated from a wider range of expressions whose meanings relate to different events.

6.1.4 Events: Reaching Frontier and Obtaining Valuables

If 'nanoworld' has been identified as a metaphor for destination, it opens itself up to representations of actions leading to obtaining VALUABLES, such as 'economic growth, population health, the environment, Europe's transport, energy production, safety assessment', and so on, an event which begins as 'society needs-driven research' (CORDIS 2003a, CORDIS 2004a, CORDIS 2005c). In one of the CORDIS reports, the Irish government minister speaks of a MISSION to advance the frontiers of nanosciences where physics, chemistry, and biology converge . . . . It is in the nano-world that discoveries will be made and technologies developed which are likely to change our lives in the coming decades' (CORDIS 2005d). These activities correspond to various 'calls for proposals' (CORDIS 2000a) where the EC ensures their evaluation and co-finances those successful. Since the creation of the European Research Council (ERC), *frontier research* or *curiosity-driven research* has aimed at topics determined by the researchers themselves. When the EU Science and Research Commissioner Janez Potocnik was defending the ERC budget for the Seventh Framework Programme (2007–13), he argued: '[The ERC] should not simply be understood as a funding mechanism for "basic research" in the traditional sense of the term . . . the term frontier research [should be used] rather than basic research, to make a clear distinction for the ERC's role, and to give the ERC a 21st century connotation, as opposed to one captive to the dynamics of research in the mid-20th century' (CORDIS 2006b). The next era of exploration was announced to put the European Union at the 'forefront of research' (CORDIS 2009a). As soon as the scientific community reaches the frontier, 'it leaves behind routine, activities filled out by all the EU member states, industry and private enterprises' (CORDIS 2002a).

Reaching the FRONTIER not only gives the image of metaphorical boundaries, it manifests pushing forward together. It represents the opportunity for a true 'Innovation Union' and 'Joint Technology Initiatives' (CORDIS 2007a), creating 'synergies' (CORDIS 2006b, CORDIS 2009b, CORDIS 2013b) and reaching necessary 'critical masses' (CORDIS 2012). There is a sort of urgency in developing consent for nanotechnology policy, where 'European nanotechnology initiatives are required to stay in the race with the US and Asia' (CORDIS 2003b). It is argued that 'European Governments are determined not to miss the boat on the next "nano" revolution' (CORDIS 2005e). The metaphor of the RACE(-ing) here extends to the 'European Union as a flagSHIP', reaching the nano-revolution as its destination. It evokes a fascinating series of events, making it seem as if every European government was participating in a marvellous adventure or CONQUEST.

Reaching a destination requires undertaking the most testing of journeys, one which involves complex NAVIGATION. These activities include a series of multi-stakeholder dialogues defined as 'horizon scanning' and 'steering committees' (CORDIS 2006d, CORDIS 2007d).

For example, ‘the role of observatory [for nanotechnologies] would be to present reliable, complete and responsible science-based and economic expert analysis across different technology sectors and establish a dialogue with decision makers and others’ (CORDIS 2008). The European Commission aims to define these relevant activities in ‘industrial roadmaps’ (CORDIS 2002b, CORDIS 2005f, CORDIS 2005g, CORDIS 2006f, CORDIS 2006g, CORDIS 2013c). Whereas the responsibility for any research infrastructure remains mainly with the EU member states, ‘a roadmap produced by the European Strategy Forum on Research Infrastructures (ESFRI) identified a pan-European infrastructure for nanostructures and nanoelectronics as a priority facility’ (CORDIS 2007e). Obtaining knowledge of the sociotechnical landscape represents the activity of MAP-ping which ‘does not just chart, [but] unlocks and formulates meaning; it forms bridges between here and there, between disparate ideas that we did not know were previously connected’ (CORDIS 2015).

6.1.5 Actions/Actors: Drivers, Gaps, Bridges, and Streams

Many of the references to locations and events involve descriptions of problems and solutions and create specific hypothetical scenarios. These statements rely on the flexibility of conventional metaphors for DRIVERS, GAPS, BRIDGES, and STREAMS, among others. Nanoscience (nanotechnology) is expected to be ‘one of the vital technological drivers for transforming the EU into a true Innovation Union’ (CORDIS 2014). It should enable actors to engage in ‘strategic relationships that drive their business successfully forward’ (CORDIS 2015). Not only does the metaphor of a driver establish PATHWAY DEPENDENCY (with ‘businesses as passengers’), nanoscience/nanotechnology as a DRIVER is framed as a powerful protagonist: ‘Nanotechnology is at an early stage but it’s the driving force of the future’ (CORDIS 2000a). It is argued that ‘nanosciences and nanotechnologies have the potential to drive growth and jobs in Europe, and their development and use should not be delayed, unbalanced or left to chance’ (CORDIS 2007b). Claims are made that ‘there is a huge market for this field, which is also driving more research’ (CORDIS 2007c).

Nanoscience (nanotechnology) is also playing an antagonistic role in its representation of RUNAWAY or MORATORIUM. It is moving without control when there is ‘innovation running ahead of regulation’, or moving too slow when there is a ‘lack of knowledge that led some participants to call for a moratorium on certain aspects of nanotechnology use and research’ (CORDIS 2003c). It is concluded as necessary ‘to track, evaluate and accept or reject new nanotechnologies, backed by an international convention on the evaluation of new technologies’ (CORDIS 2004c). The European Commission takes decisions to mainstream safety concerns: ‘The most immediate priority is to prevent those who have the most to gain—big business—from beating the regulation race’ (CORDIS 2003c). This also suggests, (big) business is a PASSENGER that

does not always follow the rules of fair competition.

In 'No Knowledge, No Future, Says Potocnik' (CORDIS 2005i), the Commissioner insisted 'building the Europe of knowledge requires resources' and the Joint European Technology Initiatives (JTIs) are 'champions for knowledge for growth'. The JTIs between industry and members states here thus represent HEROic alliances. Nanoscientists work with engineers on a 'nano-switch', a system that 'BRIDGEs biological and nano- worlds' (CORDIS 2003d, CORDIS 2006c). Policy makers point out that 'the EU has the tools in place to avoid what has been known as the "European Paradox"—the phenomenon by which Europe invests in research, but then fails to transfer the results into products, and instead imports the resulting technologies from elsewhere. We have the tools to change the paradigm and to make a jump of quality' (CORDIS 2007f). The European paradox as a (knowledge) GAP captures difficult terrain of the innovation landscape. It requires Europe to make a radical move on the innovation journey—a 'jump of quality'. There are gaps between science and the market, different innovation phases, as well as a 'nano-divide' (CORDIS 2005h, in ref. to the North-South divide) representing the exclusion of certain groups from innovation outcomes.

CORDIS contains reports from policymakers which make reference to STREAMs when designing pathways to the nanoworld and reaching the public: 'We know how to anticipate this technological revolution, prepare the discoveries upstream and transform the trials downstream, by making all the actors in this field work in perfect synergy' (CORDIS 2004e).[54] There are lessons learned from GMOs: 'Citizens should be involved upstream' (CORDIS 2006e); for this to happen, 'foresight and social sciences must try to build bridges between demand pulled technological fields (agri-food, manufacturing, environment) and supply-pushed areas (nano- and biotechnologies, IT and cognitive sciences)' (CORDIS 2005d). The public is represented as 'measurer of all things and GUARDIAN of the world' (CORDIS 2003e, *capital letters added*), while the role of the social scientist is to 'examine the barriers to public acceptance of nanotechnologies . . . as trust can also be lost when the results of risk evaluation assessments are not consistent' (Ibid.). The metaphors for public trust as VALUABLE or a CONTAINER appear in an article entitled 'Trust and communication: keys to public acceptance of nanotechnology' (CORDIS 2007g), and also, in 'Communication and risk assessment: keys to unleashing nano-potential' (CORDIS 2006e). These metaphors denote trust as a valuable object over which the final trial is won or lost.

6.1.6 Metaphor Topology and Narrative Structure: Innovation Journey

The above metaphors correspond to Lakoff's (1993) model in terms of LOCATIONS (Lisbon, the

[54] For example, the European Research Council's 'Synergy Grant' is rhetorically related to 'channeling funds [upstream] into the most promising new fields with a degree of flexibility not always possible in other funding schemes' (CORDIS 2006b).

ERA, the nanoworld, pathways), EVENTS (journeys, leaps, driving, bridging, streaming, overcoming a series of trials), and other related structures of the sociotechnical landscape (ships, observatories, bridges, maps, valuables), including ACTORS (heroes, travellers, observers, and guardians). The topology of these metaphors can be listed as the following:

- Lisbon Agenda/the ERA/nanoworld is location (departure/convergence/destination);
- Growing economy, public health, etc. are valuables (objects in the nanoworld);
- Public trust is valuable/container (object);
- Innovation is journey/race/conquest (distance/speed/reward); and in particular,
- Nanotechnology development is a pathway/jump (evolutionary/radical);
- Development phases are milestones (feasibility and traceability of opportunities/threats);
- The European Union is ship; and
- Collective action is synergy, reaching the frontier, or critical mass.
- The European Commission is sender (calls for proposals);
- European governments, JTIs (partnerships) are heroes (crew);
- Nanoscience/nanotechnology is helper (society- and curiosity-driven); and also,
- Nanoscience/nanotechnology is opponent (avoiding regulation and competition).
- The public is receiver/guardian (receives valuables/gives trust) and represents
- The upstream (delivering discoveries)/downstream (transforming trials) challenge.
- Knowledge is vision (building observatory, map);
- Decision-making is direction-giving (knowledge of the landscape);
- Crisis/European paradox is gap (lower ground); and
- Solutions are paths/leaps/bridges (upper or middle ground).

The narrative structure is formed along the line between the subject and object, described as a (heroic) journey to the nanoworld (axis of desire); the sender and receiver are connected as the EC (sender) sends heroes and the public (receiver) prepares their trials (axis of legitimacy). A specific opposition is between helper and opponent (axis of alliances), represented by the ambiguous character of nanotechnology: competition and regulation vs synergy and value or economic chains. The storyline could be as follows: Heroes hear the call and board the EU ship to set out for the nanoworld. Thereafter, they are confronted by adversaries (big business/industry) and aided by experts (drivers, observers, cartographers) in their challenges, they consult an observatory (experts), acquire better knowledge of the (future) territory, navigate across valleys and build bridges, and finally, face (public) trials. The stepping stones or milestones indicate which objectives can be reached, valuables are presented to the public in terms of nanotechnology solutions for ecology, energy, quality of life, and such. If successful in passing the public trials, the heroes receive trust and their journey comes to an end (also in Figure 6.2).

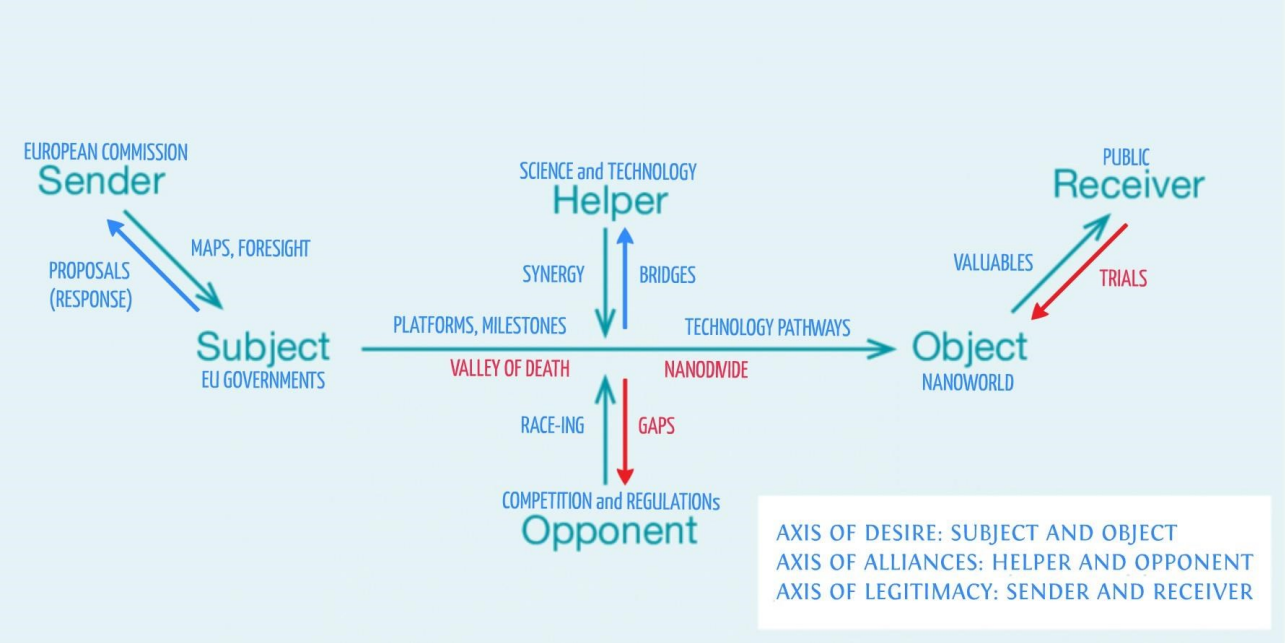


Figure 6.2 Narrative structure, adapted from Greimas (1983) to the EC nanotechnology policy.

In the Figure 6.2 above, the narrative structure has three phases (from left, middle, to right): the qualifying event (*épreuve qualifiante*), the main event (*épreuve principale*), and the glorifying event (*épreuve glorifiante*). The arrows indicate the specific modality of actions: The European Commission proposes EU governments undertake a journey to the nanoworld so that they can return with powerful artefacts and pass a series of trials (manipulation: having-to-do). The governments set out on this innovation journey (performance). Their success depends on helpers and the intervention of competition/regulation, as well as new abilities (competence: knowing-how-to-do and being-able-to-do). Together, they arrive at a destination with the objects (performance). This is a location where heroes pass a series of trials (manipulation: having-to-do). Unlocking access to the public is focused on the public's power or attribute in its possession—that is, granting trust or mistrust (reward/sanction).

6.3 Spatio-temporal Consolidation of EC Nanotechnology Policy (Discussion)

All the examples above involve highly conventional ways of metaphorically describing goals as 'destinations', actions as 'steps', positive change or success as 'moving forward' and 'progress', and negative change as 'going down' and into a 'gap' (cf. Semino 2008: 110). In a given institutional setting, however, they arguably outline unique patterns and topologies which resonate with nanotechnology policymaking. In the next section, I will address my research questions; that is, how metaphors are linked to European nanotechnology policy, exploring in particular the antagonism, consensus, competition, and the indifference of different actors through the narrative of a journey and pointing to a larger discursive formation. This formation will be explored in more detail in a synthesis of findings of the preceding as well as forthcoming case studies. Here, it will be

argued that the metaphorical structures have particular consequences in the overall form and coherence of EC nanotechnology policy, as well as implications for discursive technology assessment.

6.3.1 Metaphors, Narratives, and Nanotechnology Policymaking

The general character of the roadmapping discourse arguably combines various models of nanotechnology policy. In Figure 6.2, the left region represents policy decisions, such as calls for proposals, which shape research priorities and where consensus on the journey is required (*policy-driven model*). The middle region is driven by research and knowledge directly applied to problem-solving, such as building bridges, synergies (*knowledge-driven model*). Finally, the right region describes a direct relationship between science and the public (*enlightenment model*). The presence of various policy models might be a good indicator that narrative structure recovered from the corpus can represent an entire discourse. These models can also illustrate the efforts to find a unifying story-form model for nanotechnology policy or even establish a form of social contract. Such a contract form, it will be argued next, is when systematic metaphors are embedded in narrative: the 'innovation journey'.

Nanotechnology development, as a type of purposeful activity, is constructed (framed) as an innovation JOURNEY. The journey is not only goal-oriented to achieve some external objective, it is also an integrating force where a common PATH appears as 'ours' (or European). Travellers must adjust to their common pathway dependencies. Somewhat allegorically, the journey includes the determination of governments; the curiosity of scientists, driven to explore beyond the main route (frontiers); or industries burdened by regulations, all together on a timely mission to the nanoworld. Overcoming the GAPs is connected to creating synergies and economic/value chains which raise bridges (axis of alliances in Figure 6.2). This narrative scenario partly contrasts with the reality of mutual suspicion and mistrust, various interests, and multiple directions (cf. Brown and Michael 2003). The supporting characters are equally problematic. Does the 'observatory' generate information for the public, for the European governments, for the Commission, or for the scientists and engineers? According to Heidrun Åm (2013), the 'ObservatoryNano' (2008–12) project was marked by demands for factuality and evidence-gathering. In such moves of scientification, nanotechnology was articulated as a technical matter—in contrast to it being a potentially controversial, political matter (Åm 2013). This ambivalent role makes 'observer' an ambiguous character rather than independent and neutral. And further, if 'Europe is a common flagSHIP', it is hoped that governments will not let it sink, meaning everybody must row—with the exception of passengers excluded from the travel. This is important as the SHIP metaphor sets up a specific *in-out* opposition in relation to social groups (cf. the CONTAINER scheme in Semino 2008: 95–97). For scientists arriving 'upstream', the public is constructed at a challenging location where there are

a series of tests (trials). The public awaits the ship's arrival with gifts from the nanoworld; 'downstream' trials grant keys or unlock public acceptance and trust. This would suggest the high status of the public, but the situation is again more ambiguous.

There is a certain incongruity represented by the contrast between the existing low 'public awareness to nanotechnology' (EuroBarometer 2010: 33) and the imaginary public that nanotechnology policy metaphorically construes. While scientists, engineers, and European governments are represented as a crew, the public is outside of the vessel. This suggests, crucially, that the public is excluded from the travel or anything which would imply steering innovation towards decisive events (the middle region in Figure 6.2). Steering the innovation is a role reserved for experts and policymakers. It might be an indicator that the European Commission does not have genuine interest in the public opinion on nanotechnology, at least not in the sense of questioning the whole purpose of the journey. For example, the Action Group on Erosion, Technology and Concentration (ETC), a Canada-based activist group, report *NanoGeoPolitics: ETC Group Surveys the Political Landscape* (2005), provides such critical feedback in one of three nanotechnology governance approaches it says are emerging: '(1) Optimists—"technology is good"—Full speed ahead (with "responsible" drivers at the wheel); (2) Realists—"technology is neutral"—Invite a few of the passengers to suggest alternative routes (the "upstream" approach); (3) Sceptics—"technology is political"—Get out the map and let everyone decide if they want to take a trip and if car, bike or bus is the best way to go' (ETC Group 2005: 7). The ETC's third option to 'get out the map' is MORATORIUM. It contrasts with the Commission being convinced that 'apart from denying society the possible benefits, it [a moratorium] may lead to the constitution of "technological paradises", i.e. where research is carried out in zones without regulatory frameworks and is open to possible misuse' (Commission 2004). Non-technical solutions are replaced with 'technological paradises' to appear outlandish (cf. Nordmann 2007a: 19) while at the same time the Commission evokes NANOWORLD as 'societal paradise'. The capacity of technology roadmaps to distribute a series of signs into new forms of relationships points to a larger formation beyond a single discourse, political or activist; that is, and without disclosing too much as this formation will be explored later as *nano-Orientalism* (in ref. to Said 1978), to capture the cartographic mapping of the seemingly unknown where there is, contrarywise, a fundamental relationship between knowledge and power concealed in maps.

The resistance to nanotechnology can be turned problematic as such, since we make rather necessary choices between different technological alternatives (cf. Edgerton 2006: 9). Nanotechnology contributes as a multi-causal and place-oriented phenomenon, not only in the sense that a variety of factors influence nanotechnology development but also in the perhaps less obvious sense that there are multiple technology pathways. The concept of RACE and CONQUEST may

still work to narrow down the options as the journey follows the fastest or most challenging pathway. These concepts anticipate no 'dead ends' or 'slow' development. One of the key findings from the analysis is that the 'nanoworld', traditionally perceived as nanoscale, is here represented as both a scale and a location in the future. There are multiple technology pathways and roads, but there is only one nanoworld. It exists as the conveyance of desire relayed through allegory (axis of desire, in Figure 2)—'true paradise'. It is a place where policy strategies for convergence can establish their credibility, to have the ability to talk *back in time* authoritatively about future actions (axis of legitimacy, in Figure 6.2). Nanoworld represents 'racing against time', 'conquest', and 'responsible research and innovation'. It can give the steering committees a permanent and important status. Just as when BRIDGE/STREAM strategies are justified through reference to a GAP, the actors can be mobilised by the notion of such a transition. The European paradox here represents such a functional setting—it provides rationale for the operations and projects of the European institutions—for example, 'the European Institute of Innovation and Technology (EIT) will also help to address the "European paradox" that excellent existing research is far from being harnessed to the full' (Commission 2011: 82).

Similarly, the European Research Council's FRONTIER research manifests the destiny of scientists to push forward together and at all costs (cf. Ceccarelli 2013), it creates a functional setting for mobilising action. The Council claims its 'grants operate on a "bottom-up" basis without predetermined priorities' (Commission 2017); in the case of the ERC Synergy grant, however, 'applications must demonstrate that the proposed research cannot be carried out by a single principal investigator working alone' (Commission 2017). This is where synergy is performative. Also, the Europe 2020 Flagship Initiative Innovation Union (2011) is a conventional use of a metaphor which represents real incentives for establishing the 'free movement of knowledge and excellence' (Commission 2010c) to 'strengthen the innovation chain and boost levels of investment throughout the Union' (Commission 2010b: 30). This altogether suggests roadmapping metaphors have certain capacities to mobilise resources, set eligibility conditions, and qualifying roles. As I will discuss next, they also carry with them potential biases.

6.2.2 Nanotechnology Policy Assessment and Two Forms of Bias

Although the knowledge of topology and narrative structure might serve as an effective blueprint for nanotechnology policymaking (and grant applications), it arguably poses a problem for nanotechnology policy assessment, and respectively, discursive and argumentative technology assessment. The first issue is due to nanotechnology development modelled as a pathway (a journey), embedding a variant of *confirmation bias.* If problems described as the 'European paradox' persist or even continue to worsen, the prediction is confirmed. If the situation improves, experts can attribute it to their decisions based on the policy model. Either way, the model works; it

predicts difficult years ahead, asks citizens to 'tighten their belts', and then promises to improve the situation after this 'difficult stage' of 'journeying', 'bridging', 'steering', and 'streaming'. Change requires time. Disasters, such as uncovering a 'valley(s) of death', and passages through the underworld are part of the larger plan and must take place. Any deterioration of the situation becomes confirmation of the prophecy and any improvement is an answer to the requirement (cf. Merton 1948). The paradox has a certain inevitability to it and may actually work as an endless mobilisation resource through 'promise-requirement cycles' (cf. van Lente 1993: 191–93, also in van Lente and Rip 1998, Rip 2012).[55] The duration is rather open unless the 'milestones' are clear and verifiable. By way of these articulations, legitimacy as a chain of significance has been successfully established between science (society-driven), industry (science-driven), and society (technology-driven). Any complex problem can be reframed and reduced to a problem of an imaginary geography which can legitimise and strengthen policies—except that it may not solve the paradox.

We should ask: Who is the sender? What are the intentions? And what is hidden? The omitted elements might be more relevant than the elements featured in the roadmap. The concept of an innovation JOURNEY does not embrace non-nanotechnological solutions, and it is important to also see the relationship between 'nanoworld' and LOCATION as arbitrary. Other conceptual metaphors can bear different meanings, such as CONTAINER ('Pandora's box'), or ANIMAL (in M. Crichton's 2003 novel, we are 'prey' to nanotechnology). Accordingly, the objective is not only to render metaphors relative and context specific but also to resist the effects of narrative and its closure, to disentangle what is constructed as both promise and requirement. The storyline advances through metaphors for events into developing a mature science policy model for nanotechnology, a reaction to policy frustration with the European paradox and nano-divide(s). These provide the story with *catharsis* (drawing a map/building a bridge) as in similar science policy narratives constituted on the model of 'tragedy' (Aristotle) or a 'hero's journey' (Campbell 1949). The EC technology roadmaps have a privileged position in the sense that they integrate what Hidemi Suganami (1996) considers a good causal narrative. The hero, who wants to arrive in the nanoworld, must become more knowing and thus accepts the ROADMAP (policy) as a powerful artefact or attribute. This *story bias* redirects our attention from causes that arise from scientific research and obstacles science policy confronts to consequences which are made collective and which may not be entirely reflected by the public.

[55] Here I invite the reader to review further any of the numerous examples of projects supported by the EC's policy (framework) programmes addressing the 'valley of death' between academic research and the uptake of innovation by companies.

6.3 Conclusion

In this chapter, I attempted to identify the metaphors of roadmapping discourse with regard to their metaphorical patterns and related narrative structure. I identified metaphors for 'locations' and 'events' used to describe the future development of a field of nanotechnology, but also society at large. In this sense, metaphors engaged all the 'actors' in an 'innovation journey' narrative, in their 'path dependence', their difficulties overcoming 'knowledge gaps', and reaching the 'nanoworld'. The investigated metaphors thus have a positive connotation within the formation of roadmapping discourse in question as they transform unknown concepts of place and future into a clear organisational identity and image. Systematic metaphors are plausible tools for harmonisation through concepts which connect nanotechnology policy with science, industry, and the public domain, yet they evoke much deeper dilemmas. Technology roadmaps may seem responsive to a variety of issues; however, they form the basis for these issues just as much, such as the European paradox. The study here also confirms that metaphors have certain capacities in mobilising resources, defining qualifying roles, and establishing eligibility conditions. This is illustrated by the unifying story-form of the nanotechnology policy, conveyed by the allegory of an 'innovation journey' and which may even work to establish a form of policy model that creates an illusion of control (science is society-driven, technology is science-driven, and society is technology-driven). The study should yet reach beyond the political (and rhetorical) strategy (governance) to a formation of discourse (governmentality). The latter relationship established between metaphor and nanotechnology in the context of technology roadmaps will be discussed further in the discussion on nano-Orientalism as a specific discursive formation.

Chapter 7. Nanotechnology and Entrepreneurial Storytelling: Weaving Ontologies and Histories (Czech Republic)

Thought is a thread, and the raconteur is a spinner of yarns—
but the true storyteller, the poet, is a weaver.
Ancient Metaphor

7.1. Identifying the Problem/Matter of Concern: Nanotechnology Controversy

In the Czech Republic, nanotechnology has been recognised to be of economic importance by many private companies. Their innovation policies have included their thematic focus on responsible research and innovation (RRI) either by directly participating in related initiatives (cf. Nano2All 2016) or by subscribing to the funding mechanism of the European framework programmes (cf. H2020). The acknowledgement of the importance of nanotechnology for the development of the country, both in economic and societal terms, has not however been engaged in any pan-national public debate to date. Even if various nanotechnology dialogue processes have been undertaken across the European landscape, it has become a quiet, almost invisible affair for the Czech media and public.

There are many factors which may have to do with this situation, for instance, the size of the media's science editorial groups, the industry profile, and activism tradition—even high rates of secularity and atheism in the country (cf. Nešpor 2006). As when Dietram Scheufele and his colleagues studied nanotechnology acceptance in the United States and Europe, they found the level of religiosity in a particular country to be one of the strongest predictors of whether or not people see nanotechnology as morally acceptable (Scheufele et al. 2009).[56] Another reason might be the intense engagement of private and public institutions in the promotion of nanotechnology. Nanotechnology has been introduced as an opportunity to increase cooperation between research projects coming from various faculties and universities, thus eliminating their particular isolation—typical for research in the Czech Republic. It also became an opportunity for activities aligned with European science policy; the Technology Centre of the Czech Academy of Sciences (TCCAS) supports the participation of the Czech Republic in the ERA. The creation and development of local innovation businesses correspond to the strategies of government agencies, such as CzechInvest, and several nanotechnology clusters (Clutex, NanoProgress, NanoAsociace, NafiGate) which promote the sector's development of new technologies and the internationalisation of Czech

[56] In the study published in the journal *Nature Nanotechnology*, survey results from the United States and Europe reveal a sharp contrast in the perception that nanotechnology is morally acceptable. Those views, according to the report, correlate directly with the aggregate levels of religious views of each country surveyed. The Czech Republic has one of the highest rates of atheism in the world (Zuckerman 2006); the secularisation of Czech society, however, is neither clear nor universal regarding state and science (Nešpor 2006).

nanotechnology.

Even though only a fraction of nanotechnology is nanofiber technology, a particular company and its machine, called Nanospider™ technology (patented in 2003), has become a symbol to the point that it has not only fuelled much hype in the national media, but it has become an acronym for Czech nanotechnology itself (cf. *Le Monde* 2010, or *New York Times* 2012). The reason why the media, science, and policy have aligned with this representational pattern of nanotechnology is manifold. In the general introduction to media (in this thesis), it was noted that there is increased investment into the learning processes of how to present nanoscale as clearly and as convincingly as possible to intended audiences (Ruivenkamp and Rip 2011). This means that scientists and governments increasingly work with communications experts to frame emerging science in a way which resonates with existing worldviews (Nisbet and Scheufele 2007). Not surprisingly, 'good examples' are extensively used by science (industry) and media to contain and highlight a desirable amount of information. Media and science are closely intertwined in the sense that the latter needs the first as a proxy for rousing public interest, and conversely, science provides interesting content in exchange. Nevertheless, what science constructs, media often threaten to deconstruct (Weingart et al. 2000). The sensationalist drive of modern media to maximise their audience does not necessarily include casting an overall positive light on science. To revive ancient metaphor, it is desirable to look at particular examples of how metaphors of the Nanospider and related narratives, as such, became 'woven' into national science policy, the rhetoric of nanotechnology companies, and media strategies.

The presented study will not only explore narratives and figures as distinct layers of nanotechnology discourse in Czech national (broadsheet) media but extend to representations of nanotechnology in other materials as well. Following the theoretical framework of this thesis, I part with nanotechnology discourse described exclusively in literal terms, emphasising rhetorical, poetic (mimetic), or even allegorical aspects. Although some authors may seek to distinguish the governmental, entrepreneurial, and media interest in nanotechnology as separate areas of practice, I will expose Nanospider technology as an imaginary within which cultural norms and values are expressed and political ends are met while its manifold identity takes different forms. Apart from discussing nanotechnology in a particular sociocultural context, the case study will also prepare ground for the final discussion on the role of ambiguity in media strategies.

Nanospider technology here provides excellent material. Its design exploits the inherent properties of available materials to accomplish specific declared goals, but it also bears a plethora of social meanings, and as such, it is open to critical discussion. The Nanospider is explored as a situated use of language marked by a tense interaction between mutually implicated yet contested tendencies between the media, science (industry), art, and policy. One of the outcomes is a

paradoxical view of the history of nanotechnology in which the Nanospider sometimes appears as the vanguard of progress but also then as a mere symptom of its context. From another perspective, this technical object rhetorically surmounts the machine to become a specimen of an enterprised-up animal, a fabricated agent of technological and social change. Exploring its altered definitions and meanings, its symptomatic implosion of dichotomies is of equal importance for our understanding of the nanotechnology discourse dynamic. It is argued that the hype surrounding revolutionary technology entails a paradox: The very expectations set through stories to gain legitimacy can also serve as the source of future disappointment. The investigated metaphors may have (historically, ontologically) worked to create a protected space for nanotechnology (for the Nanospider technology). However, the metaphorical entailments should also be regarded as significant sources of ambiguity.

7.1.1 Nanospider Reaches Beyond the Laboratory: A Boundary Object

In its complex and constantly evolving design, Nanospider technology consists of a rotating drum partially submerged in a polymer solution while high voltage pulls the forming chains of polymer to a collector disk located above. There, the nanofibers can be assembled into controlled patterns and grid arrays (also in Figure 7.1). The origins of the Nanospider trace back to the Technical University of Liberec (TUL) in the Czech Republic, where a team of researchers and technicians introduced a new method of *electrospinning* fibres from a free liquid surface in 2003. A business model soon emerged for academia and industry to work in close collaboration, expanding into a growing global market for nanofibers. Nowadays, Nanospider technology has already reached small and medium enterprises (SME), such as Elmarco, Kertak, Nanoprotex, and Nanovia, as well as large companies and institutions, such as BASF, Avon, General Motors, MIT, NASA, and the US military, among others. Over the time, the Nanospider has received support from national organisations (the integrated electricity conglomerate ČEZ Group, CzechInvest, or the Ministry of Industry and Trade) and obtained funding from the 'Operational Programme Enterprise and Innovation (EU)' for building modern nanotechnology facilities in the North Bohemian city of Liberec.

It represents cutting-edge technology where stakeholders continue to speculate about all the possible ways in which nanofibers could find new applications in medicine (stem cell scaffolds), the textile industry (smart materials), filtration (air and liquid filter media), and energy production (solar cells and battery coatings), among others. In addition to its different context of use comprising different trading zones, and where the Nanospider takes the form of a common *boundary object*, it evinces a material-semiotic character.[57] That is, the Nanospider has

[57] Nanospider technology is relatively established as a boundary object which maintains relations 'stable enough to

an undoubtedly material dimension, which consists of a matrix of its components, devices, and people, but it also has a semiotic (and rhetorical) dimension, represented by their figures, narratives, and imaginaries. In addition to its materiality, it thus becomes equally important how technology is narrated, read, and re-read by different actors. Nanospider technology *figures* in marketing demonstrations, manuals, instructions, training workshops, university lectures, feedback sessions, scientific articles, media reports, and so on. A closer look at these would take us beyond the nomenclature of technical description or official histories of electrospinning technology as such, and the perspective would give only a partial account of what the Nanospider is and what it means. It also reminds us that situating the Nanospider inside and outside the research laboratory has many different strands— each yielding adequate and multiple understandings of the Nanospider.

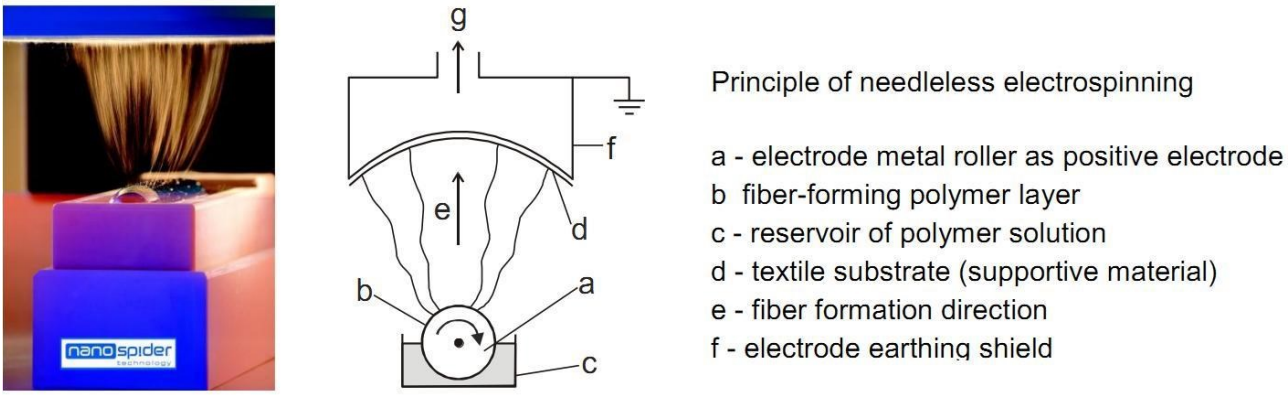


Figure 7.1 A thin layer of polymer solution film (b) is raised by a metal roller (a), which is at the same time the positive electrode. This electrode is partially submerged in the polymer solution (c), and nanofibers are created between the spinning electrode and the collector (f, negative electrode) due an extremely high-intensity electrostatic field (e). The solvent evaporates and the fibres stretch at room- or elevated-temperature and are collected by a polypropylene non-woven fabric (d) on the negative electrode (f). *Sources:* NY Times 2012 (left image), Kubinová et al. 2009 (right image)

7.1.2 Nanospider as the Vanguard of Progress: Nano Silk and the Invisible Revolution

There are many types of figures which can be related to Nanospider technology ranging from technical graphs for the density of electrospun nanofiber meshes (filtration media) to social images of futures and expected applications (social impact): respirators and filters for 'trapping biological and chemical substances' including Ebola, AIDS, SARS, but also the 'common' flu (CMC 2005); 'radiation' protection (CMC 2011a and 2011b); 'stronger than Kevlar' bullet proof clothing (CMC 2004a); 'smart textiles' (CMC 2013a); improved efficiency of 'solar energy' (CMC 2009a); replacement of E additives in food (CMC 2009b); or 'stem cell scaffolds' (CMC 2012a). These figures can provide appropriate material for further insight into the complexity of alliances, that is texts, images, and people within the Nanospider discourse.

enable coordination across communities of practice' (see Star and Griesemer 1989; Ewenstein and Whyte 2009).

A particular example worthy of our attention is from the 2010 World Exposition in Shanghai, a day when 'nanotechnology will amaze China' (CMC 2010a). There, the Czech delegation, represented by the company Elmarco (and the Liberec science centre, iQPARK), organised a special event which introduced the Nanospider by wrapping a model of planet Earth in nanofibers (Figure 7.2a and 7.2b).

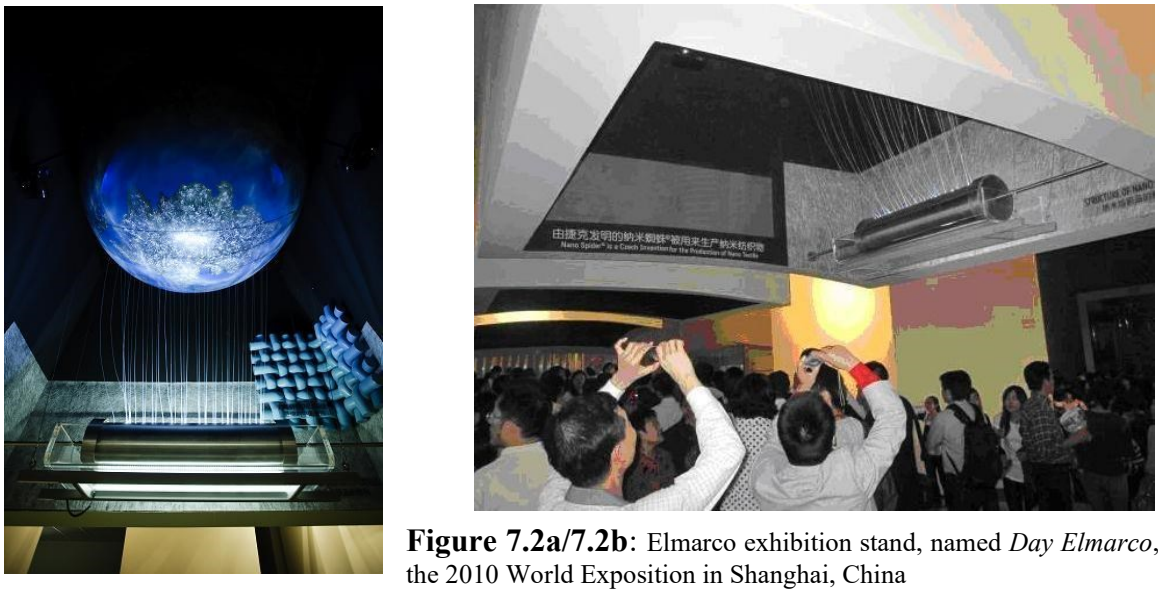


Figure 7.2a/7.2b: Elmarco exhibition stand, named *Day Elmarco*, from the 2010 World Exposition in Shanghai, China
Sources: (2a) Elmarco 2010a (2b) Elmarco 2010b

The authors of the exhibition stand reported:

> The exhibit Nano for Future consists of the giant sculptured Elmarco's Nanospider™ which shows the production process to the visitors. Fibres rise from a huge reservoir made of glass, which contains the cylindrical electrode, 'coating' the globe model of the earth placed over the visitors' heads. This picture symbolizes the possible nanofiber benefits for improving the quality of human life and represents a contemporary example of the creativity and innovative abilities of Czech scientists and technicians. Visitors can also observe examples of practical uses of nanofiber textiles including seawater desalination. (Elmarco 2010a)

The modality of representation introduces something moving beyond words which cannot be fully accounted for in literal forms. Chinese silk is exhibited and scaled to nanofibers (in Figure 7.2a, top right part of the image), but moves beyond literal as an imaginary. In connecting the nanofibers into a network with Chinese silk, this rhetorical strategy, together with other supportive practices, is the way sociotechnical imaginaries work in order to achieve different ends. They both are intermediaries, they reflect or symbolise a world that is constructed and performed, and they both represent elements in cultural (and collective) imaginaries now challenged in the exhibition stand. Let us consider how, in a single snapshot, 'nanofiber is nano SILK' mobilises and challenges the reputation of whole national economies! By the same practice, we could argue Nanospider

technology is being placed atop the history of precedent production techniques (LOOMS) as it denounces mastery and the art of silk production in its historical context. It also resonates with the historically important international trade route between China and Europe. The narrative construction of histories, or narration of histories, happens in a sense that the invention and its founders, company, or management are portrayed as influential in shaping the course of historical events (CMC 2009f) as CONQUERORs of the (nano)world (CMC 2009g, CMC 2010b, CMC 2013b, CMC 2015a). Nanospider stands for the 'Czech company [that] weaves nanofibers for the industry, first in Europe' (CMC 2011e).

Nanomaterials have histories and their utilisation places them and rejects them in particular genealogies. They also have narrated histories, and more specifically, enter particular discourses with their own historicity. It happened as such at the exhibition on a day called *Day Elmarco* in narrative time when spectators were invited to see the Nanospider rise above their heads as a driving force of progress (Figure 2b). It was unveiled against the background context of its many applications, which established the object as a heroic figure. Every so often it seems, an innovation, such as the weaving loom, the steam engine, electricity, or the computer, brings a new age into being. Similarly, the proponents announced the Nanospider technology as the vanguard of the NANO-AGE (CMC 2008a),[58] representing technology for the '3rd Millennium' (CMC 2008b, CMC 2008c, CMC 2009c, CMC 2009d, CMC 2009e) or an 'invisible revolution' (CMC 2011c):[59] 'The silver cylinder moves so quickly that its surface blends in. Not surprisingly, the speed of three thousand revolutions per minute is not visible to the eye—just like the nanofibers that roll on the roller. We are in Dolní Dobrouč, in one of the laboratories of Contipro Pharma, and we observing the possible future of medicine' (CMC 2014a).

The scientists from Liberec are themselves convinced of the future and hosted the summit 'Nanofibers for the 3rd Millennium (N3M)' in this regard (CMC 2009h). In January 2009, a research and development centre was opened in Liberec by Elmarco. The nanotechnology company participated in, together with TUL, the development of the patented machine for the production of nanofibers: 'The material of the 3rd millennium is being further developed in a three thousand-square-meter area centre, built in the Liberec industrial zone for 190 million CZK, providing the services to the world's leading companies and organisations, such as NASA. The European Union has contributed 75 million CZK to its construction from its structural funds' (CMC 2009c). In the same year, it was announced that 'materials for the 3rd millennium will be taught at the Technical

[58] According to the inventor of Nanospider technology, Oldřich Jirsák, the nanofibers have 'applications in every field of human activity . . . imagine that you were in the stone age and someone brought iron. Today, iron can do almost everything. And that idea is parallel with nanofibers' (transl. from CMC 2008a).

[59] The invention (the Nanospider) 'started an invisible revolution . . . these fibres are on an order of tens to hundreds of nanometers and about 200 times thinner than a human hair. At the same time, they are so light that only a slightly larger amount than one gram of nanofibers could circle the Earth around the equator.' (CMC 2011c).

University in Liberec. This area of nanotechnology has not been offered at any school in the Czech Republic or Central Europe' (CMC 2009d). The '3rd Millennium' metaphor thus represents and also endorses nanotechnology development, but also centres, study programmes, funding, etc.

Even then, the situation demands a critical view of these innovation-centric accounts and the hype which surrounds the technology accounting strategies. The Nanospider merges into a context of other media messages and all other *nano-talk* about transitions to new economies and new times. The relativisation between accounting for technology as a vanguard of progress and the context of its multiple genealogies happens in terms of their role in international competitiveness and modernisation but also in terms of perceived risks. The strong belief in the benefits of nanofibers does not mean there are no actual (or potential) reservations about their economics (CMC 2013c) or ecological (CMC 2009j) impact.[60] Nanofibers are discussed as improving traditional methods of making textiles (CMC 2011e), preserving food, and replacing E additives in nutrition (CMC 2009b) in the aftermath of the public backlash which followed GMOs. While the Nanospider spins 'Nano for Future' and 'Nano for Life' (CMC 2009h), projecting a future world where nanofibers are omnipresent, the same figurative idea—a world that completely embraced nanotechnology—does engender other conceptual frameworks, including those most critical.

It is a 'pan-European issue' argues science journalist Martin Rychlík in 'Policy (is) louder than science' (CMC 2014f). He points out that 'hi-tech innovation can bring social, industrial, and economic risks. The Czech Republic had only two chief executives [chief science advisors] behind Nečas's government: Prof. Petr Fiala and Rudolf Haňka. It would not be out of the question to have a trustworthy (and impartial!) authority that would inform the inquisitive public whether we should be afraid of nanotechnology or welcome it.' This debate would be timely as, it is argued, 'long nanofibers can be potentially lethal' (CMC 2012d): 'Scientists warn of long nanofibers. Inhalation of fibres produced by the nanotechnology industry can cause similar health problems to asbestos. Scientists have found in mice fibres longer than five microns trapped in their lungs. The Czech media mention some of the dangers of nanomaterials with "carbon nanofibers as the (new) asbestos"' (CMC 2008e). One of the greatest challenges for nanofibers is thus diffusion and reception of imaginaries of materials and technologies previously assessed as dangerous and which cannot shake off the nanoscale; this ranges from military equipment for 'soldiers of the future' (CMC 2001); the 'toxicity of nanomaterials' (CMC 2009j); and also extends to fears of out of control nanotechnology and the 'grey goo' scenario (CMC 2003). In the Czech cultural context, reference to a 'nano-R.U.R.' (CMC 2004b) metaphor is particularly interesting as it was the early

[60] 'In the future, we are focusing on nanotechnology, but it cannot save (redeem) the whole textile industry', (CMC 2013c) the entrepreneur argues, 'Generally, high hopes are often placed on nanofibers. However, I think it is unlikely that nanofibers will completely pull off [orig. *vytrhnout*] Czech textiles [industry], because, for example, what [amount of material] will go for medical purposes will be the range of meters. It cannot provide jobs for thousands of people'.

twentieth-century author, Karel Čapek, who in his science-fiction play *R.U.R.* (1921) introduced the word 'robot' (in reference to 'work') into common language. Against the drama of the theatre play, the article has a real equivalent in its reporting on the research of General Dynamics (a NASA contractor) which created 'self-replicating nano-tools' with molecular precision. The entrepreneurial storytelling (a 'success story') is here distorted with the metaphor that 'General Dynamics (a company) is *R.U.R* (also a company)', in this case, carrying the meaning of the NANOWORLD concept as a dystopian story and scenario of catastrophe, and where (nano)MACHINES ('our tools') kill and replace humanity. Elsewhere, 'nanobots controlling our lives is perhaps worse than Orwell' (CMC 2004c), says musical artist Marek Huňát, ironically remarking that robots implanted in our heads could make us like lousy music.

These imaginaries occupying the nanotechnology discourse are not at its margins. The Nanospider is a 'nano-machine' which cannot be completely isolated from these imaginaries. In an article, entitled 'Deadly Nanoparticles? Let's not panic.' (CMC 2009j), professor Oldřich Jirsák, the author of the revolutionary process argues that everyone should watch out for 'hoaxes' arising from ignorance and inaccurate generalisations:

> To say that nanoparticles are dangerous to human health is the same as saying chemicals are dangerous to human health. It depends of course what kind of chemicals. The civilised world behaves prudently to nanomaterials, and in a short time, there will be international standards for their classification, evaluation, authorisation and handling. It would certainly be a pity, however, if alarmist reports would slow development of nanomaterials and that already does and will in the future certainly bring a lot of progress.

The narrative of nanotechnology, just like confidence in public oversight in the PROGRESS/FEARs concepts has also stirred the public debate by pointing at the boundary between ANIMAL/MACHINE. This figure, in particular, is interesting for the many imaginaries and discourses being translated into each other, introducing an ontological figure with an epistemological twist to the whole story.

7.1.3 Nanospider as an Ontological Figure: Machine-animal Hybrid

By following the nanospider figure alone, its ontology is unclear. It entails metaphorical correspondence to the machine as nanospider, a word which hardly shakes off its etymology. The formation of the word includes a spider image (or *gestalt*) of a creature which is transferred and from which *nano*spider is derived. The prefix nano- may yet have a confusing signification as it does not intend to represent an extremely small spider, but rather, combined with metonymy, it relates to what the machine is capable of, that is 'electrospinning the webs of nanofibers' (CMC 2010c, CMC 2010d). The interpretation involves semantic fields which already exist, taxonomies of

machine and organism into which it introduces a twist or derivation that makes it say something new, capable of creating new meaning. The accessibility of new meaning is conditioned by our previous experience and knowledge of the animal and technical design.

The figure points to something which might be argued as *biomimesis*: a metaphorical resonance between two concepts—organism and technical system—'Inspired by Nature' (CMC 2007). We can assume that in reference to spinning a 'web', the word 'nanospider' is likely to lose its metaphorical focus, in other words, by being a sedimented metaphor like many technical terms and when the frequency breeds literalness.[61] Being that the genuine (ontological) metaphor for MACHINE is (spider) ANIMAL, the question arises as to how seriously we can possibly treat the figure in reference to the research practice. Or put another way, in what respect does spider (as a language ornament) provide genuine insight into the technical system? Naming the object includes contemplation of the similarities, but it also involves an element of falsehood as we may sense the absurdity of pointing out the many ways in which (inanimate) technical systems are not (biological or self-aware) organisms.

We might apply the position of philosopher and historian of science Andrew Pickering (Pickering 1995), which allows us to perceive the laboratory as a hybrid—a blended space of people, animals, and machines. The whole set of this scene could extend to a metaphor of artificial life in a post-modern TERRARIUM (VIVARIUM): An 'enclosure with glass sides, and sometimes a glass top, arranged for keeping plants or terrestrial or semi-terrestrial animals indoors. The purpose may be decoration, scientific observation, or plant or animal propagation' (Encyclopedia Britannica 2015). This extended metaphor embraces the laboratory environment to describe its inhabitants and practices in a way different to traditional descriptions which treat people and machines as separate entities in their ontologies (see Figure 7.3 below). As Andrew Pickering (2003: 100–106) argues, histories of science and technology should be histories of couplings between people and machines.

[61] The silk-spinning organ of a spider is called a spinneret, which by analogy is also the technical term for a device used to create (nano)fibres in electrospinning. The Nanospider's spinneret is the full surface of the spinning electrode—the part where the evaporation of a solvent happens.

Figure 7.3 The Nanospider Production Line NS 4S1000U. Can a postmodern vivarium (terrarium) be understood as an appropriate metaphor for social structures and practices in the laboratory in its entirety? An assumption which appears too excessive. But perhaps we should also consider how the surrounding architecture is part of the hybrid. *Source:* Elmarco 2011.

Technoscientists themselves, in the laboratory, are not likely to make such a metaphysical judgement—that is, taking the responsiveness of the Nanospider as anything other than machinist. Its metaphorical content may have become a matter of indifference to them, as Peter Galison (2006), a science and physics historian, mentioned: 'Nanoscientists aim to build—not to demonstrate existence. They are after an engineering way of being in science, rather than that of a pure natural philosopher' (ref. in Nordmann 2008: 218). A more ethnographic method would be needed to provide a clearer answer on the reception of the nanospider figure among scientists themselves. From a more naïve and realist position, there remains a danger of the Nanospider technology being misread as belonging to a relevant technoscientific category. After all, as Mohamed El-Newehy (2011), head of the nanofibres research team at King Saud University reported at an annual meeting of the American Chemical Society (ACS): 'Nanospider works much like a cotton candy machine. We used it to spin a web of nanofibres which encapsulate the antibiotic within.' The author's description of a 'cotton candy MACHINE' points to a certain level of liberty in describing what the technical system *does* and *is*. Especially when industrial exploitation (applicability, marketability, profitability) is mentioned, the engineers turn to the common metaphor of the Nanospider as a SPINNING JENNY/WEAVING LOOM (CMC 2008d, CMC 2011c, CMC 2012b, CMC 2012c, CMC 2012g, or CMC 2013a). Nevertheless, this is not necessarily outside the ontology of a spider (animal) reduced to spinning technology for the exploitation of bio-polymer fibre or silk (Figure 7.4a and 7.4b).

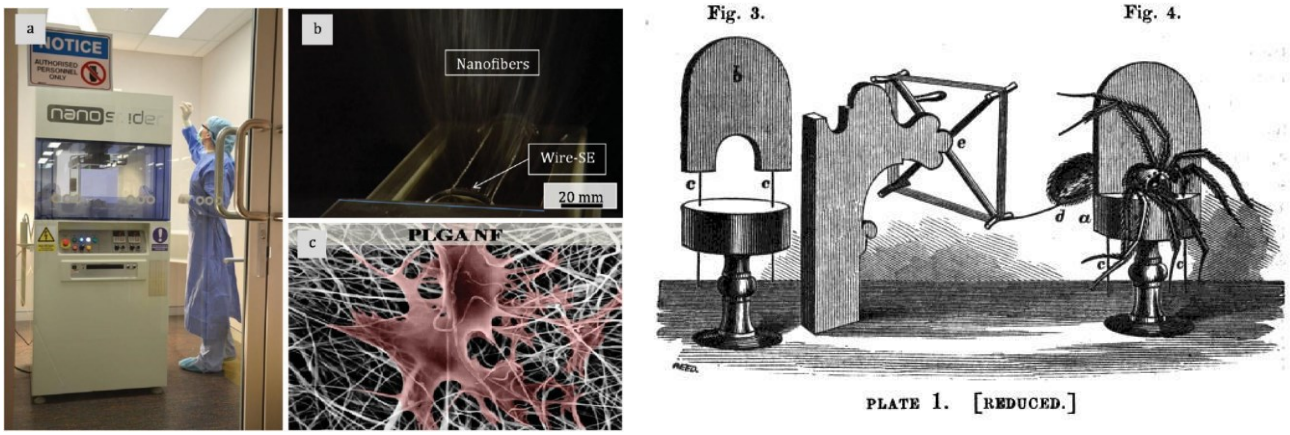


Figure 7.4a *Left*, The Nanospider was invented by a team of researchers at the Department of Nonwoven Textiles at the Technical University of Liberec in Czech Republic in 2003. The pictures (a-c) capture one of its applications in nanomedicine, where nanofibers are spun into grid-arrays (scaffolds) for growing stem cells. **Figure 7.4b** *Right*, The history of spinning techniques should also include other, unsuccessful experiments. Here, the nineteenth century experimenter Raimond Maria de Termeyer (1866) integrated a spider's body into a spinning wheel to obtain the spider's silk from its spinneret. This can be reunited on the grounds of common discourse with Nanospider™ technology. Both technologies and their experiments accentuate(d) solutions to a common problem related to industrial exploitation of polymer fibres.[62] *Sources:* (3a) Alamein et al. 2013 (3b) De Termeyer 2009.

As can be seen in Figure 7.4a, cooperation in nanotechnology is based on the role played by objects or instruments. The Nanospider is a 'boundary object' (Star and Griesemer 1989) or 'intermediary object' (Vinck 1999) as physicists, biologists, chemists, and engineers overlap and share a working scale—and thus common instruments and objects (Marcovich and Shinn 2010). Nanospider is (nano)MACHINE/nanomachine is (nano)SPIDER is a genuine hybrid. It reaches various discourses and domains of practice. The Nanospider is 'not' a mere MACHINE. The imaginary, advanced by many proponents of the Nanospider, has been that 'the Czech Republic is not an ASSEMBLY-LINE (anymore)' (CMC 2014d; *Česko už není montovna*). The metaphor is mobilised not only to show the fascinating things which happen and reach beyond the laboratory, it is also to dilute/deconstruct a machine with the essence of otherness ('alterity'). Because, beyond Elmarco's marketed image of the Nanospider's AntimicrobeWeb™ or AcousticWeb™ (Stranska and Petrik 2007: 46–47), there is something more.

7.1.4 Shroud of Venice: Religious Artefacts and the Nanoworld

The Nanospider extends from science to discourse which is artful and religious, shifting further our perception of both temporality and ontology. In collaboration with the laboratories of TUL's Faculty of Nonwovens, artist Irena Jůzová used electrospinning methods to create a series of facial imprints (lat. *sudarium*)—nanofiber shrouds. A cultural ARTEFACT as an object of religious, cultural, and personal significance was created: The *Shroud of Venice* (CMC 2012g), which is a paraphrase of the Shroud of Turin (Figure 7.5 below).

[62] For an example of the structured and necessarily selected history of the science and technology of electrospinning from 1600 to 1995, see Tucker et al. 2012.

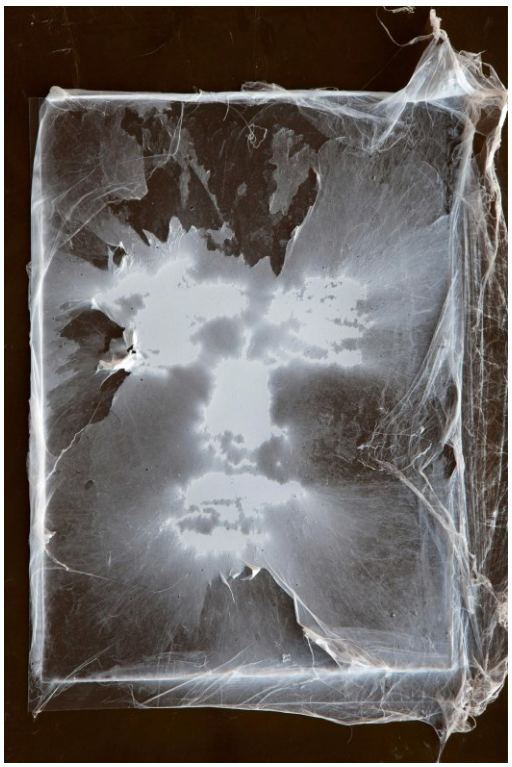


Figure 7.5 The *Shroud of Venice*

The author perhaps has left our imagination to work, whereas the exhibition curator and entrepreneur, Martina Vítková, wrote:

> Nanotechnology has more in common with religion than we suspect. Both are shrouded with mystery and what they offer can be called a miracle. We have little experience with the transcendent miracles as well as with nanotechnology, so when we talk about them the most appropriate is the word faith . . . . Indestructible fragility which abounds nanofiber is also an expression of the soul, future; what has been and what is yet to come, and that we can trace behind purposely non-descriptive forms of prints. The desire to have a future soul. That the time which is coming now is not soulless (Vítková 2012).

The *Shroud of Venice* was created with the support of an interdisciplinary project aimed explicitly at connecting art, science, and technology (ISWA 2011–13). The interaction here included an artist (sculptor), a TUL scientist, and an entrepreneur.[63] Out of the possible meanings of this boundary object, the words which emerge are 'mystery', 'miracle', 'faith', and 'indestructible fragility', pointing at the ways in which the human mind is imprinted in nanotechnology future. What is represented implies a metaphor: 'Nanofiber scaffolds is (scientific and religious) ARTEFACT'. The curator of the shroud notes:

> The imprint is a non-presence becoming present [orig. *otisk zpřítomňuje nepřítomné*], such as the traces of the Buddha's feet, traces of Christ, or the saints. It's amazing how much

[63] The author, Irena Jůzová, created her artwork in Benátky nad Jizerou (translated literally as Venice upon Jizera), Czech Republic. The artefact was created with the support of the Faculty of Textile at TUL in cooperation with the team of Professor RNDr. David Lukáš, CSc. at the Department of Nonwoven Technology in cooperation with Doc. Pavel Pokorný CSc. The curator of the exposition was Martina Vítková, a director of NWT holding.

> respect can be created by empty space and the place of contact, the interface between matter and sacred emptiness, a surface touched by divinity, whose aura at that point we still suspect . . . . The photographs from scientific tests of the Shroud of Turin [in reference to the analysis of the shroud] depict the most important scientists of the world next to NASA technology and equipment, clergy persons, cardinals, and the Pope's commissioners. Each group is expecting something else from the analyses, but what they have in common is curiosity, a fully human desire to solve the mystery while having confidence in the capacities of sciences (transl. from Vítková 2012).

In essence, there is an intertwining of the two worlds, scientific and religious, 'uncovering the miracles of nanotechnology' (CMC 2009i). The science (nanotechnology) is more religious and the RELIGION is more (like) SCIENCE. 'Nanocompanies searching for partners' (CMC 2012h)' make the 'world of business' inseparable from this equation. Placing the Nanospider into an (museum) exposition brings/translates the technical, scientific, and other symbolic systems closer together and provides an opportunity to develop attitudes to the NANOWORLD. A museum is thus non-neutral ground where the public gets acculturated through *exposition/exposure* and also at an early age:

> We want to allow children to look into the nanoworld. Show them what this world, which is one-billionths of a meter in size, looks like. What's important, however, is that children are able to get acquainted with real nanofibers produced using Czech Nanospider technology. (CMC 2014e)

> When we talk to children about the nanoworld, they are looking for inspiration in nature—beetles and spiders. (CMC 2014g)

The models of nature and religious symbolism are thus both substantial resources mobilised for generating the meaning of the technology.

7.1.5 Narrative Dimension of Nanotechnology in the Czech Media

Nanotechnology representations, therefore, rest upon associations which were established between various discourses. Nanotechnology discourse is also narrated, making the relationships intelligible through stories with multiple actors. There are human actors, scientists, engineers, economists, government, artists, the public, among others. They represent structures of coalitions as well as antagonisms, and various events. However, many non-human actors are involved in these structures and activities. Not only can the Nanospider be considered an actor, but so too can nanofibers, nanowebs, nano- or Chinese silk, nanoviruses, and so on. Many of these actors were translated by proponents to mobilise the support of the Czech government. The translation here equals inserting (also weaving) more elements into the narratives, helpers, and opponents. Scientists, industrialists,

environmentalists, and other experts spoke on behalf of the Nanospider during the 2011 EXPO in Geneva, in which they intervened to defend its interests and it intervened to defend theirs. This mutual implication is achieved through entrepreneurial storytelling at various levels. The story involves science, which discovers and provides new knowledge, and an alliance with the industry, which fights competition. It is argued, the Nanospider's 'success has awakened the nano-imposters' (in CMC 2015d). Even though the Nanospider fights environmental evils, he can be inserted as a helper in narratives of competition (who reproduce his success). Helpers that provide various resources—from material resources provided by (EU) governments to highly symbolic (conceptual) resources such as nature (also in Figure 7.6)—are variable and work towards his elusive identity (see later argument on the vmetaphor of a 'trickster').

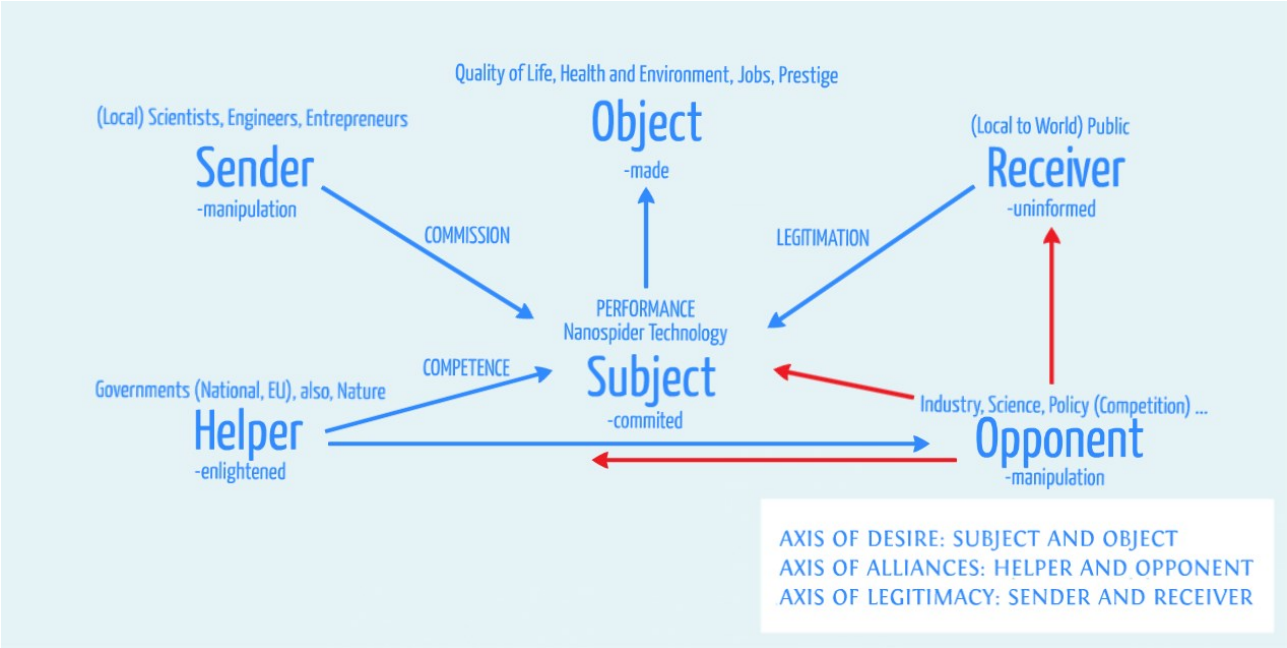


Figure 7.6 Entrepreneurial storytelling in Czech broadsheet media.

The sender invents and commissions the subject (Nanospider) who develops their own competence based on the helpers support, that is, government or strategic partnerships (e.g. the Nafigate portal) which help in 'navigating' through the competitive landscape and mimicking nature—among its common strengths. The opponents are recruited from the common semantic domains which balance the heroic character with mere context. Another foundation of the narrative structure is the formation of a subject-object relationship (an axis of desire) which targets quality of life in terms of health, improving environmental conditions, as well as providing new jobs, or international prestige (performance) versus counter-narratives considering the predatory nature of nanomachines, toxicity of nanomaterials, and others (misperformance).

The media has a more ambiguous role as they accentuate the inherent uncertainties in nanotechnology. They question the reality of the nanofibers' profitability and the powerful master narrative of the world of business. The entrepreneurs themselves aim to control the problematic

connection between ‘ideas of the academic world’ and the ‘world of business’. And as the nanocompanies search for partners in science and art—helpers—the entrepreneurial/projective storytelling of science (and industry) extends to the public. The Czech Nanotechnology Industries Association has introduced an additional metaphor, ‘Czech is NANO’ (orig. *Česko je Nano*), with the objective of popularising the field, in other words, to extend the alliance and entrepreneurial storytelling to the public. ‘We will be organising presentations in regional cities from mid-year. We would like to attract young people to study nanotechnology’ (CMC 2015c), says Jiří Kůs, the president of the association and director of the company Nanospace—a company which uses Nanospider technology. The notion of the GAP resonates with an additional figure, the international portal for nanofiber technology, Nafigate, a nanofiber GATEWAY (in CMC 2011d, CMC 2012e, CMC 2012f). The proponents of the nanotechnology gateway have pointed out that:

> The nanofibers have not yet reached their destination and talking about the Czech Republic as a nanofiber superpower would be premature—we are still missing the end of the fairy tale. That is getting nanofibers into the industry, into final products. It is nice that the university is developing something, but what does our country have? It is necessary to get nanofibers to the final phase, which could enable the company and the state to make money. (CMC 2011c)

Nafigate (Nanofibers Gateway) has established a close partnership with the agency CzechInvest, which also cooperates with world universities. ‘Our common goal is to create a foundation which will support science, research, and the introduction of new nanofibrous-based products’ (CMC 2012e), Elmarco CEO, Ladislav Mareš, explained during a Nafigate portal presentation. The storytelling then extends to the European paradox. ‘In Europe, there is a gap between the development and production base. This is typical for batteries. Europe has a third of the patents, but essentially no production facilities. Everything is produced in China and the US’ (CMC 2015c), notes Christos Tokamanis, a representative of the European Commission’s Directorate-General for Research and Innovation. As we can see from the quotes above, entrepreneurial storytelling has deviated from the early projections, and the narrative of a fairy tale is reconstructed against a threat of a loss of legitimacy (disappointing stakeholders). Just as when a disappointing cycle in the hype occurs, actors must reconstitute their image by repairing any loss of legitimacy, especially when expectations are not met (Garud et al., 2014). The entrepreneurship is an ongoing storytelling process, where maintaining or regaining legitimacy happens through reconfigurations. These reconfigurations should allow for the re-establishment of credibility and maintenance of strategic alliances.

7.2. Nanotechnology Controversy: Repertoires and Compositions (Discussion)

The nanotechnology controversy should be considered adequate to specific communication strategies, stylistic ends (*rhetorics*), and re-figurations which concern histories and ontologies. Nanospider technology, as the main character in the Czech Republic's nanotechnology controversy, will in the following discussion provide insight into these formations of discourse. Still, we should not too readily abandon understanding the Nanospider in terms of reference to reality (*poetics* and *mimésis*), which uses metaphor to convey truth / serve the logic of discovery.

7.2.1 Nanospider Technology Reaching Outside the Laboratory

There is something disturbingly fascinating about the figure in the context of the latest research and experiments in biotechnology. In one of its branches, scientists and genetic engineers have been intensively preoccupied with work on recombinant spider silk[64] proteins which are further spun into threads (see Nexia Biotechnologies Inc. in Lazaris et al. 2002; or Kraig Biocraft Laboratories in Chung, Kim, and Lee 2012). The research has also been focused on the development of recombinant silk proteins which mimic the properties of a natural spider's silk using electro-spinning methods (see Humenik, Smith, and Scheibel 2011). Such a situation may further question the widely accepted and straightforward division between the technical and the natural—a substantive incentive to approach the Nanospider discourse in the language of hybrids. After all, STS scholars have been convincing and coherent in saying that technoscience, with its investigations, experiments, and insights, reshapes the view of nature and culture (see Canguilhem 1965: 143, Haraway 1990: 152). The debate on nanotechnology expands when considering what 'nature and technology mean in its context' (cf. Bensaude-Vincent 2009: 110). It could be argued that the Nanospider as an object of technoscience, a *hybrid*, surmounts the animate objects of nature. In this sense, it can be inserted onto a revolutionary trajectory, where it appears as something descended from the biological spider (or the model of NATURE). *As if*, as an artificial or scientifically created artificial life form, it was an object similar in appearances to speculative fiction. The accepted ideals or privileged position of biological creatures is being challenged—that is, including the image of technoscientists as active choreographers of nature (Kaku 1998: 5). The Nanospider may represent just as much the desire (subject-object relationship) to create a more docile nature. The way this particular example of nanotechnology transgresses the borders between nature and culture but also science and art has an important effect on our assessment of the Nanospider's identity—it is a true TRICKSTER. It evokes what several scholars argued about nanotechnology as nearing a techno-animist environment (Mordini 2007a: 20)—the *techno-*

[64] Spider silk is part of a class of materials known as biopolymers, while recombinant relates to genetically engineered DNA.

animism of the Nanospider can be understood as the spiritual response to more profound semiotic anxieties about where or how to draw boundaries between persons, animals, and things. It appears that such views on nanotechnology may lead us from a secularisation thesis to a post-secularisation hypothesis (see later discussion in this thesis).

The Nanospider is a persuasive and systematic metaphor. It is a conventional pattern of an ANIMAL describing the unconventional feats of a MACHINE and where two entities form one. Like the models of a NANOWORLD or the religious symbolism of an ARTEFACT which makes the Nanospider story intelligible to wider audiences, it creates an assemblage where all the entities come together to form a new strategic unity. The ANIMAL metaphor can be related semantically to metaphorical expressions such as 'trapping a foreign agent', which is used to describe the benefits of nanotechnology in terms of an enemy entity (toxicity, dirt, pollution, infection, erratic energy) being trapped within. In other words, the embedding of the metaphor into a narrative leaves out a number of inferences. First, none of the semantic domains which can outline different scenarios—'spiderweb as trap', 'spider as predator', with 'a poison', and so on—have been used to utter negative outcomes. The metaphor is set into the narrative frame of a cooperative animal placed in the enclosed environment of a laboratory/company. It describes a technology trajectory unlike the conventional metaphors for 'poison' or 'suffering pain' caused by biting or trapping. The ability of the Nanospider discourse to embrace counter-narratives, however, can be pointed out by the spider's figurative entailments and the most undesirable ones for technology proponents. The issues could incline a reader to explore nanotechnology against the spider's venom (toxicity) or predatory nature (technology out of control)—technophobia imported from the animal kingdom. Even if we discount its hybrid character and accept its progression from industrial machine (loom/spinning jenny), the image could be forced to open doors into the history of industrial exploitation and the kind of techno-critique which gave birth to neo-Luddism. Afterall, Luddites were destroying looms! Such interpretations of the figure's flexibility, imposed on the reader's behalf, suggest that almost any nanotechnology can be re-worked or challenged to one's own ends. It is not *just* the texts and images which shape interpretation but also those other texts which interpreters may variably bring to the interpretation process (Fairclough 1992: 85). So why has the nanotechnology controversy in the Czech Republic not reached this *critical* overlay? As I want to argue next, it is due to the media adopting 'entrepreneurial storytelling', in addition to various other reasons.

7.2.2 Entrepreneurial Storytelling: Maintaining Hype and Eliciting the 'Right' Emotions

Entrepreneurial storytelling relies on temporal and also ontological transformations. The Nanospider technology branding used a HERO archetype to redefine what we can call a *green nanotechnology* narrative. It also reverts the debate from potential nanotechnology risks and against specific negative momentum. It combats environmental evils, revitalises the economy, and all that

through the supportive stance of the public to further innovation (collaboration with *all* stakeholders). The Nanospider MACHINE, through the language of its proponents, while weaving narratives, emerges as an enterprised-up ANIMAL to combat environmental evils, but just as much because it is based on the future tense—it is a creature of the future tense. It portrays grand twenty-first century challenges to galvanise an image of nanotechnology which will deliver legitimisation through figures of the *quality of life*, a paradise delivered by *Czech excellence*—a world free from environmental evils. Here also, the media hype 'lives through' compelling entrepreneurial stories as well by narratives of crisis. The example of the Shanghai exhibition shows these are not neutral spaces for the representation of science, just as science museums are part of the broader sociopolitical process which shapes the role of science and, more generally, contemporary citizenship (cf. Laurent 2012). My results suggest the media have partly abandoned the hyped narrative which has surrounded the Nanospider. The economy-oriented media (such as the magazine *E15*) in particular, who had voiced the invention as revolutionising the industry, were forced to criticism by evidence contrasting investment in technology and the promises given by its proponents. This is also where entrepreneurial storytelling has the potential to transform into a narrative of crisis (Aristotelian tragedy).

Over the past several decades, a number of STS sociologists and historians have argued that our ways of understanding technology, technological change, and the role of technology in our lives is severely distorted by innovation-centric accounts (see Edgerton 2006: 12). For sociologist Trevor Pinch (1990), today's knowledge is always treated as better than what we had in the past, and as his colleague Harry Collins (1975) has aptly noted, science is all about the 'ethnocentrism of now'. All kinds of determinism are involved in shaping our accounting on nanotechnology; the knowledge economy is one of its common factors and also another of its prominent figures. Nanospider technology, as any modern science invention, is based on knowledge-intensive activities which contribute to an accelerated pace of technical and scientific advance as well as their rapid obsolescence (cf. Powell and Snellman 2004). It can represent the historical transforming effects of the weaving LOOM/MACHINE (cf. Luddism) as well as the continuity of the order of phenomenal NATURE. In contrast to innovation-centric accounts mixing reality with fiction and where the Nanospider is omnipresent (Figure 7.2a), nanofibers are not yet used in high volume (see 'use-centric-histories of technology' as an alternative in Edgerton 2006: 14). They also require considerable mobilisation of resources to remain competitive. We should consider to what extent the impetus of research—and certainly the funding—goes through the formation of success stories, and forming identity through corresponding archetypes, as well as future experiences.

In virtue of its novelty and narrative dimension (whereas metaphor extends to allegory), the metaphor becomes relevant, noticeable, and memorable, and it may enable readers to arrive at fresh

insights into the experience of a laboratory (company) or renewed awareness of nanotechnology and its social aspects. Some readers may feel that because of Elmarco's description, they know what it is like to be in a nanoscience/nanotech laboratory, even though they have never been in one themselves. Others may well find the Nanospider metaphor far-fetched, even repulsive: The more creative and audacious the metaphor, the greater the *risk* that writers may confuse and/or alienate part of their audience (see Toolan et al. 1988 in Semino 2008: 41). Other than being designed (modelled) upon a living being, which must be acknowledged as confined within the minds of its inventors, Nanospider technology may have been named because these 'imaginative metaphors are needed to capture the liveliness of scientific practice' (Ihde and Selinger 2003). How people look at materiality depends on what people are allowed, willing, or unwilling to see (Ibid., 11). To build further on this statement, consider the extent to which figures (metaphors) intensify some perceptions while screening (filtering) others out of attention (see Black 1962: 39–47). Metaphor *acts* as a filter or screen which selects, organises, and transforms what we see. It shapes perceptions of both facts and values but also elicits emotions (Lakoff and Johnson 1980). And so, it also becomes a political issue when one figure is used instead of another (others). The Nanospider metaphor is a way in which the unobservable and sensible is made political (cf. Charteris-Black 2005). As such, the metaphor can be said to stand on intense storytelling, since without coherent strategy, it would require a much greater leap of faith and imagination. Finally, considering the role of ambiguity (neither animal nor machine) should not be understood as if the actors themselves were uncertain of the expectations of nanotechnology. Instead, the ambiguity should be investigated where it can serve researchers, engineers, policymakers, and the media in effectively aligning with their strategic interests. Such a role of ambiguity will also be scrutinised in the following analytical chapters.

7.3 Conclusion

It should be more apparent that nanotechnology is not uniquely the result of its inherent attributes, but includes intense entrepreneurial storytelling, in other words, the production of hundreds of texts and images which support ideas about what nanotechnology is, who should use it, and for what purposes. The nanotechnology representations in the Czech media have relied on orchestrating dramatic narratives and scenes, and on the important role of metaphors in assessing future expectations. Entrepreneurial storytelling is aligned with strategies which transform histories, as well as ontologies within nanotechnology discourse. The practices and policies with which entrepreneurs deploy metaphors to make sense of ongoing expectation dynamics in a specific field may have, however, questionable effects on innovation and the governance of an emergent field (nanotechnology risks and public investment loses). In recent years, the Nanospider technology has

received increased (media) attention and high expectations circulated, and this intertwining of science and the media has been driven by the framing of problems and potential solutions, incorporating different narratives (epistemologies, actors, and networks). The emergence of issues which entrepreneurial descriptions overlay (risks and uncertainties) should force us to be more reflexive of their position: On the one hand, the metaphors actively keep expectations high about the technology, while on the other hand, they can be less critical about (over) promising and exaggerations.

The identity of the Nanospider also breaks down into scenarios mixing artistic or scientific images, adding to the mystery of nanotechnology rather than combating the common unawareness of the public towards nanotechnology (cf. EuroBarometer 2010). This should not be taken as criticism of mixing scientific images and other (religious) beliefs. Their intertwining (and not opposition, which creates resonance) leaves the Nanospider identity ever elusive, extending endlessly into the world via chains of significations and relations to other images and texts. Finally, by following an overly discursive trend in the description of nanotechnology, this chapter may lead readers to the particular conclusion that all reality (i.e. history and ontology) of the Nanospider as a discernible entity of technoscience is socially constructed via means of narratives and metaphors. To respond to such a critique, I assert that such a textualist position is untenable. I have tried to expose the nanotechnology controversy in the Czech Republic (and one of its central objects, a thing, a matter of concern), which has transformed into many reality-fictions generated by mediated meaning effects. Or, in other words, there is a little bit of truth in fiction and some fiction in truth-claiming descriptions. Despite or because of the existing lack of public awareness of nanotechnology, these have the potential to become powerful catalysts in future public debates.

Chapter 8. Grenoble Model(s) and Metaphors: Promising, Contesting, and Abandoning Nanotechnology (France)

How often do the minds meet; how often do they completely miss each other? How many of the words misfortunes are due to such misses?

Stuart Chase, in *Tyranny of Words*

Let us cultivate our garden.

Voltaire, in *Candide*

8.1. Identifying the Problem/Matter of Concern: Nanotechnology Controversy

Grenoble is a city in the French Alps which has become a major research hub in nanoscience and nanotechnology since the late 1990s. It has been a prominent scientific site with thousands of researchers, hundreds of labs, and a record of multiple grand international projects. Among the major research organisations in the Grenoble area is the Atomic Energy Commission (*Commissariat à l'Energie Atomique*; CEA) and its laboratory, LETI (*Laboratoire d'electronique et de technolgie de l'information*/laboratory of electronics, technology, and instrumentation), which focuses on electronics, imaging technologies, and micro and nanotechnology. Grenoble has been developed on a grandiose vision of strong links among administrative and policy institutions (CEA, EU), public research organisations and academia (INGP, former Joseph-Fournier University), and private companies (such as STMicroeletronics, Philips, and Motorola, among others), rooted altogether in a local agglomeration community (la Métro).

The historical importance of strong ties among the Grenoble institutions has been cited as the Grenoble model, and it was widely accepted that current nanotechnology initiatives should follow (Laurent 2010: 301). In this sense, the Grenoble model represents an *innovation* (*business) model* which depicts the content, structure, and governance of transactions designed to create value-added in the production of goods, services, or expert publications and to enable innovation and valorisation of research with the corresponding technological options, patents, and core competencies of start-up firms (Amit et al. 2001, Robinson et al. 2007). In that regard, the Grenoble model has been a site of great hope for science, industry, and community (nation). However, in the aftermath of GMOs and nuclear technology, for which Grenoble has a tradition of opposition, several groups targeted nanotechnology and created a dramatic disjunction with science, policy, and the public. The disjunction, which is also a metaphor of the 'gap'/'nano-divide', was one of the main reasons for the Grenoble area administration (La Métro) sponsored public engagement mechanisms. The Grenoble model had extended in this regard to policies to master nanotechnology socially, issuing a cycle of public debates, involving local STS scholars, and creating strategic alliances to advance a *socially robust model* of nanotechnology development. Despite these efforts,

there has been much criticism of the use of citizen participation in the *public debates*—becoming *consultations*—to merely enrol the public and induce trust in science-based issues, producing acceptance rather than ensure a genuine contribution to decision-making (Joly and Kaufman 2008). These dramatic disjunctions cannot be reduced to a mere information gap between experts and the general public as envisaged by the *deficit model* of communication. It would overlook the activities of the public (Greenpeace, ETC Group). Not only did these various groups articulate different visions of public engagement, but they advanced even in some cases to the rejection of it. As the French sociologist Brice Laurent (2007) noted, rather than representing Grenoble as a *deliberative (socially robust) model* of collaboration between different public and private actors (sectors), it became equally characterised by divergence and ambivalence between the local elite, scientists, and activists. For Laurent, there has been not one, but three different visions of public engagement which still compete between each other in Grenoble: that of officials' and social scientists' and also that of the activists'—an *enlightenment*, *constructivist*, and *critical* inquiry model, respectively. These models are related to different framings of the issue at stake—nanotechnology research namely, but also different definitions of the role of the citizen in the relationships between science and policy (cf. Laurent 2007: 351). The coexistence of different Grenoble models questions the role of both the citizens and experts in this system of co-construction (cf. Jasanoff 2004) and further differentiates them into material-semiotic networks. It also questions the appropriateness of communication channels for the debate.[65]

To put it differently, there are many different storylines. The nanotechnology controversy in Grenoble begins with an essentially political mobilisation of municipal, regional, and scientific and industrial resources (Vinck et al. 2009). The mobilisation is also symbolic. Its development advanced from the local scientific elite, a small network of professional and extra-professional ties which has managed to convince various players to converge in a great adventure, 'an epic story making Grenoble a destined city of technology' (Bensaude-Vincent 2009: 190–91). Such a perspective is consistent with the theoretical setting of this thesis in arguing institution emergence, legitimisation, as well as crises are processes which unfold through intensive narrativisation and counter-narrativisation (cf. Cooren 2001). The contrasting Grenoble models are thus useful for the analysis as they allow a focus to be cast on the inner organisation of a controversy. The comparative techniques can involve metaphorical concepts to describe where there are actors common to both narratives, but also uniting real and fictional stories (for example, who is a hero, who is an anti-hero, who is a helper and deceiver, and so on). And further, nanotechnology and the public are

[65] The nanotechnology controversy here supports a practical inadequacy in our usual models of communication, which generally assign consensus as the purpose of dialogue, as 'with nanotechnology, we are no longer in an universalist (irenic—operating towards moderation and peace) public space as conceived by the philosopher Habermas, but in a fundamentally conflictual arena' (transl. FNC interview with Denis Vernant, also paraphrased in Vernant 2014: 337).

categories which are themselves constructed through discourses and practices *during* the debate, thus how these categories are being established should be part of studying the discourse dynamic. Hence, as in the previous case study on Nanospider technology, the Grenoble nanotechnology controversy can be narrated like fiction, where different characters and temporalities interact—as their conceptual, narrative, and discursive formation.

While we cannot go through all the literal or even metaphorical content of the nanotechnology controversy in France (or in Grenoble), I will approach particular metaphorical images and representations of nanotechnology in the media, between 1999-2015. During the studied period, various actors engaged in the processes to promote and question nanotechnology, and government launched a nationwide public debate on nanotechnology (Débat Public, planned for 2009-2010). The case study focuses on the dynamic of expectations and where contestations over redefinitions exist, forming various counter-narratives, extending to allegories and various archetypes. In this sense, Grenoble also emerges in the study, but as not only a physical site, a place for different institutions and material instruments located in the French Alps. It is equally an imaginary site of encounter between different social actors, representations concerning what nanotechnology is, who should use it, and for what purposes. In the array of multiple stories behind nanotechnology (Mordini 2007a), the conceptual metaphor (Lakoff and Johnson 1980, Semino 2008) and narrative grammar (Greimas 1976) can serve to access various actors and their antagonisms, desires, competences, and performances which emerge throughout a controversy. By focusing on metaphorical representations which circled in the national media, it will be more evident how the nanotechnology controversy in (Grenoble) France is embedded in technoscientific images, policy plans, local communities, and culture. Finally, this should contribute to expanding the discussion on how media themselves effectively used metaphors to channel ambivalence and ambiguity to their strategic ends.

8.1.1 Grenoble Giant(s): Big Science, Big Brother, and the Nanotechnology Wave

As early as 1999, the media were informing that nano constitutes a strategic issue for France, and though the applications may be far off, it could not ignore the competition (FMC 1999a). By creating a larger ‘national network of micro and nanotechnologies’ (FMC 1999b, FMC 1999c), or ‘a federation of all actors (and sectors)’, Grenoble represented, with its various projects, becoming a ‘cluster of excellence and competitiveness’ (FMC 2004a, FMC 2004b, FMC 2004c). The objective was to create a global leader with grand centres, such as LETI, which would ‘spearhead’ (FMC 2006e) innovation and technology. Grenoble was the ‘heart of European nanotechnologies’ (FMC 2006c), which at the time had two rivals in Albany (USA) and Selete (Japan).

In ‘Grenoble, International Stature in Nanotechnologies’ (FMC 2004d; ‘Grenoble, une stature internationale dans les nanotechnologies’), the companies are being born in the ‘Grenoblian

crucible' (le creuscet grenoblois)—formed out of cooperation between university and industry, a key setting in the dynamic of innovation, explains Jean Therme, director of CEA Grenoble at the time. Grenoble is a 'real crucible of creativity and innovation' (véritable creusets de créativité et d'innovation) where basic research works with enterprises (FMC 2009b). Similarly, the 'Grenoblian cauldron' (chaudron grenoblois) describes an industry which has always worked with the research and does research with the university, 'showing a state of mind which originated in nineteenth century Grenoble' (FMC 2005c). What 'melts' inside are scientific cultures with a culture of industry. 'We wanted to have a place where science and technology are mixed up [mêler] at the atomic scale', adds Christian Joachim from the National Centre for Scientific Research (Centre national de la recherche scientifique; CNRS) (FMC 2013). The Grenoble model here corresponds to the conceptual metaphor that Grenoble (culture) is (in a smelting) CRUCIBLE. It involves certain dynamics of expectations. As Jean Therme underscores, 'The only solution was to bring together on the same site a critical mass of resources and skills' (FMC 2006b). The project baptised as GIANT (Grenoble, Isére, Alpes, Nanotechnologies) is not only a rhetorical figure for the unison or a giant which emerges from the Grenoblian crucible, it represents the concept of BIG SCIENCE.[66] In this context, Minatec emerges as the initiative of CEA-LETI and the Grenoble Institute of Technology (formerly INPG or the Institut polytechnique de Grenoble), a future 'techno-polis' of twenty hectares (FMC 2001a). 'There is no other project such as Minatec in Europe', argues Jean-Luc Guibert, director of Minatec, as well as Jean Therme. The Minatec project is the foundation of the new 'scientific-polis' (*polygone scientifique* in FMC 2001b, *pole d'innovation* in FMC 2003a, FMC 2005b). The media work with the analogy denoting Grenoble as a future 'French Silicon Valley' (FMC 2002a) or a 'super species' of '(MIT) *à la française*' (FMC 2005a, FMC 2008a, FMC 2009a).

The symbolism for the institution extends further. Minatec (Grenoble) is the 'temple of high technology', where Jean Therme, now as former director of CEA Grenoble, states he 'is taking his pilgrim staff' (baton de pelerin) as 'father-initiator' of numerous projects (FMC 2006b, Figure 8.1a).[67] The media inform of Jean Therme's declaration that 'French research in nanotechnologies has a gap between the production of knowledge and valorisation', describing Therme himself as 'a Great Manitou of these new technologies, the director of technologies at the CEA who has just

[66] The technology of the infinitely small advances in 'giant' leaps (FMC 2002c). 'Grenoble is (a growing) nanotechnology giant' which accommodates 'great mammoths' of high technology (FMC 2006a)—French-Italian STMElectronics, US Freescale, Dutch Phillips, and Minatec are giants (FMC 2006b). Phillips, Motorolla, and STMElectronics equal giants of electronics (nanotechnology). The 'giants (make) steps in the infinitely small' (FMC 2007h).

[67] Elsewhere, seemingly on a more profane note, Jean_Therme is called an 'activist of the infinitely small' or the 'father of the micropolis and nanotech—Minatec' (FMC 2006d). He is depicted by the newspaper *Le Monde* as 'looking to the great outdoors', a scene set to represent a person with vision. We do not know exactly if he is looking at the scenery or future (Figure 8.1a).

proposed to the Ministry of Research a strategic plan' (FMC 2009a). Jean Therme as 'a Great Manitou' is the spiritual and fundamental LEADER, and Minatec (CEA) his TEMPLE. The biggest European institution capable of manipulating atoms to create powerful nano-objects, it is a place of devotion (in 'Isère—Grenoble invests in an area devoted to micro and nanotechnologies', FMC 2001b).

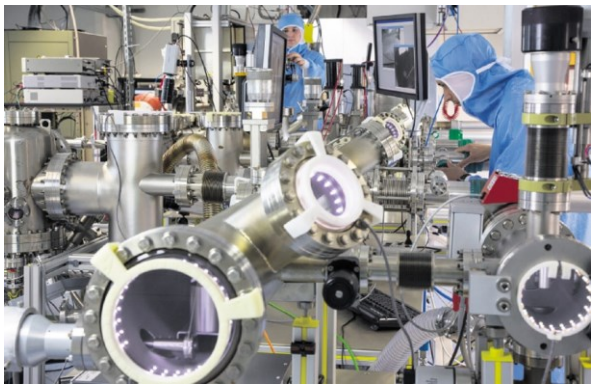


Figure 8.1a *Left*, 'Jean Therme—The activist of the infinitely small' (Title; 'Jean Therme – L'activiste de l'infiniment petit'): 'The father of the micro and nanotechnolgies polis Minatec, which will be inaugurated Friday, June 2 in Grenoble' (le père du pôle de micro et nanotechnologies Minatec, qui sera inauguré vendredi 2 juin à Grenoble). **Figure 8.1b** *Right*, 'Builders of Nanoworlds' ('Bâttisseurs de nanomondes'). The scientists at CNRS (Toulouse) are 'builders of nanoworlds' (masters) who ascend from / descend to the nanoworld with powerful artefacts, but also are 'distracted by the vibrations from our world, that interferes with the calibration of their instruments'. Source: FMC 2006d (8.1a), FMC 2013a (8.1b).

In evoking a particular representation of the Grenoble (institutions), scientists (nanotechnologists) and government can, through media, presumably work to legitimise the leadership of the institution but still be questioned at the time. From the outset, the Grenoble institution is described as the '(European) Mecca of nanotechnology' in France (FMC 2005d, FMC 2006g), which further extends a complex conceptual metaphor of the science institution as HOLY PLACE or also '(Science) Life is a (pilgrims) JOURNEY. The sacred character here concerns reaching the HEAVENS (also in Figure 8.2a) and establishing one's authority and credibility as holders of power and wisdom, creating a worldview, and even giving nanotechnology an exalted status. The extended metaphor can also represent a process which scientists must go through, in a religious worldview, to achieve salvation (cf. Semino 2008: 65)—a trial or rite of passage. In retrospect, however, it has been argued that the National Debate (débat public) on nanotechnology (2009–10) between experts (science, engineering, industry) and the public, did not achieve an 'apotheosis' (FMC 2010a)—that is, nanotechnology did not reach a divine level. Grenoble as a (holy) PLACE of great devotion got branded as a 'nécrotechnology' (FMC 2006h), as if the scientists and engineers were not 'adventurers' in pursuit of better worlds but practitioners of some 'dark cult, or necromancy'. The necrotechnologies which originate in the 'Grenoblian laboratory' impose an 'artificialisation of the world'—a 'vampirism of technical system on ecosystem' (FMC 2005e). As an illustration of the catastrophe unleashed from the laboratory, the media assigned the

scientists/engineers the role of 'Sorcerer's Apprentice' (FMC 2006i). Similarly, a 'Lord of the Nano' (FMC 2003h; 'Le seigneur des nanos'), in reference to the novel *Lord of the Rings* ('Le seigneur des anneaux'), illustrates the caricature of the progressive scientist who defends the cause, yet threatens society through their unending will to rule the world and satisfy desires. The media reiterate this image by voicing French philosopher Jean-Pierre Dupuy. This author is persuaded that 'the engineer of tomorrow will not be a sorcerer's apprentice due to negligence or incompetence, but due to purpose' (FMC 2006f).[68] The SORCERER's/NECROMANCER's (apprentice) metaphors allow nanotechnology to be addressed as a metaphysical or even theological problem, but especially an ethical one. The contestation emerges over representations of the grand technoscientific projects of BIG SCIENCE (i.e. *GIANT* in FMC 2008a; *NanoBio* FMC 2006i), and those branded a BIG BROTHER (FMC 2006i). These metaphors encourage readers (audience) to question their assumptions of how the world is/or will be organised, and how events will unfold.

In 1999, the journal *Liberation* wrote about the 'conquest of the nanoworld' (conquête du nanomonde), where Jean-Marie Lehn, a Nobel Prize in Chemistry laureate, estimated 'the United States and Japan left first to conquer this nanoworld, but we're catching up' (FMC 1999d; Etats-Unis et Japon partent les premiers à la conquête de ce nanomonde mais nous rattrapons notre retard). The nanotechnology projects are ambitious as they represent the 'spirit of conquest' (FMC 2002a; l'esprit de conquête). Scientists venture like missionaries into the exotic NANOWORLD at the 'dawn of an industrial revolution without precedent', and further perceive the massive scale of applications under the common theme of 'domesticating the atom' (FMC 2001c). An adventure calls for curiosity but also modesty and prudence, whereas the goal is to create a 'more docile nature' (in 'Discovering the Nanoworld' [FMC 2003b; 'A la découverte du nanomonde']). The nanoworld here stands as a symbol for necessity, responding to the need for research; as an asset for industrial valorisation and local employment; and as 'the promised land of science adventurers' (FMC 2003c; la terre promise des aventuriers de la science). In 'On the Discovery of the Nanoworld' (FMC 2003b; 'A la découverte du nanomonde'), media reported about experts from the semi-conductor industry (at CEA Grenoble) who explore the new continent opened to scientists; it is denoted as 'the promised land of science adventurers' (FMC 2003c; la terre promise des aventurier de la science). An yet another example is the first European network dedicated to nano-

[68] 'The Sorcerer's Apprentice' ('Der Zauberlehrling') is a poem by Goethe written in 1797. The story begins as an old sorcerer departs his workshop, leaving his apprentice with chores to perform. The apprentice enchants a broom to do the work for him using magic in which he is not yet fully trained. The floor is soon awash with water, and the apprentice realises that he cannot stop the broom because he does not know how. Known in French as *Les apprentis sorciers: demain la biologie,* the non-fiction book *Who Should Play God? The Artificial Creation of Life and What it Means for the Future of the Human Race* (1979,) by Jeremy Rifkin and Ted Howard reports on recombinant DNA research in America, what it is, how it developed, where it may take us, and who is leading the way. In our case, the ideas reiterated by protesters against Minatec resonate with the position of philosopher Jean-Pierre Dupuy, who sees in nanotechnology sorcerer's apprenticeship and possible end of democracy (see also Dupuy 2004).

bio-technologies: 'Nano2life, piloted by LETI, goes to the nanoworld' (FMC 2004e). The 'nanoworld is at our doors' (FMC 2006e) as scientists stay 'on course to the nanosphere' (FMC 2006f). And, as 'France resolutely embarks on this adventure'—today the 'dwarf universe, tomorrow, to govern the world'—these are the 'grand promises of the infinitely small which start at Grenoble' (FMC 2002b). The 'Grenoblian ambition' is to be on the front line of the race to the infinitely small' (FMC 2000; figurer dans le peloton de tete de la course a l'infiniment petit).

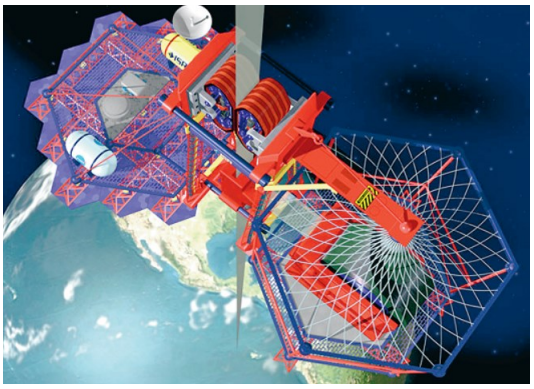


Figure 8.2a *Left*, 'Nanomaterials for building a path between sky (heaven) and Earth' (Les nanomatériaux pour construire un chemin entre ciel et Terre), from 'Space Elevator to the Cosmos' (Title): 'Jules Verne had not thought of it, but his Russian contemporary Konstantin Tsiolkovsky, seeing the Eiffel Tower in 1895, had imagined a "celestial castle" connected to the Earth. Sir Arthur C. Clarke, in his novel *Fountains of Paradise* (1980), had engineers construct a space elevator on an island on the equator'. **Figure 8.2b** *Right* '(Let's) Stop Everything' from 'Grenoble Activists Against "Necrotechnologies"' (Title). The anti-nanotech group here used a spectacular mode of action, putting themselves at risk but producing an effect on what stakeholders call 'public opinion' and 'public perception'; They try to unveil dynamics and processes—things being done 'in action' (cf. Chateauraynaud 2009: 15).[69] *Source*: FMC 2004f (2a); FMC 2005e (2b).

However, whereas the French media has given space to proponents who set the scene in the future—'Tomorrow the Nanoworld: Voyage to Heart of the Minuscule' (FMC 2003b; 'Demain le nanomonde: Voyage au coeur du minuscule')[70]—the activists frame the argument in the present as 'Today the Nanoworld: Nanotechnology, Project of the Totalitarian Society' (FMC 2009i and also in Figure 8.2b; 'Aujourd'hui le nanomonde: nanotechnologies, un projet de société totalitaire'). This language game of extrapolations creates an interesting temporal envelope which shifts times and modes; it constantly moves the horizon of expectations, contrasting figures between 'there will be one day (tomorrow)' and 'besides there is already', and 'already there' and 'not there yet' (cf. *déjà-là* and *pas encore là* figurations in Chateauraynaud 2005/2006: 5). The shifting temporality should be considered engraved in two dramatically different metaphors of the nanoworld: building/reaching PARADISE (FMC 2004f, or 'High-tech Eden' in FMC 2011b and 'New Eldorado' in FMC 2005f) and the dystopian reality of TOTALITARIAN REGIME (cf. 'World à la

[69] 'Like the "voluntary mowers" who destroy the fields of experience to study the possible dangers of GMOs, there are other determined opponents of empirical knowledge, debate and the most elementary freedom of expression. What is it about? Why such resistance and fears about new technologies?' (FMC 2010h).

[70] Jean-Louis Pautrat is a physicist specialising in semiconductors, researcher and scientific adviser at the Atomic Energy Commission (CEA). He participated in the creation of the MINATEC cluster in Grenoble and also authored the book *Demain le nanomonde: Voyage au coeur du minuscule* (2002).

Orwell' in FMC 2005e). As one the above articles noted, the nanoworld is not tomorrow, 'it's already here'.

The experts argue that nanotechnology will be the origin of a 'new wave of innovations' (FMC 2003d, FMC 2003e, FMC 2015c). All industrial processes are concerned: 'The wave of nanotechnology now reaches the fibre and textile industry . . . the technological revolution of the twenty-first century (FMC 2004g), and also, the use of nanotechnologies carries a new wave of technological development, next to which there is obviously no question of passing' (FMC 2008b). An occupational physician at the Atomic Energy Commission (CEA) Daniel Bloch, sums it up: 'From medicine to computers, to the textile and cosmetics industry, the "nano" tidal wave seems to have no limits' (FMC 2008c). It is argued that a combination of factors are creating a massive 'nano tidal wave' (FMC 2006j; la déferlante nano): 'The 'nano's' are landing in Grenoble which has the ambition to become the European benchmark' (FMC 2002c). The CNRS director of research, Valérie Lefevre-Seguin, speaks of the wave as the upcoming 'fourth industrial revolution', one in which France occupies a prominent position (FMC 2006j).

The WAVE brings with it an effect: A 'new flood of knowledge' (FMC 2007a; déferlement de connaissances nouvelles). As a cycle of extraordinary knowledge, it poses certain risks: 'It [nanotechnology] will inevitably lead to an unprecedented rise in both the level and the life expectancy of populations. These developments will certainly pose a thousand problems in terms of ecology, wealth sharing, global regulation, but they are there, already engaged' (FMC 2015a).[71] Journalists add that there is a need for transparency regarding the known, uncertain, and unknown. Otherwise, one is exposed to unpleasant surprises like the 'current wave of climate scepticism' (FMC 2010b). In line with WAVE and FLOOD as concepts in the dynamics of expectations (and implications), in 'Nanotechnologies—Ethics can Wait' (FMC 2003f), media inform that the 'gap between nanoscience and ethics is getting wider and wider'. The author concludes that the GAP is also caused by bad priorities which first analyse the benefits of nanotechnology for the environment and health and eventually study the adverse effects. This resonates with the pronounced critique of various groups, called 'anti-nanos'—PMO (L'atelier de Bricolage—Pièces et Main-d'Oeuvre), Greenpeace, and the ETC Group, all of whom represent a call for a 'moratorium', or to 'stop everything' (FMC 2005g, FMC 2006k, FMC 2010c, FMC 2010d, FMC 2010e, FMC 2010f, FMC 2007b). Here, the anti-nanos oppose nanotechnology by criticising the invasion of *all* aspects of social and individual life by industrial products and the colonisation of all human activities through nano-materials, machines, systems, regimes, and (local) governments. The content of the Grenoblian CRUCIBLE metaphor became contested as activists claimed to defend 'true science';

[71] Orig. 'Il [nanotechnologie] débouchera inévitablement sur une élévation sans précédent du niveau comme de l'espérance de vie des populations. Ces évolutions poseront certes mille problèmes en termes d'écologie, de partage des richesses, de régulation mondiale, mais elles sont là, déjà enclenchées' (2015a).

that is, science that is pure, without the mixture of politics (government, army) and industry (private). For the opponents of nanotechnology, the Grenoble model is an unacceptable 'techno-gratin dauphinois' (FMC 2009c), blending different social, political, and local collectivity elements.[72]

The WAVE is a concept which brings about hyperbolic perspectives on nanotechnology and therefore can serve to provide an additional form to the dynamic of expectations. The metaphor here has the capacity to create a scenario concerning the arrival of nano and its positive consequences, WEALTH, ENERGY, and KNOWLEDGE, and it can become a part of the crisis scenario based on the conceptual metaphors of FLOOD, INVASION (DISASTER), and SCEPTICISM (emotions). The impact of the extraordinary is then a question of perspective and positioning (Figure 8.3a and 8.3b).

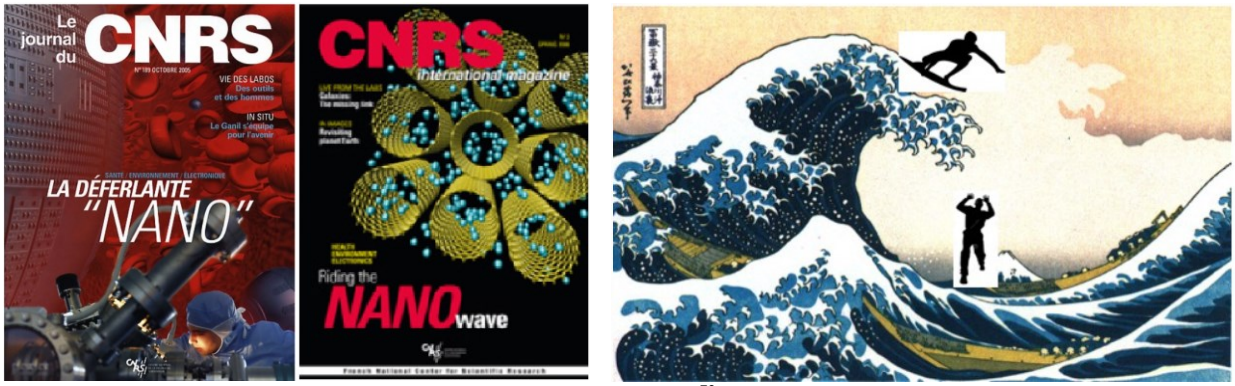


Figure 8.3a *Left*, 'La déferlante "nano"' and 'Riding the Nanowave'.[73] **Figure 8.3b** *Right*, 'The impact of extraordinary is a matter of perspective' (image is *The Great Wave* by Hokusai, c. 1830). To outline the WAVE scenario and positioning, let us assume the proponents tend to think of how to align the force of nanotechnology with the right strategy (metaphor of surfing the *big kahuna*), harnessing its energy when it arrives, whereas other characters in the scenario are standing against this invasive force, risking being wiped out. *Source*: FMC 2006j (8.2a) Sullivan 2017 (8.2b)

8.1.2 More Ambiguity: Nano-bio(s) and Anti-nano(s)

In 2004, CEA-LETI (and Minatec) launched, in cooperation with industry and academia, the innovation platform (cluster) NanoBio, to coordinate the European Network of Excellence Nano2Life (FMC 2004l, FMC 2005i, FMC 2010z, FMC 2008e). NanoBio is a platform and a metaphor linked to applications which target the 'life sciences' (sciences de la vie), introducing nanotechnology as biochips, DNA analysis, new methods for Parkinson treatment, and territory surveillance, among others.[74]

The sociotechnical imaginary of 'lab-on-a-chip' (FMC 2004i, FMC 2006q, FMC 2006u)

[72] 'Techno-gratin' stands for techno-elites or technocrats since 'gratin' is a slang word for elite. There is also a specific gastronomic reference since *gratin dauphinois* is the local traditional meal (ref. in Joly and Kaufmann 2008: 5).

[73] *Le journal du CNRS* (n° 189, oct. 2005) and *CNRS International Magazine* (n° 2, Spring 2006) available at http://www.cnrs.fr/cnrs-images/nano/ressources_web.html

[74] NanoBio is a collaborative project supported by local administrative bodies. Launched in 2001 by CEA and Joseph-Fournier University, it connects over three hundred researchers active in the field of micro and nanotechnology applied to biology and healthcare. The related Clinatec at Minatec is a clinic for experimentation on cancer of the brain, Parkinson's, epilepsy, and other neurovegetative illnesses.

aimed at reaching a higher status of nanotechnology in service of the *bio*, *socio*, and *eco* by presenting a future quality of life. However, shortly after the concept of a biometric lab-on-a-chip (RFID) was introduced, the media began to include opposition in their reporting, voiced by metaphors of the advent of a 'nano-BROTHER' (FMC 2006k, FMC 2006h). This metaphor became the source of many uncertainties and raised a multitude of problems—above all, it has already proved to work in different contexts. The world of Huxley, brought into line with images described in George Orwell's *1984* (published in 1949), served once again to introduce the concept of control in a more directly coercive and undemocratic sense: 'The surveillance society of Big Brother, and a merciless project of totalitarian society related to CEA Grenoble's NanoBio' (FMC 2006i). In 2006 (June 2nd), activists rallied against the opening of Grenoble-Minatec, declaring a 'new war against the totalitarian nanoworld' (FMC 2006m; La nouvelle guerre). In previous interviews, the activists (PMO) had relentlessly denounced 'techno-totalitarianism, the artificialisation of the world, and destructive growth' (FMC 2005e). Their ability for neologisms manifests in a particularly spectacular way in a metaphor which pairs the anti-nano opposition in Grenoble with the global anti-GMO protests: 'ATOMICALLY MODIFIED ORGANISMs' and just 'AMO' (FMC 2006e, FMC 2006l, FMC 2006h, FMC 2007b). The Grenoble opposition, which has also traditionally opposed GMOs and nuclear, framed Minatec as representing AMO and the 'technification of the world imposed on the populations' (FMC 2006e). The revision of the GMO metaphor created resonance in the nanotechnology debate, extending it to 'dependence on machine' (FMC 2010r) and 'slavery to machine' (FMC 2010d). The AMO has become a dominant frame for the nanotechnology controversy: Of all the evils of technology, it represents 'everything that must be stopped' (as in Figure 8.2b), from electronics to nanomedicine.[75] The media adopted these associations in their agenda while being critical of the AMO metaphor: 'Transhumanism might seem to be an engineering delusion confusing biology and mechanics, a little like Dr Frankenstein who believed that by assembling pieces of corpses we could revive a man. Our modern transhumanists are not as modern as that, ultimately, their scientific conceptions date from a period between the middle of the seventeenth and nineteenth centuries, between Descartes and Darwin' (FMC 2015b). The translation between BIO and NANO and the vague perimeter of these unstable images have created fear of backlash amidst proponents of nanotechnology.

As Dorothée Benoit-Browaeys, president of the VivAgora association, notes: 'We are reproducing the democratic disaster of biotechnology, developed without anticipation in terms of information, consultation, and citizen participation' (FMC 2006k). Similarly, when the CNRS

[75] This extensive re-figuration is also likely due to the fact that, through CEA, nanotechnology has become tied to civilian research centres (*Polygone Scientifique*) as well as to divisions of defence and military applications (DAM) that build the surveillance technology or nuclear weapons of the French military and design the power plants for the French Navy's nuclear submarines.

Ethics Committee (Comets) published its recommendations, it noticed nano spreads fear as it is framed as a 'new asbestos' (FMC 2006n).[76] The Minatec project in the Grenoble region has been confronted with the emergence of anti-nanotechnology activism 'as minor as it is virulent', inciting 'fears that it may end up influencing local public opinion' (FMC 2006r). The effort to combat these images materialised in projects such as the Minatec Ideas Laboratory (an adopted model of the MIT Media Lab), which started to conduct acceptability tests (focus groups, among others) so as to 'avoid false paths leading to products which do not find their market . . . to try to prevent a hostile drift of public opinion that nanotechnology at Minatec incarnates . . . put forward ideas to disarm contestation (dissent) . . . [and] prevent "GMO syndrome"' (FMC 2006s). Altogether, Big Brother, GMOs, and asbestos are SYNDROME(S) and, more generally, 'the fear of the unknown which arouses concern (FMC 2006o). It was noted that 'the problem of "nano-toxicity" for public health or "surveillance technology" should not be discounted as "paranoias", even if the images of "grey goo" [framed as the "Prince Charles" thesis]—infinitely self-assembling nanomachines, devouring everything in its path, including humans and planet Earth—can harm the anti-nano credibility' (FMC 2005g). Images like these inspire fears, but scientists draw boundaries between *their science* and *science fiction*. 'Our scientific findings are far removed from all these delusions', says Christian Joachim, a researcher at CNRS in Toulouse (FMC 2003g). Proponents of the technology invite the public to abandon their fears, to embrace the future with confidence, and to revive the so much decried modernity: 'We are afraid of what we don't know. It is the aphorism which applies to the sciences as well as to social life. It can provoke attitudes of rejection' (FMC 2009d). The conceptual metaphors for FEAR and DISEASE here not only frame the nanotechnology opposition, they are taken as the irrational/uninformed cause of rejection which deflects the debate from the content to the contender.

In 'Should we fear nanotechnologies?' (Faut-il craindre les nanotechnologies?), Alain-Louis Benabid, a scientific advisor to the CEA and in charge of the Clinatec project, argues that 'because the opposition does not publish serious studies, we cannot debate with them'. Moreover, a 'moratorium is a ridiculous idea' because it would imply 'stopping all activities where nano is involved—[meaning] to stop science' (FMC 2010g). As Valérie Lefevre-Seguin, director of research at the CNRS, points out, 'If a country decided to stop everything because of the risks that existed and it needed twenty-five years of research to know more before continuing, we must not delude ourselves: This will not prevent others like the United States or China from continuing'; and thus, the 'race against time has started' adds the journalist (FMC 2006j). The debate is then acceptable provided it does not waste time. As one of the interviewees pointed out, ethics

[76] The idea that 'nanomaterials are a new asbestos' has been reiterated on several occasions (FMC 2006l, FMC 2006n, FMC 2008d)

committees (e.g. on the project NanoBio) should not be held back by technological projects because our competitors, especially in emerging countries, do not deal with ethical or democratic conditions. This idea resonates in Jean Therme's assessment: 'In these technologies, the speed of implementation is essential' (FMC 2001b). Nanotechnology acceptance is MOVING FORWARD, whereas resistance means STOPPING EVERYTHING, and a sign of paralysis due to fear. Do not panic, scientists say, 'Everything new is always scary, but fear is a bad counsellor . . . we must continue' (FMC 2006h; tout nouveaux fait peur, mais peur est mauvaise conseillére . . . il faut continuer). It appears as if the spirit of CONQUEST struggled with the spirit of (panic) / advisor of FEAR.

The above metaphors have something in common. They construct nanoscience/ nanotechnology as well as the public as quite undifferentiated entities which breakdown to either support for innovation or mounting social resistance to technology. The public has a rather limited choice between nanotechnology 'dream or nightmare' (FMC 2006e; aux choix, un reve ou en cauchemar) as 'nanofobia and nanomania' stretches across the discourse on nanotechnology. The article 'Nanoworld Maxi-anxiety' ('Nanomonde, maxi-angoisse') noted the debate was locked in this dualistic view, despite the fact that 'the arguments of the "anti-nanos" are as varied and unexpected as the nanotechnologies themselves, shamelessly blending plausible reality and science fiction—as the "pro-nanos" do' (FMC 2005g). Any effort to debate causes 'infinite confusion' (FMC 2006m). The way out of the confusion is seen in forming the right partnerships:

> It is not a matter of imposing on the concerned population, in the name of international competition or the inevitability of globalisation, innovations that would or could prove to be dangerous. It is a question of collectively controlling the risk—and for this to understand it—debating the innumerable applications of nanosciences and democratically deciding what we want. (FMC 2010h)

As the French minister for research, Valérie Pécresse, argued, the debate has been 'polluted' to the point where nanotechnology cannot be accepted or rejected as a whole: 'This world is protean. We cannot compare drug research in the future—with promising work on the targeting of anti-cancer treatments—and the development of nanotextiles to remove bad odours from socks' (FMC 2010f). This suggests, among the above metaphors considered, that scientists and politicians do not favour the ambiguity which has surrounded the representation of the public debate.

8.1.3 Dramas, Fields, and Metaphors: The Pied Piper and Luddites as Tricksters

The National Debate on nanotechnology, organised for the years 2009 and 2010 by the National Commission for Public Debate (la Commission nationale du débat public; CNDP), provoked

resistance in a number of cities. The activists-protestors opposed both nanotechnology and also the very conditions under which the debate was handled by the authorities. Of the eight meetings held, six went on as best they could, a seventh, on 17 November in Lille, and eighth on 1 December in Grenoble, were cut short. The following debates planned for Montpellier, Nantes, or Paris were cancelled. In the following section, I will be concerned with various kinds of social actions during the public debate and how they related to, and came to acquire meaning through, metaphors.

In Lille, dozens of activists marched in the room where the debates were being held, stamped their feet and shouted slogans: 'No, no, nano!—We do not care for this debate, we do not want nanos at all' (FMC 2009f; Non non nano!—Le débat, on s'en fout! On veut pas d'nanos du tout!). The meeting ended early as many participants were left in an environment where speakers could not be heard. Other meetings happened under similar circumstances—the nanotechnology-minded had been invited to almost every meeting, some of them listened in an orderly fashion, while others displayed banners, chanted slogans, and interrupted speakers. As the meeting was interrupted by activists, the format of the National Debate then shifted to videoconferencing. The organisers referred to this as a necessary step 'to guarantee serenity and free expression by everyone' against the perturbations of anti-nano actors (FMC 2009e). This led to a further refiguration of the debate and reinforced metaphors which blamed the 'debate of [playing] the flute—nano is not funny'. (FMC 2009f, FMC 2009e, also in Figure 8.4a; Débat pipeau—nano pas rigolo).

Figure 8.4a. *Left*, 'Playing the flute' stands for pretentious and one-way communication; the metaphor spreads before the audience as a screen or a filter—National Debate in Lille, 17 November 2009. **Figure 8.4b.** *Right*, The Pied Piper of Hamelin, a traditional story, leads the children out of a village, playing the enchanted flute. Source: VeilleNano 2015 (8.4a); Greenaway 1889 (8.4b)

Playing the FLUTE/MUSIC, according to which the debate is framed, is both a situational and cultural metaphor. First, the choice of source domain is inspired by the situational context in which communication takes place. It evokes the format of 'one-way' communication, where one 'plays music' and the other 'listens'. Through this dynamic metaphor, the activists (PMO) targeted the virtual debate in every respect—'decisions already taken' (FMC 2010h)—but even more corresponding to the videoconferencing format, where the role of the audience is strengthened in

silent consent. In 'Débat Pipeau', the public debates are a one-man show, where ordinary citizens, instead of directly discussing issues, are lost in the representation of a debate.

Moreover, in this case, the choice of metaphor can represent a variety of cultural stories about the *Pied Piper*, an ambiguous character known from fairy tales. The Pied Piper creates a powerful illusion through his melody to control the minds of village dwellers (Figure 8.4b). His role conceals the archetype of a TRICKSTER, metaphorically impersonated here by proponents of nanotechnology during the debate. In common tongue, 'playing the flute' (jouer du pipeau) means doing tricks or even deliberately telling lies. The Grenoble opposition (PMO) to nanotechnology argues that the 'debate is a masquerade' (FMC 2006p). The conceptual metaphor for (public) debate is MASQUERADE extends to other metaphors, such as a 'parody of democracy', arguing 'it has been more than ten years since the big decisions were taken' (FMC 2010i). Similarly, Friends of the Earth withdrew from the 'simulacra' (FMC 2010j), disqualifying the debate as no longer serving its original purpose (i.e. to 'debate'). It is a 'pseudo public debate' and 'nanotechnology promotion tour' (FMC 2010k), as if the debate was the work of a (nomadic) THEATRE group. For activists, the fact that major decisions had already been made discredited the public engagement: 'Decisions are made by a clan of a few CEA decision-makers. There is no prior debate, no pluralistic analysis, in short, no democracy. It is a nanodemocracy, that is, technocrats who take up the political space and the public funds that go with it' (FMC 2010g). The officially declared goal of participative consultation by the organisers (CNDP) is perceived by anti-nano as 'nanodemocracy' provided the 'decisions are already taken—democracy is in crisis' (FMC 2010h). This is a more general communication problem, the reviewers of the debate argue—systematic 'obscurantism' (FMC 2015a and FMC 2015c; obscurantisme) or the deliberate restriction of knowledge, which can block any precautionary principle, and also, action (cf. 'culture of secrecy' in BMC).[77] As strong as the 'wave of nanotechnology' is, knowledge of its impact is filtered. It is argued that 'in this kingdom of the blind . . . the industrialists are more willingly studying the benefits than the risks of the technologies in which they invest, it is the regulation to compel them to restore the balance' (FMC 2014b).

On the opposite end, the proponent's employ caricatures which could also be placed under the TRICKSTER concept. Anti-nano is assigned a role similar to 'independent weavers who in nineteenth century England destroyed the weaving looms of industrial factories based on the belief they made man slave to the machine' (FMC 2010d). While recounting activists as a public that

[77] *Obscurantism*, as a continuous problem in the National Debate, is exposed on many rhetorical levels. For example, in 'Silence of the Nanos' (FMC 2014; 'Le silence des nanos'), the author's reference to the movie thriller *Silence of the Lambs* (agneau), images of invisible nanoparticles are conflated with the ignorance of their potential risks. Nanos are the lambs—beautiful, innocent, and helpless—walking through a world full of evil. The 'silence' then refers to 'the "secret", [as] industrialists conceal some of the substances' (Ibid.).

'sabotaged' organised debates (FMC 2009e, FMC 2010d, FMC 2010k, FMC 2010a, FMC 2010h), the media raise the spectre of anti-nano as (neo)LUDDITE.[78] Silent consent is not part of a character who chants to his own tune/music: 'Decisions are already taken—democracy is in crisis' (FMC 2010h; Les décisions déjà prises—une démocratie en crise). To Jean Bergougnoux, the chairman of the CNDP, the identity of the PMO activists has been clear since their earlier appearance in Grenoble: 'Its paradoxically them who, while being afraid of totalitarianism in a society of nano, adopt totalitarian methods' (FMC 2006p). The protesters themselves react, claiming the sabotage of the CNDP meetings was 'in the name of uncompromising vigilance' (FMC 2010d). Bergougnoux judges to the contrary: 'They wanted to prevent the free expression of public debate. This is a very serious attack on participatory democracy' (FMC 2010k). For the CNDP organisers, the debate is not over. They insist on standing above the ambiguity, 'on the side of civil society', while declaring 'the unanimous demand for a new governance of nanotechnologies, in the form of a national consultative body, ensuring transparent information' (FMC 2010e). Bergougnoux recalls that 'to participate is to defend positions' (FMC 2009g). 'It is the decisions that the government will make, following this report, which will make it possible to judge whether the debates were useful' (FMC 2010m), underlines the president of the Commission.

In 'Dramas, Fields, and Metaphors' (1974), anthropologist Victor Turner examined social dramas, ancient and modern, to find them often centering around religious personalities or sacred figure. Here, we can evoke a similar image. The Pied Piper here matches the contrasting figure of a neo-Luddite (Ned Ludd), shifting both between fiction and reality. Both sides have presented their own background stories, songs, and sphere of action while refusing their determination to the 'true' debate (against 'nanodemocracy'). This metaphorisation could not have prevented, however, all the participants from becoming locked in the debate as both are placed in the role of the TRICKSTER and the lack of trust the character represents. 'There is a methodological problem', said Dorothée Benoit-Browaeys from the Vivagora association for citizen engagement in technology governance, 'on such a vast subject, the debate cannot be reduced to a few months, information cannot come from above and the separation of roles must be clear. She sees only one solution: 'to suspend and rethink a consultation which has become counterproductive' (FMC 2009e). Such a position implies nanotechnology is a reality which can be effectively communicated if 'framed' in ways appropriate to specific roles (experts, the public, etc.). This, however, was not achieved as both groups contested the enforcement of roles as representing double agendas and imply a 'lack of trust'. The strength of the metaphorical perspective should also be apparent in the following development of the debate.

[78] The PMO is an organisation which, in a press conference, explained why they oppose 'necrotechnology' and the 'pseudo-public debate' on the subject, fighting 'a battle of ideas' against 'technological tyranny'. Members of the PMO say they want to 'revive a true science, independent of industry' (FMC 2010d).

8.1.4 On the Way Out of a Controversy: Nanodispositive(s) and Candide's Garden

The media have contrasted different social actors in their incongruent positions, extending to representations of various mechanisms. The nanotechnology debate here advanced towards descriptions of different DISPOSITIVES (mechanisms and apparatuses) and GARDEN (balance and harmony) metaphors. It is a challenging task to show that these metaphors have been processed as metaphorical and influential in the debate. Moreover, their particular use extends and translate various issues in the nanotechnology discourse, which raises more ambiguity. However, the following will attempt to do so, and what is more, I will argue it allowed the media to secure a role for themselves of an expert/arbiter.

On a more literal level, a nanodispositive refers to physical devices, such as nanotubes, nanofibers, circuits, switches, transistors, and so on. For example, micro- and nano-electro-mechanics systems (MEMS and NEMS) integrate different dispositives to the scale of microchips (FMC 2002b, FMC 2012c). Here, the nano-dispositive is a mesostate between materials and machines 'because a nanomachine is neither a nanodispositive nor a nanocomponent . . . a nanomachine is a molecule which one would like to fulfil a function alone, such as a computation or a complex movement, whereas nanodispositives and nanocomponents are only bricks leading through assembly to the construction of a mesomachine' (FMC 2001d). A nano-dispositive is MACHINE, a metaphor for device, mechanism, but also leverage which translates the nanoscale to a biological level, just as when 'the increasing miniaturisation of the devices [*dispositif*s] opens up interesting prospects for diagnosis and treatment' (FMC 2006q). Nanotechnology could one day block the effects of Parkinson's disease with a 'dispositif situated at the interface between man and machine' (FMC 2006z) or introduce 'dispositives for biopsy and the treatment of cancer' (FMC 2010q). The applications of nanodispositives stretch across every aspect of the environment, from agri-food and territorial surveillance (FMC 2004i, FMC 2009h) to nanomedicine (FMC 2014c). In particular, the company NanoBiotix has become a national reference to nanomedicine in France, introducing the dispositive to 'fight against cancer' (FMC 2013b).

The metaphors for WAR, MACHINE, and ECOSYSTEM are the common vocabulary of the nanomedicine discourse (cf. McCarron and Faheem 2010, Bensaude-Vincent and Loeve 2013, Yan et al. 2015) but also referents for the many interactions between bio- and nano-. The 'nano-bio' metaphor, as mentioned earlier in this study, inflated the debate over mechanisms which fully translate into society where our freedoms can however be 'endangered by future undetectable surveillance dispositives, capable of tracking the citizens' (FMC 2010m). The nanotechnology dispositive thus figuratively unveils a crisis scenario: 'The social consequences of technologies combining microelectronics and biology (from medical diagnosis to cerebral implant), resulting in a much more complex dispositif of surveillance' (FMC 2005f, FMC 2007e). In other words, the

'nano-dispositive' not only refers to a *mechanical* device but also translates to *biological* and then to *social* mechanisms, including 'nanomedicine', 'police state', and 'war machine' (see also Figure 8.5a and 8.5b).

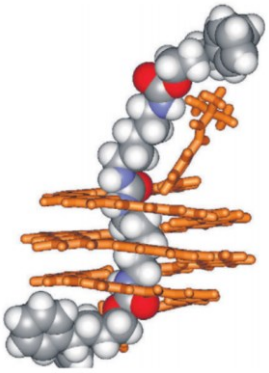


Figure 8.5a *Left*, *Nanotechnology: A Microscopic Piston*. This dispositive consists of one long molecule serving as an axis and another as a spiral acting as a moving part. Depending on the degree of acidity of the medium in which the vessel is driven, the affinity and hence the position of the spring with respect to the ends of the axis is modified. Its designers consider several types of applications, such as artificial muscles or surfaces with a change of conductivity. **Figure 8.5b** *Right*, *Des muscles artificiels fonctionnant à l'alcool* (artificial muscles working with alcohol). Nanodispositive has numerous future applications. The above image refers to the use of artificial muscle which may be able to adapt to the prostheses, for example, for military and victims of war. Sources: FMC 2011a, FMC 2006e.

NANODISPOSITIVEs are thus more than devices (sensors, transistors, actuators, etc.) or autonomous nanomachines, they are a 'set directions for research, but are also rhetorical arguments intended to convince investors and mobilise resources' (from an interview with B. Bensaude-Vincent in FMC 2007f)—they put in place funding mechanisms and sociotechnical imaginaries. In 'Minatec Wants to Create Consensus on Nanotechnologies' (2006), the author describes 'nanodispositive' as the 'increasingly common use of nanotechnologies in consumer products . . . these "devices" with practical applications work to "demystify" nanotechnologies' (FMC 2006s). The philosopher Denis Vernant (Grenoble) thinks the advent of nanotechnologies demands careful analysis and critical reflexivity. On one side, Grenoble is situated on the terrain of a practised system of convergence between nanotechnology, biotechnology, informatics, and telecommunications—the *dispositif of convergence*—a new mechanism of collaboration and scientific practice. On the other, nanotechnology as such represents a *rhizomatic (mixed) dispositif*, which is deployed in different dimensions. It brings together scientists, technicians, industrialists, politicians, academics, and the media; a new dispositive is characterised by a divergence of interests, concerns, objectives, and actors (FMC 2006t). Elsewhere, a *governmental dispositif* is described as a mechanism for the 'valorisation of research' in Grenoble by the creation of 'networks' for micro and nanotechnologies (FMC 1999a, FMC 2005h), a selection of research 'projects' based on the criteria of excellence (FMC 2004j, FMC 2009b) rather than relying on 'traditional' disciplines—this is the future 'pole of competitiveness' (FMC 2004k). The absence or deficit of a *regulatory dispositif* (e.g. a REACH shortcoming) provokes fears of risks which are new

and poorly understood (FMC 2007b, FMC 2007g, FMC 2010n, FMC 2012a). In the absence of regulation, it is essential to anticipate and take political decisions (regulatory dispositive as 'politics of anticipation' in FMC 2007g), argues Dominique Vinck, a sociologist at INPG.

Finally, the National Debate put in place a 'surrealist dispositive, announced as "experimental"'. It aimed to 'ensure the serenity of the debates and guarantee the free expression of each', justifies Jean Bergougnoux, chairman of the debate committee, 'clearly, to avoid meetings being disturbed or even prevented by the "anti-nanos"'. (FMC 2009e). The PMO responded arguing, 'Technology is politics that does not say its name; it implies a choice of society, so we want every citizen to give his opinion, without the speech being confiscated by the expert, or the government putting in place a dispositive to force the acceptance of its accession' (FMC 2010d). The DISPOSITIVE is metaphor used to raise a question as to the true character of 'consultations' (industry with environmental associations), which was officially framed as *dispositive of the consensus conference* (dispositif de la conférence de consensus)—to provide a *dispositive of participatory democracy* (dispositif de democratie participative) through a 'citizen's assembly', using 'panels of opinions', and 'giving recommendations' (FMC 2006r). While the variability of the dispositives stems from the polyvalency of the word, it becomes apparent that it has multiple functions in the public debate. It is an essential feature through which technoscientific possibilities are translated to social implications. Media gives voice to experts as they evoke different DISPOSITIVEs metaphors which condense science-society relationships. These frame the nanotechnology controversy via extension of the MACHINE metaphor, or also, debate that is conceivable as mechanism.

In the article 'Voyage to the Centre of Nanotechnologies' (FMC 2006l), a reference is made to 'the author, a journalist with *La Tribune,* [who] evokes Candide, free of prejudice, to understand the issues of the nanoworld. He recalls that the nano-industry is running anyway and that only knowledge will help control its development' (Ibid.). The article had adapted information from the book *Les nanotechnologies, Espoir, Menace ou Mirage?* (2006; The nanotechnologies: Hope, threat, or mirage?), where Yan de Kerorguen, a science journalist recommends the character of Candide (Voltaire's assault on optimism) as a model character in the current nanotechnology debate: 'We must take care of our garden . . . the best of all possible worlds . . . free of prejudice, to understand issues of nanotechnology—only knowledge will help us master the development—calling for debate that is largely absent' (FMC 2006l). The allegory here represents active engagement in the nanotechnology debate, a shift from passivity to realistic assessments of the debate and taking positive action to change adverse situations. It is a cultural metaphor with figurative entailments used to frame the *end* phase of the debate. The position is strengthened by the

conceptual metaphor of Candide's GARDEN, its symbolism, and imagery.[79] The garden metaphor implies searching for harmony and where actors, values, and ideas are PLANTS. The metaphor of the ECOSYSTEM then provides additional contrast to THEATRICAL and MACHINIST/DISPOSITIVE descriptions of the debate, even indicating a search for closure of the controversy.

8.1.5 Narrative Dimension and Discursive Formation

Reconstructing the narrative dimension of the nanotechnology controversy in France (Grenoble) is a delicate task since there are various metaphorical concepts at play and which contrast and exchange roles and positions. It all depends on the arbitrary choice of subject, which in this case won't be any real actor, such as scientist, politician, or the public, but the National Debate as such. In the following part, I will also attempt to make extensive use of related metaphors which not only represent but also intervene in this narrative schema as actors/actants.

When nanotechnology first appeared, media articles enumerated the advantages that nanotechnology offered. However, after the Grenoble (innovation) model could not contain the opposition, the media began to transform the multitude of inter-textual and meta-textual elements, forcing them into dominant frames as well as techno-critique. The National Debate came as a reaction to this techno-critique, with its objective being incoherent with the single Grenoble model discussed in the introduction of this chapter. Following Greimas (1966: 178), and our arbitrary choice of 'subject' (National Debate), we can still identify in the articles an *object of desire*, represented by the lost trust, which becomes valuable currency in the eyes of all participants and which is missing. This constitutes the objective, the goal, or what Greimas calls the *mission*/*quest*. In order to fulfil this quest, there are side-quests and missions which mobilise a series of helpers and overcome several obstacles and opponents. The narrative dimension of the controversy can thus be described as a series of quests embedded within each other.

As we have seen, trust has not been redeemed by advertising the benefits of a conquest of the nanoworld or by denying fears—even the involvement of an official authority (CNDP) did not guarantee neutral ground. All the actors have been observed shifting between the role of a helper/opponent. In the debate's state of constant reconfiguration, the manipulation phase (mobilisation of alliances) became stuck between duplicities of pro- and anti-nano. The public is not a consumer/receiver of the hero's actions, it can become an opponent in the debate. Neither

[79]In *Candide: or, All for the Best* (1759; *Candide, ou l'optimisme*), Voltaire assaults optimism. Candide is a character that experiences hardship in the world and 'cultivating the garden' is the final metaphor in Candide. Candide, and the friends he met on a journey, decides to give up his philosophic ideals in exchange for productive practicality. This change in focus shows that Candide has recognised the imperfection of his world and man's inability to comprehend, let alone conquer, the evil in his world. One of Candide's journeys is to Eldorado—a kind of world imagined by utopian philosophers who can here represent the inhuman world of the nanoscale (and the future—the nanoworld). The people of Eldorado (here 'nanos') grant Candide unimaginable riches, a wealth which he loses on the journey.

scientists nor activists are heroes in the debate but ambiguous characters, where both pro-nano and anti-nano are TRICKSTERs. All the characters can be put in a narrative schema as indicated in Figure 8.6 below.

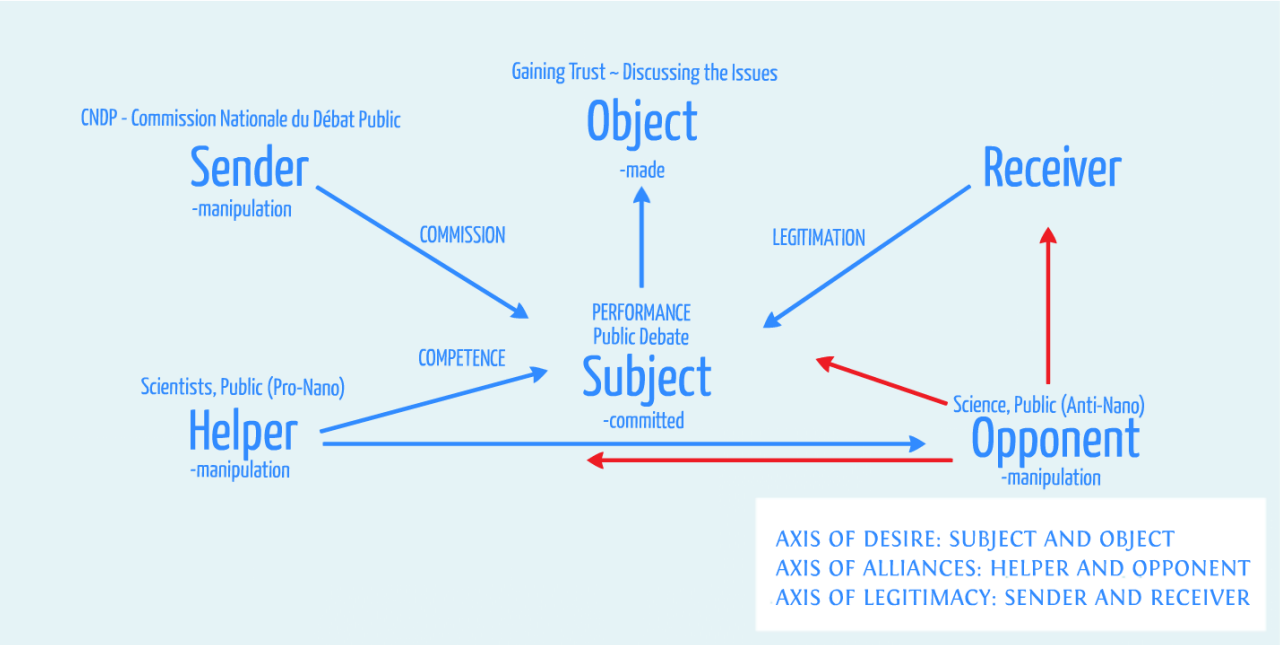


Figure 8.6 Narrative dimension and the National Debate in France (Grenoble).

It is difficult to assess under the given setting who is the receiver of the debate. More importantly, this has dire consequences as there is no one to legitimise the debate. Apart from the CNDP, who issued the debate, there are no clear separations of roles. Scientists are helpers but also opponents of the subjected debate as they denounce the role of the 'uninformed public' which 'does not publish any serious studies' (and therefore scientists cannot debate with them, cf. FMC 2010g). Fulfilment of the 'public debate' quest—the *performance*—constitutes an important but also impossible phase of a narrative (cf. 'débat impossible' in FMC 2009i). Neither can ultimately lead to the completion of the mission which would make all the actors agree on the conditions under which the objective is reached. The mission fails. Greimas calls a *sanction* the final phase of the narrative schema, a stage in which the subject is rewarded or blamed for succeeding or failing in the performance of his or her mission (also in Cooren 2001: 182). The latter is the case of the National Debate. The media is challenged in maintaining their authority as an *objective observer*; retelling the story of a controversy can set a role for themselves as an arbiter. They maintain an ambiguous role themselves by not making clear who is the receiver in a given setting of the debate since all the actors occupy the space of an opponent (also Figure 8.1). Journalists engage in framing the public consultations, providing the reasons the National Debate (as a multiple quest) has failed:

1. PMO [activists] prevents the debate,
2. But this is a problem of education [social scientists]: The 'gap' between available technology and

knowledge [uninformed public] has never been greater.

3. The scientist (enculturation) must understand they do not live in an 'ivory tower' anymore; their hyper-specialisation—[nanoscientists] lack a 'general culture'.

4. The organisation of the debate, which comes very late: Nanos are already here and the 'state' continues to invest [government].

(arguments selected from FMC 2010p, FMC 2010e)

The multiple metaphors which represent the debate (incl. 'ivory tower', '[impure] crucible', 'wave', 'syndrome', 'fear', 'tricksters', 'theatre', 'dispositive surrealist', and even 'garden', etc.) frame the above arguments around which boundaries and the distance, or 'GAP' between scientists (experts), policy (government), and the public (activists) is built up. They also point at the presence of ambiguity within the evolution of nanotechnology controversy. This will be elaborated in more detail in the following discussion.

8.2 Nanotechnology Controversy: Repertoires and Compositions (Discussion)

The metaphors investigated in this study are arguably in the repertoire of the actor's which evoke them as particular characters, scenarios, and narratives. Indeed, there are multiple stories and framing of problems which sustain continuous strategies. There are several conceptual metaphors I would like to discuss so as to gain more insight into these strategies and also to point out the inner dynamic of the nanotechnology discourse.

8.2.1 Controversy Intertwining: Between Big Science and Big Brother

The CONTAINER metaphor has been used to conceptualise a wide variety of entities. Grenoble emerged as a TEMPLE of nanotechnology and the nanoworld as PARADISE. The religious metaphors (discourse), if present, may thus have a completely different role than providing vocabulary to ethical debates and techno-critique. When 'Grenoble' is defined metaphorically as a 'temple of nanotechnology' or a 'ship going to the nanoworld', the researchers enter a conceptual paradise where their particular activities acquire universality, legitimacy, and finality. It has been, however, argued that scientists are representing SORCERER's apprentices living in ivory towers. Their instruments are powerful artefacts which, at the same time, represent a kind of hyper-agency, begetting the TOTALITARIAN regime known from George Orwell or the catastrophe described by A. Huxley and M. Crichton. One of the consequences of the CONTAINER schema noted by cognitive linguists is the creation of a contrast between what is 'inside' and what is 'outside' (Semino 2008: 95). It has specific applications in the political arena where groups, institutions, and particularly nation states, are conventionally constructed as containers, so that belonging (to a group, institution, nation, etc.) corresponds to being 'inside' and not 'outside' (see Chilton 2004: 204, Mio 1997).

The containers involve the notion of resistance and protection against pressure from entities

outside the container (see Chilton 1996: 50–51), causing problems as 'bursting', 'overflowing', or the threat of external forces, such as FLOOD (cf. FLOOD in 'waves of immigration' in Charteris-Black 2004), PLAGUE (necrotechnology), or DISASTER (Big Brother prison). However, combined with the CONTAINER and WAVE image schema, metaphors can underlie very specific and elaborate scenarios, such as a 'wave of nanotechnology' which is surfacing the 'crucible' or which uses its energy as a 'ship'. There is not a single isolated schema but rather a sequence of interpretative choices. The 'melted' can be (epistemic) cultures inside the crucible, as well as detrimental effects on society (freedoms) as when the nanotechnology tidal wave reaches the ship. In our example, the proponents hope the city will fulfil its role as a laboratory of innovation—scientific and technological, but also urban and social. The Grenoble crucible further represents the concept of BIG SCIENCE (GIANT). On the other hand, the conceptual metaphor is inter-discursive, and so it happens that the 'melting pot' (crucible, cauldron) and 'big science' (giant) cannot shake off the discourse of globalisation. Indeed, the sentiment against globalisation which the cluster represents may be particularly strong in the region. Grenoble reaches universities and institutes, big instruments and labs, start-ups and SMEs, which aim for the valorisation of research in a capitalist economy which has a local opposition. It stands against the image of 'pure' science which activists defend against BIG BROTHER and the crucible of the 'techno-gratin dauphinois'; these metaphors are cultural and originating in local contexts.

The WAVE metaphor, on the other hand, is used conventionally in French, as well as in other languages; in many situations, it is inter-discursive. However, even conventional metaphors should not be underestimated. First, it frames innovation as a cumulative (collective) effect. Moreover, the trajectory of the tidal wave is characterised by strength as well as by radical uncertainty about the possible outputs and associated risks. The main choice of metaphor should thus be considered triggered by the topics of situations which are characteristic of both pro-nano and anti-nano discourses as well as considered deeper cognitive schemas and ethical dilemmas. Nanotechnology takes the form of a massive 'tidal wave' which represents a 'revolution' in progress and something we can miss as an event. The media here effectively channel the dilemma of the cultural (technology) GAP (in fr. écart technologique), which simply states, 'If one country decided to stop everything and do some more analysis (about safety, ethics, etc.), this does not prevent others (competition) from continuing'. Therefore, the WAVE metaphor paradoxically moderates any extreme debates about nanotechnology risks. Actors can use the metaphorical concept to frame a delayed decision to participate as possibly causing difficulties for the whole region, nation, or, Europe. The wave concept bestows an illusory inevitability of a JOURNEY. Any action which points beyond the horizon of this conception appears irrational and regressive. As it was argued in the chapter on the nanoworld: *progress is virtue, motion is progress*. According to

Joly and Kaufmann (2008: 7), however, the problem with this imaginary contrast with 'upstream engagement' is that it implicitly refers to a linear model of innovation as a one-way 'flow' from basic research to the users. The coherence with the 'upstream' (engagement of the public) metaphor is questionable, if not mutually exclusive. After all, 'since the late nineties, a wave of "nano" has swept the world of science and technological development. We can ask ourselves if it is a fashionable, passing effect or the logical consequence of a programmed technological evolution or a heavy tendency imposed on the actors' (Vinck 2011: 69). Another characteristic of the 'wave' metaphor is that it is used to describe *an increase in the rate* of innovation by conceptualising nanotechnology development in terms of the flow of water. The rhetorical contrast between a situation where there was less nanotechnology and one in which there is more highlights the emerging nature of nanotechnology and that innovation is a process liable to fluctuation over time (cf. Kondriatiev's waves of technological cycles). It thus imposes a certain vision of the world. Nanotechnology (revolution) as a WAVE is a naturally occurring resource of universal, (from now on) cultural relevance which exists without individual or collective (here French) intervention, and its potential can be harnessed through the use of appropriate technology (here policy and funding). The wave of nanotechnology as a naturalised phenomenon can hardly be avoided and it takes significant power to negotiate away from the opposition.

Altogether, these metaphors arguably participate in constructing a particular 'science', 'policy', and a 'public' afraid of technological developments and unable to make good decisions due to the inability to discern differences (e.g. suffering from 'syndromes' or reactive rather than proactive 'emotion'). It should also be noted that industrial culture is represented by 'speed and economic competition' which cannot be fully aligned with the public debate and citizen participation. The WAVE metaphor enframes the debate as only acceptable provided it does not waste time! Progress is not to be held back by non-linear projects because our competitors, especially in other developed countries (United States, China), do not have the same ethical or 'participative democratic' conditions when they 'journey to the nanoworld' through the shortest technology pathways available (socially acceptable)—this idea resonates across a wider fora (cf. EuroNanoForum 2017). Adherence to the debate here represents a brake on creativity and the development of nanotechnologies. This all would suggest that the public is quite helpless in being defined according to the dominant frame of science (policy) and governance discourse, and it further suggests that strategies are used to assign the public (not only opposition) a particular identity. This is where the activist (Grenoble) metaphors in the nanotechnology debate come in.

8.2.2 Metaphors for Public Debate: Theatre (Music), Machine, and Ecosystem

The metaphor of the 'Pied Piper' as a representation of the debate (débat pipeau) was evoked by opponents of (the debate on) nanotechnology to refuse the scripted dialogue. The public had a

limited role in changing the script, and experts may have expected to strengthen their positions by being asked the right questions. As Brian Wynne observes, it happens often that policymakers are 'hitting the notes but missing the music', failing to acknowledge the deeper challenges of opening up their institutions and assumptions to critical debate (Wynne 2006). The stories of the Pied Piper, the Sorcerer's Apprentice, Luddites, and even Candide are not only metaphors, they are archetypes which have incorporated cultural elements into the (re)interpretation of the debate on nanotechnology. The archetypes (from myths, legends, novels) assign roles (archetypical or stereotypical) and provide narrative structure as meaning-generating schema. When someone is a TRICKSTER, they are a person who incites suspicion, defies (moral) authority, etc. Similarly, a LUDDITE is (an additional trickster archetype) characterised by strong will, persuasive concerning the flaws of industry, and also violent (an adversary) towards the MACHINE. The perspective captures the social groups who were labelled as being outside the central core values of consensus over nanotechnology and as posing a threat to both the values of science and society itself, hence the term 'anti-nano'/'Luddite'/'Pied Piper'. Labelling the opponents of nanotechnology as LUDITTES sets a role for them as 'alarmists' rather than stating facts—driven by emotion rather than reasonable conduct. In the language of sociology, pathology-based rhetoric about nanotechnology tended to resemble what Stanley Cohen calls 'folk devils' (cf. 'moral panic' in Cohen 2002). Metaphor was exploited not only in the construction and negotiation, for example, when it is used to express attitudes and emotions, it was also used to maintain or attack the 'faces' of others, replacing 'masks' (cf. Brown and Levinson 1987; or Turner 1974). How can you engage in a dialogue with someone you do not trust? This is where the metaphor of a TRICKSTER was performative and had influence on the debate's failure. In addition, CANDIDE introduced a powerful image/mask which media placed on itself. It assigned a hero-character which comes through a personal transformation from initial naivety (philosophy of optimism) but finishes as a strictly practical precept: 'We should take care of our garden'. The emergence of this metaphor for debating how controversy 'should' end also shows how 'figurative expressions occur regularly in topic transition sequences, and specifically in the turn where a topic is summarized, thereby initiating the closing of a topic' (Drew and Holt 1998: 495).

The metaphor of DISPOSITIVE has a conventional use as a technical term. In the theoretical framework of Michel Foucault, it represents the mechanism ('le dispositif') which designates certain practices and discursive elements as fundamental to the modern understanding of governmentality. While Foucault's work has a crucial impact on discourse research, the analytical potential of the dispositive as an object of analysis is not exhausted. The conceptual metaphor DISPOSITIVE is probably not as conclusive as the metaphor of a GARDEN (the end of Candide's journey), but it does represent a particularly extensive imaginary which fills multiple storylines in

nanotechnology discourse. When relatively 'closed' metaphors used by scientists are 'opened' in the public domain, there is also a danger that they will be used in a way which goes beyond, or even against, the scientist's original intentions (Nerlich et al. 2000, Weigman 2004). For example, the 'biochip', framed as a new method of gathering bio-information on small electronic devices, is relatively closed. When it is described as a mesostate for medical applications in 'treating diseases' and 'the surveillance of (endangered) animals', it opens itself to many social implications. In the public domain though, it can open further, as it does when related to 'surveillance society'/'Big Brother'/'the tyranny of technology'/'slavery to machine', or when 'smart dust' (biochip as a sensing device) becomes 'killer dust' (grey goo or a predatory nanomachine). In other words, some of the dominant metaphors in nanotechnology discourse (and resp. nanoscience) can lend themselves to supporting techno-critique; their meaning is not fixed once and for all as they enter the public (media) discourse.

In nanotechnology discourse, mechanisms of MACHINE contrast with the conceptual domain of ECOSYSTEM. The media set for themselves a role as 'gardeners' who have no illusion of control. They create the right growing conditions, nurture a debate, set up perspectives and a framework, and plant a diverse variety of opinions and watch them grow. But ultimately, the end result almost always includes failures and unexpected successes. The garden metaphor is also persuasive due to the fact that we need to identify how we create the right growing conditions for healthy and productive ideas—we need to find leverage points where we can provide incentives for 'good' growth and disincentives for the 'bad' (Grover 2009). And we need to allow a diverse range of opinions, community groups, technologies, and even models to coexist. Critiquing different models is vital as we strive for better ones. As with (sustainable) gardening, regulation is done with the end goal of a healthy overall system in mind. Still, just as a weed is really a plant in the wrong place (or one we have not found a use for yet), so too can ideas become PLANTS which do not fit our own personal (group) visions, necrotechnology or green nanotechnology being perhaps perfect examples. The garden metaphor is attractive as well because it allows the dialogue problem to be addressed with a therapeutic project. Yet, the garden metaphor is neither sufficient nor necessary. The GARDEN metaphor is open to a more *dialogical* metaphor and offers an ecological vision for the debate. The public debate can only thrive with the respectful and fair behaviour of all stakeholders towards each other. Yet, it does not completely exclude situations of conflict. If 'plants are IDEAS', it remains a challenge to the democratic mechanism to flourish/blossom and not to be 'pulled as a weed'. In the end, it is moderators as gardeners, as well as participants of the debate who may 'unroot' or 'plant seeds of suspicion and doubt'.

Thus, there are no shortcuts with which to model dialogue for the creation of a socially robust technology. Any single metaphor of the debate represented no viable alternative which could

have moderated the Grenoble controversy by designating dialogical roles and objectives. Still, in their own right, metaphors have enframed/enriched the Grenoble model, which shifted between deficit, enlightened, and critical inquiry. Balancing these accounts as well as investigating the metaphor capacities will be part of a broader discussion.

8.3 Conclusion

In this chapter, the role of metaphors and narratives has been considered in the French media debate on nanotechnology (discourse). It involved representations of global issues set in local contexts. I demonstrated how metaphors are used to capture hype, construct characters and their roles, and assign identity to the institutions (Grenoble/Minatec). I discussed the interaction between various actors and metaphors in projecting contested versions of the nanoworld, from the promised land (PARADISE) to a dystopic society (TOTALITARIANISM) among others. The analysis of the National Debate showed how the metaphorical patterns evoked particular frames of the extended durability of the ideologies targeting nanotechnology, but also GMOs and nuclear, and how these interacted in a specific context—in other words, metaphors here emerged as both topic- and context-triggered phenomena to provide particular representations of issues, situations, and events. The study involved a wide variety of conceptual metaphors, such as CONTAINER, WAVE, THEATRE, DISPOSITIVE/MACHINE, and GARDEN/ECOSYSTEM, each of which introduced (in a given context of use) a particular (action) frame. The National Debate (Le débat public national sur les nanotechnologies), inflated as it was by the media between the years 2009 and 2010, did not just have a direct connection to these articulations. Metaphors and narratives played their role in the representation of the benefits of building research centres as well as the shortcomings of government regulatory mechanisms. Metaphors emerged within the initial deficit of communication (as one of the Grenoble models) and carried over the objective of establishing a dialogue with the public as a multi-actor/construction model. I also showed how a variety of metaphors were used by participants to talk about different aspects of nanotechnology, and I noted some significant differences between the metaphors used by proponents (forced to shift from the role of promoters to defenders) and opponents (in the virulent moral panic marked as anti-nanos). The study suggests that the ambiguity, also carried over by the metaphor of a TRICKSTER, was one of the reasons the dialogical mechanism (and the objectives of the National Debate) failed. The science journalists (media) who moderated the debate, however, used this ambiguity to set a role for themselves as arbiters. In this sense, the public debate emerged as a specific discursive formation where various matters of concern and metaphors of acceptance interacted. Altogether, this chapter demonstrates that the capacity of metaphor can be mobilised to impose or subvert particular models by assigning identities, maintaining hype, and even framing the genre of communication. It shows how ambiguity can be a carrying structure as well as plotted strategy.

Chapter 9. Master Builders and Uninformed Citizens: Nanotechnology Controversy in the United Kingdom

O wonder!
How many goodly creatures are there here!
How beauteous mankind is!
O brave new world
That has such people in it!

W. Shakespeare, *Tempest*

9.1. Identifying the Problem/Matter of Concern: Nanotechnology Controversy

The United Kingdom invested early in nanotechnology, and the universities offer one of the best programmes in nanotechnology. Unlike the genetic modification (GMO) debate, in which the UK government failed to take into consideration the distinct nature of the new technology (Grove-White et al. 2004), the initiatives were made to embrace the nanotechnology debate early on, thereby promoting public confidence and building legitimacy in the processes (Bowman and Hodge 2009). This has led to important policy events such as the publication of the Royal Society and Royal Academy of Engineering's report in July 2004 where more effective strategies for 'upstream communication' of nanotechnology were discussed (Anderson et al. 2005). Other initiatives such as 'NanoJury UK' and the effort that went into its direct expert and public consultation are now well known internationally (cf. Rogers-Hayden and Pidgeon 2006 and 2008, Doubleday 2007). A specific feature of the United Kingdom's nanotechnology discourse is thus considerable stress being laid on public engagement and reinforcement of deliberative experimentation (Seifert and Plows 2014: 80).

As government is not the sole arbiter of the debate, this feature has also allowed for the array of actors engaging in public debate on nanotechnology to be seen (Macnaghten et al. 2005). The Royal Society and Royal Academy of Engineering's consultations, as well as other initiatives, such as Greenpeace, the ETC Group (formerly Rural Advancement Foundation International), and the independent think tank Demos, drew on a wide range of actors which proliferated science images to the national media. In some cases, the initiatives used the media directly as their communication platform (such as *The Guardian*) in voicing their views, allowing the public to express their opinions. The actors' contestations over what is at stake with nanotechnology have created a chain of interactions and given birth to new representations of nanotechnology. One example stood out when Prince Charles expressed concern for 'self-replicating nano-machines consuming the whole planet' (BMC 2003a). Before reaching a panic threshold, this narrative scenario appeared as a concept in the vision of an American engineer Eric Drexler (1986) as the 'grey goo' scenario, reprised in Michael Crichton's (2002) novel *Prey*, and reintroduced by the ETC (activist) Group, and finally, integrated by the Royal Society (expert/government institution) in their

2004 report. However, a considerable amount of hype has been evaluated in the context of previous experiences on emerging technologies and scientific developments. The previous studies pointed out the close relationship between nanotechnology and genetically modified food or genetically modified organisms (cf. Friedman and Egolf 2005, Throne-Holst et al. 2007, Pidgeon & Rogers-Hayden 2007).[80]

For this dynamic, I find *reconfigurations* a more appropriate term as the debate became less an issue of reference (accentuating truth claiming descriptions) and more of re-figuration (blending reality and fiction with past and future experience). This not only requires us to look at various actors engaged in these accounts but the chain of significations (and assemblages).[81] The question is also how the media themselves have used different expert knowledge, science images, policies, and public objectives, as well as how the media have used these to reconfigure and narrate nanotechnology. These complex/changing relationships between science (technology), policies, and the public demands that social science research find stable ground in analysing the development of the nanotechnology controversy. By undertaking a metaphor analysis of the nanotechnology discourse in the British newspaper press during the selected period, we might gain more insight into how representations of nanotechnology in the news coverage were established, translated from different contexts, and endure.

The presented study targets metaphorical concepts and dynamic of inferences which underlie social representations of nanotechnology controversy that occurred in the UK media. In line with the methodology and corpus compilation, I will investigate how the nanotechnology controversy was framed in the British national newspaper press between 1999 and 2015, a time when a number of pertinent nanotechnology issues began to achieve public salience. The compilation of the UK corpus during the 1999–2015 period offers some comparative lines that could determine whether there are additional overlaps or cultural differences with the Czech and French media corpora. However, studying UK corpus is important to our discussion exactly because many of the above-mentioned dialogue processes began in the United Kingdom relatively early and still continue. Articles for the broadsheet sample were selected from major mainstream newspapers and periodicals (see data section). According to the conventional methodology design used in this dissertation, I considered common conceptual metaphors which originated in different contexts to study narrative structures. The metaphor analysis thus followed by translating metaphorical

[80] The public engagement processes on science and technology in the United Kingdom have been undeniably shaped by two previous 'regulatory failures', most notably the outbreak of bovine spongiform encephalopathy (BSE or mad-cow disease) during the 1990s (Vogel, 2001a), and shortly thereafter, the highly politicised public opposition to genetically modified (GMO) products (Bowman and Hodge 2009).

[81] According to Anderson et al. (2005), a number of pertinent nanotechnology issues began to achieve public salience, commencing with the public intervention of Prince Charles. His sharply expressed views about nanotechnology sparked a wide-ranging debate in the press. The involvement of a celebrity and a report may have played a crucial role in enhancing the newsworthiness of the issue, influencing its subsequent framing in the news.

concepts into narrative schema (cf. Greimas). Finally, the role of these different figurations has been re-evaluated against a discursive formation and controversy development.

It will be argued that the public images of nanotechnology in the United Kingdom have been elevated by various metaphors, mixing real events with fictional narratives while targeting figures of nano-scientists, members of the Royal Academy, as well as the English monarchy. The science journalists presented worrying precedents/concerns about what can happen when the dialogue between scientists (engineers) and the public breaks down. Also, nanotechnology in the food industry sparked off a critical moment of the debate which has reopened the previous GMO controversy and generated further ambiguities. In retrospect, the media not only reported about nanotechnology in terms of 'mastery' with risks and benefits but also included the previous 'regulatory failures' and '(uninformed) public fears' in their coverage. Their embedding in 'success' and 'scare stories' (closely related to the GMO case) included images of 'mad' scientists and an 'irrational' public, providing a carrying structure for framing what else can go wrong and what has to be done. Finally, the nanotechnology discourse entering the public sphere has also been carried over by the transforming GMO controversy. These examples have pressed upon government the need for science accountability while demonstrating deeper cultural patterns. The story of nanotechnology in the United Kingdom remains open-ended as a part of the wide-ranging discursive formation.

9.1.1 Tower of Babel, Grey Goo, and Dr. NaNo: Mastery Metaphors

In the early coverage of nanotechnology in the UK media, a journalist brought 'news from the nanoworld' (BMC 1999), voicing a researcher who asks:

> What are we to make of the predicted nanotechnology revolution? I think the brave new world of infinite wealth is still a dream. But even if the nanotechnological revolution does not materialise quite so soon in everyday life, and if a few more generations will have to work in traditional factories rather than delegating their work to nanorobots: it would be helpful if we could develop molecular motors as efficient as our muscles, data storage devices as compact as DNA, and a method for the reduction of molecular nitrogen at atmospheric pressure and room temperature. Nature has taught us that these can be achieved.

In 2003, an economy expert being interviewed noted that 'for the moment though it's mainly a brave new world of conferences and networking events' (BMC 2003i). Elsewhere, a protagonist in a fictional story wakes up in a 'brave new world' (BMC 2006a) surrounded by 'smart' nanotechnology. Then also, 'looking ahead to a brave new nanoworld [with] major advances in atom-scale research' (BMC 2004a) might be just as real as waking from a dream within a dream. Nevertheless, the BRAVE NEW WORLD metaphor is effectively used to point out the emerging

possibilities in building a better world(s). The expressions, such as in an article entitled 'The Brave New Risks of Nanotechnology' (BMC 2007b), however, might suggest the metaphor is being worked with to challenge its own culture. It provides meaning to the NANOWORLD concealed in English historical drama and fiction reaching to William Shakespeare's and Aldous Huxley's 'brave new world'. Here, the images of a future world resonate with more distant pasts by integrating emerging technology into older storylines. The brave new worlds which these previous dramas portray, and journalists evoke, are not always, in fact, wondrous places. The phrase is basically a placeholder for dramatic irony—that something may only appear wondrous.

In 'Welcome to the Nanostate' (BMC 2003a), nanotechnology is compared to the Tower of Babel: 'Unlike the Old Testament Tower of Babel—this convergence will last . . . that simple fact—that all substances are qualitatively the same at the nanoscale, that life and non-life, mind and matter, are all made up of atoms arranged in different ways—has caught the imagination of some of the world's most senior technologists and the world's most powerful government' (BMC 2003a). By looking at the original story (also in Figure 9.1a), we are led to the Bible—specifically to the book of Genesis—which describes how the tower comes to be a project of audacious MASTERY. As the story reads, after the great flood (which fits the WAVE metaphor) people constructed the tall tower in efforts to reach heaven and God himself. Displeased by this project, God is said to have confounded their speech so that they could not understand one another and then scattered them all over the world. However, the proponent of the nanotechnology convergence argues that 'this Tower will last' (Ibid.). At the nanoscale, the metaphors for LANDSCAPE and BUILDINGS are common pattern-making practice (see Figure 9.1b). However, we are dealing with a conceptual metaphor which also indicates the process of convergence as a (common) LANGUAGE. This represents an improvement in non-material culture. After all, as one of the journalists noted in an article about innovation: 'The stone age didn't come to an end because we ran out of stones' (BMC 2015a).

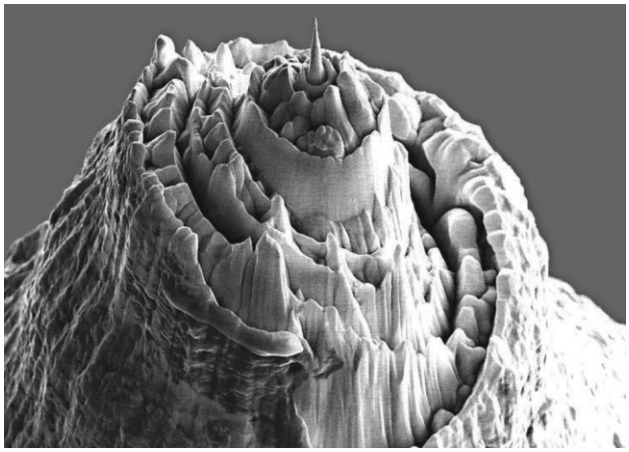



Figure 9.1a *Left*, *The Tower of Babel*, c. 1563 by Pieter Bruegel the Elder. The Tower of Babel as a MASTERY (power) metaphor is a challenge to the traditional view of the world. Its BUILDERS (cf. 'Bâtisseurs de nanomondes' in FMC 2013a) are not only trying to reach the heavens (cf. A.C. Clarke's *Fountains of Paradise* in BMC 2010a), but with a convergence argument, they project the future as a unity of nanoscientific LANGUAGE, providing a protected space for nanotechnology development (see later discussion). **Figure 9.1b** *Right*, Making a (modern) point: a gold tip used in microscopy (in *Nature* 2007). The BUILDERS discourse is also the language of an extraordinary materials science. 'We are "connoisseurs of chaos", patterners. So we look for resemblances to things in our experience . . . The gold tip is a digital Tower of Babel' says Roald Hoffmann, winner of the 1981 Nobel Prize in Chemistry, in his introduction to Lucia Covi's book *Blow Up: Images from the Nanoworld* (2012).

The LANGUAGE (MASTERY) of nanotechnology establishes a link between various epistemic cultures, which further translates into a connection between nanotechnology building blocks at different scales. The logic of *convergence* which lies in the *material unity of the nanoscale* thus proceeds as language code to an entire society. Since everything operates from the bottom up, beginning with atoms which combine to form all larger structures, visionaries argue we can control events on the macroscale if we can manipulate events at the nanoscale (cf. Roco and Bainbridge 2001, López 2008). At the nanoscale, scientists synthesise DNA molecules: 'DNA controls the formation of proteins that may ultimately determine the health and behaviour of entire organisms. The behaviour of individual organisms largely determines collective behaviour and, hence, the behaviour of society' (BMC 2003a). Nanotechnology is then not only about cultural feats similar to building the 'Tower of Babel' (BMC 2003a) or 'Stonehenge' (BMC 2003b), nor to distinguish between the four biochemical 'letters' of DNA (cf. Oxford Nanopore Technologies in BMC 2015b). It is about reading the entire CODE of nature, and then, initiating global agency. It is the ability 'to mimic the feats of nature, where molecular "machines" drive our muscles and transport cargo around cells among other things. A biologist might use DNA origami to take proteins that occur separately in nature and organise them into a multi-enzyme factory that hands a chemical product from one enzyme machine to the next in the manner of an assembly line' (BMC 2006b).[82] The

[82] Just as another author reprises a popular book, arguing in 'Nature Got There First' (from Peter Forbes book 2005 *Gecko's Foot*) that it 'revealed an enthralling catalogue of modern technological inventions that turned out to have some predecessor in the natural world . . . inviting wonder at the technological sophistication of both natural and human manufacture . . . into labs that practise "bio-inspiration": the attempt to develop new technologies explicitly modelled

MASTERY metaphor here extends to the concept of ASSEMBLY ('self-assembly' and 'self-replication') structures and complex nanosystems, with applications mimicking the behaviour of phenomena in nature.

The conceptual metaphor backfired, however, when Prince Charles tasked the Royal Society with investigating the nanotechnology risks of the so-called grey goo scenario. Even though the authority of the science community (represented by the Royal Society) discounted a '"quest" of tiny machines turning everything in grey goo as science fiction' (BMC 2004b), it became representative of MASTERY with the dramatic implications of nanotechnology. One of the articles warned that 'it's a timely question. As smoke poured from the Buncefield oil depot fire recently there were dire predictions about the health effects it might have, an issue that investigators are addressing. Of the many potentially toxic constituents of the huge grey cloud, nanoparticles were singled out for special concern. What if they were to enter our bodies?' (BMC 2006c). The grey cloud of nanoparticles may only be loosely connected to the scenario; nevertheless, it has been uttered together with 'nano-porous' and 'killer dust', an 'asbestos of the future' (BMC 2006d), or even referring to privacy issues with 'smart dust'—that is, microchips (BMC 2002a) and a 'Big Brother' scenario (BMC 2003d). One of the most promising applications of '(nano) POWDERS' could significantly increase the energy density of batteries (BMC 2008b). For example, a 'carbon nanotube [a hollow cylindrical arrangement of carbon atoms] could give your central heating system an energy-efficiency boost . . . [which] demonstrates remarkable properties of strength, flexibility and electrical conductivity. This miracle material looks like a very fine black powder' (BMC 2006e). The article, however, further argues that 'nanoparticles are already here—in tough shin pads, water-repellent clothing and self-cleaning windows. But putting them in your central heating system is a trickier proposition. How, for example, would you ensure the carbon nanotubes—all you need is a few percents by volume—remain evenly dispersed and don't clog your radiators with a black goo?' 'We're focusing on getting the formulation right', states a scientist, who claims the project is three to five years away from use (BMC 2006e).

GREY GOO became a conceptual metaphor which has established multiple storylines with various actors. These actors have become protagonists in metaphorical scenarios, balancing real and fictional accounts and sometimes implied alternation between the positive and negative roles of scientists and technologists. For example, in 2003, a time when the grey goo controversy was hyped by the media as a hyperbole of the future, a journalist brought forward a caricature of the 'nanotechnologist as Dr. Na-No'. The other Dr. No is an evil genius seen in a James Bond film but the journalist insisted on the analogy: 'Meet Dr Tom Pike, a senior electrical engineering lecturer at

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on natural phenomena . . . Peter Forbes is in no doubt about the capacity of evolution to do the job, and this is no children's book' (BMC 2005a).

Imperial College London, where he designs machines 1,000 times bigger than nanobots for space missions, and also dallies with nanomaterials.' A classical 'what-if' scenario is evoked as the story unfolds: 'Dr Na-No, Dr Pike has plenty of inspiration to draw on. The "grey-goo problem" was floated in 1986 by the futurist Eric Drexler in his book *Engines of Creation*. Three years ago, Bill Joy, co-founder of Sun Microsystems, remarked: Gray goo would surely be a depressing ending to our human adventure on Earth... and one that could stem from a simple laboratory accident. Oops' (BMC 2003e). To create a self-replicating nanobot would take, a nanotechnologist estimates, billions of atoms: 'The end result would not be a true nanobot but something bigger. In fact, nature teems with them: bacteria. At around 1,000 nanometres, they count as microbots, not nanobots—viruses are smaller, at 20-100 nanometres, but need living cells to multiply, that's too restrictive to be a grey-goo "bot contender"' (Ibid.). This provides evidence the media systematically grounded the metaphor in hypothetical scenarios resonating with real events as their metaphorical referents, thus, opening space for new concerns. It will also become more apparent that the policymakers and the public have themselves exhibited a range of roles, some of which contributed to the increased ambiguity and polarisation of the nanotechnology debate.

9.1.2 The Prince, the Inquisition, and Janus Face of Nanotechnology

Prince Charles, alarmed by an ETC Group report ('The Big Down') on nanotechnology, described the 'incalculable risks' of nanotechnology and wanted to discuss the emerging technology with experts proposed by the Royal Society (2004). 'The Prince sensibly reminds us that there are important unanswered questions relating to the control and ownership of these technologies . . . . [The Prince] has spoken out about the potential dangers of nanotechnology and his concerns led to a scientific investigation by the Royal Society, it concluded that there is serious cause for concern. It recommended that the Government should take action by funding research into the potential risks' (BMC 2004c / BMC 2005b), said Jim Thomas of the Canadian-based ETC Group. Nevertheless, the Prince's authority has been accepted positively as much as it has been disqualified. The meaning of his rejection of nanotechnology became framed among 'scare stories such as the Earth being smothered in a "grey goo" of nanoparticles' (BMC 2006f)—a science fiction.[83]

In 'The Real Goo—Nanotechnology must not be Strangled at Birth' (2003), the author warns that 'grey goo' represents 'the latest idea to become the subject of anxious scrutiny by those who set themselves up as scientific inquisitors . . . . So far, this is little more than an idea in search of an application, but that has not prevented some absurd claims about the threat it poses being made and, sadly, given endorsement by the Prince of Wales' (BMC 2003g). The Prince had become a leader of an INQUISITION, where modern science is under attack from false authorities, pseudo-

[83] Grey goo is 'dismissed by scientists, that self-replicating nanobots could requisition molecules from other matter, rapidly consuming the world . . . if it sounds like science fiction, that's because it is: the idea was featured by Michael Crichton, the author of *Jurassic Park*, in his recent novel *Prey*' (BMC 2004d).

scientists, and anti- and non-scientists. ‘Prince Charles and his allies, such as the Green MEP Caroline Lucas, are hung up on “grey goo”’ (BMC 2004d), with the advocates of nanotechnology arguing that ‘grey goo is the purest Luddism. It must not be allowed to stand in the way of research, for the fear of progress really is a recipe for stagnation and decline’ (BMC 2003g). The proponents thus managed to establish new domains for the main actors of the controversy, grey goo as such becoming metaphorical. Prince Charles (and his allies) is INQUISITOR(s); grey goo is (purest) LUDDISM, a RECIPE to stagnation and decline, and a FEAR of progress.

The FEAR metaphors are known to us from previous case studies. Here however they become directly integrated into the story of nanotechnology. In the article entitled ‘Spare Us All from Royal Nanoangst’ (2003), the proponent of nanotechnology wonders ‘what would have happened if a “proto prince” was around when one of our smarter ancestors figured out how to make fire by rubbing sticks together. You can sterilise food, make it taste better and stay warm, says the inventor. But you can also burn people, torch their houses and reduce their crops to charcoal, replies the Stone Age prince’ (BMC 2003f). As the critic of Prince Charles continues, ‘The only grey goo that really worries me is the stuff between the Prince’s ears. Just once, it would be nice to hear him acknowledge the achievements of science, rather than knock it (he was nowhere to be seen during last week’s DNA celebrations). Yet again, Charles seems inspired by the opportunism of the Green movement’ (Ibid.). Among the metaphors worth noticing, we find nanotechnology is FIRE, and ‘Prince Charles is a proto-PRINCE’, who suffers from ‘grey goo’ as an affliction of his MIND. His rejection of nanotechnology belongs to a mindset of the STONE AGE. The storyteller, nevertheless, is faithful to dramatic transitions as the story further unfolds into ambiguity: ‘Perhaps the Prince will be heartened to learn that Mother Nature is a nanotechnologist. Perhaps not. A virus is nothing more than genetic code in a protein overcoat. Lying at the borderline of the living and the dead, this self-replicating machine can sometimes run amok, as is happening now in the Far East: the Sars virus is a natural nanomachine’ (BMC 2003f). The argument gives scientists a role in which they are ‘merely’ mimicking NATURE in their agency. This includes the metaphors for DNA as well as VIRUSES—that is, figurative entailments of nanotechnology—are MOTHER NATURE. Proponents say, ‘Scientists can barely make molecular motors, let alone self-replicating machines’, with Sir Harry Kroto, a Nobel laureate, saying such worries ‘show a complete disconnection from reality. Yet this prospect has inspired calls for a moratorium on all research’ (BMC 2004d).

The activist groups argue that regulatory control of nanomaterials should include mandatory reporting, safety assessments, emissions minimisation, labelling, and liability for new and existing nanomaterials: ‘Until there is a fully researched understanding of the health and environmental impacts and appropriate regulation in place, we call for a moratorium on the commercial and

environmental release of further engineered nanomaterials. We urge the Government to commit to a deadline by which mandatory regulations will be introduced' (BMC 2006g).[84] The same article warns, however, that 'behind such [moratorium] efforts loom the spectres of a new generation of environmental cleanup sites or, much worse, the same downward spiral in public confidence that blighted agricultural biotechnology and nuclear power' (BMC 2004e). The moratorium as (looming) SPECTRE and nanotechnology personification strategies add to representations of nanotechnology as a (ambiguous) BEING. As it has been previously noted, nanotechnology is FIRE (BMC 2003f) and 'Mother Nature is NANOTECHNOLOGIST' as well (Ibid.). These metaphors have in common a specific blindness to right or wrong, typical of *yes* and *no* statements (see also Table 9.1 below), similar to when media produces experts looking to ancient Rome to make a modern point. 'Like Janus, the Roman god with two faces who looked simultaneously forwards and backwards, scientists working on nanotechnology, and society more broadly, need to consider the "dichotomy" of the technology', said professor of nanomedicine, Kostas Kostarelos. He added, 'Nanotechnology could be seen as a scientific marvel or a health hazard, . . . it could offer the dream of tiny "machines" to fix individual cells, or the nightmare of asbestos-like particles stuck in the lungs. "We need to understand there are these dichotomies . . . and we must avoid hype, both positive and negative"' (BMC 2012). The opportunities and risks thus represent two figures of the JANUS FACE (see Figure 9.2 below).

Table 9.1 Should the Government call a moratorium on nanotechnology? (Source: BMC 2008c)

YES	**NO**
The risks are simply too great to carry on business as usual until we know more.	We already enjoy too many benefits from nanotechnology to be able to straightforwardly stop now
We have managed perfectly well so far without nanotechnology, so why take the chance?	The risks are hypothetical, and it would be a mistake to stop without harder evidence that the risk is real.
If there is any doubt at all, it would do no harm to call a temporary halt until we know more.	The potential benefits, which are just around the corner, far outweigh any possible risks.

Figure 9.2 'The Janus Face of Nanotechnology' is a metaphor for assessing the impact of nanotechnology as a two-faced matter of risks and opportunities. It also introduces rhetoric within this dual regime, whereas one face is looking backwards and the other into future. It depends exactly on the context which one, risk or opportunity, is looking backwards (Leroueil et al. 2006; *Image source*: Nowack 2008).

[84] The actors listed in the letter calling for moratorium are Dr Doug Parr, chief scientist at Greenpeace UK; Peter Melchett, policy director of The Soil Association; Tony Juniper, director at Friends of the Earth (England, Wales, and Northern Ireland); Andrew Scott, director of policy for Practical Action; Pat Mooney, the executive director of the ETC Group; Dr Andre Menache, scientific consultant at Animal Aid; Olaf Bayer, a researcher at Corporate Watch; and Rory O'Neil, a health, safety, and environment officer with the International Federation of Journalists;

When it comes to nanotechnology applications, there is a relatively clear consensus that good regulation will be crucial. 'I'm not somebody who thinks technology is malicious—I think it's humans that put that on to the technology', said Illuminato, from the campaign group Friends of the Earth, 'It's how we manage these things that's going to be important' (BMC 2013a). However, the Royal Academy of Engineering report finds 'support from the government has been weak and only now have there been signs of interest' (BMC 2008f).

9.1.3 Secret Society, Frankenstein Food, Malthusian Catastrophe: GMO Revisited

The House of Lords Science and Technology Committee conducted an in-depth investigation, and its report joined criticism of the food industry for its secrecy on the subject. The industry is 'keeping a low profile because of experience with GMO . . . fears have inspired a culture of secrecy about nanotechnology in the food industry because it is worried about a repeat of the GM crop safety scare' (BMC 2010b). The Food and Agriculture Organisation of the United Nations report on food and nanotechnology raised similar concerns about a *lack of transparency* about what the food industry was doing with nanotechnology (BMC 2008q). These reports voiced by the media address industry as a SECRET SOCIETY lacking the initiative for public debate which could dispel FEARs and prevent nanotechnology from being labelled as '(another) GMO' (BMC 2004f). Finding a way to involve the public in the fast-moving field of nanotechnology, the proponents believe, would help avoiding another '"GM-style fiasco", where businesses charged ahead oblivious to public sentiment . . . misunderstanding, fuelled by alarmist headlines, bred "irrational fear" of a potentially powerful technology' (BMC 2005d). Some proponents of the regulation, such as David Arculus, chairman of the Better Regulation Task Force (an independent watchdog), have been consistent in saying 'well-framed regulations could win acceptance for their work in the face of irrational fears . . . . One of the problems with (genetic modification) was that there we did not have a well-informed debate to frame the regulations in the first place' (BMC 2002b).

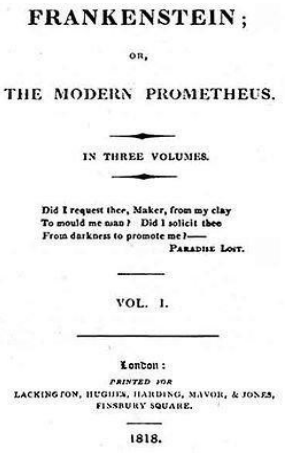
Some voices have been saying the GMO analogy has little to no value, it is false, just a 'scare story' (BMC 2003h), while others acknowledge the industry is 'set up amid fears that without public consultation nanotechnology could suffer a backlash similar to that over genetically modified food' (BMC 2005c). The story of nanotechnology extends to GMO from further in the past: 'Had the 19th century suffered such a failure of nerve, the railways would have been stillborn, the telephone derided, and the horseless carriage anathematised from every pulpit. Sometimes the blessings of new technologies are mixed. Nothing is wholly beneficent, and even the most well-meant of inventions may have negative implications. But the kneejerk response to new technology has become an enemy of progress' (BMC 2003g). When James Wilsdon, head of strategy at Demos, said their report called for a public debate on nanotechnology, he argued, 'Unless a meaningful debate gets under way soon, nanotechnology has the potential to turn into the next GM, with

scientists forced to defend themselves against an anti-science backlash. The kind of health scares which turned GM technology into "Frankenfoods" could easily erupt around nanoparticles, which are already in everyday consumer products such as sunscreen and cosmetics' (BMC 2004h). Nanotechnology is the FRANKENSTEIN MONSTER, returning us to the original Mary Shelley story (also in Figure 9.3a below), with critics warning that 'the science of these Franken-molecules is still in its infancy, but already nanoparticles are being used or developed for use in consumer products . . . . The strategy seems to be: sell first, safety later. And that is a recipe for lawsuits, or worse—a crisis of consumer confidence that could doom the future of this revolutionary new technology' (BMC 2007b).

Whereas the advocates of strong nanotechnology regulation see out of control technology and evoke particular crisis scenarios, such as an 'escaped monster' and a problem for 'food democracy', for proponents, it is the demography going out of control. The narrative of FEAR becomes inverted. Nanotechnology is redefined as the possible solution to an inevitable Malthusian catastrophe (also in Figure 9.3b): 'Food processing is now a fact of life . . . it's a romantic view to think that we can feed the 7 billion people on this planet with traditional agricultural practices. And as the population grows, so too will the importance of new food technologies' (BMC 2013c). The article continues,

> The future is about realigning food with planetary sustainability . . . . This tension between food control and food democracy is not new. In the late 18th century, British economist and demographer Thomas Malthus painted a pessimistic picture of the future, where agriculture could not feed a growing population . . . . In doing so, he posed an important question: what is the relationship between people, the planet, and our food supply? (BMC 2013c)

Nanoscientist Clara Silvestre, who works at the Institute of Chemistry and Technology of Polymers in Napoli, Italy, says that 'nanotechnology could play a key role in increasing sustainability, because roughly 30-40% of food is currently wasted' (BMC 2013b).


FRANKENSTEIN;

OR,

THE MODERN PROMETHEUS.

IN THREE VOLUMES.

Did I request thee, Maker, from my clay
To mould me man? Did I solicit thee
From darkness to promote me?—
PARADISE LOST.

VOL. I.

London:
PRINTED FOR
LACKINGTON, HUGHES, HARDING, MAVOR, & JONES,
FINSBURY SQUARE.

1818.

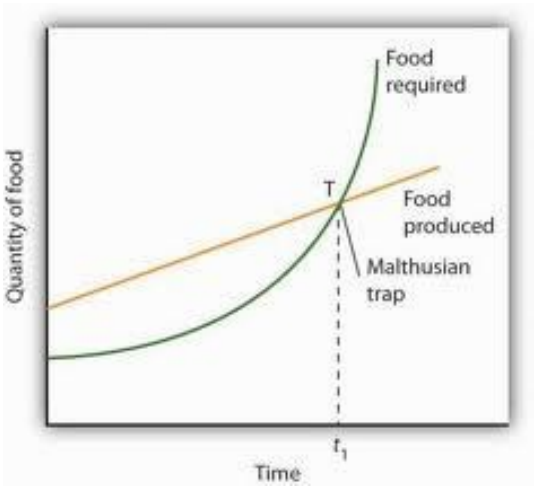


Figure 9.3a *Left*, Mary Shelley's *Frankenstein, or Modern Prometheus* (first edition in 1818) is used as warning to what might have a negative outcome, producing 'Frankenstein nanofood', i.e. scientist's creation alluding to its unnatural origin. **Figure 9.3b** *Right*, Thomas Malthus in 1798 postulated a theory that population, which grows exponentially/geometrically, would outpace the linear/arithmetic growth of food production. Nanotechnology was described in the chapter on the nanoworld (Chapter I) as a quest for exponential progress. The conferences of consensus are held to answer the question in the equation: 'Can nanofood have a role in feeding the planet?' (BMC 2013e). Both cases, Frankenstein 'nanofood' and the Malthusian 'trap', are figures describing a point of crisis, as well as a moment of catharsis in the nanotechnology narrative: It is through the involvement of 'nanofood' (metaphor) that the crisis is introduced or resolved.

These narratives of fear had an arguable effect in further reconfiguring the debate. The strong influence of public backlashes, and especially that of GMOs, materialised in the decision of the Nanoscience Centre at the University of Cambridge, a laboratory of 120 scientists which appointed Rob Doubleday as its first lab-based sociologist in 2004: **'**His task is to help his colleagues reflect on the social and ethical implications of their research into technology that takes place on a scale of billionths of a metre' (BMC 2004g). One journalist summed up the motives behind his appointment in two letters: 'GM. After almost a decade of battles over genetically modified crops and foods, scientists and policymakers are desperate to avoid nanotechnology becoming the stage for the next big showdown between science and society' (BMC 2004g). The Nanoscience Centre at the University of Cambridge teamed up with Greenpeace and *The Guardian* newspaper to launch a public debate on nanotechnology and what has since become known as 'NanoJury UK'. A five-week citizens' assembly would 'hear evidence on risks and opportunities linked to nanotechnology and by mid-September give a "verdict", which will feed into the government's nanotechnology group' (BMC 2005c). Doug Parr of Greenpeace said, 'We want to provide an opportunity for people to give their perspectives . . . at a time when we hope they can still make a difference' (Ibid.). With the jury, the social representation of the public as '(irrational and) fearful' shifted to an 'enlightened' model of citizen able to take decisions within its own (social/contextually grounded) rationality. After five weeks of debate, an independent citizens' jury delivered its 'verdict' on the emerging field of nanotechnology, giving recommendations, including more transparency on research projects and a greater emphasis on health, equity, and environmental protection: 'Manufactured nanoparticles, measuring just billionths of a metre across, should be

treated as if they were new substances and tested in controlled environments before being released' (BMC 2005e). The meeting not only established a new identity for the public as JURY but also nano as a (new) SUBSTANCE. As Mark (a member of the jury from the public) concluded at the end of the meeting: 'The only parallel nanotechnology has with GM is that a lot of people don't understand what it's about. The biggest risk is ignorance' (BMC 2005d). The jury's report pointed out that nanomaterials need to be assessed on a 'case-by-case basis'.

However, according to the ETC Group report *Down on the Farm* (2004), 'From soil to supper, nanotechnology will not only change how every step of the food chain operates, but it will also change who is involved' (BMC 2008q).[85] 'The problem is that the qualities that make nanomaterials so attractive to researchers and industry across a wide range of fields, including food processing, are the same qualities that could make them harmful to human health' (BMC 2013b), says Kathy Jo Wetter, who works on nanotechnology issues for the ETC Group, the Canadian technology WATCHDOG (BMC 2008q). In 'The Science of Nanotechnology is Already Revolutionising the Worlds of Medicine and Construction' (2008q), NANOFOOD represents health and environmental concerns at all three stages of production: farming, packaging, and processing. The reluctance to accept nanotechnology in the food industry is shared by Ian Illuminato, from the campaign group Friends of the Earth, who believes that many questions about nanotechnology remain unanswered: 'Nanoparticles can be more chemically reactive, they can have greater access to our bodies than larger particles, and when they become more bio-available there's a question of whether that also introduces new toxicity risks', (BMC 2013a) said Illuminato. The rise of nanotechnology in the food industry is perceived as being developed far in advance of public awareness: 'We've been here before: additives, irradiation, and genetic modification were all fixes promoted by industry which came unstuck on public opinion' (BMC 2013c). However, drawing the line between conventional food and 'nanofood' is not as clear as it might seem. 'Despite some earlier concerns that the use of nanomaterials in food was essentially unregulated, it is clear that nanotechnologies in food are regulated . . . . All foods that include nanomaterials, or are processed using nanotechnology, fall under the same regulations as conventional food' (BMC 2013 P318), says Diana Bowman, an expert in risk and public health at the University of Michigan.[86] The experts agreed that it is vital to investigate and debate the use of nanotechnologies in food now,

[85] Not only production but packaging too may change: 'Coatings made from smart nanoparticles that can sniff out the telltale gases given off by deteriorating food will trigger colour changes on labels. The label will also tell you when something is ripe. It's called intelligent packaging' (BMC 2008q).

[86] Something nano-sized is not automatically dangerous, says Mihail Roco, senior adviser for nanotechnology at the National Science Foundation in Washington DC, one of the US government's main research funding agencies. It is argued as important to remember that natural nanostructures abound in our food already: 'If you say nano-structures are dangerous, then you can't eat anything' (BMC 2013b). As physicist Frans Kampers argues, 'Food is naturally a nanostructured material . . . . Now we have the ability to study exactly what happens at that scale, and use that knowledge to design new nanostructures that improve our food' (BMC 2013c).

rather than waiting until there is a consumer backlash.

On one such ccasion, experts met NGOs at a *Guardian* seminar staged together with the European Commission (in 'Nanotech's role in feeding the planet: At the table', BMC 2013e) to debate 'how we will continue to feed the world' (BMC 2013a).[87] The invited panellists—Terry Jones, Kathy Groves, and Ian Illuminato, chaired by Alok Jha—considered how important nanotechnology is likely to be in this task. 'The scale of the challenge is reasonably well known', suggested Jones, director of communications at the trade association, the Food and Drink Federation, 'The more pressing number, I think, is the eight billion people on the planet by 2025. If we're going to feed them, then we need to produce more food, from fewer resources, with a smaller impact on the environment—and that's going to require us to think differently' (Ibid.). If nanotechnology is THINKING DIFFERENTLY, the same applies to regulation. 'I'm increasingly beginning to view regulation of the UK and EU food industry as positive', said Jones, 'But it has to be smart regulation—it has to enable new technology' (Ibid.).

It is difficult to talk about the role of nanotechnology in increasing the intensification and sustainability of agriculture without discussing genetic modification (GMO). Jones includes GMOs in his 'hypothetical toolbox' for tackling food security, alongside boosting traditional plant-breeding programmes: 'I think all parts of the supply chain [need] to look at the technological solutions that may be at hand—or to embrace new ones—and there are a whole range of potential tools in that toolbox' (BMC 2013a). Jones does not believe there is no role for nanotechnology in food security even though it is unlikely to produce more food: 'It could be one of the technologies that reduces water, food waste, packaging waste and the impact of agricultural production' (Ibid.). Jones describes nanotechnology (i.e. nano-enhanced food) as the 'smart answer' to global food security: 'If we're going to do this sustainable intensification of food security, it is technologies like nano that have the potential to help us with that sustainability side of the equation' (Ibid.). However, audience member Hilary Sutcliffe, director of Matter, a think tank on responsible innovation, emphasised the limits of nanotechnology in food, saying 'that people should be realistic about its use for tackling the impending global food crisis'. 'Nothing about nanotechnology is in relation to anything except Western, expensive foods that are slightly gratuitous and not particularly necessary', she said before adding that nanofood is not currently helping to feed the world, 'If you are going to talk about feeding the world, be brave, take on GM, let's have that discussion' (Ibid.).[88]

[87] The roundtable report was moderated by *The Guardian* and sponsored by the European Commission. It included Alok Jha, a science and environment correspondent from *The Guardian* as chair; Kathy Groves, a food microscopist from Leatherhead Food Research; Terry Jones, director of communications at the Food and Drink Federation; and Ian Illuminato from Friends of the Earth. The members of an invited public were in the audience and were also able to put questions to the panel.

[88] Similarly, science writer for *The Daily Telegraph*, Teresa Livermore, argued, 'GM is a hotly debated and often controversial area, but one with massive potential in terms of economic and human benefits. We need to make progress

The public is more willing to accept new technologies as medical treatments than in their foods. 'If using nanotechnology or other technologies in drug research will help them combat cancer, say, people say yes. They're all for that because the choice is to take the new drug or suffer severe consequences' (Ibid.), said Kathy Groves, food microscopist at Leatherhead Food Research. *The Guardian* panel recognised people just do not see the same issues for food. In nanomedicine, THINKING DIFFERENTLY is welcomed as when 'therapy thinks small to deliver the heat to stubborn tumours' (BMC 2014a). The author here argues that nanomedicine (therapy) is an acceptable label: 'It has already secured European regulatory approval because, classified as a medical device rather than a drug, it did not need to go through lengthy clinical trials' (Ibid.). More straightforward than the new generation of genetically targeted personalised medicines under development, '[f]or the genomics guys, this is not exciting . . . . This is just physics' (Ibid.), says the scientist. This all suggests the reconfiguration, and one that would secure a new label for nanotechnology in the aftermath of biotechnology (GMO), continues.

9.1.4 Prince Charles and the Shifting Role of the Science-policy-public Relationship

The previous metaphors and their systematic use can help to uncover a contrast in related arguments and provide an overview of the various alliances which emerged over the course of the nanotechnology controversy. According to metaphors related to the grey goo controversy, Prince Charles is among the actors coming early on the scene, bidding scientists in the Royal Academy to report on nanotechnology, in the sense of sending a modality object—the 'grey goo' metaphor. Prince Charles is a metaphorical PRINCE who had a nightmarish vision where 'nanoparticles could envelop the world in a "grey goo" that could finish us all off' (BMC 2005b) and who has given the nanotechnology threat a name and global image. His concerns are formulated prophetically in the future tense. The loyal Royal Academy transits from the initial phase—that is, hearing a call (manipulation)—and carries out an analysis (competence), after which it takes on the role of a helper and opponent.

The Royal Society's report (2004) was a genuine actor as it acted during the controversy as any human actor would. What a legal/official document like the report says can be as important as, or even more important than, what a human actor says (cf. Cooren 2001: 190). Setting up the report can be understood as an insertion into the Prince's narrative schema. Here, the government strategy to align the Royal Society report with the sub-schema contrasts with the insertion of the report in the moratorium call by activist groups. It can be considered a competence phase or narrative sub-schema. The report also translated as intermediary by calling the government to account for taking a

in assessing the safety of GM plants and changing opinions among the general public. If we are going to continue using biofuels, which take up much of the area that could be devoted to food crops, it will become ever more important to maximise agricultural productivity if we want to avoid sky-high food prices' (BMC 2008g).

decision in managing innovation regarding investment and safety checks. In this regard, the Royal Academy of Engineering (who made the report) appeared to be a powerful ally or helper (but also a sender). More importantly, however, the narrative schema splits into two different storylines. Prince Charles and the Royal Society did not necessarily share the same interest in being associated with the same technoscientific project (and imaginary). The Royal Society might have merely aimed at ensuring the fulfilment of its role as expert, which falls under its own legitimisation axis. Similarly, the Royal Society could also be considered a helper inserted within the government's quest, that is, by discounting the grey goo controversy as a mere scare story.

Even though the Royal Society found no evidence of harm to health or the environment from nanomaterials, the 'absence of evidence [should not be taken as] evidence of absence' (BMC 2008c). The chair of the Royal Society and Royal Academy of Engineering working group on nanotechnologies, Ann Dowling, argues:

> Far from eschewing public debate around nanotechnology, our study actually recommends that the government should initiate a public dialogue around this emerging area of science. This should happen at a stage when such discussions can inform key decisions and before polarised positions appear. Our report provides wide-ranging recommendations and we expect the government to consider them fully and carry out its own commitment to respond by the end of the year. (BMC 2004i)

The royal report thus passes another modality object which involves delegating other actors by authority (manipulation phase: 'having to do'). The government must perform and support the debate. Industry and governments seeking public trust (*desire* in Greimas) must not only assess the risk (competence) but become themselves transparent.[89]

As one of the articles mentioned, 'Its fully in their hands' (BMC 2008h). There is thus a fulfilment of the role where the subject lacks a certain object or has lost status, and this causes the sender (authority figure) to enter into a 'social contract' (BMC 2007b). The main axis of public debate (or *communication* in Greimas) is thus between industry (government) and the public. The public debate in the *enlightenment* phase represents public engagement of the citizens' jury. We can identify a stakeholder's commitment to a public debate which appears to be at the epicentre of the *commission* or *manipulation* that has mobilised a set of actors: the Royal Academy, NGOs, researchers, and the public from NanoJury and other initiatives (also in Figure 9.4). However, does the involvement of helpers and such a vast array of actors suffice to enable a successful performance against the opponents of the public debate? Are the media portraying clearly defined roles?

[89] More 'transparency' instead of 'secrecy'/'arrogance'. Which means, scientists/engineers should be telling the public what they are working on. Their 'culture of secrecy' has an emotional undertone, qualities ascribed to an opponent. The public is 'uninformed' which is also an ascribed status. In other words, the public debate is basically about combating emotionality coming from different strands as all involved happen to desire a more 'predictable' outcome.

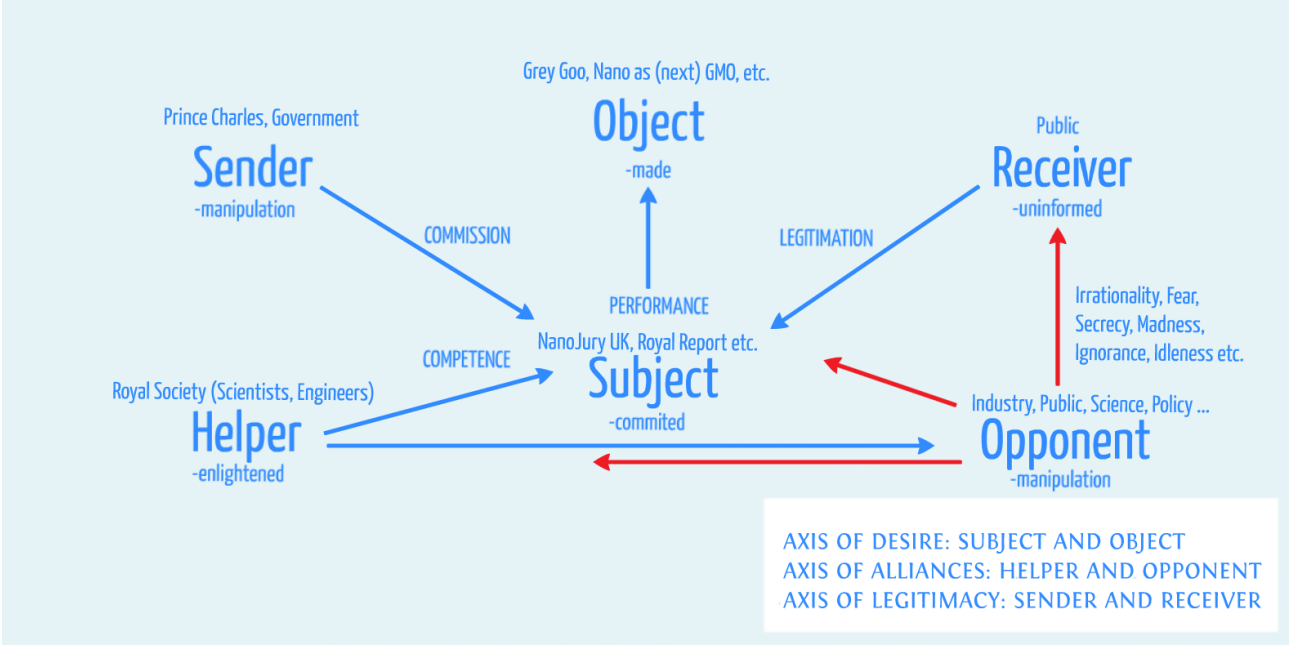


Figure 9.4 The narrative structure and storylines of the public debate in the UK media.

The problematic role of the public debate can be broken down into (two) different storylines as there are ambiguities in characters roles, evincing a polarisation of the nanotechnology controversy. Prince Charles is a public figure, not necessarily the hero or villain in the story. The choice between the two depended on the perspective adopted by the narrator—as it would when any opponent becomes the anti-subject. The tension created by the two opposing desires provides a priori the frame of the story (Cooren 2001: 188), and the events can be included narratively within these two schemas. For Prince Charles, self-replicating nanosystems (and machines) amounted to a threat to his order, that is, the environmentalist views for which he is known. This makes Prince Charles paradoxically a helper to activists and an opponent of scientists and innovators. In 2003, Prince Charles (proto-prince) brought the accusation based on his vision of a nanoworld consumed by nanotechnology. In the vocabulary of narrative structure, he is the beginning of the narrative with a public denunciation of science and government followed by the tasking of institutions which are supposed to respond in their performance; injustice can be formulated such that it may be judged by other institutions (cf. Boltanski et al. 1984). The prophecy is taken as an act of 'clairvoyance' or, conversely, as 'science inquisition'. This is where the narrative splits into two different storylines. What follows is a series of 'quests' to prove the functionality of the institutions as well as work towards their legitimisation. The UK government, sensitised by experience with genetically modified crops, recognises the object (the Prince's vision) and, in 2003, asks 'the Royal Society and the Royal Academy of Engineering to look into the environmental, safety, ethical and social implications of nanotechnology . . . the academies released a report, calling for tighter regulations and more research into the risks posed by ultra-small particles' (BMC 2005f). The

report request is a modality object (in the Greimasian sense) accepted by experts who issue 'dialogue' (debate) as a consequential event.

The high number of actors and their ambiguous character, however, effects their performance(s). The scientists are experts (helpers), but they also take on the role of 'mad scientists' (opponents); thus, we find another archetype of a TRICKSTER. Similarly, the industry takes on the role of receiver of governance support, as well as that of an opponent ('culture of secrecy'). In other words, its performance as such is questioned. Business, the government, and the public need to work out a new 'social contract' over nanotechnology, says Mr Rejeski, the director of the Wilson Center's nanotechnology project at the time, or venture capitalists will not risk their resources on a technology which might sink beneath 'public opprobrium' (BMC 2007b). Not convinced by government advances and science performance regarding ethical, legal, and social aspects, Pat Mooney, executive director of the ETC Group, thinks researchers must be careful*:* 'If people are too blasé about nanotechnology and it gets off on the wrong foot, then it's a problem. It is critical that scientists get it right' (BNC 2004e). Furthermore, if senders are described as enlightened (public) RULERs/LEADERs who, based on their clairvoyance (and prophecy), task the Royal Academy, they are also described as opponents with a fanatic zeal against nanotechnology ('science INQUISITION') set on achieving a moratorium. For scientists, and the UK government, nanotechnology amounted to a step forward in the fulfilment of a new role for academic science and technology (framed as building a TOWER). But Prince Charles became the intermediary of the science-fiction based quest (GREY GOO), hence why he is viewed by the scientists as an opponent in their quest.

There are several side-quests to the story of nanotechnology. The ETC Group (translated by Prince Charles as its intermediary) and the Royal Society both expressed their concerns over regulating nanotechnology. However, they really did not share the same quest; in other words, their outcome differed as the ETC Group's objective is the MORATORIUM, whereas the Royal Society issued government regulation with investment into nanotechnology. The ETC Group's strategic report, in general, is often inserted into nanotechnology narratives of resistance, and it can be inserted into a various, related sub-schemas. Activist and NGO groups call for a moratorium as this is the ultimate *sanction* for lack of transparency; by demanding a moratorium on nanotechnology various groups decided to align their action with the ETC Group and therefore diverge from government schema (forming helper-opponent alliances). Other alliances are represented between activists, scientists, and the public, such as when Greenpeace, the University of Cambridge, and *The Guardian* decided to unify their voice and their quests to establish a public debate. As we can see, the nanotechnology controversy advanced from a relatively simple situation to a more complex state of affairs.

Similar complexity is found in a dimension of the controversy where one subject (individual, or collective) aimed to discount the label 'Nano as (not) GMO', whereas other groups aimed to redefine the nanotechnology project as GMO. The articulation that occurred here between multiple actors had, however, a common project of setting up a public debate (this is important and contrasts with the French corpus, where activists boycotted the public debate). According to Cooren, a collective entity essentially achieves its identity by being given a voice (Cooren 2001, Taylor and Cooren 1997). On one hand, the translation was successful as there was a clear consensus that good regulation is essential. On the other hand, problems emerged as more actors started to speak on behalf of the public. When Greenpeace, the University of Cambridge, and *The Guardian* suggested holding a joint public debate, this initiated a phase of manipulation which would reformulate (translate) the role of the public—before that moment, represented by Prince Charles (i.e. techno-critique). It was to be associated with a 'citizens jury', which went against their previously translated role as a receiver (legitimising science and government) who was an 'irrational' and 'fearful' opponent. Here also, a problem specific to collective entities occurred.

The nanotechnology controversy in the United Kingdom was introduced and maintained by different metaphorical patterns and structures which extend to complex narratives with several contrasting figures and a vast array of actors, including nanoscientists, the government (also the Royal Society), activist groups, the wider public, and even a member of the British monarchy. The metaphor analysis enabled access to a level of the controversy characterised by ambiguities in issues, events, concepts, and ideas. In the following paragraphs, the discussion will focus on these unique metaphorical patterns and narrative structures, as well as providing arguments for the general discussion—that is, comparative measures in the final discussion.

9.2 Nanotechnology Controversy: Repertoires and Compositions (Discussion)

From the outset, the UK media coverage of nanotechnology resonated with various conceptual metaphors showing the richness/complexity of inferences as well as the capacity to impose general orientation of perceived values, attitudes, and, potentially, regulations. Articulation of these various positions offers a perspective on the durability of certain images, and it demonstrates shifts in nanotechnology perceptions. If we look at the nanotechnology controversy through the prism of these metaphors, we begin to understand the nature of media hype as well as how it became juxtaposed with techno-critique. These ambiguities related to nanotechnology seem to be in line with generic attitudes across wider technology areas and are not necessarily specific to nanotechnology. In many cases, media used metaphorical images to channel traditional ideologies in nanotechnology discourse (e.g. neo-Luddism, Malthusianism, capitalism, technology fix).

9.2.1 Mastery Metaphors and Moratorium: Building and Language

We could argue that MASTER (BUILDER) is an underlying (root) metaphor not only used for theory-constitutive purposes but also to provides a narrative structure for the view of development within several ideological positions, or put differently, how matters of concern unfolded. For example, the 'Tower of Babel' as a symbol from an ancient story is integrated into a prolific modern-day myth with a clear message for nanotechnology development—a programme of convergence and building post-modern science. The particular expression that 'Nanotechnology is Tower of Babel' here includes a LANGUAGE domain as the 'convergence is (universal) LANGUAGE'. The idea is that given the right LANGUAGE CODE—algorithms and culture—all of humankind's problems can be solved, effectively making life totally calculable and trouble-free. Nanotechnology resonates with stories about using biotechnology as a 'smart solution' to combat overpopulation and food crisis (Malthusianism); in this sense, nanotechnology is framed as an 'ultimate toolbox' in the repertoire of production, packaging, and consumption (still an issue for food democracy). The 'toolbox' is an imaginary of technology fix; it has an explanatory function as it provides a clear model for the political process under discussion, and it contributes to the persuasiveness of the main argument: BUILDING the world atom by atom and the union of all LANGUAGEs. As a consequence, these metaphors of MASTERY represent nanotechnology as an engineering and communication issue rather than an ethical problem. It aspires to bring about convergence encompassing the whole society. It uses ancient myth-telling to form narrative and argumentation in favour of nanotechnology—'a tower that will last' (BMC 2003a). The use of the LANGUAGE and COMMUNICATION (MASTERY) metaphors are closely related to the conceptual CODE metaphor used in biotechnology (genetic research) discourse: 'This code is essence of mankind, and as long as human beings exist, this code is going to be important and will be used' (Nerlich and Dingwall 2003: 420). The Tower of Babel could thus be understood as a strategy of creating protected space for science. A similar strategy is naturalising nanotechnology through the metaphor MOTHER NATURE (MASTERY), which forces the argument that 'any natural food is nanofood' and 'nanofood is any food'. As long as these phenomena are found in nature, there is no question as to the legitimacy of projects which are mimicking (not bending) nature to increasing quality of life. The MASTERY metaphors thus provided a certain protected space.

However, this protected space has been breached from within by re-figuration of the above concepts, as realised by expressions such as 'grey goo', 'virus', and 'Frankenstein nanofood', as well as other metaphors evoking particular scenarios of what can go wrong. As such, these question the MASTERY concept which cannot be shaken off when 'things get out of hand' as its counter-imaginary. There is more to the scenario than a type of planetary horror story where

'nanomachines' eat planet Earth. The metaphor shifts from multiple representations and becomes a challenging issue for regulatory bodies, questioning the legitimacy of institutions. Grey goo is not thus just futurology, a post-catastrophic science fiction scenario, it extends to the regulation discourse as well; ultimately, the media represents grey goo as a regulatory issue. The LANGUAGE metaphor also applies here, contrary to the prevalent MACHINE/ANIMAL concepts for robots and insects. Grey goo has been defined in the corpus as a form of (viral) ideology which inflicts collective MIND, spreading ANXIETIES and FEARS from within the anti-technology movement (cf. reference Dawkins and 'ideas as viruses'). If convergence is (good) LANGUAGE (THINKING) and grey goo is (bad) LANGUAGE (THINKING), Nanotechnology is contested on the ground of the LANGUAGE/MIND metaphor, shifting the semantic of containment and cure. The metaphors used to make nanotechnology convergence accessible, in a way that is broadly understood by the public, are again used creatively in new contexts, and as we have seen, they may even serve opposite purposes spelling out arguments which do not support nanotechnology.

One of the effects of the ongoing controversy is that the media uses metaphors not only to emphasise the magnitude of scientific achievements but to simultaneously deny assurance to the public that this research would only lead to positive outcomes. At no point were clear answers given as to whether there should be a MORATORIUM. Or at least there were as many euphoric and reassuring metaphors as there were catastrophic and phobic ones. It is a common saying that 'fear thrives on the lack of knowledge'. The media provides a certain level of knowledge, but they also exploit the ambiguity concealed in metaphors, exhibiting a certain 'politics of fear' (cf. Furedi 1997 and 2005). The metaphors are used not only to provide familiarity (and appropriate nanotechnology culturally) but to exploit/use its ambiguity as a resource as well. The Royal Society and Royal Academy of Engineering report changed the discourse to the point that it was highly influential internationally and led to the United Kingdom being seen as a world leader in its engagement with nanotechnology. The Royal Society's report (2004) and its intertextual use shows how the media uses expert knowledge to advance concerns about nanotechnology. Translating the concerns in its own assessments with the 'report', the media describe nanotechnology based on scientists and technologists from diverse fields, activists and watchdogs dedicated to exposing government and corporate misuse, etc. They also assist in assembling public perceptions from a panel of opinions (NanoJury and *The Guardian* panel) and where discussion turned back to GMOs. Altogether, nanotechnology extends to other controversies on a metaphorical level which relate to nanotechnology through the MASTERY metaphor, including images of 'mad scientists' or 'regulatory failure' in the deliberation processes so as to connect more robust science with the public.

9.2.2 Nano is GMO: A Controversy Reopening

The narrative analysis also proved to be a viable approach in exposing the ambiguity of the nanotechnology controversy. The public trial of grey goo—in other words, the failed mastery of science—was initially seen as a contributing factor in the perceived risks but also irrationality and fearful reaction, even a zealous campaign against nanotechnology on behalf of the ecological movement. And further, the nanotechnology controversy here alternated between sub-schemas of 'science mastery' and what we might even call the 'narrative of the (mad) scientist', in which the phenomenon under investigation, 'the scientific activity', is the object; the (public) policy narrative and what we might call the '(uninformed) public narrative', in which the phenomenon under investigation, 'the public trust', is the object. Whereas the first narrative follows the processes that occur at the nanoscale and in the laboratory—or simply the activities of the scientists who do experiments—the second narrative follows the public as it is enclosed in their emotionality or in relation to public doing policy (political processes), blinded by their emotions and sentiments such as with GMO syndrome. The public thus took on multiple roles of receiver, opponent, and helper. The role of industry was described as incompetent (anxious, fearful) and competent ('it is in their hands'). There are practitioners and recipients, but these categories were not as clear cut. The public is a fearful and irrational force swayed in their emotionality against nanotechnology by activist movements which proclaim 'nano as (the next) GMO'. As a jury, they possess rationality. Interestingly, the helper-opponent relationship can be abstracted at another level as representing scientists and the public through different rationalities. As much as it represents an axis of alliances, the objective of the debate in finding a balance between different 'social rationalities' may have been accomplished. At the same time, some of the re-figurations ('Nano is [not] GMO') during NanoJury and *The Guardian* panel are reasons why the nanotechnology controversy remains open-ended.

The case of GMOs suggests metaphors allow for controversy re-opening. The study shows how actors experience with the GMO controversy translates to nanotechnology, and in Knudsen's (2003) terms, authors 'open it up'. They use it systematically and creatively to structure their arguments, explain scientific issues and hypotheses in common language clearly and vividly, and entertain readers with some humorous phrasings and ambiguities (Semino 2008: 144). This capacity is foundational for analyses of the transformations (thesis) and where former conventional metaphors and stable meanings get activated and translated into new contexts; they provide dynamism and momentum. In other words, the attention given to nanotechnology as 'another GMO' might/should be understood as an important mechanism of transference. The media compared GMO (syndrome) to nanotechnology based on the implications for the food industry alongside more recent attitudes towards democracy and sustainability. And as much as nano *is* or *is*

not (the next) GMO, the metaphor works. What is more, it is genetic modification which becomes more like nanotechnology.[90] The case of nanotechnology opens the GMO case as well. Rather than leaving GMO as a coherent and stable source domain, the GMO case shifts through nanotechnology discourse into a new figuration, one that potentially favours it among the solutions to our food problems (in ref. to Malthus). As one of the panellists remarked, 'Be brave by taking GMO back', as a part of the 'toolbox'. To provide another example outside the corpus, we can consider the 2018 argument in *New Scientist* informing about 'august bodies' (i.e. institutions worth respect and admiration). The author argues that from the US National Academy of Sciences to the United Kingdom's Royal Society, all agree that food from genetically modified organisms (GMOs) is as safe as any other: 'Refusing to accept GM food is safe is like climate change denial'. The nanotechnology controversy case study here shows a mutual resonance with other controversies. It suggests the inter-discursive strategies of metaphor-driven rhetoric prevent the public debate on nanotechnology from reaching closure or ending. As with previous case studies, such capacities of metaphors and discursive formation will be explored further in the final discussion.

9.3 Conclusion

The UK experience with nanotechnology has been shaped by expectations of future applications as well as by previous regulatory failures. The study found it thus important to follow the social representations in their dynamic and the way the media translates between scientific research, policies, and the public images. In particular, nanotechnology, as an issue of public acceptability, oscillated between recognition of science 'mastery' to 'moratorium' based on various rationalities. These rationalities as such were metaphorised as, for instance, 'buildings' and 'language', or questioned as 'madness' (science), 'secrecy' (industry policy), or 'uninformed fear' (public). Therefore, the various metaphors allowed for the articulation of positions supportive and critical of the various contents of public debate. Metaphors, such as 'grey goo' and 'nanofood' (also GMO), were used in relation to scientific issues that may not have been directly relevant to scientific research as such, but had an influence on public and political opinion, and potentially, nanotechnology development. The Royal Society report and NanoJury in particular, are well known cases worldwide, and this study updates the understanding of them in the context of a media which made attempts to include public and expert opinion so as to channel contradicting views. The study of metaphors in the UK media coverage indicates that controversies are more related, multilayered, and co-exist in a re-figuration. In other words, nanotechnology, as a multilayered controversy,

[90] The metaphorical resonance is activated even when the argumentation was based on the metaphorical transference of 'Nano is (the next) GMO'. The theory of metaphor has been consistent in saying that even when '*X* is NOT *Y*' (cf. 'Man is not a wolf' in Black 1962), it implies a metaphorical transfer as the two semantic domains come together.

mutually merges images from science, policy, and public into each other, and these provide mutual dynamism and momentum. The effort to reduce nanotechnology to a problem of scientific research versus public acceptance contrasts with a tendency of the actors to take multiple roles in a narrative schema without any clear ending and that could serve to close the controversy. Still, the nanotechnology controversy in the UK shows how all actors mobilised their alliances and number of metaphors to reach their strategic objectives. As in previous case studies, we could observe that ambiguity played a role in these strategies.

Part VI Discussion

Chapter 10. On the Relationship Between Metaphor and Nanotechnology

The case studies, limited as they are in reaching the complexity of issues, revealed remarkable variation in the social representations of nanotechnology. This variation exists during a time when science and the government (EU) science policies would lead one to believe that models of development are moving toward standardisation and that convergence is the last word. Still, by reassembling the social representations of nanotechnology in three distinct corpora, the evidence suggests a greater variability. Nanotechnology seems historically and ontologically bound to perspectives of opportunities and risks, and all the actors involved try to mould technoscientific possibilities into clear economic, political, and social relevance. Yet, it seems the public debates, especially with unbiased, transparent information and dialogue in mind, haven't resolved concerns about *nano*. As the national (cultural) contexts of nanotechnology suggest, there are complex, multifaceted problems which require complex solutions. Moreover, the investigated nanotechnology discourses suggest the nature of these transformations requires opening up to further historical, as well as epistemological questions. This has significant implications for future research which are outlined in the following discussion concerning the integration of both the actor (repertoire) and the structural (compositional) perspective.

The title of the presented thesis promised a 'comparative' study. The comparative aspect is tied to how all the case studies can be arranged with respect to metaphors (also common concepts) and their capacities, narrativisation, and discursive formations, and, finally, how the *transformation* thesis can be addressed in light of the empirical evidence. The terms we investigated in Web of Science, CORDIS, and the national media corpora are not accidental. They are organisers of actions, concepts to indicate perceptions, issues worth studying, and actions worth taking. The emergence of nanotechnology discourse can be reviewed as a comparative view on various capacities, the composition of the nanotechnology discourse concealed in the narrative dimension and root/master metaphors which unfold into discursive formations. The discussion will thus refer back to the theory and establish what I found consistent with the existing literature, and what was somewhat unexpected or controversial. Finally, I address the question of *where to go from here*—to return to a metaphor of a crossroad.

Metaphors may not be immediately recognised as crucial for identity and boundary work, or identification of a group, and their strategic use remains concealed. Yet, their functionality still reaches beyond their cognitive value—meaning they are more than a perspective giving rhetorical device. In the following subsection, metaphorical capacities will be addressed as powerful, flexible tools for articulating political positions, for assigning or denying authority and legitimacy, and for re-conceptualising future. They reach to the future as they establish links to former and fictional storylines, ancient technology myths (allegories, monomyths), and even archetypes. By understanding the capacities of metaphor(s), we can begin to understand how they shape and intervene in technology development. As the times and locations between any of the cases studies are rather disconnected, we can still identify common chains of signification and, arguably, metaphorical transferences (*re-figuration*) within the narrative dimension. The narratives will be discussed as they perform dynamic transformations resulting in the formation of ontologies and the creation of complex accounts of identities and histories. Finally, the discursive formations of *creative evolution*, *nano-Orientalism*, and *risk/fear controversies* discussed in this chapter are taken as evidence of strong and fundamental convictions about the nature of progress alongside multiple transformation points between science, policy, and the public. In particular, 'Moore's law', 'technology roadmaps' and 'Nano is X(X')' are *root/master* metaphors which portray the emergence of the above formations while pointing at an elementary iteration of metaphors for (science) policies and public debates articulated against clearly developed technoscientific prowess.

10.1 Activating, Generative, and Organisational Capacities: Repertoire View

In the presented thesis, I found enough evidence to suggest that metaphor does not merely represent (for) something in terms of something else, it is not simply a new mirror to represent reality, it also represents and intervenes at the same time; representation and intervention are entangled. If we adjust metaphor to lenses of discourse analysis, it emerges as a powerful device in nanotechnology discourse. It creates cognitive spaces for the strategic practices of different actors and institutions. It may change who and what counts, creating and sustaining relationships. Metaphor can shape strategies which trigger matters of concern, providing space to new strategic actors. To capture this relationship between metaphor *and* nanotechnology, I propose three concepts: *activating*, *generative*, and *organisational* capacities.

10.1.1 Activating Capacity

First, we should consider metaphor in terms of its emergence and widest applicability in articulating political, scientific, or public matters. To articulate matters of concern is an activating capacity. The way metaphor is applicable to a large variety of situations (contexts) makes it an *active* instrument

or language in action. This capacity can be approached through concepts such as ‘flexible words’ (Edelman 1977), ‘metaphors-in-practice’ (Yanow 2005), and metaphorical intertextuality and inter-discursivity (cf. Bono 1990, Koller 2004).

The core of this capacity relies on new metaphors which dynamically unfold over time in an interaction (cf. Müller and Tag 2010). First, metaphors are coined ad hoc to express some new insight. They are in fact dynamic tools, although they are, to a large extent, conventional metaphors within science and strategic planning—and the media discourse. There is yet an important dynamic in their becoming conventional or novel. Anything can be metaphorical to anything, and even conventional metaphors can become dynamic in new contexts. For example, the category referred to as ‘roadmap’ can be described by a list of distinguishing features, but it is difficult to enumerate these features exhaustively. The speaker can create new utterances within the concept of event or location, and the hearer can associate additional qualities, such as when we consider aspects of the various maps that are marine, military, treasure maps, references to different shortcuts and passengers, and such, each of which allows new insight into a strategic plan. Here, the fundamental difference is when activating capacity is triggered and actors are not interpreting within a systematic metaphor (roadmap generative readings) but approach the concept differently to create an entirely new reading of the roadmap. This means metaphors are used as a tool in counter-argumentation to empower those who wield it with the ‘force’ to break through those ‘protected spaces’, like imaginary ships, temples, laws, and so on. For example, the ETC Group produced a series of reports on the social implications of nanotechnology, some of which actively exploit the ROADMAP concept not to support or follow regulation but to subvert it. The MASTERY metaphor can likewise serve to sustain or subvert meanings within discursive formation of ‘creative evolution’, such as when it becomes involved in narratives of the mad scientist’s creativity with nature as in the ‘Frankenstein NanoFood’ or ‘Nanospider webs’ metaphors, which became a powerful imaginary for technoscientific projects and their techno-critique.

The strongest activation effect of metaphor is when the reconfiguration within and between discourses happens. The reconfigurations allow the extension of the discourse or even the establishment of opposing views. Such is the case of techno-critique based inter-discursivity. ‘Nano is GMO’ translates discourses and activates systems of association, thereby normative systems. Similar relations concern religious metaphors. For example, the Minatec innovation cluster, founded by the Grenoble Institute of Technology and CEA Grenoble, has been represented as the ‘temple of nanotechnology’, a creative metaphor that provides insight on behalf of our knowledge of other temples and sanctuaries. Religious discourse thus becomes implicated in the emergence of transcendental visions of nanotechnology and how these visions are articulated, conceptualised, and institutionalised—how science policymakers and nanoscientists are becoming the clerics of the new

age. Similarly, as a BIG SCIENCE concept, it can be re-figured into BIG BROTHER, allowing techno-critique and activism to extend the discourse on nanotechnology. Moreover, in regard to the public debate, we have seen how the image of a TRICKSTER was used not only to describe science (scientists as Dr. NaNo, *R.U.R.*, the Sorcerer's Apprentice) but also policy (organisers of the debate as Pied Pipers) and the public (activists as Luddites). The activating aspect of the debate relied on a mechanism of metaphor which introduced counter-imaginaries but was not limited to them. The utility of dynamic MACHINE/NATURE metaphors for science modelling, meta-regulation, or socialisation (and techno-critique) crucially depends upon the figurative open-endedness and inter-discursivity. Metaphors activated a certain extension or chain of signification which was, at the same time, restrictive (deactivates). Activating capacity sheds light on use, whereas 'metaphor effectively frames the situation and at the same time it blinds us toward other possible ways of reframing it' (in Yanow 2005: 7). Furthermore, this does not remain in the domain of interpretation, but action frames. This is best described by generative capacity.

10.1.2 Generative Capacity

Generative capacity of a metaphor is best characterised as a relationship between defining a problem and, by the same transference, defining a (future) solution (cf. Schön 1993, or Rip 2006 and 2012). What should not be omitted is that, conversely, a description of the solution (it can be an expectation or anything else which figures in the future) can feed back into the definition of a current problem or affair. Sociologists know the effect as the power to transform current practices through the 'self-fulfilling prophecy' mechanism (cf. Merton 1948). The prophecy is a consequence of collective action based on the definition of a situation which is accepted as a true description. It is powerful exactly because it also concerns a shift to figurative truth under the current expectations of future states. It is more than a meaning generating mechanism.

For example, Moore's law is a metaphor for PROPHECY adapted to technoscientific networks. It generates relationships in different contexts based on prediction/expectation and problem-requirement cycles (cf. van Lente and Rip 1998, Rip 2012). As we have seen in the first case study, the transistor is an ANIMAL that 'lives or dies' according to the law, and it exists in many forms as generation of SPECIES with an adherence to the law. It is the character of metaphor which allows transmission to various scales: from the density of transistors on a chip and the engineering (industrial) roadmap to even society developing according to *the* law and its principles of exponential growth, NOOGENESIS, and creative evolution. Perceiving the transistor through the metaphor of an animal and Moore's law as elements of creative evolution, however, arguably has effects on *naturalising* technology that go beyond the image of the TREE (dendriform metaphor of biological evolution). In this sense, the generative effect works towards legitimisation, which concealed in a ROADMAP accentuates the aspect of control (evolution is DRIVEN) and current or

future efforts to maintain it.

Generative capacity creates links between disciplines, institutions, and practices, and also relies on 'boundary objects' (cf. Star and Griesmeser 1989, Joly and Kaufmann 2008): 'In natural history work, boundary objects are produced when sponsors, theorists and amateurs collaborate to produce representations of nature. Among these objects are specimens, field notes, museums and maps of particular territories' (Star and Griesemer 1989: 407). The objects maintain relations 'stable enough to enable coordination across communities of practice' (Ewenstein and Whyte 2009). As Brigitte Nerlich (2014) argues, 'Once widely spread, buzzwords [like responsible innovation] establish something like a "trading zone" in which people from different backgrounds . . . can communicate without however having to be too explicit about what they are saying.' With a somewhat more normative agenda, Gorman et al. (2009: 185) examine the role of ethicists in nanotechnology research and argue for 'the establishment of a "trading zone" coupled with moral imagination' to facilitate collaboration and effective communication. The material-semiotic character of Moore's law but also of technological inventions such as Nanospider technology here suggests a certain degree of 'immutability' and 'mobility' applicable to various knowledge (objects) in technoscientific networks (cf. Latour 1987). The objects being translated retain some of their key features in a figurative form. After all, as has been argued, Moore's law and its corresponding immutability retains status as figurative truth or prophecy. When Moore's law 1.0 or 2.0 'dies', it is 'reborn' to become 'king/ruler'. Similarly, metaphors of a spider WEB or WEAVING allow for the constitution of a generative schema which gets filled out by each actor, collective or individual, putting it to work in a certain contextual setting. It has multiple forms, meanings, and interpretations and thus allows different people and groups to appear to be 'speaking the same language' while still retaining different perspectives on the object of knowledge.

The technology ROADMAPs, but also WAVES, CRUCIBLES and so on, analysed in this thesis have a similar generative capacity which concerns complex sociotechnical landscapes with evolutionary pathways, gaps, and bridges and various events both, controllable or inevitable. After all, Moore's law can be considered just *a* type of roadmap. The generative effect here emerges when the technology roadmap, combined with a metaphor of a journey, creates a conceptual space for the actor's qualifying roles: travellers, passengers, drivers, competitors who set impediments to motion, and so forth. In the European Union in particular, the generative capacity is put into practice as an *open method of coordination* (OMC). With this method, the European Commission attempts to improve coordination and coherence of national policies, translating the ERA objectives into specific targets and policy measures for each member state (Commission 2002: 19). Nanotechnology's 'generic roadmap' may still seem unrealistic since the field is too broad and technology roadmaps are preferably applied to market sectors which have reached sufficient

maturity (cf. Commission 2004). The European Strategy Forum on Research Infrastructures (ESFRI) roadmap fulfils such criteria of generative readings at the pan-European level, even though other, sector-specific roadmaps may require more restricted codes.

The generative capacity that can be related to Nanospider technology concerns it as hybrid MACHINE/ANIMAL object. The Nanospider represents an object of technoscience and a hybrid specimen which passes through multiple generative translations from nature's MASTERY to engineering. It is translated from its place in the laboratory (its VIVARIUM-like ecosystem) to a unit of economic exchange and cultural value. The Nanospider catches environmental evils in its nanofiber webs, but the meaning of the specimen outside the laboratory never becomes fixed. If it were not for its robust structures, it would fall apart under the circumstances of its implementation across different scientific cultures, managerial platforms, and market pulls. 'Nanomachine is a spider' is intended as a pro-nanotechnology statement about a competent practitioner—the transposition of MACHINE and ANIMAL—and as such should be considered within associated correspondences that belong to the domain of rhetoric (naturalising technology), poetics (bio-mimesis), and also pragmatics. The relation of the Nanospider to 'nano-silk' as something descended from Chinese silk, further generates images of the 'nanospider in a vivarium' or frames the creators of the 'nature-like-device'. Altogether, these images generate arguments about problems (industrial exploitation of silk), competence (electrospinning webs), and performance (capturing a virus, expected valorisation of research, etc.).

The generative capacity suggests metaphors are deliberately vague and sketchy. And while this can be regarded as a weakness for allowing a further practical grasp upon them, it is also among their key strengths. With generative capacity, there is a trade-off between saying too much and too little, between providing maximum reusability while still yielding efficient, concrete implementations. Related to that, generative capacity, as a specific set of correspondences, alone does not explain well the selective directionality and intentionality of a speaker; in other words, why particular conceptual domains are 'forced' together to create a particular blend. Yet, the generated metaphors are a specific projection. Context must be added to explain why particular entities come together, such as 'science policies are roadmaps' (their implementation are journeys), 'nanotechnology centres as temples' (their scientists as priests),[91] 'nano-scientist as Frankenstein' (Dr. NaNo, Nano R.U.R., Sorcerer's Apprentice, etc.), 'nanomaterials as GMOs' (but also nuclear or asbestos), and so on. The critical discourse analysis is ideally suited to point out that these metaphors are strategic and ideological because they come to represent specific values and views and intervene as attitudes and actions.

[91] Generating images of nanotechnology centres as 'temples' is not trivial rhetoric; to the contrary, it transforms 'profane' science into a sacred ordeal. In other words, metaphors have the capacity to link or otherwise relabel/reconfigure the 'profane' and 'sacred'.

10.1.3 Organisational Capacity

Metaphors are organisational in the sense that they allow actants to align together, uncovering their competences and roles. The *organisational* capacity manifests itself when a systematic metaphor is established and relies on narrating as a fundamental organising process. It is also a capacity through which the order of discourse manifests itself as certain rules of engagement between various actors, whether it is scientific research, policy, or public debate.

The Moore's law or technology roadmap metaphors, for example, offer the most coherent view on organisational capacity to determine nanotechnology development through metaphorical scenarios, networks, and narratives. The metaphorical perspective on the law revealed a structure of elements to indicate states, events and relationships, actor's roles, competences, values, and so forth. By exploring the European Commission's documents in CORDIS, we have seen roadmap metaphors and their embedding into narratives which may have implications for the organisation of texts, as well as for the policies of organisations. The implications for the organisation reach beyond the literal, extending to various regulatory commands of soft laws and the open method of coordination (OMC) in the European Union. When we speak of metaphor as organisers of actions, we have in mind a process which relates to perceptions and attitudes, even reaching emotions. This idea reflects one of the most important messages of the Frankenstein narrative: Scientists constantly reinforce the notion that nature and even people should be manipulated and perfected through the practice of science (Passmore 1978). Nanotechnology here interferes with imagining scientists as authority figures who like to interfere with the natural order of things. Scientists are therefore considered dangerous and inconstant experts (cf. Mulkay 1993). Metaphors such as Frankenstein food (UK), the Sorcerer's Apprentice (FR), or nano-R.U.R. (CZ) are responsible for the emotional as well as strategic ambiguity in the public debates (see later discussion) as they organise the story of nanotechnology. Metaphors such as the Tower of Babel, Brave New nano-World, or the Pied Piper are other examples of stories which are 'cultural storehouses of organisational information', where sensemaking and organising processes are interconnected (cf. Brown 1985: 28).

The organisational capacity points towards the problematic role of metaphor, which here includes public debates set within the conditions of functional/organised 'ambiguity', only seemingly a sign of '(dis-)order'. Even the strategic imposition of ambiguity should be considered an extension of this mechanism and a true 'mastery' of metaphor. In the Foucauldian tradition, however, we must deal with the organisational capacities as they revolve around mechanisms (incl. 'nano-DISPOSITIVE') of power-knowledge, a much deeper mechanism represented by ordering words (cf. *mot d'ordre* in Deleuze and Guattari) and an organised field of practices. The function of such metaphorical ordering (therefore a *métaphore d'ordre*) is to effect transformation. It predicates and describes the scale of future changes but also points out how change can or should happen at

the societal level. Even if the validity of one of the most prominent nanoworld laws changes (Moore's law), as a re-figuration or metaphor, it has capacity to reorganise its former 'success story' into a meaningful narrative and one that corresponds with further unveiling of the law through creative evolution (cf. the 'naturalisation' of Moore's law through biological evolution in Joly and Kaufmann 2008). The issue with Moore's law is not a trivial one since it is a price-performance figure related to high financial costs and the social organisation of whole economies and industries. It also suggests a rationale for the existence of a laboratory under its current organisational form. It is the reasoning behind the existence, structure, behaviour, and relationships. The organisational capacity will be explored further in the next section on nanotechnology narratives.

All in all, even though the above capacities (activating, generating, and organising) of metaphors are placed in ideal-typical categories, this does not mean their functions are not mutually implicated and may not be fully consistent between actors, topics, and genres, or that they cannot lose some of their capacities in the context of their use. Moreover, the three capacities are equally all applicable to the relationship between metaphor and nanotechnology, with a concomitant shift between the metaphor *of* nanotechnology to the metaphor *for* nanotechnology. In line with structuralist and hermeneutic theory, a metaphor is a structure and equally a creative *force* that revitalises language (and social reality), something which, through the nanotechnology-minded individual, happens as an organising 'event' to the discourse. The activating capacity is triggered and at its peak, when a new metaphor is introduced, whereas the generative capacity increases with the systematicity. The essence of a metaphor's dynamics is based on conventionality vs novelty. This situation includes, however, both when the (conceptual) metaphor is embedded in a counter-narrativisation or counter-argumentation. Activating capacity may be weak in dead or sedimented metaphors, but this is a rather temporary situation based on the actor, who can use an old metaphor creatively (context-dependent). Organisational capacity is given by the size and quality of a network, strategic alliances of actors, and by metaphor embedded in narratives (see next section). Table 10.1 (below) summarises the above-mentioned capacities of metaphors and provides examples of their functions.

Table 10.1 Metaphor Capacities (Repertoire view).

Metaphor Capacity	Examples of Capacities
Activating	Opens/(un)locks venues
Generative	Problem-solution (promise-requirement) cycle
Organisational	Designates roles (incl. ambiguity)

10.2. Narrative Dimension of Nanotechnology: Compositional View (Part 1)

To further discuss the above capacities, I will now advance to modelling nanotechnology discourse at the narrative level. Each particular nanotechnology controversy studied in the analytical chapter has been previously read like a narrative allegory (narrative with metaphorical operators). This particularly extreme form of narrativity can be advanced even further. The presented section will now combine evidence to show how the narrative accounts and seemingly fictional stories may be used to capture the inner structures of formations which characterise the entire science-policy-public interface.

10.2.1 Nanoscience and Promethean Ambitions (Narrative within Creative Evolution)

There is strong evidence that nanoscientists themselves cannot approach some problems (e.g. associated with the nature of nanoworld) without mobilising the metaphorical domain. And this reaches inside and also outside the laboratory; it transmits from repertoire to composition. In the studied science corpus, the metaphor 'creative evolution' relied on the metaphor for molecular (self-) ASSEMBLY and using nature as a RESOURCE. Self-assembly is also a technical term but one which can be worked with historically to revoke the argument of nanotechnology as post-modern alchemy (Mordini 2007a). Nanotechnology, like alchemy, has aspirations to uncover the mysteries of nature so as to possibly provide technical, political, and social solutions, from the generation of single-molecule transistors (WoS) to electro-spun nano-silk (CZ), healthy nano-food (UK), or artificial nano-muscles (FR). The alchemy period (between 300 BCE and the seventeenth century), the predecessor to modern chemistry, was dominated by metaphors rather than systematically controlling them (cf. Gentner and Jeziorski 1993). However, there are clearly common grounds that also apply to nanotechnology as its story is filled with allegories and archetypes of transformations. Do nanoscientists, like alchemists, have passions and aspirations comparable to that of discovering the Philosopher's Stone? Alchemy resonates with the theoretical concept of the 'universal molecular assembler', questioning if any material or form can be constructed from the nano level—something like Star Trek's 'replicator'. This has still incited much

controversy and critical discussion (cf. discussion between R. Smalley and E. Drexler on 'bottom up' techniques in Baum 2003). In these controversial debates, the science as well as the researchers' and engineers' credibility can be subjected to metaphorisation.

When Mary Shelley wrote her novel *Frankenstein* (first published in 1818), she introduced it with the subtitle 'Modern Prometheus'. In her rendition of the ancient myth, the story was, in plot and characters, ranging between nobility and lowness, from luck to misfortune, mimicking actions from the much older tragedy. Nevertheless, it was already a creative act of time experience through a story emplotment: The plot was part of the older circle or mimetic arch, and a new combination of mythos and mimesis (cf. Ricoeur 1990). Such a narrative still shows metaphorical overlap between the present, the past, and the future, and on the psychoanalytic level of denotation, even *archetypical/archetypal*. For instance, it has been argued the 'Frankenstein's nanofood' metaphor frames understanding not only of the moral but also the emotional content of the public debate on nanotechnology. In this case, the scare story of 'nanotechnology as (the next) GMO' reaches *Frankenstein: Or Modern Prometheus* (1818), and it becomes a carrying structure for the story of nanotechnology. The metaphor, at the level of media message, served the demands of the 'moratorium' on nanotechnology (food industry), just as it has been previously used for years to label genetically modified organisms (GMOs). It is clear that the media here have reduced two (GMOs and nano) initially separate manifold phenomena (areas) under one orientation frame. It is about moving a certain experience (or group of images), a gestalt, a story about Frankenstein, to redraw our time experience or to create another kind of experience, that is the story of 'nanotechnology'. Nanotechnology is metaphorically linked to a certain, in this case, archetypical meaning, where the continuity is systematic, structured, and with a plot (also in Figure 10.2 below).

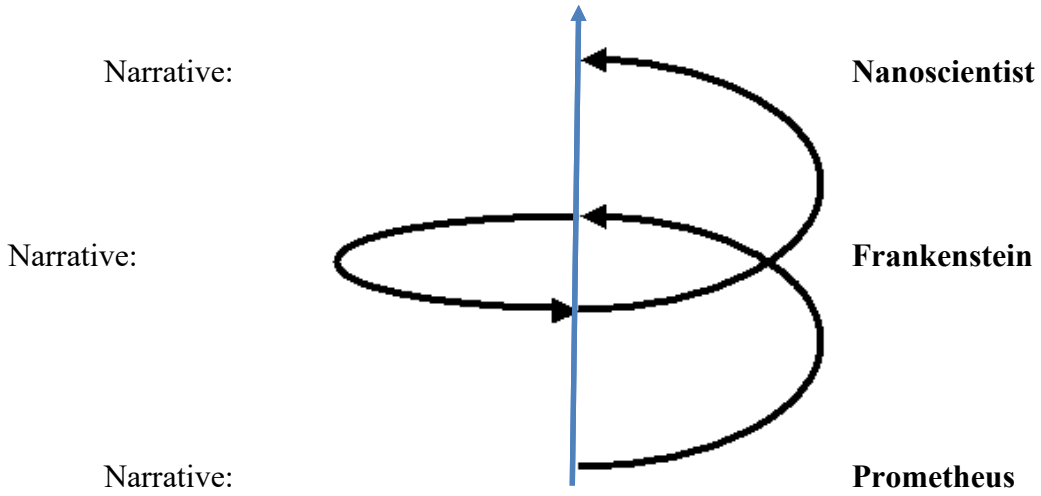


Figure 10.2 Transformation as narrativisation (inspired by Ricoeur 1990: 88).

In Figure 10.2, the relationship between metaphor and nanotechnology is formalised as a chain of signification within the dynamic semantic framework. The schema also corresponds to

some of the basic questions regarding the identity of nanoscientists and their relation to the world and its objects, their needs and desires, etc. The characters themselves embody *creative imagination*—the ability to form meaning—pointing to a certain *self-creative* and *self-transformative* capacity. Similarly, Johann P. Arnason considers these imaginary significations as 'universes of meaning', so-called 'semantic complexes', which can be understood as 'implicit or pre-given answers to questions about the human condition' and which shape the cultural profiles of the respective societies (Arnason 2003: 227, cf. Castoriadis 1997[1987]: 147–56).

Among such semantic complexes, which are related to the above re-figuration, is the Prometheus complex—the ambition to change the world (cf. William R. Newman and his *Promethean Ambitions: Alchemy and Quest to Perfect Nature*, 2005). Concealed in this complex are movements of the mind which have led to the development of ancient alchemy, medieval and modern chemistry, and genetics. According to Newman, these historically interconnected sciences represent the same pattern of human endeavour to overcome the boundaries between the natural and the artificially created, having ethical consequences, echoes of fame, and social resistance. Similarly, for the French philosopher and phenomenologist Gaston Bachelard, the Promethean (Prometheus) complex is the 'will to intellectuality . . . all those tendencies which impel us to know as much as our fathers, more than our fathers, as much as our teachers, more than our teachers . . . the Prometheus complex is the Oedipus complex of the life of the intellect' (Bachelard 1994: 11). Promethean desire, based on the 'intellectual' control of fire, is abstractly transferable to overcoming all authoritative limitations, including new boundaries of nature. My analysis confirms such a seemingly trivial analogy—'nanotechnology is FIRE'. In Hans Moravec's (1988, 1999) terms, a philosopher and mathematician who generalises Moore's law(!), a disruptive technology is a 'Mind Fire' (Moravec 1999: 165). However, where Ray Kurzweil (2005) sees the ability to create in our minds the model of the world and thereby expand our understanding of the world and universe by merging with the machine, a 'transcendent mind' / 'mind fire' in Moravec's vision will sweep over the cosmos. It is the moment we lose to artificial intelligence on the roadmap of evolution.

The narrative includes people and machines who act like subjects (à la Greimas), fictional or non-human, for example, Frankenstein, Dr. NaNo, the Pied Piper, or the Nanospider, among others. As we have seen in the case studies of controversies, all these characters represent an archetype of a rebel who refuses to subordinate to existing structures (authorities) and who can entice his surroundings with gigantic ideas of his own ability to change the world. In the symbolism of creative evolution, we can see these characters throughout the history of the Enlightenment, ideas about the progress of humanity, independence, and emancipation (see Kurtz 2006, Johnson 1991). The mythical symbolism of the nanotechnology narrative is strengthened by yet another alternative

interpretation based on the Promethean complex, and that is the hero's *fall*. The media have resonated this concern with the hero's inability to embrace the boundaries and limitations of their actions, bold originality and creativity that does not leave (even in the dualism of the myth) the character only in the light on the way to happiness. Just as the Swiss psychiatrist and author Carl G. Jung writes about the TRICKSTER: 'The so-called civilized man has forgotten the trickster. He remembers him only figuratively and metaphorically, when, irritated by his own ineptitude, he speaks of fate playing tricks on him or of things being bewitched. He never suspects that his own hidden and apparently harmless shadow had qualities whose dangerousness exceeds his wildest dreams' (Jung 1954, also in 2005: 173). Some other authors make reference to the 'shadow' of the Promethean complex (Prokešová 2004), which takes the form of an ecological disaster, a nuclear conflict, and the potential risks of biotechnology and an ever-shrinking, invisible world of nanotechnology (Jollands and Small 2005).

Nanotechnology here more resembles the narrative 'emplotment' (Ricoeur's term) of a tragedy, a passage between a triumph and fall and their interconnection, showing the features of duality which carry the structure of the nanotechnology controversy—'passage to nano'—how society deals with uncertainties (cf. Vinck 2009). The MASTERY metaphor (and creative evolution), in the light of these considerations, can be more convincing, showing the narrative dimension of nanotechnology anchored in a seemingly timeless web of meanings. The utterances are unique but still repeatable and transformable into other utterances and ultimately embodied in a dense network of relationships to other utterances. The question arises as to what degree the development of technology (esp. legitimisation), such as nanotechnology, is dependent on the ability to develop a story which mobilises and integrates a number of existing stories and archetypes—a question of composition returns us to the repertoire view of a strategy.

10.2.2 Technology Roadmaps and Crossing the Chasm (Innovation Journey Narrative)

The JOURNEY concept is common in many of the metaphor studies which have accumulated over the years (Kövecses 2002, Semino 2008, Hellsten 2002). The conceptual metaphor for JOURNEY is generally pervasive and conventional in a language (cf. Kövecses 2002: 107). More specifically, purposes are conventionally constructed as destinations to be reached, problems as obstacles, means as pathways, and so on (Semino 2008: 81). This suggests a pragmatic (repertoire) as well as a structural (composition) effect. Based on my case studies, this metaphor finds its place in nanotechnology discourse, especially science (innovation) is a JOURNEY. This metaphor will be explored through several categories of issues.

My empirical evidence speaks for the alignment of the metaphor through means of metaphorical scenarios and narratives. Nanotechnology development has been narrated as an allegory of undertaking a fascinating journey to the nanoworld. As Nordmann emphasises, the

images of the nanoscale 'remind us of the conquest of outer space that will now be matched by a conquest of inner space' (2004: 49; see also Lösch 2006), which brings scholars to argue it cannot but lead to a sense of estrangement from the space in which our quotidian experiences unfold (López 2010). The nanotechnology revolution brings tidal WAVEs, and the corresponding reactions are SHIPs to the nanoworld or technology ROADMAPs. These form metaphorical scenarios and narratives of the estranged space in which key actors live out an ODYSSEY. When sailors used to sail with their ships beyond the charts in their maps, before they could draw new maps, they used to say 'here be dragons' (Guston 2010).[92] The unknown territories have always been the subject of intense figurations. Because beneath the literal, images speak of an uncharted land as if it has defied discovery until now, as if spoken of in legends—the land where (even) God did not finish creation. Many believe there is a treasure at the end of a RAINBOW the likes of which we cannot imagine. Its CONQUEST is seen as an opportunity to find new resources, medicine, the cure for cancer, or other implications of the scientific discoveries. And even those who do not know what is out there are moved by / worried with FEAR as others venture there. They have various images of LANDSCAPEs and draw new MAPs. These may be twisted by the instruments and hands drawing them, yet they elicit imaginations which develop into full-fledged policies.

The European Commission science policy rhetoric is perhaps a modern organisation but one grounded in more traditional models which allow their narrators and opponents to tell stories resembling (indigenous) folktales—they feature hero-figures, villains and acceptors, helpers, treasures, and maps. This should not be underestimated if we consider these metaphors together form models for policies to become dogmatic images of the (future) world. The specific challenge is to bridge the conceptual GAP between our world and the nanoworld while modelling the actions/steps necessary to reach that world, so far removed from our own. Just like the European Commission is confronted with the gap, so too does it design a series of trials. It is presented as an architect of BRIDGEs which can connect the world of scarcity with a world of abundance. Bridging the 'valley of death' between the early adopters of nanotechnology and the 'early majority', who represent a growing acceptance of nanotechnology (by the mass market), is here presented as the biggest challenge the European Commission faces—the European paradox.[93]

The allegory of the JOURNEY extends to the public. In *The Hero with a Thousand Faces*

[92] 'Nanotechnology is a multidisciplinary field and for that also we have perhaps the least understanding of what happens technically, environmentally, or culturally if and when nanoscience and nanotechnologies converge with synthetic biology, with robotics and information technologies, and with neurotechnologies—because beyond that point lies a set of possibilities so vast and wild that, like mapmakers of old we are tempted to write them off as "here be dragons"' (Guston 2010: 8, Introduction).

[93] The metaphor for GAP which the European Commission evokes through the 'valley of death' is known to economists as *Crossing the Chasm* (1991), introduced by Geoffrey A. Moore. It describes the diffusion of innovations, arguing there is a chasm between the early adopters of the product (the technology enthusiasts and visionaries) and the early majority (the pragmatists).

(1968), Joseph Campbell presents a complex allegory which he summarised as the 'hero's journey' or a 'monomyth'. The story goes as follows: 'A hero ventures forth from the world of common day into a region of supernatural wonder: fabulous forces are there encountered and a decisive victory is won: the hero comes back from this mysterious adventure with the power to bestow boons on his fellow man' (Campbell 2008: 23). It could be argued that the modern usage of this mythological trope is 'heroes of the nanoworld'. The *apotheosis* of a hero also appears here as one of the stages Campbell finds in many heroic stories. Just as in *The Pilgrim's Progress* (1678), the hero faces many difficulties and encounters characters with names such as Hopeful, Faithful, and Giant Despair. In this sense, the journey is interpreted as a metaphor for the process which human beings must go through, from a Christian worldview, to achieve salvation (also in Semino 2008: 65). The experience which exists in the fictional world can be systematically, metaphorically mapped onto life and experience in the real world (Crisp 2001: 8). No matter whether these are only the narrator's constructs (as if dreams of the fictional world), they arguably have the capacity to represent and intervene in a particular imaginary of the world being transformed by nanotechnology. Similarly, 'necrotechnologies' and 'vampirism' are representations which alter heroic image and the status of nanotechnology. With these metaphors, the opponents of nanotechnology (activists) become heroes in their own right, facing adversaries-scientists while entering the science world from the ordinary world. Finally, we find the public is also a hero, a Candide character which passes through a transition from optimism to deeply practical precept.

10.2.3 Temples, Pilgrims, and Techno-animism (Narratives and Cultural Syncretism)

The various stories found in cultural (local, national) contexts (Candide, Pied Piper, Tower of Babel, R.U.R., or the fable of the Nanospider) were considered. Altogether, I found nanotechnology discourse contained images in a specific form of cultural syncretism (or what sociologist Simon Locke [1999b: 38] calls 'discursive syncretism'), including rituals and practices, which also translated between scientific and various religious symbols. In this section, I will look into some of these narratives and modern-day myths, and which arguably also suggest the relevance of religious narratives and discourse in the public perception and acceptance of nanotechnology.

The issue of utmost importance is how to understand religious metaphors in particular. According to Chris Toumey, religious beliefs are strongly related to critical attitudes of science and technology, yet 'almost all of its [nanotechnology] aspects are expressed in secular voices and religious commentaries about nanotechnology have been much more rare' (Toumey 2011: 251). His research survey of the 'Seven Religious Reactions to Nanotechnology' (2011) indicates that religious belief can still become one of the most powerful influences in shaping public views about nanotechnology: 'Religiosity has potential to become the dominant predictor of moral acceptance of nanotechnology' (Toumey 2011). Other studies indicate that more secular nations are more positive

about nanotechnology and the more religious ones are more wary (Gaskell et al. 2005, Brossard et al. 2009, Scheufele et al. 2009). If we consider scientific, political, and media texts in our studied corpora at face value, there seems to be little space dedicated to religious reactions to nanotechnology, or rather few explicitly religious commentaries. Safety, commercial control, accountability, and responsible application, these seem to run quite successfully using secular language. It all depends on how we understand what constitutes scientific knowledge and religious belief. The studies which show a strong negative attitude of religious beliefs in technologies have a potential drawback in working with a rather limited definition of what constitutes the concept of *religion* and *sacred*.

It might be surprising that even in the science corpus, religious metaphors are represented, for instance, as the immortality of the transistor. As an inscription of expectations, Moore's law has become new dogma. The proponents of nanotechnology research believe following Moore's law will radically transform our natural states and even beat death (cf. Kurzweil 2005). Adherence to the law is being maintained by a key position between nature (or 'natural laws') and culture (or the 'spirit of the law'); this is perhaps not unlike religious belief based on a distinction between matter and spirit (cf. neognosticism in Harari 2011: 248). The transistor is engraved in this dualist dichotomy precisely because it helps address the problems and solutions—from electron movement to the market economy. The opposition is a cornerstone on the nanotechnology roadmap in electronics, but it translates even further to society as a whole and to the philosophy of transhumanism. The allegorical view on the transistor and the way Moore's law fulfils the role of a religious symbol is perhaps far-fetched. Still, on a metaphorical level, the transistor takes the anthropomorphising role of a KING, a reincarnated prodigal son, and, together with the 'law of nature' and the 'spirit of law', might figure as the (holy) Trinity! Is the fabled transistor an allegory for 'reincarnation'? An embodiment of the path known from religious discourse or a cultural expression of a 'trickster'? Or both?

Nanotechnology then more resembles the view where scientists are constituted as a secular priesthood able to conquer and replace nature, therein providing technoscientific salvation (Haraway 1997: 147–50). As such, the (religious) MISSION to the 'nanoworld' extends the secular form of CONQUEST of the new world. This perspective applies to the 'nanoworld' and the European Commission roadmaps which express an idea of the common SHIP on a transcendental JOURNEY. In addition, nanotechnology discourse is built on beliefs which also rely on animist legacies not limited to the anthropomorphism of the transistor, but more generally, to the 'soul' of a machine. Nanospider nanotechnology, as a technical object, here passes through a type of transformation which suggests a somewhat techno-animist environment (VIVARIUM). Other religious symbols are woven into its fabric by an artist as a SUDARIUM (holy relic). These are

reassuring and euphoric metaphors for the identity of objects, institutions, and researchers that have emerged from religious discourse: SUDARIUM, TEMPLE, PILGRIMs, and MECCA are juxtaposed to be supportive of nanotechnology. And then, there are the more disquieting ones where scientists and engineers are SORCERERs apprentices in IVORY TOWERs. It is very likely that such symbolism, used in relation to scientific endeavour, has an influence on public opinion, and potentially, public policy. In other words, the systematic use of religious metaphors may not just be an expression of religious beliefs but also a strategic way of representing one's own identity as a (potential) leader, denying or defying authority, establishing common ground with some parts of the public and a lack of common ground with others—exploiting associations of religious images for rhetorical ends (Semino 2008: 104).

It is fascinating how many different ways nanoscience (and nanotechnology) merges with religious discourse; how its practice, seemingly defiant to all kinds of authorities, leads straight back to it. The character of 'Frankenstein' is an example of the metaphor for agency transcending the boundaries between the profane and sacred. Yet those expressing doubts about nanotechnology were themselves referred to as HERETICs and INQUISITORs (such as Prince Charles). The very reaction to the critique of nanoscience represented by Prince Charles and his allies as inquisitors showed how the rhetoric is used to move opposition to the sphere of 'non-science'. This metaphorical expression paradoxically points to the dogmatism of science in condemning the techno-critique as an act of searching for heresy (or rather of) something unclean and non-sacred. Thus, the advocates of science are for themselves seeking a certain process of purification and scientific celebration, which, more than a substantive debate with the public (with exceptions for their own 'fallibility' tests), is more like an apotheosis. These strategic practices may influence an adjustment of our image from the 'Republic of Science' (Michael Polanyi 1962)—organised, in a way, according to economic and political principles—to the 'Church (Temple) of Science', which we find on a figurative level in our case studies of the Czech (Nanofiber sudarium), French (Mecca of Nanotechnology), or British (Tower of Babel) corpora.[94]

No matter how far-fetched these arguments may seem, my case studies suggest that the metaphorical (and narrative) perspective is essential in closing the distance between religious symbols and their referents. Nanotechnology discourse is being constituted through beliefs, endowed devotees, and faithful gurus and prophets, dogmatic texts, baptism rites (a project's inauguration rites and ceremonies), miraculous discoveries, and undisclosed mysteries, even eschatologies. After all, even 'technocritics in their diversity might as well be the atheists of our time, sceptics in a world populated by faithful, believers and devotees, victims of "machine

[94] The point raised here is close to Arnold Toynbee and technology as a form of idolatry, as in *A Historian's Approach to Religion* (1956) or Jacques Ellul in *The New Demons* (1973; Les nouveaux possédé).

fetishism", that is to say belief in the demiurgic power of techniques supposed to solve all our problems' (transl. from Jarrige 2016: 352). Even the most critical reactions and offences to religious beliefs in social representation(s) of technology may serve for symbolism of religion—all the more so when they look as its utmost heresy. In religion, saving orthodoxy often happens through fighting radical heresy, or to quote T.S. Elliot: 'It is only by the struggle against constantly appearing false ideas that truth is enlarged and clarified, and in the conflict with heresy that orthodoxy is developed to meet the needs of the time' (in *Notes Towards a Definition of Culture,* an essay on social criticism, 1949: 83). Far from exhausting all the interactions or common foundations with religious discourse, nanotechnology has common features. More importantly, what I would like to point out is that finding nanotechnology discourse effectively incorporating religious metaphors does not imply they fulfil the original purposes characteristic of religious texts or fairy tales. Clearly, religious discourse is a significant and complex phenomenon which has different manifestations and implications in different languages, countries, and cultures (see Charteris-Black 2004: 171–240). The presence of (modern) myths such as the 'Tower of Babel', introduced by scientists themselves as a perspective on the nanoworld, suggests however that religious discourse is not juxtaposed as a techno-critique (cf. Toumey 2011, or Scheufele et al. 2009 studies on religious reactions to nanotechnology). Building the 'Tower' as a symbol for the unity of every scientific language (discipline) targets the reformation of traditional science culture and advances the project of convergence. It is a social representation of the defiance and of the programme to advance post-academic science. In short, metaphors are cultural filters and that includes the basis of dogma.

10.3 Discursive Formations: Creative Evolution, Nano-Orientalism, and Risk/Fear Controversy (Compositional View, Part 2)

Nanotechnology is not uniform regarding its *constellations of meaning*(s), and there are particular discursive formations which I have identified to correspond to its meta-format. These formations may seem to originate with, but are not restricted to, nanoscience, policy, and the public, respectively. Moreover, they are not simply semantic but with a deeply practical precept of interpretations, attitudes, and actions. They mediate, negotiate, and arrange nanotechnology as a communicative 'event' at the interface between science, policy, and the public. As compared to metaphor capacities and narratives, here metaphor is not a result of a strategy of the subject but rather it emerges from a discursive formation in which social practices and institutional (also cultural) contexts frame the relationship between knowledge and power.

In particular, creative evolution, nano-Orientalism, and the risk/fear controversy are discursive formations which carry social meanings and establish a 'cultural horizon' of acceptability (cf. Feenberg 1992). The formations are constituted by root metaphors, previously described as the general assumptions behind technology development, and a group of statements via constant, abiding concepts (also in Table 10.3). Their relationship with non-discursive formations (institutions, political events, and economic processes) is one of relative autonomy. Nevertheless, the formations integrate and expand into a clear organisational identity and image, occur in common institutions, and are implicated in materiality and the conduct of public debates. Such a discursive formation should also be understood within a specific normative framework as they represent shifts to technocracy, governmentality, and even ethical relativism.

Table 10.3 Discursive formations, root metaphors, and conceptual domains (compositional view).

Discursive formations	**Master metaphors**	**Metaphor(s) concepts**
Creative evolution	Moore's law	- Noogenesis, mimesis, … - Convergence, exponentiality - Pathway, roadmap
Nano-Orientalism	Technology roadmap	- Nanoworld scale/future - Ships, drivers, passengers - Pathways, gaps, bridges
Risk/fear controversy	Nano is X(X')	- Temple/tower, container, gap - Waves, syndromes, tricksters - Theatre, garden, dispositive

10.3.1 Creative Evolution (and Imaginary of the Nanoworld)

Creative evolution is a term with a long history and with various structural resonances between biological evolution and the evolution of a culture (cf. Bergson 1907, Spengler 1918, Dawkins 1976, Dennett 1995, Austin 2010). Henri Bergson, in his *Creative Evolution* (1907; *L'évolution créatrice*), was one of the first to propose evolution is 'creative' and cannot necessarily be explained by Darwinian natural selection alone. Similarly, Oswald Spengler, in his *Decline of the West* (1918), maintained the metaphor on the assumption that the course of world history is governed by laws similar to the laws of life. Civilisations are born, grow, and die because they lose their ability to solve new problems creatively. In my study of the nanoworld, creative evolution emerges as a phenomenon which takes place in the cultural settings of scientific cultures (their CONVERGENCE), as well as within the sphere of the *human soul* (NOOSPHERE). It is also represented through the concept of CIVILISATION.[95] As such, it can be understood from the historical perspective as well as from the depth of human existence.

Creative evolution in the sphere of the human mind (existence) has perhaps the strongest resonance with the Promethean complex and evolution (development) as a 'progress from decay' and, inherently, its antimony, a 'decay from progress' (cf. Patočka 1975: 104). In this sense, creative evolution is more than a psychological category, it is a discursive formation with its own historicity, psychology, and even economy (cf. Patočka 1975: 120). It shapes what is likely and possible to be felt, thought, and said (*enoncé*) and what is considered (un)acceptable, socially, economically, and politically. According to Johann P. Arnason, who builds on Jan Patočka's work, all traditional civilisations are associated with a 'specific definition of being in the world' or 'the construction of an exclusive identity' (Arnason 2010: 29, also in Homolka 2016). There are always certain *visions and projects* which are associated within culture-specific interpretations. The visions and projects associated with creative evolution (and nanotechnology) are about rationality capable of expansion, and it is a referential constellation of meanings in given cultural contexts. An example worthy of consideration is Moore's law as a specific constellation of meaning (exponential growth, accelerating returns) and as one that is being promoted to become a collective meaning for the human endeavour—it is the root/master metaphor. At the same time, this expansion is hindered by many obstacles since the spread of this specific cultural vision meets the resistance of other, alternative visions (cf. Arnason 2010: 32). The contrast can be extremely well demonstrated by the argument for an 'heirloom industry' following the death of Moore's law's, and more generally, by

[95] Creative evolution has the potential to be subjected to 'civilisation analysis', i.e. comparing with the current theories of modernity: civilisation continuity (Elias 1939 [1994] or Huntington 1996), but also (new) civilisation (Eisenstadt 1973, 1982), rational civilisation/supercivilisation (Patočka 1950-? [1996b] and 1975, also in Arnason 2010 and Homolka 2016), or post-civilisation state (Giddens 1990, Delanty 2016, Delanty and O'Mahony 2002). It is beyond the scope of this chapter to critically scrutinise all these perspectives. In consequence, it would take us to incongruent positions on particular constellations of social, political, and cultural forces which might have shaped modernity but also reach beyond its projects.

the tension between 'autonomy' and 'social control', or even to what extent social control is imposing limits on human creativity (cf. Eisenstadt 1994/1999: 62). In the media corpus, for example, we can recognise tensions between the nanotechnology expansion in electronics (RFID projects) and the vision of a 'surveillance society'. These are interpretive frames which relate to concrete projects and more profound sociotechnical imaginaries. They carry a specific definition of being in the world and the construction of an exclusive identity.

Creative evolution is thus associated with a number of antinomies and internal conflicts which means there are different, often contradictory ideas about how to realise nanotechnology development (regulation, for example, that is timely but which does not waste time as the progress becomes universal imperative). There are many examples in analytical chapters which can serve to testify/give evidence to the tension between a view of a society transformed by nanotechnology(-ies) and a pluralising perspective which prioritises the choice through morphology of a roadmap but also naturalises nanotechnology. Moore's law has arguably become the dominant interpretative frame at the 'world-opening' and 'world-articulating' level, which is becoming a cultural horizon of acceptability (cf. Feenberg 1992). Creative evolution, as such, in its assumptions and consequences, raises the question of 'reflexivity' (cf. Giddens 1998) and to what extent an approach which no longer distinguishes the difference between knowledge and control of nature can be applied. How can nanotechnological development and its relationship to society/culture (and nature) proceed? Creative evolution should be understood not only as a cultural program or a horizon but also as a specific discursive formation which represents modernity and transcends its ontological and historical visions (cf. Eisenstadt 1973: 203) in its relationship to nature and culture. It should also shift our attention from a problem of governance (technocracy) to governmentality (how governing happens and is thought of) as the 'conduct of conducts' (Foucault 2002: 337), a roadmap for all nanotechnology roadmaps.

10.3.2 Nano-Orientalism (and Imaginary of Cartographic Mapping)

As much as the previous discursive formation may provide insight into the cultural, normative, psychological, and even some epistemological challenges, it does not capture the nanotechnology discourse at its fullest, especially in an institutional setting, for example, the deployment of policies. In order to provide an umbrella term for such a discursive formation description, I coined the term *nano-Orientalism* to come to terms with how the nanoworld has become known as well as how this knowledge is advanced as a discursive strategy. As in the previous case, however, we are not looking at a simple formation of discipline(s) which can serve as rationales (justifications) for resource allocation. Rather, there are arguably much deeper *power-knowledge* relations.

Nano-Orientalism involves a vision of the nanoscale, but its indigenous people are not atoms or molecules, even though these are the genuine inhabitants of the nanoworld. Rather, nano-

Orientalism represents a rupture within our society and nanotechnology discourse's 'orientation' to the future. Just like the Orient described in the works of Edward Said (1978), the nanoworld is essentially strange, exotic, and mysterious but also sensual, irrational, and potentially dangerous. This nanoworld strangeness is grasped by the experts, and in particular by those with skills in nanoscience, politics, or activism. In analogy to Said's principal argument in *Orientalism,* nano-Orientalism means that experts reconstruct an impression of the nanoworld to reflect what they desire and imagine the nanoworld to be through a process which would dominate, restructure, and hold authority over the nanoworld (cf. Said 1978: 3). It allows one to see themselves as modern and civilised, the opportunity to contrast themselves with the 'indigenous' population, which is perceived to be backward and even inferior to debate with. The task of nano-Orientalism is to reduce the bewildering complexity of the nanoworld (scale/society) to some comprehensible and, therefore, manageable and governable level. Within the perspective of Foucault's analysis of knowledge, we can now treat nano-Orientalism as a discursive formation which creates typologies and topologies within which actors-characters can be distributed and governed.

This process of distribution and organisation is consolidated by metaphors, such as ROADMAPs, as an instrument of governmentality and of its subversion, subjection, and emancipation, of (dis)appropriation, of con- and divergence (cf. Lazarus-Black and Hirsch 1994). Cartographic mapping has historically been a key strategy of governmentality (Rose-Redwood 2006). Drawing on Foucault affirms that European governments produce 'maps . . . [which] extend and reinforce the legal statutes, territorial imperatives, and values stemming from the exercise of political power' (Harley 1989). Although the official rhetoric advances the common notion of the European Commission's initiatives of 'collaborative mapping'—where there are 'the many surveilling the many' (cf. Joyce 2003)—it is not as idealistic imagery of symmetry. There is much more to offer further historical and ethnographic illustration. Edward Said, who in the Foucauldian tradition developed his critique of Orientalism, to this end proposed the concept of the 'imaginary geography' as both the vehicle and outcome of a CONQUEST. The imaginary geography does not mean 'false' or 'made-up', but rather 'perceived'. It refers to the perception of spaces and futures created through certain images, texts, or discourses. For Said, Orientalism 'expresses and represents that part culturally and even ideologically as a mode of discourse with supporting institutions, vocabulary, scholarship, imagery, doctrines, even colonial bureaucracies and colonial styles' (Said 1978: 1–2). 'Mapping' is here a process that does not just 'chart, it unlocks and formulates meaning; it forms bridges between here and there, between disparate ideas that we did not know were previously connected' (NanoMed 2020 Map Project). In the name of universal 'progress', all stakeholders are connected to a superior European strategy planning its policy versions: H2020, Framework Programme for Research and Innovation (2014–20), and the

ESFRI roadmap (being updated since 2006). Nanotechnology roadmaps are an additional human activity where this mode of discourse (and practices) manifests itself, invoked by metaphors of a GAP, such as 'RACE-ing' or the 'nano-DIVIDE'. By representing the Other, the roadmaps create a sense of belonging and exclusion. Nanotechnology as a place-oriented activity of research at the nanoscale and a symptomatic orientation of the discourse to a future world (society) makes the idea of coherent discursive formation even more compelling (cf. Nordmann 2004a and 2004b, Schummer 2007, Ruivenkamp and Rip 2011).[96] It becomes less of an issue to localise this exercised power in the rhetoric of the European Commission. Rather, it is the institutionalisation of the *future* as a mechanism spreading in all power-knowledge relations.

The imaginary geography of nanoworld is applicable here to the ERA and the European Union, which are also *imagined communities*. The imaginary forms the basis for a shared sense of belonging and attachment to a political community (cf. Anderson 1983); it provides the gaze through which the Other is constructed and represented (Said 1978). Nano-Orientalism, the argument goes, is straightforward enough. 'The European Governments are determined not to miss the boat on the next "nano" revolution' (CORDIS 2005a); however, the government's determination has never been enough when lacking anything approaching citizen consent. Incongruity already surfaces from the contrast between the existing low 'public awareness to nanotechnology' (EuroBarometer 2010: 33) and the 'imaginary public' that the European governments construe. This imaginary public is as concerned 'upstream' with the moral order of European markets as it is with that of the commons; it is not anti-commercial or anti-government as this would mean being anti-technology. More ambiguity develops within the kind of techno-critique which is intrinsic to emerging technologies in the European countries, especially in the follow up to the GMO, nuclear, and asbestos controversies. Whenever debates were established, which have also often had a unidirectional mode of communication, they have laid the ground for doubts and resistance (cf. Jarrige 2014: 324–31). However, as David Edgerton pointed out, the idea of 'resistance to technology' does not have much sense since there is no substitute. In other words, actors never resist technology in general, not as such. They rather contest over dispositives and specific technology trajectories. Therefore, speaking of resistances is perhaps a bit simplistic as we would rather make necessary choices between different technological alternatives (cf. Edgerton 2006: 9). At this point, it becomes apparent though that the EC rhetoric and nanotechnology governance metaphors offer interesting material for colonial studies, but also the recently established field of nanoethics.

[96] Critical discourse perspective demands a search for metaphor and rhetoric in maps where previously scholars had found only measurement and topography. Its central question is reminiscent of Korzybski's much older dictum 'the map is not the territory' (Korzybski 1933); however, deconstruction goes further in bringing the issue of how the map represents *place* and *future* into much sharper focus (cf. Harley 1989: 3).

10.3.3 Risk/Fear Controversy (and Imaginary of Public Debate)

Creative evolution and nano-Orientalism are discursive formations which may have become formative to the dispersion of utterances, concerns, themes, actors, and strategies with an institutional background in science research and policies, for which they create protected spaces. There is, however, another discursive formation characteristic of nanotechnology discourse, and it becomes the determining factor in how we relate to nanotechnology, especially with regards to the engagement of the public: risk/fear controversy formation. As Michael Warner (2002) argues, publics can only really exist in and through discourse. That is, a discourse brings a public into being by presupposing and anticipating its response, and requires for its existence 'renewed attention' (Warner 2002: 419). Thus, while we can consider various public reactions to nanotechnology, we must also assume the public exists through nanotechnology discourse and its formation in a first place (as 'public backlash' to nanotechnology, for instance). The representation of the public here reaches beyond any particular corpora we studied as a dispersion of actors, objects, and strategies, and, as I want to argue, exists as well through the public debate. The public debate can itself be understood as a system of metaphors being characterised by a number of metaphorical concepts for choice, risk, fear, and, finally, ambiguity.

Traditionally, public debates have features of explicit encounters between various actors, where different matters of concerns are discussed. As we have observed in multiple niches of nanotechnology discourse, these actors and matters are *metaphorised*, for example, when the BIG SCIENCE/WAVE/TOWER/CRUCIBLE of nanotechnology is debated as potentially dangerous for the environment (GREY GOO) or when undermining human dignity through a 'nano' BIG BROTHER. The representation of the nanoworld at the nanoscale is never free from imaginations of society reaching sustainability or even PARADISE, redefining the new (national) identity as an embodiment of the spirit of CONQUEST and proving the necessity to take actions so as to be ahead of competition. These public images have become critical to discussions over regulation, deliberation, robustness, among others. Also, the representations of these debates, such as THEATRE or GARDEN, spread markedly between images of the public 'not having a choice to say no to progress' (public as passive observers) or 'being "brave" in finding solutions to global problems' (public as active participants). Here Mordini argues, fear is not the sole emotion that can enable integration of new concepts into mental schemes, two other powerful emotional forces should be considered: wonder and curiosity (Mordini 2007b). This is not as trivial as it might seem if we consider to whom these powerful emotions are assigned. It is fascinating how public debates on nanotechnology seem to converge towards notion of fearful public (fearing the unknown, suffering from syndromes) and fearless experts (missionaries, conquerors, explorers). The climate change discourse, for instance, might offer interesting comparison how these roles are attributed,

inverted, but more importantly, how they are occasionally reversed by the media as a form of psychodrama technique. In short, media voice the fearful expert if it serves their readership.

For example, we have encountered metaphorical representations of various actors and their *uninformed* FEARs or *collective* SYNDROMEs (such as GMOs or AMO). When 'fear is uninformed' it stands for the idea that communities lack the emotional and psychological resources necessary to deal with change, to make choices, or to deal with adversity. At the same time, 'syndrome' makes the public appear incompetent and vulnerable, opening avenues to specific policies. In relation to that, the media seem to take advantage of the public having a lack of experience with nanotechnology through the narrative of fear, taking it as a cultural resource (cf. Oreskes and Conway 2010). This explains regularities in the practices of the media, and the use of ambiguity in particular. A degree of saliency and ambiguity is strongly linked to media practices which adopt dominant frames of modelling benefits and risks. We can understand this practice as an intentional argumentative pattern, maintained by the media themselves as *yes ... but* (cf. Mouro and Castro 2010, Castro and Mouro 2011: 369). '*Yes*, nanotechnology is a novelty associated with great future opportunities that will improve our lives, *but* it comes with some unknown qualities and potential risks for the environment and human health' (Bertoldo et al. 2016: 769, emphasis added; i.e. nano balances between 'great deeds or great risks'). In metaphorical forms, translation occurs one way or another. As Eisenberg (1984) argues, the idea of translation is congruent with 'strategic ambiguity' and which, through inserted and shared meanings, constitutes a coalition or an organisation. In that case, 'translations [can] become treasons' for some actors (Cooren 2001: 190). For the media, however, this represents a genuine resource to be exploited as inserting 'ambiguity as objectivity' in the reporting. The ambiguity has a general metaphorical form 'nano is *x*(*x*')', where the variation on *x*/*x*' roughly stands for opportunities *and* risks. In other words, ambiguity as objectivity is a major media strategy to create conditions that ensure the multiplicity of socially available narratives and interpretations. The metaphors of fear appear to provide a provisional solution to moral uncertainty and are, for that reason, embraced by a variety of interests, parties, and individuals as specific politics (cf. Furedi 2018). Fear, confusion, and ambiguity is as much a characteristic of human existence as well as being generated by language. In this second sense, I would like to argue on behalf of my empirical evidence that the ambiguity is not only processed strategically.

The fear plays a key role in the unfolding of public debates over nanotechnology that goes beyond the conscious strategy. In all of the investigated corpora, debates on nanotechnology engaged with various issues through a reference to fear. It reached both experts ('Moore's law breakdown') and policy ('valley of death') and the public ('AMO'). The concept of FEAR/ANXIETIES explored in this thesis is a good example to show how debates on

nanotechnology integrate a number of cultural specific scripts: 'Determined by the self, and the interaction of the self with others; it [the public debate] is also shaped by a cultural script that instructs people on how to respond to threats to their security' (Furedi 1997: 5). The presence of metaphors such as 'nano-R.U.R.', 'prey / grey goo / killer dust', and 'Frankenstein nanofood' in various texts from the national media corpora are a testimony to the cultural significance of fear. The important finding in this thesis is not to locate fear as a strategy or key emotion in nanotechnology discourse, or not as such. Nor does it aim at fear as a specific politics, that is to say, an argument that the political significance of fear reaches beyond the social and cultural significance (cf. 'politics of fear' in Furedi 2005). As Frank Furedi (2018) argues, fear has become more and better defined as specific fears have been cultivated—to revive Candide's metaphor of a GARDEN—media is then a platform on which fear is cultivated and proliferates. The metaphor is thus not entirely conclusive or therapeutic.

Even if the strategic ambiguity should be understood as a form of discourse strategy, which, according to van Dijk (1997: 31), constitutes the means by which actors achieve goals within discourse. It is only partial image. Whereas Teun van Dijk relates ambiguity especially to the intertextuality within discourse, the above metaphor analysis allows to extend it on interdiscursivity, even as a discursive formation. Any form of collective endeavour presupposes different translations of the various actions performed by the actors concerned (Cooren 2001: 197). This idea subscribes to the conceptual metaphor of nano-DISPOSITIVE and its meaning-generating mechanism, which nevertheless produces ambiguous terms that actors use to fulfil agendas and can later resurface as conflicting. This ambiguity is also represented in the role of a TRICKSTER, a concept which is partly a strategy and partly cultural-cognitive pattern, or archetype. It concerns the representation of nanotechnology's Janus Face (lab-on-a-chip, Nanospider) and scientists (Frankenstein, Dr. NaNo, Sorcerer's Apprentice, etc.), but also policymakers (Pied Piper) and the public (Luddites). Altogether, the cultural and specifically local perspectives on nanotechnology bound to ambiguity create conditions for accepting moral relativism and justification for doing whatever one wishes: 'Let us decide which technology we want'. Public debates are essentially about the pertinence of actors' *choices* while facing various risks and dealing with anxieties about the future. They threaten protected spaces.

Part VII Conclusion

Chapter 11. On the Relationship Between Metaphor and Nanotechnology

The main conclusions drawn from previous discussion will be readdressed as the relationship between metaphor and nanotechnology within three main key points. In my conclusion, I will address research questions, and restate my aims and objectives in order to pass on a message concerning future research and challenges. Even though this might raise some open questions—these are intended to set the scene by providing thoughts about possible future work.

11.1 Rethinking Nanotechnology Discourse (Transformation Thesis Revisited)

Among the initial theoretical assumptions was that science, technology, and society are rapidly changing, and the ways in which research is produced are no exception. The policies put increasing emphasis on (responsible) research by governments and the 'best' practises of technology regulation. The public is not merely an acceptor of technology but also a prime mover/resource of societal objectives and concerns. It was also assumed that (national) communities integrate nanotechnology development into their agendas; science-society relationships are becoming more complex and multifaceted; and an expanding and more diversified set of actors and stakeholders is involved in the research process, or is able to influence it. Moreover, these transformations are occurring in an uneven and non-linear way, and their future trajectories are uncertain. Based on these assumptions, it might be less surprising to find that scientific and technological research in the 'knowledge society' is and probably will be increasingly different—in terms of structures, functioning, meanings, social and political significance, governance, and public perceptions. As we have seen, the metaphors used have led more naturally to some perspectives (hypotheses and conclusions) then to others. Their essential role in public debates on scientific research and its broader social and political implications, however, must be continuously validated.

The social theory of metaphor and related research objectives and questions of this thesis (from page 20 and 87) were formulated to point at the existing gap between perceptions, attitudes, and actions that social sciences should strive to bridge. Nevertheless, the main objective was not only to show how metaphors are used to develop new understandings of phenomena, explain

scientific issues and advances, or to persuade audiences about particular and even unpopular decisions. In scientific discourse, nanotechnology emerged as a unique, but not unambiguous project to be carried out on the basis of creative evolution. Nanoworld is here a complex social representation involving a large array of laws and actors, with strategies fully embedded in culture and taking into account dimensions of human creativity, biological evolution, and the industrial economy which on the basis of metaphors seem less distant concepts. Yet, the imaginary of technological convergence (also as Nano Age, noogenesis, and civilisation) here contrasts with anything that could resemble the national identity and local political decision-making. Nanotechnology in local (cultural) contexts, on the other hand, shows the culture-specific variation. It exists during a time when EU science policy is governed by social representations which are translating technical to social convergence. The three case studies set in the media certainly do not cover all the possible cultural spaces in which technologies are culturally articulated in society, nor do they aspire to be fully comprehensive with respect to the specific metaphors and narratives they consider. However, taken together, they can draw, at least in part, the relationships between metaphor and nanotechnology which have developed into complex cultural arrangements. This has significant implications for future nanotechnology development as metaphorical patterns convey particular experiences and project contrasting worldviews.

It is also important to consider that debates over nanotechnology in the media are about spreading compelling evidence as much as they are about eliciting the right emotions (fear and awe), creating *protected spaces* or producing even *more ambiguity* which is hard to maintain across multiple storylines. Metaphors appear central to the success of the media as they mobilise widely resonant images and ambiguity. While strategically effective, metaphors hold dubious implications in the media. They entrench or naturalise unequal power relations in the social world and can even deflect attention away from problematic political and economic choices. The situation with nanotechnology (cultural) appropriation is then problematic if it is to be limited to 'how the public can accept that the technology is already invented and regulated' as opposed to accepting that public understanding would have an active influence on technology development. As we have seen, one-way communication processes, and even technology roadmaps aiming to 'bring everyone in', do not necessarily lead to an end in social opposition, and resistance to new technologies. This is an important reason for governments to start thinking about their science policies differently. They should consider metaphor formative in the sense that it is in the hands of scientists, policymakers, journalists, and also the public (nano-visionaries and techno-prophets as well as technophobes and social movements) which, through discursive strategies, try to convince others that the metaphorical representations reflect an (un-)desired reality. The future is not a scenario we should prepare for, but a process we enact in the present. Through material-rhetorical practices, metaphor intervenes in

the construction of actions and actors, and we can follow concrete contingent networks, narratives, and discursive formations in which metaphors are engaged. In short, the transformation thesis suggests a shifting between perspectives: from the metaphor *of* nanotechnology to the metaphor *for* nanotechnology.

11.1.1 Multiple Transformation Points

Altogether, the case studies are taken as evidence of strong and fundamental convictions about the nature of progress, alongside multiple transformation points between science, policy, and the public. Based on the presented thesis of the multiple transformations of nanotechnology, we must acknowledge that by joining scientists, politicians, and the public in discussions on regulation, research funding, development, and innovation, there emerged a reciprocal problem of a (public) dialogue set in a particular (local) context. It has been found desirable by protagonists of various stories of the public debates that participatory processes should improve and adapt to specific issues and contexts (cf. Joly and Kaufmann 2008). This turned into experimentation with common language as one of the necessary conditions (politics of metaphor) as well as exploration of culturally-bound meanings, which seem indispensable in fostering dialogue. The investigations have taken us behind the science images and scenes (or better yet, sceneries) of science policy, yet, for public engagement to matter, it did not go beyond anything which has previously resembled the predicament of (local) cultures (cf. Clifford 1988). Still, the emergence of nanotechnology coincides with a greater demand for openness in science and innovation policy. The metaphors empower actors but also create a challenging condition as much as previous conversations with the public do not provide easy answers.

The key argument is that multiple transformation points can be reformulated from the perspective of ethical debate, which is implied as a required response to the above issues. In his book *Future Shock* (1970), Alvin Toffler described a certain psychological state of disorientation whereby individuals and entire societies are challenged with ‘too much change in too short a period of time’ (Toffler 1970: 2). If convergence and the exponential growth are indeed valid concerns raised by scientists, as the case study on nanoworld would suggest, then societies are even more vulnerable to controversial science policies when citizens are overly emotionally and physically distracted by hype from dreamy outcomes and fears of disasters to mount an effective resistance. For nanoethics scholars though, the nanoworld confronts the human agent with a contingent and indeterminate character which does not hamper but expands the scope of purposeful action (cf. Nordmann 2007b). Its uncertainty should be regarded as a resource for an expanding will rather than a drawback for a disoriented agent (cf. Pellizzoni 2012: 257, but also Bauman 1993 and his criticism of modernity and its drive to create order out of chaos and ambivalence). In our case, the ethical debate can be reinforced, not subverted, by recollecting metaphors and their ambiguity and

contingency, by making them *objects* of the debate, leading to increased reflexivity. The ethical point of view on the versions of the future nanoworld reaffirms for us that democratic technology needs transparency, and therefore, we need to study more overt aspects of the discourse, especially with regard to the issues of nanotechnology announced as omnipotent and omnipresent. Starting to calculate the potential and drawbacks of active interventions in the development of nanotechnology without regard to the *meta*-level is a prerequisite for losing this reflexivity. The starting point of this corrected attitude might be in approximating *transformation thesis* to *transformative learning* (cf. Mezirow 1981 and 1991) as the additional capacity of an individual to reframe previous beliefs to transform perspectives of meaning; a form of critically reflective action can follow. This argument might also be reviewed in response to the perspective of modern technology which, according to Hans Jonas (1984: 7–8), 'has introduced actions of such a novel scale, objects, and consequences that the framework of former ethics can no longer contain them'. There may be an ever-widening gap between emerging technology, sociotechnical imagination, and moral capacity, yet my investigations suggest there is space for exploring the (metaphorical) capacities without losing sight of the nanoscience, politics, and culture of nanotechnology.

11.1.2 Differently Probable Ontologies and Epistemological Challenges

Nanotechnology development is cutting across European countries as well as the rest of the world. Nevertheless, it is not immediately clear what the issues are in the various parts of Europe (member states, local communities) and how they can best be addressed. Nanotechnology (and responsible research and innovation [RRI]) works most of the time alone as a 'metaphor' which means different things (from universalism and nationalism to environmentalism or even market protectionism), and it is difficult to keep a reasonable distance between 'literal' and 'metaphorical' models and practices. At the same time, the definition or characterisation of nanotechnology is rather too open, creating difficulties to operationalise it directly in each of the science policy plans. The fact that some metaphors may allow stakeholders to enter the debate over nanotechnology development (inciting 'empowerment') does not mean they are innocent. They can paradoxically augment misunderstanding as they are based on concepts which equally constrain mutual encounter between scientists, policymakers, and the public. This also has to do with the fact that nanotechnology works differently in different domains and for different industrial and societal challenges. These are under influence of the discursive formations (they are interdiscursive) that work also as regimes of truths.

Concerning the investigations into metaphor capacities, narrative dimension, and discursive formations, a key point being made is than on reflexivity – acknowledging that nanotechnology should be viewed as having no single history and ontology but various possible histories and ontologies. In most cases, the likelihood of a certain group of representations is neutralised, but in some cases, the probabilities of some other histories and ontologies are amplified. A particularly

important implication is a sense that if the nanotechnology and its social relevance is being modelled metaphorically in a particular way for science to matter and for political purposes, any of these metaphorical models of reality have limitations and possible alternatives (see Grenoble models back in chapter 8, for instance). As Taber (2001) points out, when metaphors are used for educational purposes, students should be encouraged to reflect in detail on the differences as well as the similarities between alternatives. The level of detail should be examined, especially between the openings and constraints they represent. Spiro et al. (1989) suggest that debates should be provided with *alternative* metaphors for the same phenomena since reliance on single metaphors can eventually prevent us from reaching more advanced levels of understanding (see also Cameron 2003: 39, or Semino 2008: 152).

And while this study aims to raise reflexivity towards processes in which nanotechnology discourse becomes grounded and stabilised, is formed and reformed by other discourses (by GMO techno-critique but also by religious syncretism, for instance), it is important to take note of the limits of the metaphorical approach. The study is an occasion for metaphor theory to be updated with empirical material, which has been recognised as driving this, still, evolving field. The position of cognitive linguistics is problematic though in the sense that these are the metaphors 'we live (and make politics or write dissertations) by'. If a proposed perspective on nanotechnologies is to be of any value while introducing new perspectives on various ontological regimes, it must be reflexive to its own metaphors. As such, creative evolution is a sensitising concept derived from analysis and a particular epistemological model. It has its own achievements—it allows one to be critical of nanotechnologies(-y) which are being protected as 'embryonary', revealing more about the technical term and a metaphor that naturalises nanotechnology. The creative evolution concept on the other hand is linear, and despite using biological evolution as its model, its vision of exponential growth is quite paradoxically limited to the point that it cannot embrace more a cyclical perspective on evolution.[97] Similarly, nano-Orientalism establishes the dramatic relationship between nanotechnology and metaphor, urging a design of nanoethics between researchers, policymakers, and the public. The model is useful as it reflects on the communication (patterns) environment and how nanotechnologies can become 'locked into' their development trajectories. Yet, we must be aware that it is a particular (though with all-encompassing ambition) story of crisis with its own epistemological challenges. Critique on the limitations of Said's Orientalism (1978) concept which has accumulated over the years can provide some direction. Finally, risk/fear controversy shows

[97] According to Oswald Spengler (1918/1922), all cultures, like biological organisms, go through a specific life cycle where each one waits for the inevitable extinction preceded by the collapse phase, called the concept of civilisation (in Homolka 2016: 118). In the work of philosopher and phenomenologist Jan Patočka, we encounter criticism of this cyclical conception of history in the statement that 'the unified law of cultural development and decline is a dead end of interpretation, the way out of exigency that arises where there is no key to the phenomenon of progress and decline in history' (Patočka 1996a transl. from Filosofie Dějin [Sebrané spisy 1 - péče o duši I: 350]).

that the more symbolic actions are involved in the shaping process, the more they can become interpreted as *ambiguity*; that is, even social structures are described to change more unexpectedly. At the same time, the unforeseen consequences of action increases and, perhaps of decisive importance, the future becomes less predictable as it is based on decisions which could have been different. Debates over sensationalism, up-to-dateness, and unequivocal clearness tend to dominate discussions of scientific controversies in the media (cf. Weingart et al. 2000 on 'climate change'). These debates should not obscure the important issue of ambiguity—yet, they are viable alternative perspectives for future reference.

11.1.3 Preservation of a Paradox and Selective Blindness

The third key point being made as the conclusion of this dissertation is not in condemnation of nanotechnology or metaphor, or the idea of another revolution in the background of nano-revolution—a revolution of social transparency. A typical dream of revolution is to promise a new age of social transparency. After the storming of the Bastille, French revolutionaries banned masks and costumes, decrying the carnivalesque custom of the masquerade as both symbolic of aristocratic tyranny and a security threat. It was believed that removing masks would make the world more transparent (Johnson 2001).[98] This active engagement corresponds to a type of unmasking of modern societies / nanotechnology discourse (science, policies, economies, media, etc.), as if they operated according to a principle that 'metaphor is people (nanotechnology) in disguise'. Its ethos emphasises that metaphor is not a neutral, boundless resource to be exploited but has significant ethical and even legal implications for the actors who use it. As much as we cannot ban masks, we may work towards unmasking their social fabric wherever they emerge. The relationship between metaphor and nanotechnology is made of paradox. Rather than preventing selective blindness which cannot be achieved, we should preserve it, since without it there is no development.

Given the communication efforts underway to increase collaboration between scientific fields, the efficiency of science policy practices (RRI governance), and the heightening of public awareness of nanotechnology, this thesis speaks for enhancing our understanding of the values and ideas which shape these practices, but their origins may have been only vaguely understood. The metaphor analysis approach offers the chance to understand transformations within a science-policy-public interface by taking a closer look at the interplay of different resources and reassembling the profile in given (cultural) contexts. In the emerging world of nanotechnology ('nanoworld'), these insights are invaluable. They should allow us to move from our own constraints to openings; if the European community is indeed facing dilemmas and frustration,

[98] As James H. Johnson (2001: 91) points out, during the French Revolution, masks were banished from the street only to emerge as a central rhetorical figure in speeches, in print, and the characterisations of conspirators both real and imagined.

perhaps space will open for more *therapeutic metaphors*. To understand the role of metaphor in nanotechnology discourse is to understand the need *to preserve the selective blindness accomplished by metaphor* and to revoke the popular dictum, 'metaphors we live by' (Lakoff and Johnson 1980). Social sciences can only benefit from a perspective which moves with the progression of nanotechnology controversies by questioning the durable and shifting figures of nanotechnology development. Moving from constraints to openings is suggested not in terms of moving from old to new metaphors but in terms of increased reflexivity within these two figurative positions.

11.2 Future Research and Challenges

The results from these case studies on the relationship between metaphor and nanotechnology carry something common into future discussions. Rather than using metaphors as an *explanans* for further techno-scientific possibilities, policy mandates, or societal objectives, they must be instead an *explanandum*, something we must explain and constantly contextualise. We must pay just as much attention to what is concealed as to what is revealed, because what is concealed may privilege some meanings, interests, and activities over others—regulation that is less overt but not necessarily less effective. In the future, individuals involved in science policy or *technology assessment* wanting to know technology development better, to evaluate their figures and possibly change direction, or to simply develop new approaches for communicating science, may find that this analytic approach offers hope for well-founded alterations. For this to occur, however, there must be a continued development of research methods sensitive to figures which may hold individuals and social groups captive or locked in the status quo. This is dependent on being open to an *exploration of contradictions* and *resonances* which create tension, especially giving attention to those metaphors which may have effectively amplified, or conversely, levelled out public debate and are already (over)flowing our minds. The challenge concerns two kinds of underlying biases, in particular: *confirmation bias*—problems and solutions are of the same conceptual or semantic domain, and together, can form a promise-requirement cycle; and *story bias*—the established connection between elements of a story and the filtering out of other elements. It is imperative to continuously assess the context of this consolidation of nanotechnology discourse. The chain of significations can be broken, especially in terms of assessing alternative concepts and storylines.[99]

Those trained in the sciences and technologies, history, sociology of sciences, and other related disciplines can and must step up to challenge the kinds of fundamentalisms confined in their

[99] 'A new thematic perspective should invite—but does not prescribe—specific inferences about the most relevant way of conceptualizing the target topic. To indicate that a scenario is open to further discussion and negotiation, speakers can employ hedging formulations or other contextual signals that make it evident to the hearer that the proposed analogy only claims partial applicability' (Musolff 2004: 174).

own disciplines and language in general—whether it is a naive faith that technologies can solve all social problems (the case for nanotechnology) or figurative accounts in reference to truth-claiming descriptions (the case for the metaphor). It is imperative that we employ our critical faculties to unravel the strategies and social practices which their relationship also entails. Interdisciplinary thought is ideally positioned to sometimes confront misguided faith in progress (or technology) and deception in metaphor (or language structures) by employing what one might call a 'techno-cultural imagination' (inspired by Mills' manifesto, *The Sociological Imagination* from 1959). Such an imagination, hopefully supported by this dissertation, allows us to ask the right sorts of questions: Which part or members of society get to decide which technologies are developed or used? What social and technical factors are at work that influence why one technology 'succeeds' and another 'fails'? To what extent do these and their combination mould technologies? Do technologies spark 'progress', or must concepts like 'progress', '(r)evolution', and the 'knowledge society' as such be explained as something that necessarily raises further expectations? What would a truly 'upstream' debate about nanotechnology look like? These kinds of questions are already circulating in the debates (ever since the 'strong programme' in the sociology of scientific knowledge) and can be updated with metaphor analysis.

As the interactions between science and society are changing, relevance to ethical, legal, and social aspects is important; expertise is needed but will always be contested. Science, policy, and the public as we know it cannot be the final word (cf. Rip and Elzinga 2002: 99). Ideally, the analysis of the relationship between metaphor and nanotechnology should always target three types of transformations: scientifications, politicisations, and socialisation (cultural appropriation). As much as the (our) current model of technology assessment speaks for interdisciplinarity, as a programme or process, it should also attempt to lead us from the pitfalls of one-sided views/perspectives on issues:

- scientification ~ technology determinism ~ technocracy
- politicisation ~ power determinism ~ governmentality
- socialisation ~ cultural determinism ~ nationalism, tribalism

How plausible are the above accounts if taken as separate and exclusive truths? I have already challenged elements of these views which can potentially drive us to the scientific, political, or local (cultural) appropriation of nanotechnology—what is at stake is a programme or process to take over, as when the public is replaced by the private (entrepreneurial), but even a change from civilian to military nanotechnology, for example, should be considered (cf. Altmann 2004 for additional discussion in this area). Nanotechnology is driven by universalism, or conversely, threatened by cultural (and also ethical) relativism. These are crude but necessary ways of approaching the question of the relationship between metaphor and nanotechnology which should

be addressed by future research. By following the nanotechnology discourse within case studies and over a particular period (1999-2015), awareness of nanotechnology and its figures should not be disguised as a position which claims to provide an absolute and full descriptive account. In other words, the richness of nanotechnology in all its forms is necessarily reduced, but these constraints should not be perceived as a handicap as they can apprehend further discussed transformations within nanotechnology discourse.

Appendix

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