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Diplomová práce

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Development of psychosocial dynamics of teams in isolation

Vývoj psychosociální dynamiky týmů v izolaci

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Prohlášení

Prohlašuji, že jsem diplomovou práci vypracovala samostatně, že jsem řádně citovala všechny použité prameny a literaturu a že práce nebyla využita v rámci jiného vysokoškolského studia či k získání jiného nebo stejného titulu.

V Praze dne 23.7. 2019 ....

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Abstract

The thesis focuses on psychosocial dynamics of teams in isolation and its development over time. Literature review summarises various psychosocial and psychological aspects of human coexistence in extreme environments. It includes the risks and psychological countermeasures, description of stressors and other challenges, the intragroup issues and their development over time. It puts emphasis on defining the most challenging parts of missions and tries to identify patterns. Additionally, the relationship between the crew and MCC is addressed. The literature review is followed by a study focused on the development of intragroup relations and the crew-MCC relations in two analogue missions, Lunar Expedition-0 and Lunar Expedition-1. The research design consisted of a questionnaire, an interview with the whole crew, and the individual interviews with all respective astronauts. Additionally, a new visualization method, *Dotty Overview of Team Interactions* (DOTI), has been created as a part of this research. DOTI was described and used to visualize the data relating mutual interactions among the crewmembers. All of the results are presented, described and discussed.

Keywords: team dynamics, crew, analogue space missions, interactions, relationship between crew and mission control

Abstrakt
Tato diplomová práce je zaměřená na psychosociální dynamiku týmů v izolaci její vývoj v čase. Literárně přehledová část shrnuje různé psychosociální a psychologické aspekty koexistence lidí v extrémních podmínkách. Tato část obsahuje rizika a psychologická protiopatření, popis stresorů a dalších těžkostí, problémy uvnitř skupiny a jejich vývoj v čase. Současně klade důraz na vymezení nejnáročnějších částí misí a snaží se identifikovat opakující se strukturu jejich výskytu. Dále je popsán vztah mezi posádkou a kontrolním střediskem. Po literárně přehledové části následuje popis studie zaměřené na vývoj interakcí uvnitř skupiny a vztah posádky a kontrolního střediska ve dvou analogických misích: Lunar Expedition-0 a Lunar Expedition-1. Výzkumný design sestával z dotazníku, rozhovoru s celou posádkou a individuálních rozhovorů se všemi jednotlivými astronauty. Součástí tohoto výzkumu byla také nová metoda vizualizace *Dotty Overview of Team Interactions*[1] (DOTI), která byla popsána a použita k vizualizaci dat týkajících se vzájemných interakcí mezi členy posádky. Výsledky byly prezentovány, popsány a diskutovány.

Klíčová slova: dynamika týmu, posádka, analogické vesmírné mise, interakce, vztah mezi posádkou a řídícím střediskem

[1] Dotty Overview of Team Interactions lze přeložit jako Přehled týmových interakcí znázorněný puntíky.

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List of acronyms and abbreviations

CapCom	Capsule (or Spacecraft) Communicator; a communication link between flight control and astronauts
DLR	German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt)
DOTI	Dotty Overview of Team Interactions
EAC	European Astronaut Centre, ESA
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
EVA	Extravehicular activity (spacewalk)
EXEMSI	Experimental Campaign for the European Manned Space Infrastructure
FMARS	Flashline Mars Arctic Research Station
FD	Flight director
GT	Grounded Theory
HERA	Human Exploration Research Analog
HUBES	Human Behaviour in Extended spaceflight
IAC	International Astronautical Congress
IMBP	Institute of Medical and Biomedical Problems in Moscow (Институт медико-биологических проблем)
ISEMSI	Isolation Study for the European Manned Space Infrastructure
ISS	International Space Station
JSC	Johnson Space Center (Texas, directs the ISS Program)
LUNA	Lunar Analogue, a facility in Cologne (DLR, 2018)
LUNEX-0	Lunar expedition 0
LUNEX-1	Lunar Expedition 1
MCC	Mission Control Centre
MDRS	Mars Desert Research Station
NASA	National Aeronautics and Space Administration
NEK	Ground-based Experimental Facility (НЭК, Наземный экспериментальный комплекс)
RQ	Research question
SFINCSS-99	Simulation of Flight of International Crew on Space Station
STS	Space shuttle, officially called the Space Transportation System

“What constitutes the dignity of a craft is that it creates a fellowship, that it binds the men together and fashions for them a common language. For there is but one veritable problem - the problem of human relations. We forget that there is no hope of joy except in human relations.”

Antoine de Saint-Exupéry Wind, Sand, and Stars (2010), p. 27

Introduction

I am fascinated by what are people capable of and how they can push the boundaries of what is possible. I have missed the era of space race with the great moments of achievement. I was not born yet. I hope I can experience something as great – a crewed mission to Mars.

I have heard on multiple occasions that a crewed mission to Mars will become reality within the next twenty years. I have been hearing it repeatedly over the last ten years although no significant progress is being made.

The only way the Mars exploration can come to a fruition is by combined effort of everyone. Therefore, I have decided to reject the passive role of an observer, and to try to come up with some findings on my own. I have focused on search for answers of few questions: How are the interactions within a crew living in extreme conditions? How will these interactions evolve over time? Is there any pattern across the projects? What are the main difficulties in terms of psychosocial and psychological aspects? How they can be addressed?

I have collected data from several scientific projects, published few scientific papers, presented my results in various occasions including conferences, workshops panels as well as public lectures.

The theoretical part of this thesis will provide a literature review of the psychosocial aspect of crewed space missions. The first chapter is devoted to the challenges of living in extreme environments. It includes a brief overview of past projects of crewed space missions as well as the future ones – a base on the Moon and mission to Mars. Additionally, the extreme conditions related to space research are described.

The second chapter summarizes the risks and psychological countermeasures linked to a crewed spaceflight. Two of the pre-mission countermeasures are described in more details – the crew selection and astronaut training.

Third chapter consists of characterization of the psychological, psychosocial, and psychiatric symptoms and stressors as well as other challenges that are typical for a stay in space. The additional stressors defined for future long-term missions are also discussed. This section is followed by a summary of intragroup issues and their development over time, with an emphasis on finding the most difficult parts of the missions. Additionally, the relationship between a crew and mission control centre (MCC) is addressed.

The empirical part provides the description and results of a study performed as a part of this thesis, during two analogue missions: Lunar Expedition-0 and Lunar Expedition-1. This study addressed mainly the development of the relations between the crewmembers. The research design consisted of a questionnaire, an interview with the whole crew, and the individual interviews with all respective astronauts. Moreover, observation from the MCC was conducted in order to gain additional context and background of the crew-MCC interactions. This contributed to the adjustment of the questionnaires and interviews. Additionally, a new visualization method, called *Dotty Overview of Team Interactions* (DOTI), was created and described as a part of this research. DOTI was used to visualize the data relating mutual interactions among the crewmembers.

This thesis is a summary of most of my work in this area so far. I have summarized findings of hundreds of studies in the theoretical part and presented my methodology, results and conclusions in the empirical part of this work. I have based this work on my bachelor thesis (Davidová, 2017b) from which some parts were used. Similarly, the description of the Lunar Expedition-0 and illustration of preliminary results were presented at International Astronautical Congress 2017 (Davidová, 2017a).

I have decided to do not distinguish among terms *an astronaut*, *a cosmonaut* or *a taikonaut* in the current thesis. I have consistently used an astronaut or a crewmember.

The references are cited according to American Psychological Association (APA) 6th edition.

I. THEORETICAL PART

1. Challenges of living of humans in extreme conditions

Any environment that demands complex adaptation for humans can be considered as an *extreme environment* (Kanas & Manzey, 2008). Notably, the definition of *an extreme environment* in a psychological meaning needs to consider that individual people may react differently to the same environment (Sandal, Leon, & Palinkas, 2007). Humans in general are adaptable to most of the environmental conditions on Earth. In contrary, a long-term stay in space poses a constant challenge to human in many ways including the psychological as well as physiological health. See *Table 1* which summarizes the main characteristics of an extreme environment.

An overview of the main characteristics of the extreme environments
▪ High reliance on technology for life support and task performance
▪ Notable degrees of physical and social isolation and confinement
▪ Inherent high-risk sand associated costs of failure
▪ High physical or physiological, psychological, psychosocial, and cognitive demands
▪ Multiple critical interfaces between human, technology and environment
▪ Critical requirements for team coordination, cooperation, and communication

Table 1: An overview of the main characteristics of the extreme environments based on (Bishop, 2006, 2011).

There many issues connected to staying in space or space-like environment including altered cognitive performance, low moods, sleep problems *etc.* (Mullin, 1960; Palinkas & Suedfeld, 2008; Zimmer, Cabral, Borges, Côco, & Hameister, 2013). Detailed understanding of the human response to an extreme environment during a prolonged time periods is needed in order to design countermeasures (Kanas et al., 2009; Manzey, 2004; Palinkas, 2001; Salas et al., 2015; Sandal, 2001) for future long-term space missions such as the Moon Village – the concept of building a bases on the Moon (Foing, 2016; Stenzel, Weiss, & Rohr, 2018; Woerner, n.d.; Woerner & Foing, 2016) and crewed mission to Mars (Barker, 2015; Harris, 2010; Horneck et al., 2006; Musk, 2017b, 2017a; Salotti & Heidmann, 2014).

Only a small number of psychosocial studies were systematically conducted on space crews—despite the fact that long-term stays in orbital stations are considered as the best source of knowledge for future long-duration space missions (Landon, Slack, &

Barrett, 2018). Moreover, most of the available papers discussing crew space missions are based on anecdotal reports and astronauts' diaries (Kanas, 2013; Kanas, Salnitskiy, Ritsher, et al., 2007; Lebedev, 1988; Stuster, 2000). Statistical data on team behaviour is rarely collected from the International Space Station (ISS) due to the busy schedules (Landon et al., 2018).

Consequently, an alternative source of valuable insight into the psychosocial challenges in extreme environments is needed. It may come from the so-called analogue missions: re-enactment events during which the volunteering astronauts are locked in confined areas that aim to partially recreate conditions of a space mission Several missions of this kind have been performed in the recent years (Davidová, 2016, 2017b, 2017a; Harasymczuk et al., 2017; Kołodziejczyk, Rudolf, et al., 2017; Kolodziejczyk et al., 2017; NASA, 2018c, 2018b; Salotti & Heidmann, 2014; Schlacht, Foing, et al., 2016).

1.1 Brief history of past crewed space missions

A brief history of the crewed space missions most relevant to this thesis will be presented in this chapter, followed by a description of possible future missions: such as a team flight to Moon or Mars. Additionally, a summary of the history of manned spaceflights is included in the *Appendix 1*. The history and the future of the crewed spaceflights will serve as a background to the space psychology hereinafter (*chapter 2*) and existing complex approaches to this problem.

Orbital stations started the era of long-duration stays in space, causing the relevant psychological and psychosocial studies to be increasingly important.

The first space station programme, named *Salyut, has been* undertaken by the Soviet Union from 1971 to 1986. It consisted of four crewed research space stations, as well as two crewed military space stations. *Salyut* had the official task of hosting crews for long-duration space stays. However, the U.S.S.R. also used this civilian program as a cover for the military Almaz stations, which flew under the Salyut designation (Zak, n.d.). It is worth adding that the U.S. has constructed the Manned Orbiting Laboratory (MOL)- a program similar to Almaz in the same time, with a target to build and to send to space a military orbital station with a crew (Astronautix, n.d.). Nonetheless, Salyut 1 became the world's first crewed space station (Britannica, n.d.-c; Wikipedia, n.d.-b).

Salyut programme has started the evolution of space stations, leading up to Mir and the International Space Station (ISS). Mir was continually manned for 10 years between 1989 and 1999 and helped to shape human space exploration: the astronauts from over than ten countries have visited the station to conduct a wide range of scientific experiments. Mir exceeded its life expectancy by five years. The station has been the inspiration for the ISS which is still in use (ESA, 2001; Harland, 2007; Launius, 2004; NASA, 2004).

ISS was built between 1998 and 2011, and the continuous operations are maintained since year 2000 (Catchpole, 2008; NASA, n.d.-e). The ISS expeditions usually last about six months and there are three to six crewmembers onboard at all time (Forrester, Kelly, & Knight, 2018; Melina, 2017). ISS stay lasts typically 6 months. The longest stay of a human at ISS was 340 days achieved by astronauts Mikhail Kornienko and Scott Kelly (Forrester et al., 2018; NASA, n.d.-c; Wall, 2018). The principals of the program are the space agencies of the United States, Russia, Europe, Japan, and Canada. As NASA mentions: "*The ISS has been the most politically complex space exploration program ever undertaken* (NASA, n.d.-d)". The ISS Program brings together international flight crews; multiple launch vehicles; globally distributed launch, training, operations, engineering, the development facilities; and the communications networks; as well as the international scientific research community. . All of the various elements provided by the ISS partners must be operated as an integrated system, thus making it more complicated than any other space flight endeavours (Catchpole, 2008; NASA, n.d.-d).

However, it is worth to add that the ISS has just few years of full functionality left. It is not clear when exactly the ISS will retire. The US Congress has extended NASA's operations of the ISS until 2024 (Grush, 2017). An extension to 2028 or beyond would enable NASA to continue critical on-orbit research in the areas of human health risks and to demonstrate the technologies that will be required for the future spaceflights to the Moon and Mars. NASA forecasted that the research on health risks will not be completed by the ISS's planned retirement in September 2024 (Martin, 2018). However, during the press conference at the last International Astronautical Congress (October 2018), the representatives of three ISS partner agencies mentioned they were open to the extending of the ISS's operations to 2028 or 2030 in order to maximize the return on investment made in the facility, in preparation for exploration activities beyond the Earth orbit (Foust, 2018). The ISS is an expensive project, requiring a cooperation with commercial partners and NASA also has to pay The Boeing Company (Boeing) and SpaceX to transport astronauts to the ISS as early as the U.S. fiscal year 2019 (Martin, 2018). Moon settlement could pose an alternative despite in terms of costs it would poses even much bigger challenge.

1.2 Future crewed missions: Moon and Mars

The crewed missions evolved and in future the long-term exploration will consist of settlement on the Moon and Mars. Therefore, both the settlement on the Moon (the Moon Village concept) and mission to Mars are considered relevant in the context of the thesis. Both will pose challenges of the long-duration stay of a crew in the extreme space condition.

The Moon village concept counts on multinational cooperation (Woerner, 2016), most likely in cooperation with China thus the crew will probably be also multinational. The head of media relations for the ESA Pal A. Hvistendahl was quoted as saying by the Associated Press: "*The Chinese have a very ambitious moon program already in place. Space has changed since the space race of the '60s. We recognize that to explore space for peaceful purposes, we do [need] international cooperation* (Futurism, 2017; Matthew Brown, 2017)." Such agreement could signal a new era for the China National Space Administration (CNSA), which has enjoyed little cooperation with other space agencies in the past (being prohibited from participating in the ISS due to its strong military connections.) However, an agreement between the ESA and China could open the way for a three-party collaboration involving NASA (Futurism, 2017). The Director General of ESA Jan Woerner directly expressed his support for the Moon Village due to a number of unsolved problems in terms of crewed mission (e.g. to Mars) including psychological, safety, and health-related issues (Woerner, 2016). Various positive and negative arguments to the question of justification of potentially risky and expensive new spaceflight programmes have been posed (Rovetto, 2013, 2016; Szocik & Tkacz, 2018; Weinberg, 2013).

It is worth to add that many of the above-mentioned issues are associated or have implications to psychology. To name some of the challenges which should be resolved before sending human to Mars or before starting settlement on the Moon, there are e.g. issues with habitability and life support systems (Drake, 2009), ethical and legal questions (Marboe, 2018; Szocik & Tkacz, 2018); law (Hermida, 2006; Schwetje, 1991) commercial interest (Szocik & Tkacz, 2018), justification of economic, political and social risks (Szocik & Tkacz, 2018); medical, physiological and psychological challenges (Clément, 2005; Kanas, 2014; Kanas & Manzey, 2008; Szocik & Tkacz, 2018); cooperation and teamwork within the crew (Mesmer-Magnus, Carter, Asencio, & DeChurch, 2016; Salas et al., 2015) can be mentioned. Out of the psychological issues already the crew selection for a long-term mission is going to be challenging especially because of the whole duration of such mission (Kanas, 2014; Kanas & Fedderson, 1971; Leonov & Lebedev, 1975).

To conclude, the Moon settlement is considered as the next step of exploration by all major space agencies. ESA, Rocosmos, and the Chinese and Indian space agencies have already announced their plans for crewed missions to the Moon which could result in permanent settlements there. Considering the costs and research advancement, collaboration appears to be necessary (Murray, 2016). As already mentioned, many of the aforementioned issues are associated with psychology. By assessing the crew development over the period of isolation and their individual well-being repeatedly, many important conclusions can be done and several of the issues solved or partly solved, e.g. crew selection, team development, assessment of potential risks which would lead to the countermeasure strategies *etc*.

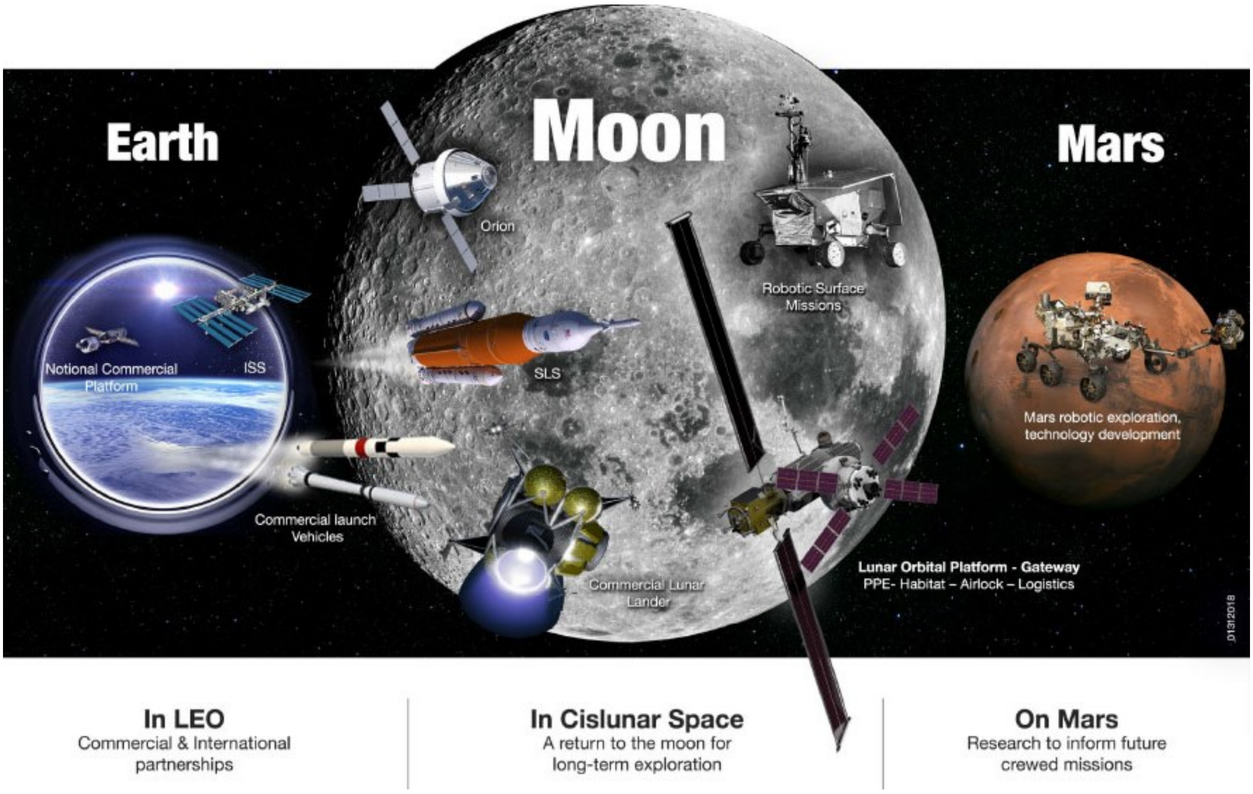

Figure 1: NASA's plan of mission to Moon and Mars. Retrieved from NASA's web page (NASA, 2018b).

NASA plans to revitalize lunar exploration and through Moon to go to Mars with the support of the current president, Donald Trump. The US president aims to return of the American astronauts to the Moon for the long-term space exploration (NASA, 2018b, 2018c).

Remarkably, public institutions are not the only organisations with the vision of bringing humans to Mars. Private companies, such as SpaceX, has also announced their plans of participating in *a race to Mars* (David, 2016; Nováková, 2016; Rachel Becker, 2016; Tyler Losier, n.d.). Interestingly, SpaceX CEO, Elon Musk claims that Mars "*would be a good place to retire*" (Harris, 2010). Admittedly, there is more private companies getting ready to Mars e.g. Lockheed Martin with Mars Base Camp e.g. (Australia's Science Channel, 2017; Galeon, 2017). The concept of Mars Base Camp is the following: transport astronauts from Earth, via the Moon, to a Mars-orbiting science laboratory where they can perform real-time scientific exploration, and to confirm the ideal place to land astronauts on the surface. The time framework is 2030s. This mission is designed to be led by NASA and its international and commercial partners (Lockheed Martin, n.d.). However, it is worth to add that private companies have different approach and objectives (Vernile, 2018) which may be less focused on the physical and psychological health of the astronauts who will have to face all of the challenges of the hostile environment over the long-term space mission.

On the other hand, all the endeavour of future crewed mission to Mars can be also strongly opposed due to the high cost and risk for human medical and psychological health. Former American astronaut Bill Anders, who was the lunar module pilot for the Apollo 8 mission (1968), which completed 10 orbits around the Moon, has spoken for BBC Radio 5 Live about mission to Mars. Mr Anders mentioned that he is a big supporter of unmanned space programs for putting their success down to low cost, although the idea of sending human crews to Mars was as he said "*almost ridiculous*". And continued: "*What's the imperative? What's pushing us to go to Mars? I don't think the public is that interested*", said Mr. Anders while referring to a lack of public support for expensive missions involving humans as the reason for his beliefs (ABC, 2018; Green, 2018). Anders' Apollo 8 crewmate, Frank Borman was not as critical as Mr. Andres, he said: "*I'm not as critical of NASA as Bill is. I firmly believe that we need robust exploration of our solar system and I think man is part of that* (Green, 2018)." However, Mr Borman drew the line at supporting Elon Musk (SpaceX) and Jeff Bezos (chief of Amazon), who both have space missions in the works. Mr Borman said: "*Musk and Bezos, they're talking about putting colonies on Mars, that's nonsense* (Green, 2018)."

Previously, manned mission to Mars has been planned to be conducted in first half of this century or even formerly (Bennahum, 1997; Horneck et al., 2006, 2003). The first study of human mission to Mars was published in 1953 by Von Braun (Von Braun, 1953) and the first reviews on psychosocial aspects of long term spaceflight were published between 1970's and 1980's (Manzey, 2004) despite all the years of studying this area, further research is still needed to asses all the specifics of the future Moon or Mars missions and their impact on the crew including crew selection and countermeasures (Connors, Harrison, & Akins, 1985; Kanas et al., 2009; Sandal, 2001) sooner these missions are planned, the more important and urgent is the psychological and psychosocial space research.

The complexity of a space mission and seriousness of psychological aspects steeply grows with the length of a stay in space. Time spent in space as a part of each individual space program was continuously growing starting on few hours, getting up to 6 months as a standard length of an ISS mission which required far more concern for habitability, crew efficiency, training, and sustenance than ever before. (Previous STS missions were designed for 2 weeks). As NASA begins to plan for a mission to Mars, many issues of high complexity must be solved in order to provide all support and services to crew members. It includes for example, physical and psychological health maintenance, training, recreation, food, clothing *etc*. (Woolford & Mount, 2012).

One of the main challenges is the length of such mission with low possibilities of resupply which might have significant consequences to the health of crewmembers. The mission to Mars would be the longest human mission in space. So far the longest single stay in space was achieved by Valery Poljakov his mission to Mir took 437 days and 18 hours (Fiona Keating, 2017; Schwirtz, 2009). NASA astronaut Peggy Whitson holds the record for longest time spent in space during a single mission since 2017 when she surpassed Italian astronaut Samantha Cristoforetti's 199 days, 16 hours. She returned to Earth in September 2017, having spent 289 days, 5 hours (Fiona Keating, 2017; James Rogers, 2017). However, ISS missions are usually taking around 6 month (Forrester et al., 2018). Crews during future long duration space missions will be involved in complicated tasks for long periods of time during future space missions involving a lunar base, or a journey to Mars. Psychological and social factors play an important role in performance and crew morale under such conditions (Kanas, 1997, 1998).

In the context of the observed psychological and physical health issues, the predicted length of the future Mars mission poses a significant challenge, with two possible scenarios lasting either around 520 days with 30 days stay on Mars or around 1000 days with 525 days spent on Mars surface (Horneck et al., 2006; Manzey, 2004). Both mentioned scenarios count with longer stay of humans in space than it has ever been achieved. Considering that, deep knowledge of psychosocial aspect of long-term cohabitation in isolated and confined area will be needed (Kanas et al., 2009; Manzey, 2004; Palinkas, 2001; Sandal, 2001). Hence all of the possible sources of knowledge are worth investigation. The possibilities and limitations of the environments analogou to space will be discussed.

1.3 Research from analogous environment

Earth-based missions that are similar, or analogous, to space can help prepare for the challenges of long-term space exploration. The analogue missions are defined as activities set in remote locations with extreme characteristics that resemble the challenges of a space mission in order to test systems and technologies to be used in potential space exploration (NASA, 2011). Additionally, it is worth to add that analogues should be similar – analogous to space conditions, but as Suedfeld stresses, they should not only look similar but most importantly they should have similar impacts on humans (Suedfeld, 2018). The analogue missions improve the understanding of issues and challenges relevant to space research, including understanding of factors affecting human functioning and well-being in space at both the physiological and the psychological levels (Bishop, 2013) moreover, they also help to obtain knowledge possibly leading to development of new strategies and countermeasures e.g. (Barratt & Pool, 2008; Binsted, Kobrick, Griofa, Bishop, & Lapierre, 2010; Bishop, 2011, 2013; Davidová, 2017a; Kanas & Manzey, 2008; Nicolas, Sandal, Weiss, & Yusupova, 2013) by providing a valuable insight to the cohabitation of humans in space or other extreme environments (Bessone, De Waele, & Sauro, 2018; Herian & Desimone, 2014; NASA, 2011; Reagan, Janoiko, Parker, & Johnson, 2012; Schlacht, Foing, et al., 2016). They are implemented to solve the unique challenges of cohabitation and working of humans in extreme environments (NASA, n.d.-g; Reagan et al., 2012).

The specific conditions of the settings of space analogues vary but most of such extreme environments share common characteristics: 1) a high reliance on technology for life support and task performance; 2) notable degrees of physical and social isolation and confinement; 3) inherent high risk sand associated costs of failure; 4) high physical or physiological, psychological, psychosocial, and cognitive demands; 5) multiple critical interfaces between human, technology and environment; and 6) critical requirements for team coordination, cooperation, and communication (Bishop, 2006, 2011). These environments so called ICEs (isolated and confined environments) are inherently and chronically "abnormal" in the eyes of most social scientists (Suedfeld, 1998).

Despite the design of analogue missions can differ, there are specific advantages of each of the typical settings, e.g. laboratory chamber studies can identified issues that might cause psychological and interpersonal problems in space or to provided empirical evidence for a number of behavioural issues anecdotally reported from space, e.g., the tendency of crews to direct aggression toward personnel at Mission Control (Kanas, 2013; Kanas et al., 2000). Mars 500 analogue astronauts Diego Urbina and

Charles Romain, pointed out that in isolation projects analogue astronauts really do not feel like they can end the simulation at any time and go home with little or no consequences and all such idea is just a common misconception among external people (Urbina & Charles, 2014).

There are many advantages of performing analogue environments, nevertheless many limitations too. Some aspects of space missions cannot be simulated on Earth. For example, microgravity (or reduced gravity relevant for Moon and Mars missions) cannot be simulated terrestrially for longer than tens of seconds; humans on Earth cannot be exposed to space radiation *etc.* (Bell, Outland, Abben, & Brown, 2015; Salotti & Suhir, 2014). Moreover ethical standards [2] relevant for experiments, prohibit conditions such as no evacuation in case of emergency, no possibility of withdrawal from an experiment *etc.* (Manzey, 2004). As Bishop (2011) mentions, some of the very attributes of the environment that have the greatest impact on performance of subjects are removed in the laboratory studies (e.g., real danger, uncontrolled events, uncertainty and the interaction with the extreme environment).

There are several kinds of analogues relevant to space conditions: expeditionary analogues including boats and submarines, polar stations, spaceflight simulations or simulations of a stay in space which are described in the sequel.

1.3.1 Expeditionary analogues and polar stations

Expeditionary analogues (e.g. oceanic, polar, desert, caving, mountaineering) are characterized by the participants having to move from one place to another. Psychosocial research on teams can be involved as a secondary to expedition goals (Bishop, 2011). Numerous psychological/psychosocial studies were done as a part of such expeditions (Bechtel & Berning, 1991; Bessone et al., 2018; Leach, 2016; Leon, Kanfer, Hoffman, & Dupre, 1994; Palinkas & Suedfeld, 2008; Stuster, 2000, 2004; Suedfeld, 2010; Weybrew, 1991) *etc.*

Stuster (2000) who reviewed many of historical expeditions—that were typically long lasting (from months to years) and characterized by broad goals and significant risks--finds many similarities between conditions as on sailing ships voyages and

[2] E.g. Declaration of Helsinki (World Medical Association, 2018) and Human Rights (United Nations, n.d.)

future space missions despite the technological differences are significant. From the perspective of engineering, a spacecraft is far more complex than a sailing ship. One of the factors that increases spacecraft complexity is the requirement of Earth based support of the crew. However, from a psychological or behavioural perspective, the differences between isolation and confinement in a small, high-technology ship scudding in interplanetary space and isolation and confinement in a small wooden ship locked in the polar icecap are probably few (Stuster, 2000, 2011).

Other options represent polar stations which can provide natural laboratories. The level, intensity, rate of change, and diversity of physical stimuli, as well as of behaviour settings or possible behaviours significantly lower than in most areas of temperate zones. There is also a very high level of control over many aspects of the situation. Both, the level of sparseness of social and physical stimuli as well as central control makes it possible to reach relatively high levels of internal validity (Suedfeld, 1998).

One of such environments represent Concordia. Concordia Station on the high Antarctic plateau is considered one of the best analogues for spaceflight or living beyond Earth. The station is occupied by a multicultural crew composed by on an average 12–14 scientists and technicians. There is no possibility of evacuation or deliveries during the 9-months long winters (from February to November) due to the environmental extremes including extremely low temperatures. Besides that, there is complete darkness from May to August. During the deepest winter, the crew members can spend outside only several minutes at a time. The people there experience distinct feeling of separation form their “normal” lives and significant others. They also have to cope with high degree of sensory, recreational, social and work monotony, with little variation in their routine (Crucian et al., 2014; Salam, 2012; Tafforin, 2009). Similarly, there is for example Japan Antarctic Syowa Station, on Ongul Island (Ohno, Otani, & Ikeda, 2019). There has been due to its distinct qualities a lot of psychological and or psychosocial research with implications for space done in the polar environment e.g. (Harrison, Clearwater, & McKay, 1991; Khandelwal, Bhatia, & Mishra, 2017; Krins, 2009; Leach, 2016; Ohno et al., 2019; Palinkas, 2003a; Palinkas & Suedfeld, 2008; Roberts, 2011; Sandal et al., 2007; Sandal, van de Vijver, & Smith, 2018; Tafforin, 2004, 2009; Zimmer et al., 2013)

1.3.2 Past projects of spaceflight simulations: isolation experiments

Space flight simulations represents controlled experiments that includes a variety of artificial, constructed environments specifically designed to be analogous to the desired condition of a spaceflight. The critical environmental factors are typically absent or blunted (Bishop, 2011).

Bishop (2011) mentions that the first systematic attempts to investigate psychological adaptation factors to isolation and confinement in simulated operational environments were conducted between late 1960s and early 1970s by putting volunteers in closed rooms for several days. Subjects had to undergo sleep deprivation and various levels of task demands with repetitive research tasks to evaluate various aspects of lowered performance (Haythorn & Altman, 1967). Currently, the main idea of isolation experiments is simulating of the most significant events, which can occur to astronauts during a long-term space journey (IMBP, 2017).

One of the earliest isolation experiments of analogue spaceflight was Štola-88, was very innovative and inspiring experiment led by Dr. Sýkora with Czechoslovak Academy of Sciences was conducted in 1988 near Tišnov, Czech Republic. (Sýkora, 1989; Sýkora, Dvořák, Bahbouh, Bernardova, & Justa, 2010).

Couple of experiments - ISEMSI and EXEMSI were carried out by ESA at 1990 and 1992. Both studies simulated long-term spaceflight. ISEMSI was comprised of 6 analogue astronauts that were in isolation for 28 days. Later EXEMSI took 60 days with 4 member-crew (Collet & Vaernes, 1996; Vaernes, 1996; Værnes, 1996; Vaernes, Schernhardt, Sundland, & Thorsen, 1993). In same time the Biosphere 2 project was conducted. It was a large 2 years long project (conducted 1991-1993) where a team of eight (four women and four men) has been sealed inside 3.15 acres in its airtight footprint ecosystem in Arizona. This ecosystem was materially closed, with air, water, and organic material being recycled, only energetically open to electricity and sunlight. The purpose of this project was to integrate humans, technology and agriculture and to research experimentally a life in ecological self-organized habitat (Nelson, Gray, & Allen, 2015; Walford et al., 1992).

HUBES (an abbreviation for *HUman Behaviour in Extended Spaceflight*) and ECOPSY was conducted in Russia. Both of these experiments simulated a spaceflight of three members crews. HUBES took 135 days, later ECOPSY 90 days of simulation (Gushin, Efimov, Smirnova, Vinokhodova, & Kanas, 1998; Gushin et al., 1997; Kanas, 2013; Mohanty, Fairburn, Imhof, Ransom, & Vogler, 2008). These experiments were followed by multicultural experiment SFINCSS-99, which simulated an ISS mission in Russia at 1999 (Inoue, Matsuzaki, & Ohshima, 2004; J. Kass & Kass, 2001a; R. Kass & Kass, 2004).

After several years, isolation experiments continued in Russia. Mars 105, simulation of Mars mission for 105 days with 6 members crew was conducted in Ground-based Experimental Facility (NEK) at 2009. This experiment was followed by Mars 520 project which was the first Earth-based, high-fidelity simulation of whole mission to Mars (in the shorter scenario) where the multinational crew of 6 males was confined in a 550 m^3 chamber for 520 days (Basner et al., 2014; ESA, 2009, 2011; IMBP, n.d.; Šolcová, Stuchlíková, & Guščin, 2014; Spring, 2010; Vinokhodova, Gushin, Eskov, & Khananashvili, 2012). Few years later also simulated Moon mission was done in Moscow's NEK. Luna-2015 was an experiment where all-women crew took part for their 9 days mission (Richards, 2015; Toscano & Kuznetsova, 2018).

All of the aforementioned past isolation experiments are summarized in *Table 2* below. This table was constructed to provide an overview of the main past spaceflight simulations. It was adopted form the authors' previous work (Davidová, 2016) which was updated and modified for the purposes of this publication. The information provided in the table was gathered from the following literature: (Bahbouh, 1996, 2012; Basner et al., 2014; Bergan, Sandal, Warncke, Ursin, & Ragnar, 1993; ESA, 2011; Eskov, 2011; Gunga, Kirsch, Röcker, Maillet, & Gharib, 1996; Gushin et al., 1998; Gushin, Pustynnikova, & Smirnova, 2001; Gushin et al., 1997; IMBP, 2017; J. Kass & Kass, 2001b; Mohanty et al., 2008; Richards, 2015; Rosnet, Caves, & Vinokhodova, 1998; Sandal, Bye, & van de Vijver, 2011; Sandal, Værnes, & Ursin, 1996; Šolcová, Gushin, Vinokhodova, & Lukavský, 2013; Šolcová et al., 2014; Sýkora, 1989; Tafforin, Vinokhodova, Chekalina, & Gushin, 2015; Toscano & Kuznetsova, 2018; Vinokhodova et al., 2012).

Name	Year	Dura-tion in days	Simulation of	Crew size	Nationality of participants	Woman in crew	Age in years	Original occupation	Lo
stola-88	1988	19*	Mars mission	2 crews of 7 and 5	Czechoslovak (all)	1	20-40	9 university students; 1 journalist, scientist, labourer	Tiš Cze ova
SEMSI	1990	28	Long term manned spaceflight	1 crew of 6	Italy, France, Holland, Germany, Sweden, Norway	No	28 in average	Engineers, Physiologist	NU Be No
XEMSI	1992	60	Long term manned spaceflight	1 crew of 4	Multinational	1	27-34	?	DL Co Ge
HUBES	1994-1995	135	Mir Space Station	1 crew of 3	Russian	No	32,36, 37	2 members of Russian astronaut team, 1 medical doctor	IM Mo
ECOPSY	1995-1996	90	Spaceflight	1 crew of 3	Russian	No	21, 21, 48	2 students, 1 members of Russian astronaut team	NU Be No
FINCSS	1999-2000	total time 263**	ISS mission	3 crews each attended by 4 members	3 Crews: 1) 4 Russians 2) 1 Ger.+ 3 Rus. 3) 1 Austrian, 1 Jap., + 1 Rus. 1 Rus.+ 1 Canadian	1 (in 3rd crew)	27-48	?	IM Mo
Mars 105	2009	105	Mars mission	1 crew of 6	4 Russian, 1 German, 1 French	No	25-40	Engineer, airline pilot, cosmonaut, cosmonaut and biologist, sports physiologist	NE Mo
Mars 500	2010-2011	520	Mars mission	1 crew of 6	3 Russians, 1 Italian, 1 French, 1 Chinese	No	27-38	ESA intern, Quality Manager, military physician, surgeon, nautical engineer taikonaut	NE Mo
una	2015	9	Noon mission	1 crew of 6	Russian	Yes	?	?	NE Mo

Experimental days were shortened to 18 hours, so the experiment took ~25 experimental days.
 There were 3 crews for a total time of 263 days in SFINCSS. 1st crew 240 days; 2nd crew 110 days; 3rd crew: 110 days. Most of the time two crews
d second crew or 1st and 3rd crew.

Table 2: The overview of the main past space

1.3.3 Current projects of Earth based analogues for Moon/Mars

In this chapter, several contemporary projects will be mentioned to provide a brief overview of the current research of teams under the simulated space conditions.

The Mars Society, the world's largest space advocacy organization dedicated to the human exploration and Mars settlement, established by Dr. Robert Zubrin and others in 1998, owns two habitats - Mars Desert Research Station (MDRS) in Utah, the USA; and Flashline Mars Arctic Research Station (FMARS) on Devon Island in Canada. These facilities regularly host crews for analogue studies (Binsted et al., 2010; “The Mars Society,” n.d.). The station on Devon Island, the largest uninhabited island in the world at Nunavut Territory, Canadian High Arctic is called FMARS which is one of two Mars analogue stations used by the Mars Society (“The Mars Society,” n.d.), a privately funded organization, to investigate life and work under Mars conditions and constraints. The temperatures reach as low as -40° Celsius at the start of the beginning of summer season, the harsh conditions simulate some of the hardships that a crew would experience during a real Mars mission (Binsted et al., 2010). The crews’ stays at the Devon Island station vary in length, but usually do not exceed 2 months. This station also provides many aspects close to space conditions (Moon or Mars) - long travel to and from Devon Island (several days), relatively harsh polar desert environment, disrupted circadian rhythms because of 24 h of daylight during the Summer field season (Crucian et al., 2014).

Another place where space mission can be simulated is HI-SEAS (Hawaii Space Exploration Analog and Simulation) which regularly host crews for long-term stays (“Hawaii Space Exploration Analog and Simulation,” n.d.).

NASA runs series of analogue experiments called HERA (Human Exploration Research Analog) (NASA, n.d.-b) and EAC (European Astronaut Centre) together with DLR (German Aerospace Centre) are building LUNA with FLEXhab - the Future Lunar Exploration habitat based Cologne, Germany (DLR, 2018; Schlacht, Punch, et al., 2016). Note that DLR also work with Envihab which is specialized research of medical implications of space missions for future crewed space exploration. The research includes artificial gravity for future long term space missions, bed-rest studied, or studies of sleep for astronauts (DLR, n.d.; ESA, 2015; Hollingham, 2017) Russian IMBP started new series of isolation studies called Sirius in the complex NEK (IMBP, 2017; Orlov, Belakovsky, & Ponomarev, 2016; ИМБП, n.d.).

Finally, new habitat Lunares Research Station was built in 2017 in Poland. This habitat is used to simulate crewed Moon and Mars missions (LUNARES, n.d.-a). Testing analogue lunar mission design to test procedures for future missions in Lunares including psychosocial investigation (Davidová, 2017a) was already conducted at August 2016 in provisional habitat. Then two projects – Lunar Expedition 1 (LunEx-1) simulating stay on Moon (Kołodziejczyk, Rudolf, et al., 2017; Kolodziejczyk et al., 2017; Mathewson, 2017) and Poland Mars Analog Simulation (PMAS) (Kolodziejczyk et al., 2017; "Poland Mars Analogue Simulation 2017," n.d.) were carried out during summer 2017 followed by ICARES-1 in autumn of 2017 ("ICARES-1," 2017; Perycz, Heinicke, Davidova, Konorski, & Wasniowski, 2018).

See *Table 3* or an overview of the most common facilities assessing psychological and psychosocial research relevant for human space exploration.

	Facilities designed for simulations of the space conditions
HERA	Simulated space habitat, NASA Johnson Space Center, TX (JSC)
:envihab	Bedrest facility, Cologne, Germany (primarily studying physiological effects, but with some psycho-behavioural studies)
LUNA and Flexab	New facility in cooperation of DLR with EAC currently
NEEMO	Aquarius, NASA Extreme Environment Mission Operations
FMARS	Devon Island, Nunavut, Canada – Mars habitat and Mars surface simulation facility, Haughton Mars Project
MDRS	Utah, USA – simulations of Mars mission, usually for 2 weeks
Lunar Palace	Beijing – Fully closed, self-sustaining spacecraft and lunar surface habitat simulation
NEK	IBMP Ground-based Experimental Complex, Moscow – Space station and Mars voyage simulator
ACC	Human-Rated Altitude Chamber Complex – Long-duration spaceflight simulator, JSC
HI-SEAS	Hawaii Space Exploration Analog and Simulation (HI-SEAS), Mauna Loa Volcano
LUNARES	Poland, simulations of Moon and Mars missions

Table 3: Overview of some of the facilities designed for simulating space conditions (Binsted et al., 2010; DLR, n.d., 2018; "Hawaii Space Exploration Analog and Simulation," n.d.; "LUNARES: Simulated Space base," n.d.; IMBP, 2017; NASA, 2018d, 2018a; Schlacht, Foing, et al., 2016; Schlacht, Punch, et al., 2016; Suedfeld, 2018).

2. Risks and psychological countermeasures for space

One of the main reasons why to study psychology and psychosocial difficulties in isolation is learning of possible threats which is important when designing procedures and countermeasure strategies for spaceflights. There are various potentially dangerous issues that could lead to hazardous situations onboard as described in more details below.

Systematic studies of human factor errors in aviation are distressing. Human error has been implicated in 70 to 80% of all civil and military aviation accidents (Shappell & Wiegmann, 2000) as found by using the Human Factors Analysis and Classification System (Wiegmann & Shappell, 2001).

Fatal disasters from space are known – it includes Soyuz 1 (parachute failure), Soyuz 11 (decompression accident) and two STS disasters Challenger and Columbia. Another 11 astronauts, as well as test pilots or other personnel have been killed during training and test flights including Apollo 1 where all the crew of 3 astronauts died due to a fire during a spacecraft test. Additionally, there were many other close to dead moments that occurred in the history of human space exploration (Shayler, 2000; Stone & Ross-Nazal, 2011; Venugopal, n.d.; Wikipedia, n.d.-a).

The above-mentioned accidents were caused by various factors including the technical issues, human factor failures or organizational failures, as well as the known and unknown risk associated with the pioneering of space travelling. For example STS disasters Challenger and Columbia can be considered as organizational failure (Hall, 2016; Winsor, 1988). Challenger disaster is also often associated with communication failure (Vakoch, 2011; Winsor, 1988).

Psychological and interpersonal dysfunction occurring either in the MCC personnel group or within the astronaut crew might considerably interfere with the safety of a crew as well as with the success of all the long-duration mission. Therefore, countermeasures should be designed. As many times mentioned, psychosocial and psychosocial research is needed to understand the issues of isolation and confinement during a prolonged time periods (Kanas et al., 2009; Landon, Vessey, & Barrett, 2015; Manzey, 2004; Palinkas, 2001; Salas et al., 2015; Sandal, 2001).

To underline the possible threats coming out from the psychological aspects several reports from the past space programs and spaceflight simulations can be told – for more details see e.g. (Collins, 1985; Space Safety Magazine, 2015). One of the examples of the psychological effects of space flight on an astronaut, is the behaviour of one of the Mercury program[3] astronauts (Carpenter) labelled as an aberrant, accompanied by an impaired judgement as a result of the specific conditions. This astronaut wasted valuable control fuel, during his Mercury mission, to obtain unauthorized photographs of scenic sunsets. The consequence could likely be fatal because the unscheduled expenditure of fuel considerably restricted the spacecraft's manoeuvrability (Douglas, 1991; Space Safety Magazine, 2015).

Another example of risky behaviour was manifested by Soviet crewmember Romanenko who attempted to undergo an unauthorized EVA. He intended to peek out and to observe the ambience of earth and space outside his orbital station. His crewmate Grechko caught his foot to prevent him from exiting the hatch. This incident was not reported until termination of the mission when the crew safely returned (Harland, 2007; Space Safety Magazine, 2015).

These incidents were chosen as an example to clearly demonstrate that even highly disciplined and trained astronauts can make serious (potentially fatal) mistakes including ignoration of precautions and procedures (Collins, 1985; Space Safety Magazine, 2015). Therefore, the research of potential failures, difficulties and its countermeasures including crew selection is highly important.

Psychological countermeasures are the measures that has the goal of reducing the risks arising from impairments of crew interactions, cognitive performance and well-being (Kanas & Manzey, 2008). As Kanas & Manzey (2008) mention, "p*sychological countermeasures include all actions and measures that alleviate the effects of the extreme living and working conditions of space flight on crew performance and behaviour* (Kanas & Manzey, 2008, p. 161).

There are two complementary kinds of countermeasures that can be distinguished. The first are those that focuses on the environmental conditions during space flight to adjust them to the specific needs and capabilities of humans. This approach contains the issues of hardware and software design that are subsumed under "habitability" or

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[3] Mercury project was the NASA's first human spaceflight program. This project was launched in 1958. See *Appendix 1 The history of human space missions* for more details.

"environmental engineering" (Fitts, 2000). Beside that it also contains organizational factors of work-design and scheduling during a mission.

The second kind of countermeasure focuses on adapting the crewmembers as best as possible to the given conditions of living and work demands. This approach includes specific psychological measures that are applied in the astronaut selection process to find those candidates that are the best suited for becoming astronauts (Kanas et al., 2002; Manzey, Schiewe, & Fassbender, 1995). These measures can be classified according to the part of the mission – see *Fig. 2*. Crew selection and training poses countermeasures that are applied prior the spaceflight whereas monitoring and support are provided when during the stay in space. Additionally, post-flight support activities are helping with the re-adjustment of astronauts to the life on Earth when being back from space (Kanas & Manzey, 2008). The process of crew selection and training will be described in more details below.

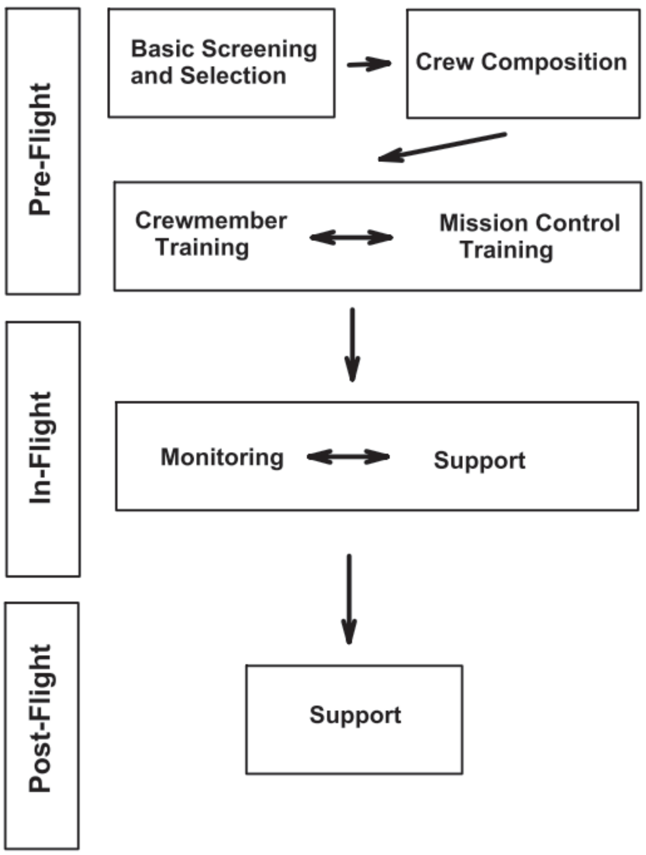

Figure 2: Psychological countermeasures for astronauts. Retrieved from (Kanas & Manzey, 2008, p.162).

The possibilities of countermeasure strategies differ in missions. There are many actions possible to be done for astronauts on orbital stations in order to mitigate stress and negative emotions onboard. For instance, flight surgeon and mission psychologist from the MCC can send favourite food and surprise presents on resupply ships. Communication between an astronaut and family or friends on Earth can be set more frequently or for longer in order to help to provide novelty and countermeasure to the effects of isolation, loneliness, and limited social contact. As well as there are also special moments created by crewmembers onboard such as celebrations of holidays and mission milestones which contribute to the maintenance of morale (Kanas, 2014). However, it is worth to add that such measures will not be possible when flying to Mars. See *Table 4* which provides a list of countermeasures and their applicability to a mission to Mars.

The countermeasures for psychological adaptation	**Applicable for journey to Mars?**
Training including periodic behavioural observations of the astronauts	Yes
Weekly private family conferences of minimal duration of 15 minutes, preferably two-way video conferences	With limitations
Regular delivery of personal packages to the crewmembers	No
Access to radio and native news	With limitations (cannot be in real time)
Family support as needed	With limitations (cannot be in real time)
Materials for wide variety of individual leisure activities (books, music *etc.*)	Yes
Daily electronic mail uplink for family and friends	Yes
Work/rest schedules, impact on personal performance and rhythms	Yes
Personal countermeasures for fatigue and sleep cycles	Yes
Personal countermeasures for maintain of effective cognition, mood and behavioural health	Yes

Table 4: Countermeasures designed for adaptation for astronauts on ISS. Retrieved from (NASA, 2003) and modified.

2.1 Crew selection

Crew selection is one of the countermeasure strategies that are done prior a spaceflight similarly as training both of these measures are discussed in sequel.

2.1.1 Selection criteria

The selection process consists of 2 steps – selecting out and selecting in. The select out is a screening procedure whereas in later select in stage, the goal is to select the best out of the remaining candidates (Suedfeld & Steel, 2000).

In the first stage candidates are screened for psychopathology, inadequate preparation or problematic life history. They undergo objective as well as projective tests and interviews. Those candidates who are considered problematic in any way are removed. The screening procedures might be overly demanding although as space agencies became more realistic about potential problems, some selection criteria loosened, e.g. candidates for spaceflight do not have to be pilots anymore, or being in septuagenarian might not be a reason for disqualification (Suedfeld & Steel, 2000). The oldest astronaut John Glenn was 77 years old when he went to space for his second spaceflight (ESA, 2008) although the age scope of most of the ISS astronauts is between 30 and 55 years (Goel et al., 2014).

The main criteria that must be fulfilled to become ESA astronaut are having a university degree (or equivalent) in natural sciences, engineering or medicine ideally with at least three years of postgraduate professional experience, or to have a pilot experience. It is also beneficial to have studied aeronautics and astronautics. Additionally, an applicant must know English well, and ideally also another foreign language (preferably Russian). They also have to pass the medical examination, must be free from any disease and any dependency on drugs, alcohol or tobacco (ESA, 2008). And similar requirements are also applied when searching the analogue astronauts in some of the spaceflight simulations (Nicolas & Gushin, 2015; Nicolas et al., 2013; Urbina & Charles, 2014; Vaernes, 1996; Vaernes, Schernhardt, et al., 1993; Vinokhodova et al., 2012).

The applicants who get through the select out stage, continue to the select in stage from where only the best fitting candidates are chosen. The main factors can be grouped under the Gunderson's three factors concept of effective individual performance: emotional stability, task motivation (ability), and social compatibility (Gunderson & Ryman, 1971). This concept is known especially in the area of polar mission thus it is sometimes called Antarctic triarchy (Roberts, 2011; Suedfeld & Steel, 2000).

The aspects corresponding to the three factors were pointed out in various papers. For example, task motivation corresponds to the most valuable personal traits of astronauts concluded by Gushin and Vinokhodova who found the activities supporting the fulfilment of professional activities such are motivation, intellect, knowledge and self-discipline as most valuable personal traits of astronauts (Vinokhodova & Gushin, 2014).

The importance of effective communication which belongs to the social compatibility factor, was pointed out by Kass, Kass and Sameltedinov (1995). They found effective communication including problem solving, decision making and dealing with conflict extremely important while concluding also that incompatible crews are far less effective than compatible ones. Moreover, the best astronaut candidates should be sensitive to psychosocial issues (Kanas, 2016; Sandal et al., 1996). They need to be able to reflect their feelings and to actively engage in problem-solving of interpersonal difficulties. It is also worth to add that personal factors begin to be important for mission lasting 1-4 months and very important for long flights longer than 6 months (Kass, Kass, & Samaltedinov, 1995), thus future long-term space journeys needs to highly consider that.

Complex study astronauts' requirements were conducted by Galarza with Holland (1990) who identified critical factors and skills for a space mission. They described the differences between the critical requirements for long-term missions and for short-term missions. The proficiencies assuming greater importance for long-term missions are for example emotional stability or group living skills factors. The *Table 5* lists the critical factors sorted in the order of importance for long and short duration missions and *Table 6* describes each of the critical factors.

Critical Factors		
Order of criticality	**Long-duration space mission**	**Short-duration space mission**
1	Mental/Emotional Stability	Performance under stressful conditions
2	Performance under stressful conditions	Mental/Emotional Stability
3	Group living skills	Judgment/Decision Making
4	Teamwork skills	Teamwork skills
5	Family Issues	Conscientiousness
6	Motivation	Family Issues
7	Judgment/Decision Making	Group living skills

8	Conscientiousness	Motivation
9	Communication skills	Communication skills
10	Leadership capability	Leadership capability

Table 5: The comparison of the critical factors required for long-duration and short-duration space missions. Retrieved and modified from (Galarza & Holland, 1999).

Factors	**Explanation**
Mental/Emotional Stability	Freedom from mental disorder, emotional stability, self-control, self-confidence
Performance under stressful conditions	Ability to perform under threat to life stress, performance under stressful conditions, flexibility and adaptability, ability to cope with limited personal stress
Group living skills	Group living and interaction skills, adaptability to crew diversity, multicultural adaptability
Teamwork skills	Teamwork skills such as conflict resolution and cooperation, priority of team over personal goals, followership skill
Family Issues	Ability to cope with prolonged separation from family and friends
Motivation	Achievement motivation, intrinsic work motivation, perseverance, goal orientation
Judgement/ Decision making	Exercising sound judgment, situational awareness and vigilance
Conscientiousness	Responsibility, attention to detail, integrity
Communication skills	Interpersonal communication skills
Leadership capability	Team leadership, effective resource management, accountability

Table 6: The description of the critical factors for space missions. Retrieved and modified from (Galarza & Holland, 1999).

Different approach based on the compatibility factors was taken by Kanas and Manzey (2008) who put together a comprehensive list of personality factors and other individual characteristics that affects psychological compatibility of a crew. This list (see *Table 7*) partly corresponds to personality aspects that are considered by Russian space psychologists. Despite the authors admit that the theoretical and empirical basis for this list is weak because the main research done on compatibility in western countries was conducted back in 1960s and 1970s and most of the studies addressed mono-cultural dyads and triads confined for relatively short periods of time thus new studies in the area of the compatibility of a crew would be beneficial.

Compatibility Factor	Description
Homogeneity of personality traits	Crewmembers have similarly high levels of Agreeableness and Conscientiousness
Complementary needs	Crewmembers have different needs and traits that complement each other
Congruent needs	Crewmembers have similar needs that can be mutually satisfied (e.g., affiliation, autonomy, achievement)
Shared interests	The extent to which crewmembers share common interests (e.g. reading, games, music, politics, sports)
Shared values and norms	The extent to which crewmembers share a common system of values, beliefs, and behavioural norms.
Emotional attitude to each other	The extent to which crewmembers like and respect each other
Common language	The extent to which crewmembers are able to express their own feelings and thoughts appropriately in a common language

Table 7: The personality factors that affect compatibility of a crew. Retrieved from (Kanas & Manzey, 2008, p. 177).

2.1.2 Crew size

Despite the number of crewmembers to be sent to Mars poses very important topic because many other aspects of planning are depended on, it varies across studies. The depended aspects are e.g. food and water supply, the size of a habitat, space transportation system, *etc*. Additionally, the number of the astronauts on journey to Mars will have a direct relationship to the cost of the mission. Additionally, the size of the crew would be probably inversely proportional to the amount of new technology that must be developed to allow all tasks to be performed (Drake, 2009).

The issue of a size of the crew has been discussed already in the earliest era of designing a Mars mission. In 1948, when the knowledge of Mars was limited, von Braun together with a group of scientists and engineers created a plan that would send 70 people to Mars (Drake, 2009; Von Braun, 1953). As science and technology has advanced, the number of crew members needed for a successful first Mars mission has steadily decreased (Drake, 2009) even though the idea of high number of people on Mars is not dead. Elon Musk would like to build a growing city there and to colonize Mars to make human lives multiplanetary (Musk, 2017a, 2017b; SpaceX, 2017).

Unlike Elon Musk, most of the scientific papers dealing with the size of a crew traveling to Mars are considering rather only the first mission for which it is usually considered to compose a crew of 4-6 astronauts (Horneck & Comet, 2006; Horneck et al., 2006; Manzey, 2004; Ursin, Comet, & Soulez-Larivière, 1992). The crew of six is considered the best option in terms of mass and complexity. It would be possible to split the crew into two teams of three and to land with small vehicles rather than bigger ones (Salotti & Heidmann, 2014; Salotti, Heidmann, & Suhir, 2014). However, it could be possibly reduced to 3-4 astronauts in order to save overall recourses, mass, costs and complexity of the mission (Salotti & Heidmann, 2014; Salotti et al., 2014). Interestingly, the number of 6 is not rare even when considering polar expeditions – analogues to space e.g. (Wood et al., 1999).

Another factor could play also even or odd number of crew members. It was pointed out that odd-numbered crew can achieve consensus more easily than even-numbered crews and larger groups are more cohesive than smaller groups because one can more likely fond find a crewmember or two who shares his interests to face the feelings of isolation (Kanas & Fedderson, 1971).

Finally, Orion spacecraft, designed by NASA for journey to Mars, has been designed for a crew of 2-6 astronauts which is the range mostly mentioned to be sent to Mars (NASA, n.d.-f, n.d.-a). Six astronauts also attended simulation projects Mars 105 and Mars 500 (Basner et al., 2014; ESA, 2011; IMBP, n.d.; Shved, Gushin, Vinokhodova, Nichiporuk, & Vasilieva, 2014; Spring, 2010).

2.1.3 Group composition and gender

Group composition and gender ratio ideal for Martin mission poses an unsolved issue where opinions vary. Russian researchers has typically favourited males over females in terms space missions (Oberg, 2005) and their programs has mostly been attended all-male crews (Goel et al., 2014) as well as most of the Russian isolation studies such as: HUBES (Gushin et al., 1997), ECOPSY (Gushin et al., 1998), Mars 105 (Gemignani et al., 2014) and Mars 500 (ESA, 2011; Spring, 2010). Russian scientist Vadim Gushin was asked about the reason for having men-only crew in recent Mars 105 and Mars 500 experiments at a conference in 2015. He found women in crew risky based on one of the issues that occurred during the experiment in 1999 (Ushakov et al., 2015). In this isolation experiment SFINCSS-99 which was consisted of multicultural crews in one of which was 1 woman, 2 major incidents occurred: a fight between Russian subjects, and one of the Russian analogue astronaut's attempt to kiss a Canadian female crewmate which resulted in unpleasant consequences including separation of groups by closing a hatch between crews, interpersonal difficulties, and withdrawal of the Japanese subject a month after the incident (Hermida, 2006; Inoue et al., 2004). It is worth noting that explanations of these issues vary a lot according to perspective of the involved party, thus often the issues are marked as a cultural misunderstanding (Gray, 2000; Hermida, 2006; Inoue et al., 2004; Trickey, 2000).

As mentioned above, SFINCSS-99 resulted in the decision to proceed with further isolation experiments (Mars 105 and Mars 500) with men-only crews although it is worth to mention that recent experiments brought women back to the interest. All-women crew has attended the 9 days isolation project LUNA[4] (IMBP, 2017; Richards, 2015; Toscano & Kuznetsova, 2018) and current series of studies Sirius is planned to be attended by mixed-gender crew (ИМБП, n.d.).

Interestingly, as a study shows, the men-only crew approach is shared by Russian astronauts. 11 Russian crewmembers who participated in long duration space missions were asked for opinion regarding future Martian mission. Six out of 11 thinks that crew should be consisted of men only. Other believes that the crew should be mixed gender in a ration favouring to men (Nechaev, Polyakov, & Morukov, 2007).

Different opinion to this problem is presented by Sýkora. Results of Štola-88 stressed that a woman can positively influence team under stressful conditions. He emphasized "mother-like type" of women as beneficial for crew for long duration spaceflight. According to Sýkora a women or women increases diversity, thus also stability of a crew in the harsh environment of duration space flight (Sýkora, Šolcová, Dvořák, Polánková, & Tomeček, 1996). The presence of a woman can serve as a stress relieving factor, that mitigates the undesirable competition among men and decreases an intragroup tension. Additionally, women tolerate chronical stress better than men (Sýkora et al., 2010, 1996).

Similarly, Aries found out that mixed-gendered teams outperform mono-gendered teams because presence of women in groups *normalize* male functioning and enhance active cope behaviour resulting to earlier resolution of conflicts (Aries, 1976; Baird, 1976). Additionally, men mitigate their aggressive and competitive behaviour if a woman is present in the group. Additionally, behaviour such as an aggression, competition, or practical joking were no longer frequent if a woman was present. In

[4] Compare the length of these experiments: 9 days of LUNA – an experiment attended by women crew with previous men-only crews experiments Mars 105 and Mars 500 that took 105 and 520 days.

contrary, female's interactional styles remained more or less same in both all-female and mixed gender groups (Aries, 1976).

An interesting finding was presented in a metanalytical review examining the impact of sex composition of groups on productivity, where was concluded that overall, all-male groups were found to perform better than all-female ones although this result might be questionable because of the tasks and settings that favoured men's interests and abilities. For instance, the interaction style of all-female groups appeared to enhance performance more than all-male groups in tasks requiring positive interpersonal activity. Thus in total there were few findings related to mixed-sex groups demonstrating a slight, though not significant, tendency for mixed-sex groups to outperform same-sex ones (Wood, 1987).

Few studies focused also on women-only teams. Khan and Leon for example found out that all-female expedition teams showed highly effective patterns of work and communication with low competitiveness and high sensitivity in emotional concerns. But it is important to add that overall the results supported the hypotheses that a women expedition would be similar to male or mixed-gender teams in many aspects but would be more sensitive to emotional concerns (Kahn & Leon, 1994).

Despite all above mentioned, only few women went to space in comparison to men (Goel et al., 2014). As of the end of year 2013, the overall number of females in space was less than 11% of the total (Clément & Bukley, 2014), and 15% of the U.S. astronauts even though the numbers are slowly increasing (Ronca et al., 2014).

Finally, there is one more approach to this problem presented by scientists who declared that they would recommended to accept married couples to a crew for a long-term spaceflight (Kanas, 1998; Ursin et al., 1992) despite they did not tested this hypotheses experimentally.

2.2 Pre-mission astronaut training

Crew selection is generally followed by a long period of training (Urbina & Charles, 2014; Vaernes, 1996) where team processes such as a team's cooperation or a team's cohesion play an important role (Sandal, 2001). Group-assessment of team's compatibility prior a project is often conducted not only before a spaceflight but also as a part a simulation of a space mission or analogue missions such as Mars 500. Prior the Mars 500 experiment psychological assessment of a crew together with last phase of a crew selection was carried out. As a part of this training, the crew had to undergo a survival training in the Russian forest (Urbina & Charles, 2014; Ushakov et al., 2015).

The training prior to an experiment is considered beneficial. IN case of ISEMSI and EXEMSI it can be even one of the reasons why these two experiments had different results in team-work qualities (Manzey as cited in Sandal, 1998). The EXEMSI crew underwent 2 months long training prior the experiment (Collet & Vaernes, 1996) and ss results shows, in the EXEMSI crew was observed considerably better team cohesion and communicational relations in comparison to ISEMSI (Sandal, 2001).

Proper training a support can help to prevent a negative interpersonal phenomena potentially occurring during a long-term space mission because they might be related to psychological and interpersonal pressures, which are affecting people under isolated and confined conditions, rather than to individual personality weaknesses (Kanas, Salnitskiy, Grund, et al., 2001).

An important aspect of a training that many studies suggest is training of both crewmembers and mission control personnel together because there is a considerable risk that they will interact maladaptively due to insufficient communication patterns. It is worth to stress that a crew and MCC are dependent upon each other in mission activities thus conflicts between them could cause significant issues. Therefore, they should undergo together a training on psychosocial education include areas such as time effects, leadership roles, cultural differences, and the displacement in relationship between crewmembers and MCC personnel (Gushin & Yusupova, 2012; Kanas, Salnitskiy, Boyd, et al., 2007; Kanas et al., 2006, 2009; Kanas, Salnitskiy, Ritsher, et al., 2007).

Finally, it is important to mention that despite all training and preparations, the mission to Mars will be extremely demanding in many ways. The crew will face fatigue, frustration, and uncertainty while they will be locked in a small and probably not very comfortable capsule definite most of the time (Suedfeld, 2010). As Suedfeld highlighted "*During the entire mission, they will be much further from home than anyone in human history had ever been, and will not have the comfort of seeing the blue globe of Earth that earlier space voyagers found so reassuring. Danger will be constant. The crew will always be aware that there is no chance of outside help or rescue in case of emergency* (Suedfeld 2010, p. 641)."

3. Psychological, psychosocial and psychiatric stressors and challenges in space

"All Antarctic groups can describe unusual if not bizarre behaviour and practices. Such behaviour has lessons for space mission planners (...). A major case in Antarctica has caused difficulty but a major case in space could be disastrous or even fatal (Lugg & Shepanek, 1999, p. 695)."

Psychological and psychosocial issues and their research have wide implications into crew selection; designing of medical, psychological and psychosocial countermeasures, architectural design (privacy places, hygiene), safety (Clément, 2005; Stuster, 1986; Stuster, Bachelard, & Suedfeld, 1999) *etc.* Thus, whole chapter will be devoted to this problem including all of the important areas that potentially affect humans in terms of psychology and psychosocial aspects in space including crew selection, the negative effects of an extreme environment that affects adjustment with potential overlap into interpersonal difficulties, intragroup conflicts; intergroup conflicts and psychosocial development of a crew in isolation.

Crews on a long-term space journey will have to both live and work in environment of microgravity (or lower than Earth gravity), in the conditions of confinement (spatial restriction, social constraints, and sensory deprivation), and isolation. Such setting requires multidisciplinary attention to solve all the unique issues which may arise (Clément, 2005; Kanas, 2015; Kanas & Manzey, 2008; Tafforin, 2018). From anecdotal reports from astronaut crews who went to the orbital stations can be concluded that The personal and interpersonal adaptive processes are of prime importance for crew performance during long-term space missions (Tafforin, 2015).

The ability of humans to sufficiently adapt and perform in an extreme environment during periods of prolonged isolation is influenced by a number of social, cultural, and psychological parameters that has a considerable consequences for humans which must be taken into account when planning future long-term space missions (Palinkas, 1988; Sandal et al., 2007).

Physical environmental factors can act as psychological stressors to negatively affect individual performance as well as interfere with team performance (Lugg & Shepanek, 1999; Muller, Lugg, Ursin, Quinn, & Donovan, 1995; Zimmer et al., 2013). Therefore, determining and understanding of such stressors is very important when planning a mission and preparing of procedures and countermeasures.

There will be many specific stressors on the journey to Mars which will make it difficult for humans to adjust. To obtain comprehensive view on stressors relevant to space, research results from space and space analogues will be summarized and few of specific categories will be described in more details.

3.1 Psychological and psychiatric symptoms and stressors

The psychological state of the individuals in extreme environment has wide implications. For example anxiety, depression, or other environmental stressors might influence the medical state of individuals such as the immunity and the ability to resist infections (Lugg & Shepanek, 1999) which are the symptoms that are commonly reported from such missions.

The typically symptoms found in crewmembers staying in polar areas are: low mood leading to depressive states, cognitive impairment (Palinkas & Suedfeld, 2008; Torello, Barbarito, Juan, Cuiuli, Golombek, & Daniel, 2018; Zimmer et al., 2013), anxiety, irritability (Palinkas & Suedfeld, 2008; Zimmer et al., 2013), slowed physical and cognitive tempo, social withdrawal, neglect of personal hygiene (Suedfeld & Weiss, 2000), susceptibility to suggestion, intellectual inertia, spontaneous fugue states (known as Antarctic stare), anger, interpersonal tension, intragroup conflicts, and conflicts towards externals (Palinkas & Suedfeld, 2008). Sleep disturbances leading to chronic polar insomnia are that common that earned a nickname “Big eye”. It ought to be mentioned that sleeping disturbances are big issue for space missions too (Kanas & Fedderson, 1971; Kanas & Manzey, 2008; J. Kass et al., 1995; Lebedev, 1988; Manzey, 2004; Palinkas, Gunderson, Johnson, & Holland, 2000; Palinkas & Suedfeld, 2008; Strollo et al., 2014; Vaernes, Bergan, et al., 1993; Zimmer et al., 2013). Realising the importance of the insufficient sleeping of astronauts, a study investigating effects of lack of sleep was conducted recently by DLR (Hollingham, 2017).

Different symptoms poses similar term “Long eye” (or “Antarctic stare”) which is also symptom that is typical for long term stay in polar areas referring to a “20-foot stare in the 10-foot room” that Suedfeld & Steel (2000) described as “a *state in which thoughts drift from current reality into a vague absence that even the individual* *cannot recall afterwards* (Suedfeld & Steel, 2000, p. 231). This symptom was also reported from historical boat expeditions (Stuster, 2000).

Another of the frequently studies symptoms in polar missions are alternations in cognitive performance. According to Zimmer et al. (2013) despite significant investments in the research station structure, mood and cognition alteration problems are still reported on polar expeditions. However, opposite finding can be found. There are studies that reported neutral or even positive effect of long term stay at Antarctica on cognitive performance (John Paul, Mandal, Ramachandran, & Panwar, 2010).

Moreover, some of the aforementioned consequences of staying in a hostile environment can be considered as a reasonable adaptation to the specific environment. For instance, slowing down of activities can help to fill otherwise empty time and keeping unchanged the routine of personal hygiene may be difficult when the access to hot water and clean clothes is limited (Suedfeld & Weiss, 2000). Additionally, humour as a coping strategy in dealing with isolated environment was reported from space missions as well as submarines (Brcic, Suedfeld, Johnson, Huynh, & Gushin, 2018; Kimhi, 2011).

To summarize the main finding from stays in polar environment, a systematic overview (Zimmer et al., 2013) found out that nearly 80% of papers found the polar environment a possible disrupter of individual or team performance. Moreover, from the medical point of view the seasonal occurrence of the typical symptoms suggests the existence of three overlapping syndromes: the winter-over syndrome, the polar T3 syndrome (referring to a variety of symptoms including sleep disruptions, mental impairment, or mood changes caused by a decrease in levels of the thyroid hormone T3), and subsyndromal seasonal affective disorder. However, only approx. 5% of these symptoms would fulfil the diagnostic criteria according to DSM-IV[5]. Mood disorders were the most common diagnoses (Palinkas, Glogower, Dembert, Hansen, & Smullen, 2004; Palinkas & Suedfeld, 2008).

The typical psychiatric issues in space include an anxiety, depression, psychosomatic symptoms, psychosis, emotional reactions related to mission stage, and asthenia (Kanas, 2010) which was researched and was not confirmed although this issue was addressed to further research (Kanas, Salnitskiy, Gushin, et al., 2001).

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[5] DSM-IV stands for the Diagnostic and Statistical Manual of Mental Disorders (4th edition)

Several astronauts reported transcendent experiences, such as religious conversions or derealization in space. These phenomena are similar to the break-off phenomenon experienced by jet pilots flying at high altitudes (Kanas, 1997).

Regardless to aforementioned, there is no evidence of major mood and thought disorders (bipolar disorder, schizophrenia *etc.*) from space missions, probably due to detailed screening of astronaut candidates (Kanas & Manzey, 2008). Psychiatric and psychological symptoms are either not reported or has been marked as posing little threat to the well-being of a crew and success of a mission (Sandal et al., 2007). However, some evidence of psychosomatic reactions has been reported based on astronauts' diaries where the most common psychiatric problems in space are adjustment reactions that generally present with symptoms of anxiety or depression, these symptoms usually resolve as they adjust to the new environment (Kanas, 1997, 2014, 2016; Kanas & Manzey, 2008).

Stressors

The main stressors connected to the long term space missions include constant risk of danger, isolation and confinement, limited contact with close people, cultural issues, personality conflicts, crew heterogeneity, high workload in some of the periods of a mission (e.g., EVAs or emergencies) but also monotony and boredom, crew size, (Kanas, 2014, 2015; Kanas & Manzey, 2008), sensory deprivation (Leach, 2016; Peldszus, Dalke, Pretlove, & Welch, 2014; Ridgway, Bachman, Otto, & Leveton, 2012; Zubek, 1969) and it is worth to add that long duration mission such as mission to Mars poses additional challenges for a crew in comparison to orbital missions. These difficulties include e.g. limited support from MCC, no evacuation extreme feelings of isolation, dependence on local resources, monotony or boredom. The list of the stressors in space and additional stressors for a Mars mission are listed in *Table 8*.

On-orbit stressors	Additional stressors for mission to Mars
Crew-ground communication (displacement)	Loss or delay in communication Limited support from ground Increased autonomy of the crew
High workload	Monotony and boredom with periods of high workload; extensive amount of free time – how to fill it with meaningful activities?
Crew size and cultural issues	Novelty (unknown issues that may arise)

Personality conflicts, leadership	Higher risks of conflicts due to personality conflicts, leadership and heterogeneity of the crew
Time effects	Psychosocial development over the time of the mission
Isolation and confinement (very limited social contact)	Earth out of view phenomenon, extreme feelings of isolation and loneliness
Possible danger	No evacuation
Food (taste, smell and structure)	Dependence on local resources
Sleep disturbances, disruption of circadian rhythms, lack of natural light	Increased risk for medical and psychiatric illness due to time away and unknown risks
Space adaptation syndrome	Irreversible changes on a body
Noise, vibration, microgravity	Crew selection: who would want to undergo dangerous mission taking several years? How to select astronauts?

Table 8: Overview of the on-orbit stressors and additional stressors for the mission to Mars. Based on (Drake, Hoffman, & Beaty, 2009; Kanas, 2010, 2014, 2015; Peldszus et al., 2014; Suedfeld & Steel, 2000; Ushakov et al., 2014)

One of the big problems encountered in the terms of a long-term space journey is dealing with monotony and boredom. There were various episodes of risky behaviour as an attempt to break the monotony reported from polar missions. These cases included breach of discipline, physical fights or unwanted sexual advances (Suedfeld & Weiss, 2000).

Diet

The diet during long term stay in isolated environments poses many challenges. Historical boat voyages were characterized by a high risk of nutritional insufficiencies including scurvy (Stuster, 2000). With current knowledge people do not doubt that astronauts eat in space but until 1961 when German Titov, became the first human who ate in space, there was no knowledge that humans would be able to swallow food in the weightlessness.

From this point, nutrition in isolated environments developed rapidly. Currently, the ISS astronauts have a wide variety of foods with an aim to provide foods that taste similar to what is eaten normally on Erath (Perchonok & Bourland, 2002). A menu with a cycle repeated after 6 to 10 days is provided to ISS crews. Approximately half of the food items are supplied by the United States and the second half by Russia (George, Casaburri, & Gardner, 1999; Perchonok & Bourland, 2002).

Despite the huge development in this area, the space diet poses a stressor for astronauts (Sandal & Bye, 2015; Sandal et al., 2011) and long duration spaceflight will require even more advancement. Astronauts have a very restricted supply of fresh food, the consistency is different than what they are used to, and the typical smell is absent (Ushakov et al., 2015). An extended spaceflights and planetary stays will require even more variety of foods and more technologic advances including plants onboard growing to provide fresh food for astronauts (Leonov & Lebedev, 1975; Perchonok & Bourland, 2002). The most critical nutrition concerns potentially affecting astronauts' health during or after long-term spaceflight are bone loss, compromised vitamin D status, and oxidative damage (Smith, Zwart, Block, Rice, & Davis-Street, 2005).

Teams staying in space-like conditions (e.g. polar expeditions) have more possibilities of food storage and more possibilities such as frozen food (Stuster, 1986; Wood, Lugg, Hysong, & Harm, 1999), however, the sameness of the food is stressful too (Stuster, 2000).

There are several kinds of issues with diet e.g. hunger, dissatisfaction with the food monotony or food qualities (food texture, smell *etc.*) reported from space or space analogues. This problem might be accepted as marginal if adequate intake of nutrients is achieved, but there is an evidence of aggravated well-being of astronauts leading to psychosocial difficulties caused by certain diet.

Hunger of the participants was reported from project Biosphere 2 causing several problems overlapping into the interpersonal difficulties. Due to limited supplies (they had just what they harvested) participants did not have enough foodstuffs to prevent themselves from hunger. Subjects had to guard the food they had in order to equally divide it into all members because stealing of food occurred (MacCallum & Poynter, 1995; Maccallum, Poynter, & Bearden, 2004; Nelson et al., 2015; Walford et al., 1992). After missing ripe bananas few times and noticing that some of the frozen supplies were also gone, it had to be locked to prevent overwhelming temptation for extra food. The crew developed various strategies how to cope with their hunger including chawing leaves from herb garden (which was a big surprise for person responsible for herbs), chewing on empty peanut shells or even the ripe bananas skin to get at least an idea of having food (Alling & Nelson, 1993).

The perception of hunger was reported also from the Mars 105. The analogue astronauts felt hungry in the first part of the mission. According to the participants, the diet insufficiencies acted as a stressor and negative affected their interactions (Sandal et al., 2011). This part of the mission was also characterized by progressive weight loss (Strollo et al., 2014).

Later Mars 500 also encountered some food issues. Crewmembers mentioned that several products were found spoiled after opening, although thanks to some food redundancy no further troubles occurred (Urbina & Charles, 2014).

Different approach was applied during an analogue mission in FMARS habitat. Crew that simulated four months of Mars mission, had to prepare their food by themselves. It was concluded that crew's satisfaction with diet and effort they put into meals preparation was surprisingly high. This approach had also positive impact to social interactions (Binsted et al., 2010).

Finally, food has been a frequent topic of discussions onboard Mars 500. Food was the theme that got the communication started and accelerated (Poláčková Šolcova, Šolcová, Stuchlíková, & Mazehóová, 2016). One of the analogue astronauts mentioned: "*Food, it was the biggest topic all the time, yes, really. We talked always about whether some food is good or food it bad, what we did with it in our country and so on* (Poláčková Šolcová et al., 2016)." In the specific environment of the Mars mission, food was a natural reason for meeting with the other astronauts and also the bridge to other topics including family, cultural differences and traditions *etc*. The talks about food provided relief and made the kitchen a nice place to meet (Poláčková Šolcova et al., 2016).

Figure 3: Photograph of the Lunar Expedition 1 crew taken by Mariusz Slonina during their common meal. Retrieved from (LUNARES, n.d.-b).

Sexual activity

Sexual life despite being one of the essential human needs, in research for space it remains taboo. Very little is known about sexual deprivation and its betterment in space and space analogues although Kanas (1998) mentions that sexual abstinence is a possibility but hardly a realistic scenario given that a long-term space mission provides a lot of time for intimate moments and enough of privacy to let them occur.

It has been a very sensitive topic with untold potential for bad publicity. It is clear that sexual activity (including masturbation) does go on in space cabins, probably in most long-duration capsules. Most of the reports keep the unwritten rule "do not ask, do not tell" (Suedfeld & Steel, 2000).

Schedules

The last problem to be briefly described in this section is a schedule for astronauts. Schedules poses one of the issues relating the relationship between a crew and MCC. The issue of scheduling and its impact to the crew was researched as a part of analogue missions (Barshi & Dempsey, 2016; Gushin, Efimov, & Smirnova, 1996; Nicolas & Gushin, 2015; Press, 1998; Stuster et al., 1999) or there is an evidence of the consequences of unrealistic schedules for example from Skylab 4. As Clément (2005) concluded all of the astronauts of the Skylab 4 mission were “rookies” - first-time in space, unlike the previous Skylab crews. They had the same busy schedule as their predecessors. Despite their complaint relating to the high workload to the MCC, their problem received low attention. The commander declared an unscheduled day off to the mission control and proceeded to the turning off of the radio for one day (Shayler, 2008). It became a rule that at least one member of a space crew on board the ISS should be a spaceflight veteran probably as a result of this event (Clément, 2005).

This issue was widely described as a mutiny in space (Douglas, 1991; Stuster, 2016) despite it was a good justified demand over the unrealistic scheduling requirements. Originally the crew should have had a day off every tenth day. However, the Skylab 4 crew sacrificed first three of their rest days trying to catch up to their schedule. Thus, when the crew was told to work through their fourth rest day, the crew commander refused and the crew could finally rest (Shayler, 2008; Stuster, 2016).

NASA learned from this incident the importance of providing time to rest for a crew. Interestingly, despite this lesson learned, the agency persists in scheduling insufficient time for the performance of many tasks (Stuster, 2016).

Remarkably, the schedules for future long duration spaceflights will have to deal with different problems such are monotony and boredom (Geuna, Brunelli, & Perino, 1995; Nicolas & Gushin, 2015; Peldszus et al., 2014; Stuster, 2010). Moreover, as already mentioned, the crew will have to manage their tasks and vehicle more autonomously from the ground support due to significant time delays in communication. Thus, their schedules will probably be rather quite flexible which supports good results from ISS, where the extended use of flexibility and task lists led to an increase in crew efficiency and productivity (Forrester et al., 2018).

3.2 Intragroup issues and their development over time

Considering space crews there are many potential issues and difficulties on the intragroup level that could be mentioned. The frequently mentioned interpersonal stressors on space crew in literature are summarized in the *Table 9* despite as illustrated below, the list could be much longer.

Summary of the interpersonal stressors on space crew
▪ Group tension ▪ Loss of group cohesion ▪ Heterogeneity of the crew ▪ Withdrawal and territorial behaviour ▪ Lack of privacy ▪ Subgrouping and scapegoating ▪ Displacement ▪ Sexual tension or attraction ▪ Leadership and authority issues

Table 9: Interpersonal stressors on a space crew (Gushin et al., 2001; Kanas, 1997, 1998, 2010, 2014; Vinokhodova & Gushin, 2014)

One of these issues to be discussed is a tension resulting from a crew heterogeneity (Gushin et al., 2001; Kanas, 2010; Vinokhodova & Gushin, 2014) due to potential cultural and gender differences, language and dialect variations, or leadership roles *etc.* (Kanas, 1998) even though the heterogeneity can be also perceived positively as a source of novelty (Binsted et al., 2010; Poláčková Šolcova et al., 2016).

Another issue is loss of a team cohesion over time (Kanas, 2014; Vinokhodova et al., 2012) which might have impact on performance (Mathieu, Kukenberger, D'Innocenzo, & Reilly, 2015).

Finally, there are also a lot of other issues relating coexistence of crewmembers in an extreme environment. need for privacy, issues involving leadership roles, issues with authority (Kanas, 1997, 2010), inefficient communication among crewmembers (Bahbouh & Děchtěrenko, 2014; Cazes, Rosnet, Bachelard, Le Scanff, & Rivolier, 1996; Ushakov et al., 2012), subgrouping (Bahbouh, Sněhotová, Děchtěrenko, & Sýkora, 2015b; Kanas, 2014; Kanas et al., 2009), scapegoating (Kanas, 2014; Kanas, Salnitskiy, Boyd, et al., 2007; Kanas et al., 2009), in group and out group effect (Gushin & Yusupova, 2012), group think (Kanas & Manzey, 2008; Sandal, 2012; Sandal, Bye, & van de Vijver, 2013) *etc.* However, the main focus of this chapter is devoted to the development of relations among crewmembers which are descried in sequel.

The psychosocial development of relations among team members is an important factor to be considered when designing a mission in extreme conditions even though the development of difficulties on board was not always acknowledged. In the first era of human spaceflight, the resistance to stress was considered irrelevant with the assumption that “right stuff”[6] would not experience any such problems. That was mostly true for first space missions, but with increasing length and complexity of further missions there was a shift in focus from invulnerability to resilience and later from the focus on pathogenesis to salutogenesis to the last phase which meant integration of all of them(Suedfeld, 2005). Moreover, when spacecraft became large enough to host 2 to 3 crewmembers the focus shifted to the interaction among crewmembers (Suedfeld, 2010).

Nowadays it was fully acknowledged that teamwork is considered essential to a mission success that there are many difficulties a crew has to face when flying to space e.g. (Landon et al., 2018; Salas et al., 2015). As mentioned by Lebedev who spent 211 days in space: “*With accumulated fatigue, serious situations and difficult moments can occur when it would be disastrous to lose control. If there is a problem, nobody can help us (Lebedev, 1988).”*

Several attempts to define a generally critical periods of a spaceflight or a list of a phases of a development of an adaptation and a team’s development realized. One of the examples of periodization of a team’s development is Tuckman’s approach. Tuckman reviewed scientific papers relating to a group development over time. He identified 4 stages: forming, storming, norming, performing (Tuckman, 1965) and later added fifth: adjourning (Tuckman & Jensen, 1977).

Space psychologists attempt to describe phases of a team’s development with the specialization to the extreme environment. Based on results from Štola-88, Sýkora (1989), noticed changes in work efficiency especially in the end of the mission already in 1980’s. Soviet investigations of simulated spaceflights found general decrease in work capability manifested by increased latency time, longer periods in decision making and mistakes in an executing of tasks (Смиричевский, 1979). Similar results were observed also in later experiments, a study from Mars 105 found the last part of the project as a critical time period characterized by decline in parameters such are cooperation among crewmembers, subjective perception of atmosphere within the

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[6] “Right stuff” means the candidates who passed the astronaut selection process. In the first era of human spaceflight those were usually people who has already coped with highly demanding and dangerous situations in military.

crew or overall crew's performance (Bahbouh, 2012; Lačev, Srb, et al., 2012) as well as decreased in the scores of positive emotions (Nicolas et al., 2013).

Different results were made from HUBES and ECOPSY that were attended by only 3 member crew[7] where was observed gradual decrease in communication associated also with qualitative changed in communication and increasing tension due to the separation of the 3 members crew into a dyad and a solitaire (Bahbouh, 1996, 2012; Fiedler & Harrison, 2010; Gushin et al., 1998).

The phenomenon of subgrouping is often present as part of development of a team does not have to cause any problems. However, difficulties occur when subgrouping escalates into the development of cliques (Palinkas, 2003b; Palinkas & Suedfeld, 2008; Stuster, 2000) or leads to an isolation of an individual from the team (Bahbouh, 1996, 2012; Gushin et al., 1998) such as happen in HUBES and ECOPSY. In both of these experiments the crews got split into a dyad and one solitaire which resulted into increased level of intragroup tension (Bahbouh, 2012; Fiedler & Harrison, 2010; Gushin, Efimov, Smirnova, & Vinokhodova, 1996; Gushin et al., 1998; Rosnet et al., 1998). Similarly, in ISEMSI the crew split and one of the crewmembers was excluded from communication (Bergan et al., 1993; Sandal, 2001). Subgrouping was observed also in other experiments, namely SFINCSS (Gushin et al., 2001; Inoue et al., 2004), Mars 105 (Srb, Bahbouh, & Sýkora, 2012; Vinokhodova et al., 2012) and Mars 500 (Bahbouh, Sněhotová, Děchtěrenko, & Sýkora, 2015a) although this trend was not always strong nor always leading to difficulties. It is also worth to add that it was observed, that if a crew is multinational, attended by members of different native language, subgroups are more likely to form from the members who speak the same native language[8]. In case there is someone whose native language is not shared with anyone else, one tends to communicate with those crewmates who also use a foreign language (Srb et al., 2012). It can be caused either by different nationalities or cultural differences (Bahbouh & Děchtěrenko, 2014; Bahbouh et al., 2015b).

Some studies were trying to identify a most critical period. For instance, the frequently examined third quarter phenomenon characterized by the lowest point of mood and morale (Bechtel & Berning, 1991). This phenomenon was repeatedly found

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[7] In contrast to Mars 105 that was attended by 6 members and Štola-88 where was 2 crews of 7 and 5

[8] Knowledge of Russian and/or English is usually required in space research projects (Urbina & Charles, 2014).

in polar missions (Bechtel & Berning, 1991; Sandal et al., 2018; Stuster et al., 1999) but not proved in space missions nor their simulations (Basner et al., 2014; Kanas, 2013; Kanas, Salnitskiy, Grund, et al., 2001; Kanas, Salnitskiy, Boyd, et al., 2007; Kanas et al., 2006; Kanas, Salnitskiy, Ritsher, et al., 2007; Šolcová et al., 2013; Wu & Wang, 2015). Important clue why the results differ between polar missions and spaceflights or simulations of space missions might be the fact that the third quarter phenomenon as a part of an Antarctic stay correspond to mid-winter which is the most challenging period of a mission (Sandal et al., 2018)(Sandal et al., 2018)

There are also different findings in term of what part of a mission might be considered the most challenging. Some studies consider mid period of a mission to be critical For example, ethological studies of both polar missions and simulated space missions (Tafforin, 1993, 2005, 2013). Few authors proposed cyclic development in course of a mission (Eskov, 2011) which was observed in Mars 500 (Tafforin, 2013).

There were also few attempts to provide approach to this problem by identifying stages of development of adaptation and interpersonal relations among team members. There is a periodization based on Lewis and Clark expedition that described five phases of isolation that might be relevant to a Mars mission. based on data from polar missions. These phases are: *acute, intermediate, long-duration, final* and *recovery*. *Acute* phase occurs in the initial busy part of adjusting to the novel situation. This phase is followed by *intermediate* phase that is characterized by fatigue, decreasing motivation, and psychosomatic and psychological problems that tend to more drastic negative changes in motivation, mood, and performance which belongs to the *long-duration* phase. Final phase was associated with euphoria and hyperactivity as the mission is approaching its end. Last recovery phase is a period after the termination of an expedition when participants are adjusting back to the normal life (Allner & Rygalov, 2006). However, as Suedfeld (2010) mentions, without replication on other missions, it is not possible to generalize.

Different results described from studies focusing on spaceflight simulations. One of them says that negative psychological symptoms appear after 14 to 16 days if mission is 1 month long. In case of duration of 3 months, these symptoms after 45 days (Gushin, Kholin, & Ivanovsky, 1993). Unfortunately, there is no clear explanation of obtaining these findings in the text.

Early soviet studies found 5 stages of adaptation to the simulated isolation environment. First 3 days are characterized by hyperexcitation with acute adaptation to the specific environment. This phase is followed by a period of unstable adaptation with fluctuations in psychophysiological parameters. The period preceding last 3 days was described as stable adaptation with increasing fatigue narrowing the scope of interests, dressed activity and increased irritability. Last three days were labelled as "final effort" typical euphoria and lack of self-control. Finally first 3 days after the experiment are typical for increased psychological tension and agitation (Gushin et al., 1993).

The last periodization to be described in this section is the result of a sociomapping study of Mars 105 (Lačev, Srb, et al., 2012; Lačev, Sýkora, Bahbouh, Lukáš, & Höschl, 2012) that describes four stages of the team dynamics. These phases are: *initial harmonization, stabilization, repetitious harmonization followed by a crisis, and final harmonization*. Most of the psychosocial changes occurred during first three data collections which were labelled as the phase of *initial harmonization*. This phase was followed by *stabilization* characterized by no demands for changes in communication frequency. Further phase was labelled as *repeated harmonization* when there was an increasing requirement of communication changes and need of support. Later *crisis phase* meant a decline in cooperation, communication and team's performance. The last phase - final harmonization was characterized by no demands on communication changes (Lačev, Srb, et al., 2012; Lačev, Sýkora, et al., 2012). However, the assumption of similar development in later experiment Mars 500 was proved only partially (Lačev, Sýkora, et al., 2012).

3.3 Intergroup issues

Any tension between a crew and the MCC can cause various issues affecting well-being, success of a mission or even safety of the astronauts on their missions. The findings from research of these issues from various studies will be presented in this section.

Valentin V. Lebedev who underwent the longest stay in space (211 days) at his time onboard Salyut 7, mentioned in his diary his attitude towards the mission control: "*Ground control senses when we have problems in the crew. … As soon as they see any conflict, everybody worries; someone is interested in seeing if we can manage* *and how we will behave. Will we blow it or not? … We cannot show any signs of friction or dissatisfaction. If we do, we will be punished when we get back. … The most dangerous thing in this situation is FCC*[9]*, which influence the crew with its constant watch and concern* (Lebedev, 1988, p. 129-130)."

The relationship between a crew and MCC can be challenging in many ways. The analysis of communication between crews on ISS and MCC showed that the distribution of communication from MCC and astronauts is culturally favourited. Each of the national MCCs (the Russian and American one) preferred to communicate with their crewmembers. MCC spoke with their own crewmembers 98% of the time spent on their communication, while only 2% of communication time remained to interaction with the astronauts of other nationalities. The separation communication between a Russian and an American channel may lead to various problems including insufficient information or different opinions of each MCC (Gushin & Yusupova, 2012).

The typical issues in terms of the crew – MCC interactions poses tension between these two groups which might anticipate real problems on board. Such tension was reported at Skylab, Salyut, Mir, and STS missions (Ursin et al., 1992). Such phenomenon might be considered as displacement of tension and dysphoria from crew to mission control. Several studies was conducted in order to support the occurrence this phenomenon mostly on Shuttle/Mir and ISS crews (Kanas, 1998; Kanas & Fedderson, 1971; Kanas, Salnitskiy, Grund, et al., 2001; Kanas, Salnitskiy, Boyd, et al., 2007; Kanas et al., 2006; Kanas, Weiss, & Marmar, 1996; Kanas, Salnitskiy, Ritsher, et al., 2007; Sandal et al., 1996; Vaernes, 1996). On the other hand, by displacing negative feelings to the outside supervisors, and repressing feelings when interacting within the crew, the crewmembers may get along better and to complete their mission without serious intragroup conflicts (Kanas & Fedderson, 1971).

The tension between the crew and MCC were reported also from analogue missions. The importance of good relationship between a crew and mission control centre was pointed out already as a part of results from Štola-88. Sýkora stressed that mission control centre should be considered as a part of a crew and came up with a Theory of lateral communication channel which refers to the communication between the crew and the Earth-based support. There are two communication channels. The main one

[9] FCC – Flight Control Centre (Ground control centre)

includes official information and the lateral one is designed for unofficial and private information. According to Sýkora, both of these communication channels are equally important (Sýkora, 1989, 1996; Sýkora et al., 2010).

Few issues were described also from HUBES. During the experiment the crewmembers demonstrated their antagonism towards one of the MCC teams. They also blamed their hostility on the outsiders' "bad mood" (Fiedler & Harrison, 2010).

Several indicators of issues between the crew and MCC was reported also from the Mars 500. The crewmembers mentioned perceived lack of acknowledgment from MCC as one of the most relevant stressors. They felt there was long waiting until their messages were answered by the MCC if they even were answered. It gave the crewmembers the impression of a low interest from the researchers which negatively affected the work morale of the crew (Urbina & Charles, 2014).

Additionally, recent results from Lunar Expedition 0 highlighted the importance of trust and good cooperation between crew and MCC (Davidová, 2017a; Kołodziejczyk, Ambroszkiewicz, et al., 2017), similarly as the findings from an EVA simulations (Harasymczuk et al., 2017).

Finally, it is worth to add an interesting finding which came from a study, where Russian crewmembers who served in various space missions, were interviewed regarding their opinion towards various issues regarding the future long-term missions. Some of the crewmembers have in particular stressed that the MCC operators should communicate with crew their ability to defend the crew's opinion before the Flight Management Administration (Nechaev et al., 2007).

3.3.1 The development of the crew-MCC communication

Based on the wide experience with space flight and their simulations and Umansky's work (Уманский, 1980), Russian scientists Yusupova et al. (Gushin & Yusupova, 2012; Юсупова, Гущин, & Ушаков, 2011) developed a scheme of communication of a small isolated group with external support group (MCC) and its development to which this subsection is devoted.

In the initial stage a crew is quite open to the influence of the external group - MCC. During the training of crewmembers, the cohesiveness of a small group gradually grows. The crew gets to the stage of the *cooperative group* with a well-developed internal structure and a high level of interactions within the group (Уманский, 1980). Although together with the crew's cohesion, the influence of MCC decreases due to the limited contacts. It is worth to mention that the isolated crew has very limited options of an interaction. Beside the interactions within the group, there are two channels of communication with externals. One of them is for communication with the support group (MCC) and the second one is the private channel of communication devoted for family and friends (Gushin & Yusupova, 2012; Юсупова et al., 2011).

Consequently, the crew's communication with MCC turns from the single-circuit (full-fledged communication) into the two-circuit communication which is limited. See the *Fig. 4* below. Later, after 4 to 6 weeks the crew reach the stage to become *autonomous group*. For this stage is typical the identification of the individual crewmembers with the group and creation of internal group norms which happens together with increasing cohesiveness of the crew. The crewmembers follow their own group norms thus the need of interactions with MCC drops. MCC might try to enhance the communication back to higher level. But autonomous crew feels forced to communicate with MCC thus the attempts from MCC to communicate closer with the crew might be perceived by crewmembers as an intrusive attack to their group norms. It causes minimalization of interactions of the crew with MCC. This phase is in accordance to the Tuckman's (Tuckman, 1965) *in-group, out-group effect* (Gushin & Yusupova, 2012; Юсупова et al., 2011).

As a part of the adaptation to the challenging conditions of isolation, the communication frequency lowers not only between crew and MCC, but also within the crew. However, there is a need to compensate all the aspects of isolation (sensory deprivation, monotony *etc.*) which is resolved by active interactions with family and friends though the private channel. The isolated crew emphasizes the quality of communication at the expense of quantity by limitation of the social connections they have. It leads to an increased level of selection of communicators. They express preferences with whom they want to communicate and to whom they prefer to avoid in communication. Such behaviour was described as *information filtration*[10].

[10] In Russian "распределенного общения" (Юсупова et al., 2011) – in exact translation it would be "distributed communication". In the current work is used the term "information filtration" as in the older scientific paper from the same authors (Gushin et al., 1997) even though it is possible to find also other translations such as "divided communication"(Gushin & Yusupova, 2012).

The *autonomous* stage despite it is a higher level of group evolution by enabling the group to cope with the arising problems by themselves (without external help), includes also some risks. This phase is accelerated and intensified due to the specific conditions of isolation (sensory deprivation, lowered social control and publicity of loneliness[11] *etc.*) and a decreased social control. Thus, there is a risk that the autonomy group may evolve into an unfavourable stage of *corporate group* which is characterized by group egoism and aggressive behaviour (Gushin & Yusupova, 2012; Юсупова et al., 2011).

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[11] In Russion "публичность одиночества" – a phenomenon typical for an isolation as part of a spaceflight when the crewmembers are constantly monitored which worsen their feelings of isolation and loneliness (Leonov & Lebedev, 1975).

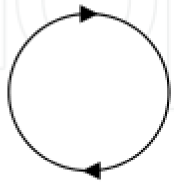
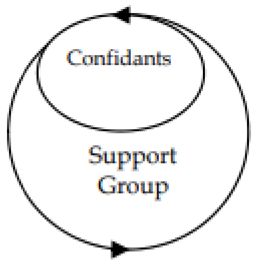
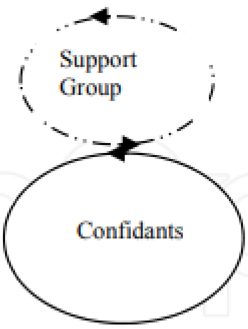
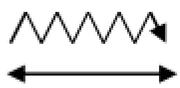
	Stages of Group Evolution (according to L.I. Umansky, 1984)	*Communication Type*	*Kind of Interaction with Society*
Ground Group Training	1) Conglomerate Group	single-circuit communication 	Open interaction with society
	2) Nominal Group		
	3) Association Group		
Orbital Flight	4) Cooperation Group (a well developed structure, a high level of cooperation – emerging in 4 to 6 weeks)	two-circuit communication 	1. Isolation from the larger community. 2. The larger community disintegrates into the support group and the group of confidants. 3. Communication decreases.
	5) Autonomy Group (group identification, separation, joint effort)	two-circuit, divided communication 	1. Decrease of social control. 2. Involuntary nature of communication.
Mission to Mars (a possible variant)	6) Corporation Group (group egoism, opposition, aggressivity)	No-circuit, monoreferential communication 	1. Delays in communication with Earth. 2. Absence of direct help of Earth.

Fig. 4: Communication between crew and MCC in certain stages: ground training, orbital flights and a possible variant of a mission to Mars. Retrieved from (Gushin & Yusupova, 2012) *or* (Юсупова et al., 2011) - *original text in Russian.*

3.3.2 The increased autonomy of a crew due to the delay in communication with MCC

Specific changes in the communication and relations to the MCC will be encountered when undergoing the mission to Mars. The constant real time communication with mission control will not be possible, thus therefore the crew wills experience increased autonomy - one of the psychosocial challenges typical for future long-duration spaceflights. Astronauts will have to be trained to the autonomous functioning, unlike orbital missions, MCC might not be available to provide quick help when needed. Time delay in communication between crew and MCC during the journey to Mars, may reach up to 24 minutes each way depending on the planets location on their orbits (Drake, 2009; Ursin et al., 1992). Such delay in communication will probably impact the astronauts' performance (Kintz, Chou, Vessey, Leveton, & Palinkas, 2016). The crew will have to be quite autonomous (Gushin, Shved, Vinokhodova, et al., 2012; Horneck & Comet, 2006; Kanas, 2014; Sandal & Bye, 2015).

The delayed communication was tested and research for example in ISS (Kintz et al., 2016) or simulated missions such are Mars 105 (Sandal et al., 2011) Mars 500 (Sandal & Bye, 2015) or several of NASA's projects (Reagan et al., 2012).

A study from ISS conducted on 3 astronauts and 18 people from mission support personnel for 166 days investigated the impacts of a communication delays taking 50 seconds one-way. The consequences of the delayed communication were significantly reduced crew's well-being and communication quality. Additionally, the communication delays were significantly associated with increased individual stress and frustration, operational outcomes and teamwork processes in particular when the tasks involved high communication demands (Kintz et al., 2016).

The high autonomy of the crew with less opportunity to communicate with MCC and less external stimulation was also simulated as a part of Mars 105. The main finding was that the crew might facilitate „*closing of communication channel*" (Gushin, Shved, Vinokhodova, et al., 2012), defined as a tendency of crewmembers to avoid sharing of feelings with outsiders (Gushin et al., 1997).

The tests investigating the delayed voice communication identified many challenges including confusion of sequence; blocked calls; wasted crew time; reduced ability to provide relevant information; losing track of which parties have heard which piece of information; threatened rapport between crew and ground; slow response to emerging events; or generally reduced situational awareness. These issues can be partially compensated by specific additional training, pre-briefings; greater attention and foresight, special procedures *etc.* However, it was concluded that despite the countermeasures that was used, delayed voice communication is difficult (Love & Reagan, 2013).

Love & Reagan (2013) made a comparison between delays of 50 and 300 s to conclude that despite the expectation, participants found both equally challenging (Love & Reagan, 2013).

Gushin et al. who studied crews in isolations experiments, found out that the content volume of the crewmembers' message correlates the individual level of adaptation to the isolated and confined environment. The better is the individual's adaptation, the less is the frequency of his official messages devoted to the operational issues and the more is the compensation of social monotony and social isolation (Gushin, Shved, Ehmann, Balazs, & Komarevtsev, 2012).

A similar study was done also on Mars-500 crew where written communication between crew and MCC was analysed by computerized content analysis in order to find frequencies of utilization of psychologically relevant semantic units (Gushin, Shved, Ehmann, et al., 2012; Shved, Gushin, Ehmann, & Balazs, 2013). This experiment also simulated communication delay between crew and MCC. The delay reached 12 minutes at the 350th day of the project (Ushakov et al., 2014). The period of high autonomy was characterized by drastic reduction of the number of questions and requests from the crewmembers. This effect can be considered as a good adaptation of the crew to the autonomous conditions despite the astronauts' need of feedback from MCC and emotional involvement (Shved et al., 2013). Besides that, complete loss of communication was simulated at the period from 320^{th} to 327^{th} day of the mission (Ushakov et al., 2014). When communication between crew and MCC was re-established, crew not only did not compensate the lack of communication with MCC, but kept the reduced level of communication (Gushin, Shved, Ehmann, et al., 2012; Shved et al., 2013).

3.3.3 The development of a crew's conformity

Gushin and Yusupova (2012)[12] devoted part of their work to study development of a crew's conformity over a spaceflight, their findings are summarized in this subsection.

An isolated crew is gradually adapting to the specific conditions of a spaceflight. Initially, the crew feels certain level of uncertainty in evaluation of current situations

[12] Same findings were summarized also in the previous work written by same authors in Russian (Юсупова et al., 2011).

which is typical especially in the period of the acute adaptation to extreme environment. In this phase the support from MCC is needed in order to reduce such uncertainties by active interaction between crew and MCC. Thus, the crew is considerably influenced by the social majority represented by MCC in this phase (Gushin & Yusupova, 2012; Юсупова et al., 2011). It is in accordance to the phenomenon of conformity to social norms as defined by Asch (Asch, 1955).

Conformity, in this case, can be perceived positively because it is a form of behaviour which helps to facilitates interaction processes by providing acceptable standards that a crew follows (Jetten, Postmes, & McAuliffe, 2002). When performing in an extreme environment the crew follows the mission's procedures which can help them to survive in difficult situations (Gushin & Yusupova, 2012; Юсупова et al., 2011).

Over the time, the competence of the crew grows. They do not feel less component than MCC anymore. The crewmembers highly respect their work and experience they have already done onboard therefore also self-esteem of the astronauts is growing. In this phase, the crew creates opinions and solutions to the emerging situations based on their own experience rather than following the expertise from MCC. The opinions and decisions of the crew in this stage are stable, it is difficult to convince them to different ones. The crew feels low need to communicate with MCC and when MCC tries to be more involved and to interact closer with the crew, the crew might perceive such attempts intrusive and offensive.

The level of conformity of individuals to majority depends on size of the majority group (Asch, 1955). However, for the isolated crew, the majority is represented by two rather small groups: MCC and the group of family or friends that are available via private channel. With the decrease of the level of the majority's social pressure, the crewmembers' obedience decreases. Another factor affecting conformity is heterogeneity of the crew. Heterogenous groups are less conform than homogenous ones (Jetten et al., 2002) therefore a crew on mission to Mars which will most likely be heterogeneous in terms of gender and nationality will be less conform to majority than homogenous crew would be.

The social information exchange between crew and MCC is low due to restricted number of communicators as well as the restricted volume and diversity of communication. Such situation leads to the opposition to the external pressure. This pressure was originally related to some operational aspects; however, it may turn to the opposition to behavioural norms represented by MCC. This phenomenon leads to a phenomenon which is called "*public conformity*" which was defined as "*a demonstration of a socially acceptable reaction stereotype* (Gushin & Yusupova, 2012, p. 226). This can be illustrated by a statement *"we are all right*". Interestingly, this attitude is different in private contacts. In case of a further evolution of the group's inconformity it might have further unpleasant consequences such as anti-social behaviour or in the extreme case even an open protest (Gushin & Yusupova, 2012; Юсупова et al., 2011).

II. EMPIRICAL PART

4. Objectives, definitions and research questions

Development of psychosocial dynamics of teams in isolation

The purpose of the current study was to investigate details relating the psychosocial and psychological aspects of coexistence of crewmembers in isolation. This study is unique for three reasons. Firstly, data were collected from two analogue missions that were both attended by the same crewmembers. That provides a comparison between the results of both projects. Secondly, very similar research design was applied in both missions therefore a comparison is possible. And third new visualization technique *Dotty Overview of Team Interactions* (DOTI) was introduced and tested.

This research project had the goal to capture and to analyse the development of psychosocial dynamics of crews under conditions of simulated isolation. This aims to identify potential difficulties, as well as positive aspects arising from space environment. Besides that, there was also focus on assessing the relations between the crew and MCC. Additionally, a comparison across two missions was done thanks to applying the same research design in more projects, with a perspective of continuation in future analogue missions. For these purposes a new comprehensive research design was created and is introduced below (in section *5. Methods*). This approach enables quick monitoring of the psychosocial dynamics by using a short questionnaire and data visualizations. Additionally, interviews with crewmembers are used in order to validate the results.

According to the focus of this research project and the objectives stated above, the research goals were summarized into research questions (RQ) listed in *Table 10*.

RQ 1	How will the team relations change over the period of a mission?
RQ 2	How is the development of the relationship between the crew and MCC? What consequences does it have to the well-being of individual astronauts?
RQ 3	What aspects of the mission were perceived as challenging by astronauts?
RQ 4	Are the results consistent across all missions?

Table 10: Research questions (RQ)

Before moving further to the research part, there are several terms that need to be defined.

- *Team dynamics* – it's rarely defined in literature due to its complexity (Bußmann, 2014). For the purpose of this research, we define it as *the development of the relations within a group over time* which includes group processes such as communication, cooperation, group efficacy *etc*. but other definitions can be found (Forsyth, 2014).
- *Team* – "*a number of persons associated together in work or activity* (Merriam-Webster Dictionary, n.d.)" or "*people working together as a group in order to achieve something* (Cambridge Dictionary, n.d.).*"*
- *Isolation* – "t*he state of being separated from other people, or a situation in which you do not have the support of other people* (Macmillan Dictionary, n.d.).*",* with a remark that in the case of this research, conditions analogous to space were simulated – hence the crew was not fully isolated as it would be if on a spaceflight.

Figure 5: The LUNEX-1 crew in the sleeping compartments, photograph taken by Monica Alcazar Duarte. Retrieved from (LUNARES, n.d.-b).

5. Methods

As illustrated in the theoretical part, coexistence in extreme conditions poses many challenges and risks for humans. Monitoring of psychosocial aspects and psychological support during such missions is crucial. Any mistake might grow to a disaster, even fatal (Clément & Bukley, 2014; Horneck & Comet, 2006; Horneck et al., 2003; Lugg & Shepanek, 1999).

There are countermeasure strategies that might contribute to prevention of potential failures and conflicts, as briefly described in section *2. Risks and psychological countermeasures for space*. However, before initiating a countermeasure, the current state of the situation onboard must be known. Thus, one of the initial steps is an adequate monitoring of psychosocial aspects of the crew and assessing the group dynamics, and development over time. That might be done in various ways, e.g. video recordings or questionnaires. Anecdotal reports indicate that astronauts prefer unobtrusive measurement techniques as opposed to traditional survey data collections that increase their workload.

On the other hand, crewmembers also highly value their privacy. Thus psychologists are confronted with a difficult dilemma between obtaining meaningful data and being intrusive. There are also other challenges and limitations in psychological and psychosocial research in analogues or spaceflights for several reasons. As Landon et al. (2018) highlight: "*Due to lack of data from spaceflight and spaceflight analogue environments, meta-analysis is simply not a viable option for examining many of the different factors that will be critical to teams on a Mars mission.*" There are still relatively few astronauts that have participated in long-term space missions and there is a limited number of analogue missions per year, especially longer than 2 weeks. Moreover, researchers use different methods and research designs (Landon et al., 2018). There is a lack of standard measures, restricted total sample sizes as well as limited comparison of findings across space and space-like environments (Landon et al., 2018; Salas et al., 2015). Finally, it is also important to mention that astronauts have tight schedules which leave them little time for participation in psychosocial studies (Landon et al., 2018).

5.1 Experiment setting

In the scope of the current thesis, two studies with a similar research design were conducted as a part of Lunar Expedition-0 (LUNEX-0) and Lunar Expedition-1 (LUNEX-1) analogue missions. Both of these missions were simulating a stay in a habitat on the Moon and both were attended by the same crewmembers.

LUNEX-0

Analogue mission LUNEX-0 has been conducted in Poland in summer 2016 (15th – 21st August). It simulated a stay of six crewmembers on the Moon. The mission was conducted in a habitat which was temporarily created for this mission in South-East Poland.

The crew consisted of four men and two women, was all Polish, and the mission communication language was English. Their roles were: commander, vice-commander, flight surgeon, communicational specialist, astrobiologist and biomedical engineer. The astronauts were performing tasks according to fixed schedules including morning briefings, common meals, scientific experiments *etc*.

The Mission Control Centre (MCC) to support the LUNEX-0 crew, was distributed into multiple locations. One office was in short distance from the base, the second one was placed in the ESA's European Space Research and Technology Centre (ESTEC) in the Netherlands, and finally the mission was supported also by a team of experts in remote locations (see the details of Lunex-0 organizational background in *Table 11*.

MCC in Poland	MCC in ESTEC	Remote location
Flight director	Flight vice-director	Project advisor
Procedures lead	Project manager and science lead	Principle investigator I
Science officer	Schedulling officer	Principle investigator II
Habitat sytems engineer	Capsule Communicator	Principle investigator III
IT system manager	Mission psychologist	
Record officer		
Habitat inventory manager		

Table 11:LUNEX-0: MCC roles and their locations.

This mission was considered as a demo mission prior to LUNEX-1. The main target of this project was to assess crew's compatibility and to test all of the organizational aspects of an analogue mission. This includes: scheduling, communication procedures, experimental procedures, equipment *etc*.

The mission part relevant to this thesis consisted of an explorational psychosocial study. It used a set of prototype methods in order to investigate the development of crew dynamics over the time of the mission. This aimed to identify difficulties, positive aspects of stay in isolated environment, as well as potential countermeasures. Additionally, the study also assessed the development of relations between the crew and the MCC.

LUNEX-1

A year later (16th -30th August 2017), LUNEX-1 was conducted in the Lunares base with the same analogue astronauts as LUNEX-0. The Lunares Research Station is a fully isolated facility built in 2017 by Space Garden in Pila, Poland. This habitat is used to simulate crewed Moon or Mars missions and includes 250 square meters of EVA terrain, which is connected to rest of the habitat via an airlock (LUNARES, n.d.-a).

One of the experiments conducted as a part of this project studied subjective time perception. It had a considerable impact on all of the mission operations, because the mission was operated in lunar time[13]. Moreover, there were scheduled time shifts.

In comparison to LUNEX-0, the LUNEX-1 crew was given flexible schedules. The crew was woken up by the MCC every morning. The schedules included morning briefing, meals, scientific experiments, outreach activities, debriefing, writing of reports, EVAs, free time, sleep (8 hours per day) etc. The astronauts could choose the order of tasks during a day.

5.1 Applied methods

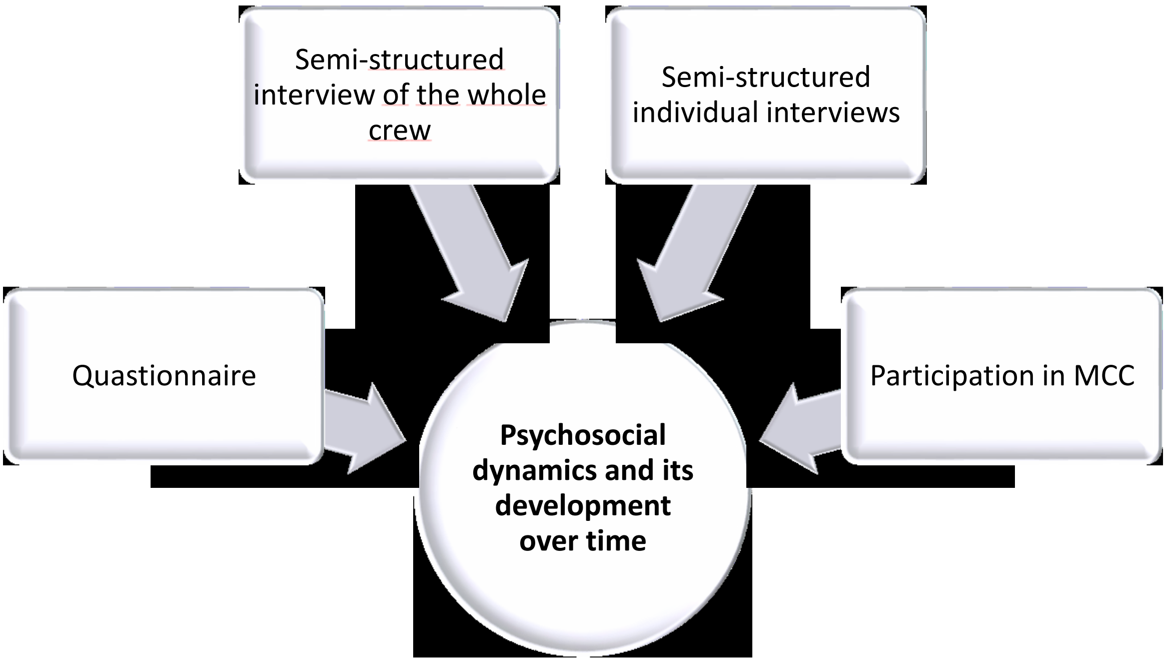


Figure 6: The methods applied in the psychosocial study of LUNEX-0 and LUNEX-1.

The current study was explorative and qualitatively oriented based on several subjective methods (as illustrated in the *Figure 6*) in order to achieve coherent results. It's worth to note that the researcher was also a mission psychologist.

The applied methods consisted of a questionnaire, an interview with the whole crew, and an individual interview conducted with each of the analogue astronauts. Additionally, the events occurring in the MCC, e.g. morning briefings, evening

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[13] All time entries in schedules were transferred into lunar time ("Lunar clock," n.d.).

debriefings, and astronaut reports were observed. These observations contributed to the preparation of the interviews, provided overall context of the mission and the background of the crew-MCC interactions. All these methods are described in *Table 12*. Below the details of used methods are presented.

Method	Obtaining data by	Researched aspects
Questionnaire and its visualization	Subjective assessment via questionnaire, mostly questions based on a 7-point scale	Intrateam processes including intragroup communication, cooperation, mutual trust, interpersonal preferences *etc*. Inter-team relations between the crewmembers and MCC. Additional subjective aspects: perceived discomforts, issues and comments
Post-mission interview with the whole crew	Semi-structured interview	Intra-team processes including interaction among subjects, team's development over time; explanation, and validation of the data collected during the mission, relations between the crewmembers and MCC. Crew's main experience, positive and negative experience, challenges, overall satisfaction.
Post-mission interviews with each astronaut individually	Semi-structured interview	Team processes including interactions among crewmembers, cooperation, and their development over time. Perceived interpersonal challenges and difficulties, individual satisfaction, relations between the crewmembers and MCC. Explanation and validation of the data collected during the mission.
Participation in MCC	Observation from MCC	Overall insight into the events onboard.

Table 12: Overview of the applied methods and their descriptions.

5.1.1 Questionnaire

The questionnaire for the LUNEX-0 mission was designed specifically for this project. It was inspired by the questionnaire which was used for the sociomapping study conducted as a part of Mars 500 (Bahbouh, 2012). See *Table 13* which provides the full list of applied questions. In some data collections, some of the questions were skipped. The number of data collections per each question is indicated in *Table 13*.

Question	Researched aspect	Ans-wers	Type	Number of data collections
How often do you communicate with following people?	Frequency of communication	1-7 scale	Relational	3
How often do you want to communicate with following people?	Desired frequency of communication	1-7 scale	Relational	3
Evaluate the quality of communication with following people (taking into account its relevance, content, timeliness, *etc*.).	Quality of communication	1-7 scale	Relational	3
Evaluate the quality of cooperation with the following people?	Quality of cooperation	1-7 scale	Relational	3
How well do you know the following people?	Current knowledge	1-7 scale	Relational	2 (first and last mission day)
How well do you want to know the following people?	Desired knowledge	1-7 scale	Relational	2 (first and last mission day)
How much do you trust the following people?	Mutual trust	1-7 scale	Non-relational	4
How is the atmosphere within the team?	Atmosphere within the team	1-7 scale	Non-relational	5
What was the performance of the entire team compared to what was expected?	Team performance	1-7 scale	Non-relational	4
Evaluate the level of discomfort you are experiencing.	Level of discomforts	1-7 scale	Non-relational	2
Have there been any misunderstandings in the team?	Misunderstan-dings within the team	1-7 scale	Non-relational	3
Evaluate the level of discomfort you are experiencing.	The level of discomfort	1-7 scale	Non-relational	1
If applicable, name the source(s) for the discomfort you are experience (e.g. noise, smell, food, sleeping problems, interpersonal conflict, *etc.*)	Discomforts	Open (text)	Open	4

You can add any comment or note (e.g. if something important happened, recommendation, how do you feel *etc.*)	Comments	Open (text)	Open	3
Evaluate the sufficiency of information provided by MCC (taking into account schedule, information sufficiency relevance, content, timeliness, *etc.*)	MCC information sufficiency	1-7 scale	Non-relational	1
How much do you trust to MCC?	MCC trust	1-7 scale	Non-relational	1
Have there been any misunderstandings among the crew and the MCC?	Misunderstan-dings between crew and MCC	1-7 scale	Non-relational	1
Evaluate the quality of cooperation with ESTEC MCC.	Cooperation with MCC	1-7 scale	Non-relational	1

Table 13: Questionnaire applied in the LUNEX-0 experiment.

The LUNEX-0 mission provided a valuable test of the research design and led to changes in the questions applied during LUNEX-1, shown in *Table 14*. The data collection has been performed via an online questionnaire five and seven times during the first and second mission, respectively.

Question	**Researched aspect**	**Type**	**Answer**
How frequently do you communicate with your crew mates? Evaluate each of your crewmates.	Frequency of communication	Relational	1-7 scale
How often would you prefer to communicate with your crew mates? Evaluate each of your crewmates.	Desired frequency of communication	Relational	1-7 scale
Evaluate the quality of communication with your crew mates (relevance, content, timeliness, *etc*.).	Quality of communication	Relational	1-7 scale
Evaluate the quality of cooperation with your crew mates?	Quality of cooperation	Relational	1-7 scale
Please, evaluate your crew mates regarding your preference to interact with them in your free time.	Personal preferences.	Relational	1-7 scale

To what the extent are you satisfied with the work of the following people from mission support team?	Satisfaction with MCC	Relational towards MCC members[14]	1-7 scale
If applicable, name the source(s) for the discomfort you are experience (e.g. noise, smell, food, sleeping problems, interpersonal conflicts, *etc.*)	Discomforts	Open	Text
Feel free to add any comment or note (e.g. if something important happened, how do you feel *etc.*).	Comments	Open	Text

Table 14: Questionnaire applied in the LUNEX-1 experiment.

5.1.2 Interview with the whole crew

The interviews with the whole crew were conducted on the last mission day, for both LUNEX-0 and LUNEX-1. The crew was asked to summarize the mission, the positive and negative aspects, and difficulties they had. Additionally, they were asked about the psychosocial aspects of coexistence in simulated lunar conditions.

5.1.3 Interviews with individual astronauts

After the termination of the missions, semi-structured, individual interviews were conducted with all the crewmembers remotely. Questions that were asked and discussed during the individual debriefings are listed in *Table 15* and *Table 16*.

Question	**Focus on**
Summarize your experience from the mission in few sentences.	Subjective experience from the mission
What was your strongest experience?	Mission milestones
What was most surprising?	Mission milestones
What have you learned during the mission? What was the most valuable?	Subjective experience
What were the positive aspects of the mission?	Protective factors
What aspects of the mission do you consider negative?	Risks

[14] Three roles from MCC were chosen to be evaluated by astronauts: Flight Director who is responsible for all important decisions, Capsule Communicator who directly communicates with the crew, and Scheduling Officer who schedules all actions to be done by crewmembers.

What do you recommend it should be done better?	Lessons learned

Table 15: Questions applied during the interviews of LUNEX-0 analogue astronauts.

Question	**Focus on**
Briefly describe you experienced of the mission.	Overview of the overall impression of the mission
What aspects were the most challenging for you? How was food and sleeping?	Identification of potential difficulties
What was the most challenging moment during the mission?	Identification of difficulties
Were there any conflicts within the crew?	Identification of interactions within the team
With whom did you interact most frequently during the mission? Who was closest to you?	Validation of the results from the questionnaire
How do you evaluate cooperation with your crewmates?	Validation of the results from the questionnaire
How do you evaluate the leadership of the crew commander? For the commander: How did you feel in the role?	Leadership
How do you evaluate the support from MCC?	Interactions with MCC
What were the best moments of the mission?	Identification of protective factors
What were the negative moments that occurred during the mission?	Identification of negative factors
Was there anything that helped you to overcome difficult moments or situation?	Identification of protective factors
Can you imagine the mission to last longer? How longer?	Overall satisfaction
What was the most valuable thing that you have learned?	Identification of protective factors

Is there anything else you would like to mention?	Identification of other potentially important aspects
Do you have any questions?	

Table 16: Questions applied to interviews of the LUNEX-1 astronauts.

5.2 Description of data analysis techniques

This visualisation technique, called *Dotty Overview of Team Interactions* (DOTI) is one of the contributions of this study. It differentiates from similar approaches by allowing both symmetrical and asymmetrical relations to be clearly visible. It can capture the current situation within a team to provide an overview of the development of the team dynamics. The interpretation of the method will be illustrated by an example which is taken from the results of LUNEX-1, second data collection (see *Fig. 7*).

In the relational questions the astronauts assessed each of their crewmembers on a 7-point scale. The results are anonymized – letters *A* to *F* represent each of the crewmembers. Each row visualizes evaluations that a given astronaut gave to other crewmembers. Each column visualizes the evaluations given to the respective astronaut. Increasing size and darkness of a dot represents arising issue related to the question. In the case of this example, the question is *quality of communication*, therefore darker, bigger dots will signal lower quality of communication. Inversely, the small and light-coloured points represent high scores (in this case high quality of communication). This visualization has been designed to highlight the low scoring cases, which might indicate an arising problem.

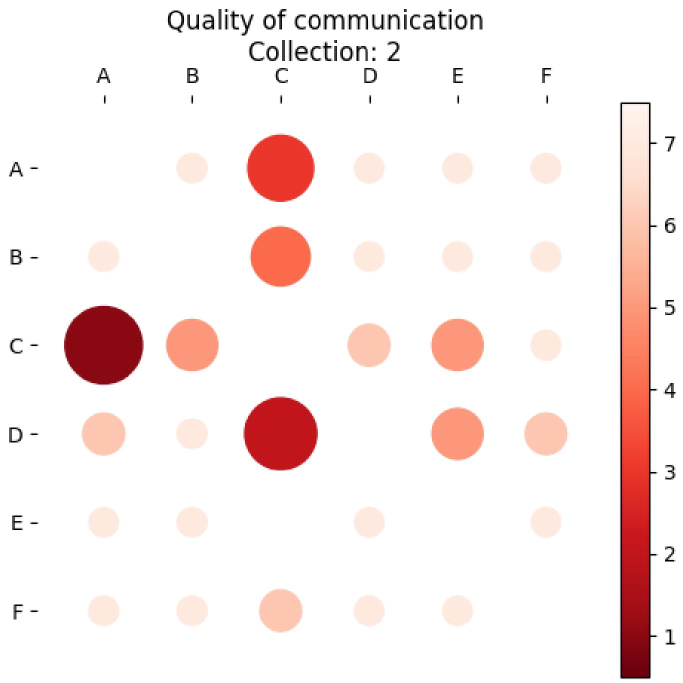

Figure 8: DOTI visualisation – an example of the results in plots chosen for a demonstration. This plot was created based on the answers of the LUNEX-1 astronauts to question: Evaluate the quality of communication with your crew mates (relevance, content, timeliness, etc.). They were given 7-point scale (from 1 -Should be much better to 7 Always above average).

From the visualization in *Figure 8*, one can conclude that the biggest communication issue in the team is the communication between astronauts *C* and *A*, represented by bigger, darker dots. Astronaut *C* gave average ratings also to astronauts *B* and *E*. Therefore, it might be concluded that astronaut C is incompatible with the rest of the crew.

The non-relational data were plotted using a bar graph. The post-mission interviews with the whole crew were summarized, similarly as the answers to open questions[15] from LUNEX-0. The individual interviews with all of the astronauts and the open questions from the LUNEX-1 questionnaire were analysed using grounded theory (Glaser, 2013; Goulding, 2002).

Grounded theory (GT) is a method developed by sociologists Barney Glaser and Anselm Strauss in 1967 in order to provide a solution that allows moving from data to

[15] Open questions in both missions were question asking about discomforts and comments, see *Table 13* and *Table 14* for more details).

theory, allowing a new theory could emerge from the data (Glaser, 2013; Goulding, 2002). Data for GT can be collected in various ways including interviews, observations, newspapers, letters, *etc*. (Corbin & Strauss, 1990). This method enables gradual identification and integration of categories of meaning from collected data. Therefore it offers both the way to identify categories and integrate them into a product – a new theory (Glaser, 2013).

The current study is explorative, hence GT was chosen for this research design. In contrast to content analysis, where categories are defined in advance, in GT categories emerge during the analysis. GT is conducted up to the point of theoretical saturation – this way all relevant data are taken into consideration because an analysis in (Coolican, 2009). The key process in GT is coding that breaks the data down into labelled component parts (Bryman, 2012).

Analysis of data by GT consists of several steps. The first step of coding is *initial* (or *open*) *coding* where each line of text gets a code (a label). Some codes might be *in vivo*, using a phrase directly from a subjects' speech (Coolican, 2009).

Then the data is reduced so that there is a manageable number of more abstract, relevant categories. This is achieved by making comparisons and asking questions (same strategies as used to identify concepts are applied).

Commonalities between concepts need to be found. This is *axial coding*, the process of putting the data back together around groups of concepts (Corbin & Holt, 2005). This process consists of combining simple codes into larger constructs which will combine and eventually lead to the explanatory categories (Coolican, 2009). Corbin & Holt (2005) add that the open and axial coding occur almost simultaneously during an analysis.

The last step of coding is *selective coding* which stands for constructing of the core categories from the identified concepts, when the most representative construct is chosen from many options (Corbin & Holt, 2005).

After the procedure of coding is finished, the memo writing follows. This procedure is applied in order to explain and justify the categories that emerged (Coolican, 2009).

6. Results

The study was mapping the crew dynamics over the course of stay in simulated lunar conditions. This chapter provides a description of the results for both missions.

During the first mission, very high scores can be observed in the terms of both frequency and quality of the interactions within the team. In most cases, the crewmembers did not know each other before the mission and were keen to get to know each other. The crew was cohesive, with a relatively stable team structure. There was only a minor indication of issues in interactions of *C* towards *D, E* and *F*. Interestingly, these relations were not symmetrical, *C* was well accepted by all of his crewmates. None of the astronauts were avoiding any of their crewmembers, quite the contrary, the crewmembers were rating each other high in all of the data collections.

In contrary, during LUNEX-1, the crew indicated certain issues from the beginning, without any significant improvement until the end of the mission. This manifested itself by an incompatibility of one of the crewmembers to the team. It was astronaut *C* who already indicated slight issues in the previous mission. This finding was supported by the individual interviews as well as DOTI plots. The astronauts reported that this crewmate was not a team player and that they were trying to avoid interactions with *C*. The interactions amongst the other five crewmembers were very good and satisfying from their perspective.

The crew ratings of the MCC varied over time, pointing out problems with trust and insufficient support during LUNEX-0. During LUNEX-1 the crew was asked to provide a more detailed scoring to the respective roles in MCC personnel. Due to some of their actions, FD has been rated relatively low in the second half of the mission. It's worth noting that the issues with MCC had implications on astronauts' well-being, which has been highlighted by the crew in open questions of the questionnaire.

Several challenging, discomforting, but also positive situations were reported from both of the missions. The most significant positive factors represent the positive interactions among the crewmates and overall gratefulness for being part of the project that provided them valuable new experiences.

The detailed results of the respective LUNEX-0 and LUNEX-1 study will be presented in the sections below. The data are anonymized – astronauts are labelled by letters *A* to *F*. Despite there were 2 women in the crew, all astronauts will be addressed as *he*.

6.1 Questionnaire

The full visualization of the data can be found in *Appendix 2* for LUNEX-0 results and *Appendix 3* for LUNEX-1 results. The development of the parameters over time is visible as well as the relations among the crewmembers. Both symmetric and asymmetric relations are visible. However, before getting to the respective descriptions of the data sets, few remarks need to be made.

During LUNEX-0 there were two questions asking about current and desired state of a given phenomenon. It included the frequency of communication within the crew and knowledge of each other. During LUNEX-1 there was only one such question: the frequency of communication within the crew. Such way of formulating the questions can reveal potential wishes to change or keep a certain state of interaction with respective crewmates. This might point to interesting conclusions, *e.g.* when a crewmember expresses a low level of communication, but does not wish to change it, it might indicate avoidant behaviour.

In the below descriptions, the term *average evaluation* stands for an average answer on the scale, *i.e.* a score of 4 on the used seven-point scale. In this scale, lower values indicate low ratings for a given question.

Finally, it is important to stress that all of the results describe subjective answers of astronauts over the course of the mission.

LUNEX-0

The results gained by questionnaire in general indicate positively perceived relations among crewmembers. The team seemed to be cohesive, no one was excluded from the interactions, and no indication of formation of subgroups has been observed. The evaluation of the MCC indicated some issues and there was an indication of minor improvement towards the end of the mission.

Paragraphs below describe the results in detail – each one is devoted to one data collection.

In the first data collection, an above average *frequency of communication* is visible for most of the crewmembers. The visualisation of the *desired frequency of communication* indicates that almost all crewmembers want to communicate the same amount or more. Only astronaut *A*, who answered that he was communicating with everybody on the highest level (*almost all the time*), preferred to communicate slightly less with all of the crewmembers. It can also be noticed that *C* communicated less with *D* and *F* and did not wish to communicate more with them, although it was asymmetrical relation as *D* and *F* wanted to communicate more with *C*. The state of *to what extent astronauts knew each other* shows that they did not know each other, the main exception being *D* and *B* who both expressed that know each other well. *The quality of communication* was all above average, except for *C*'s evaluation of *F*, which was around average. All of the astronauts expressed that they *wish to know each other* a lot more, only C expressed that he would like to get to know *D* and *F* just a bit more. It is another example of asymmetric relations because *D* and *F* wanted to get to know *C* significantly more. The *cooperation within the team* was mostly above average. *Mutual trust* among the crewmembers was also above average, with only the rating of *D* to *E* and *F* being below average. The *atmosphere within the team* was evaluated as very high (very positive). *Misunderstandings within the team* were below average, half of the crew did not perceive any.

The second data collection was more focused on the relationship between the crew and MCC although few questions regarding the crew appeared as well. The *atmosphere within the team* was again evaluated as very high, and the *team performance* was perceived to be very good. On the other hand, the *relationship towards MCC* varied more among crewmembers, especially in terms of perceived misunderstandings between the crew and MCC. Three crewmembers gave ratings below the average – two of them have even given the lowest rating possible – and three crewmembers rated the relationship to MCC above the average. The *perceived trust towards MCC* also varied significantly among the crewmembers with the rating ranging 2 to 7. Finally, *the sufficiency of the information provided by MCC* received twice the lowest rating (*should always be better*), a total of four ratings below average, one average rating and rating above average. Those discrepancies have later been attributed to the fact that astronauts were not sure which of the MCC offices they were evaluating.

Third data collection contained more relational than the previous one. It is visible that *C* communicated less frequently with *D*, *E* and *F* than in the previous data collection, as all of these 3 crewmembers received a rating below average from *C*. It's also interesting to note that he did not want to communicate more with them. And same as in the previous data collection *D* and *F* gave a higher rating to *C* than what *C* gave them. *F* communicates with an average frequency with all his crewmembers except *D* with whom he communicates more frequently. He also indicates that he would like to have more frequent communication with crewmates. The rest the crew communicates with each other above average and do not wish to change it. Quality of communication was in general above average, except for *C* rating average on *D*, *E*, and *F*. *Quality of cooperation* was perceived very similarly as *quality of communication*. *Mutual trust* among crewmembers was evaluated similarly high as in the previous data collection, except for *C* who had low trust to *E*. In contrary, *A*, *B* and *F* highly trusted all other crewmembers. *Atmosphere within the team* was very good, only one crewmember gave one point below the highest score. *Misunderstandings within the team* were almost none.

Fourth data collection assessed mutual trust among crewmembers, the *atmosphere within the team*, *the level of perceived discomforts* and *cooperation with MCC*. *Mutual trust* among crewmembers was perceived mostly above average or average. Only *C* had, similarly as in the previous data collections, lower than average trust to E. In comparison to the previous data collection the trust of *E* towards *C* dropped slightly. In contrary, *A, B* and *F* highly trusted to all of their crewmembers. *Atmosphere within the team* was perceived still as very positive. *The level of perceived discomfort* was low for all crewmembers. Evaluation of the *cooperation with MCC* (specifically the MCC located in ESTEC) varied among crewmembers between 2 and 5, with three astronauts giving the average rating.

On the last data collection, the current *frequency of communication* and *desired frequency of communication* were very similar, only *F* wanted to communicate a bit more with all his crewmates. The lowest *frequency of communication*, but without desire to increase, was expressed by *C* towards *F*. However, the *frequency of communication* of *C* towards *D* and *F* increased in comparison to previous data collections. The *quality of communication* as well as *cooperation* was perceived in general very high. *Mutual trust* among crewmembers was high, even *C* rated *E* around the average which was a higher rating than before. The crew also rated how much they *knew each other* in the end of the mission, in comparison to the first day of the mission. In general, they marked that they *know each other* more than in the beginning and they mostly wanted to get to know their crewmates even more. The crew did not report almost any *misunderstandings within the team* and both *the atmosphere within the team* and *team performance* received the highest rating from all of the crewmembers.

The last part of the LUNEX-0 questionnaire results to be described are the answers to the open questions. The crewmembers were mostly referring to the team being great, e.g. "*I am really pleased to work and spend time with such a nice team!*" On the other hand, they also mentioned negative "outside factors[16]" and low trust to MCC at around the middle of the mission as a discomforting situation. Additionally, one of the astronauts reported a smelly toilet. The comments were quite consistent, astronauts were mentioning only the above-mentioned topics.

Overall crew interactions can be evaluated as high, except for the ratings provided by *C* to some of his crewmates. This has proven harmless in the first mission, but has evolved into more serious issues during LUNEX-1.

LUNEX-1

The overall results indicate difficulties with astronaut *C*. This is visible already in the first data collection and gets more apparent over time especially in the second half of the mission. Astronaut *C* was receiving lower ratings than the rest of the crew and he was giving mostly lower ratings, especially in the second half of the mission. The rest of the crew seemed to be cohesive without significant issues nor changes over time. The relationship towards the MCC will be discussed separately.

In the first data collection, the *frequency of communication* towards and from *C* is lower than for other astronauts. It is also visible that he mostly did not want to communicate more. With *A* and *B*, he preferred to communicate even less, with *D* and *F* a bit more and on the same level with *E*. On the other hand, *F* who perceived his communication with all of the crewmates around the average, preferred to communicate more with all of his crewmates, except *C*. *C* gave *A* a very low rating in the *quality of communication*, despite A rating the communication with C as average. In contrary *B* and *D* rated the quality of communication with *C* low, but *C* evaluated his communication with them around the average. The *quality of cooperation* was in general high, only *C* received lower ratings. In the last question, asking about the

[16] These aspects cannot be described in details from confidentiality reasons.

preferences to interact with crewmates in free time, *C* and received lower ratings than the rest of the crew.

The second data collection, similarly as the first one, shows lower ratings of astronaut *C* and his ratings towards the crew. The comparison between the *current* and *desired frequency of communication* reveals that *C* would like to communicate less with everybody except *F*, and *F* would like to be communicating more with everybody. The *quality of communication* was mostly high, however *C*, same as in the previous data collection, perceived very low *quality of communication* with *A*, and *A* sees the quality of communication rather low with *C*. Additionally, there is also an asymmetrical relation between *C* and *D*. *D* rated the *quality of communication* with *C* low while *C* rated the quality of communication with *D* high. *Quality of cooperation* was very high among the crewmembers, except for *C*. Similarly, also the plot of the preferences to interact with crewmembers in free time shows lower rating for *C*, despite that he indicated that he would like to spend more time with his crewmates than in the previous data collection.

The results of the third data collection show higher *frequency of communication* of *F* towards others in comparison to previous data collection. *F* still would like to communicate with his crewmates more. On the contrary *C*, similarly as in the previous data collection, would like to communicate less with most of his crewmates. *Quality of communication* was in general high, except for *C*. He gave as well as received lower ratings than his crewmates, however in this case the ratings were around average and the very bad quality of communication that *C* had with A had improved. The *quality of cooperation* was very high for most of the crewmembers, except for two scores for *C*. There is however a visible improvement in comparison to the previous data collection. The personal preferences to spend free time together were similar as in the last data collection with the difference that *C* gave slightly lower ratings to some of his crewmates.

The fourth data collection was conducted at the middle part of the mission. The position of *C* worsened in all the questionnaire items. In contrary, the rest of the crew gave to each other very high ratings.

The fifth data collection shows similar results as the fourth one, only the ratings given to and received from *C* worsened in some cases.

In the sixth data collection the *C* communicates less with his crewmates and does not wish to communicate more. *A*, *B* and *F* wish to communicate more with him. On the contrary, *F* and *D* want to communicate less with *C*. In the other three visualizations from this data collection, *C* is mainly visible for his low ratings towards others as well as from others. In the question asking about *preferences* on spending free time with respective crewmates, *C* got the lowest score twice and gave the lowest score possible to *D*. Same as in the previous data collection, the rest of the crew, except *C*, gave as well as received very high evaluations from each other.

The last data collection did not show significant difference from the previous one. *C* got and gave low ratings again while the rest of the crew evaluated each other very high.

Besides the aforementioned results, there were also a question regarding the support from MCC and 2 open questions. The question towards the MCC was: *To what the extent are you satisfied with the work of the following people from MCC?* The Flight director, CapCom and scheduling officer were rated separately on the scale of 1 to 7: 1 meaning that their work is insufficient, 7 meaning that their work is amazing. The results are shown in the *Figure 9*, which depicts the average of responses of the crewmembers from each of the data collections. It is visible that the satisfaction with FD varied over the data collections. In the first half of the mission the rating towards FD were rather high but from the fourth data collection it dropped and did not significantly increase over time. The scheduling officer received the highest ratings in the middle part of the mission and none of the ratings towards the scheduling officer was below average. Finally, the crew was rather satisfied with CapCom who received high ratings over the course of the mission.

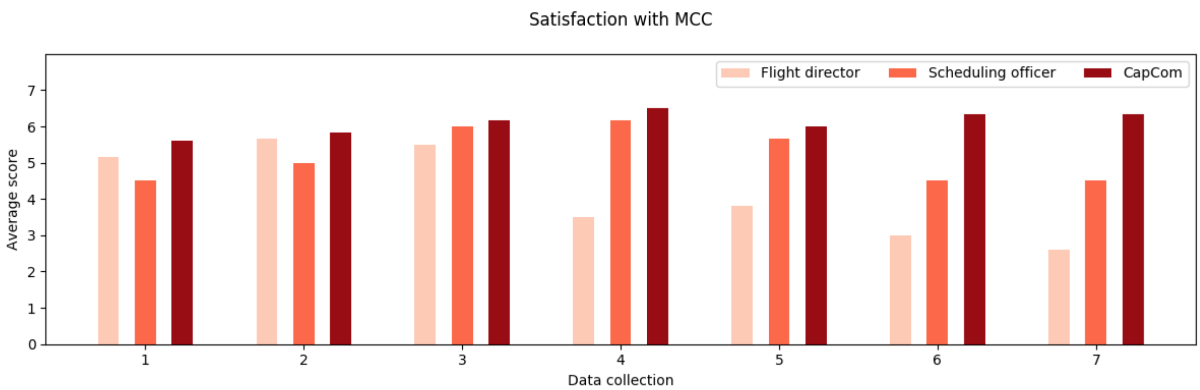

Figure 9: The LUNEX-1 results of the question "To what the extent are you satisfied with the work of the following people from MCC?" with the separate rating of FD, CapCom and scheduling officer. Average scores from each data collection.

Open questions[17] of the LUNEX-1 questionnaire were analysed separately with the application of Grounded Theory and are described in *Table 17*.

The results provided additional information and context of the events onboard. Similarly as in the relational data, the issues with astronaut *C* were observed. Crewmates were commenting that he was not a team player or that he was a spy to the Flight director. It is noteworthy that astronaut *C* had his own opinions that usually did not match with the rest of the crew. The most frequently mentioned issues were connected to the time shift experiment. Crewmembers reported that they felt tired and unproductive. There were also comments addressing issues with the FD, the content of schedules, and few other specific discomforting things. Nevertheless, the crew also mentioned many positive aspects, *e.g.* the excitement for the mission, the crew being together or cooking experiments that resulted in improved meals.

Category	Number of mentions	Example	Explanation
Issues caused by time shifts	9	*"Yesterday I couldn't fall asleep and today I had to take a nap during the day."*	The crew reported feeling tired, low productivity and problems with asleep due to the experiment of time perception that was shifting time.
Happy and excited for the mission	6	*"I really am happy to be part of this mission!"*	Overall happiness to be a part of the mission and excitement was reported in the first days.
Astronaut *C* not a team player	4	*"[astronaut C] is not a team player and I don't like his behaviour."*	The astronauts reported that astronaut *C* was not a team player, he was making decisions on his own *etc*.
Astronaut *C* himself sees it differently	3 entries all from astronaut C	*"Annoyed by the relaxed atmosphere. I am pro work…"*	Astronaut *C* had different perspective of the mission and events that happened.
Spy	3	*"First of all, we have a spy on board…"*	The crew thought one of the crewmembers (C) was privately in touch with FD.

[17] See *Table 14* for more details.

MCC/FD issue	6	*"Well, today's morning issue should have been handled a bit more gentle."*	The crew did not like certain actions of MCC, especially direct improper communication of FD reported as overreaction.
Dissatisfaction with schedules content	4	*"I did not learn nothing new. My daily schedule is distracted."*	Crewmembers expressed dissatisfaction with the scheduled tasks.
Together	3	*"Having yoga together every day is really funny (...) I just feel really good doing something fun with the whole the team."*	Astronauts appreciated the time had together and the interactions among them.
Cooking experiments	2	*"I like our cooking experiments..."*	Astronauts appreciated improvements of their meals.
Specific discomforts	3	*"Temperature in the habitat - it is getting really cold during some nights."*	Other specific discomforts that were mentioned: temperature, insect, smell at toilet, mess.

Table 17: The results of answers of the opened questions from the questionnaire regarding LUNEX-1 mission.

6.2 Interviews

In both, LUNEX-0 and LUNEX-1 projects, the interview with the whole crew was conducted around the time of the termination of the mission. The individual debriefings with analogue astronauts were conducted after the termination of the mission in dependence on availability of the respective astronaut remotely via call. The amount of time spent on the individual debriefings with each astronaut varied between 0,5 an hour to nearly hour and half after the LUNEX-0 mission, and between 25 minutes to approx. an hour after LUNEX-1 depending on the participants' needs. The result will be described separately for LUNEX-0 and LUNEX-1 in the following sections.

LUNEX-0

Highly positive atmosphere was observed during the common debriefing conducted with LUNEX-0 crew. All of the crewmembers took an active part in the discussions. First of all, astronauts were asked to summarize the milestones of the mission. Then the results of the results gained by questionnaire were presented. Astronauts were asked whether they prefer to see anonymized visualization of data or the non-anonymized version. All of them wanted to see non-anonymized version. The results were discussed with the crewmembers. All astronauts agreed with the presented results. All the astronauts also expressed very positive emotions regarding the overall experience of the mission. A lot of laugh and joking were observed within the crew.

The interviews with all of the astronauts individually were analysed by GT, see results in *Table 18*.

Described category	**Number of astronauts who mentioned**	**Example**	**Explanation**
Great time	All 6	*"I really did have a great time with those guys. I have no problems they have different backgrounds. (…) I was very happy being there."*	The overall satisfaction with the mission was very high.
Surprisingly good crew interactions	All 6	*"…well positively surprising was how the crew interact with each other we did not expect that really, we met each other just before the mission … it was a big experience that we really worked nice and interacted nice together without any argue or whatsoever."*	The crewmembers were highly satisfied with the interactions within the team and the teamwork in general.
Lessons learned for future	All 6	*"There was a lot of negative as well but if we learn from them, it is OK."*	This mission was marked as testing thus obtaining lessons learned was one of the main goals.
Negative outside factors	All 6	Cannot be provided from confidentiality reasons.	Organizational issues that occurred before and during the mission.
Excitement for future mission	All 6	*"We had a lot fun; we want to close ourselves to the habitat again."*	LUNEX-0 was a testing mission prior to LUNEX-1, crew was excited for the future mission.
Learning from experiments	3	*"It [experiments] was really exciting because I am not biologist, everything was new for me."*	Experiments were found interesting, astronauts appreciated they learned something new.

		"I learned a lot of stuff from the medical perspective, biology, microgravity experiments…"	
Insufficient repetitive diet	2	*"We did not have enough healthy food. (…) Somebody did not like the taste. I didn't mind that much."*	Some astronauts mentioned food being too repetitive and not enough.
Schedules	2	*"Schedules were not good, but they got better."*	Schedules were found insufficient in the initial period.

Table 18: Results from LUNEX-0 individual interviews.

All of the astronauts were very positive about the mission. They were very glad they got to know each other. They all expressed high satisfaction and positive emotions about the overall functioning and relations within the team which was mentioned by each of them many times in various opportunities during the interviews. It can be illustrated on few quotations of the astronauts:

"*It was for all like we are doing it because we really like it and we really enjoyed. (…) It was very natural for us. We did what we were supposed to do and we were very glad to do it.***"**

"*I really did have a great time with those guys. I have no problems they have different backgrounds. (…) I was very happy being there.*"

When the astronauts were asked about their most positive experience from the mission, they often referred to the interactions within the crew again.

"*…that might be the strongest thing, you are closed with five unknown people and of course there some interpersonal things usually happening but it turned out that it was absolutely not an issue.*"

Three of the astronauts mentioned scientific experiments as interesting opportunity to learn something new.

As negative aspects, on the other hand, all of the astronauts mentioned organizational issues including last minute changes, unexpected events and "outside factors[18]". Nevertheless, astronauts were excited about incorporating lessons learned into the planning of the next mission. Additionally, one of the astronauts said that the *outside issues* helped them to interact on deeper level with the crewmembers because they had common challenges, they had to overcome thus it boosted their discussions and sharing of opinions towards certain aspects of the mission.

Two out of the six astronauts mentioned dissatisfaction with the diet they have had for the food being too repetitive. Additionally, one of the astronauts mentioned that he felt hungry between meals.

Two out of the six astronauts mentioned as a negative aspect schedules[19] that were found insufficient in the beginning of the mission due to many changes. Interestingly, one of the astronauts mentioned also positive experience regarding schedules when he mentioned that as he said "*living in the schedule and having everything planned*" was really interesting experience for him.

All of the astronauts expressed big excitement for the next mission (LUNEX-1) which was in the process of planning that time.

LUNEX-1

The findings of the LUNEX-1 interviews will be discussed below. This interview was conducted the last mission day around the time of the termination of the mission remotely via videocall.

Astronauts were asked to summarize the mission, the positive and negative moments, challenges, their favourite activities, differences when comparing to the LUNEX-0, teamwork, and the relationship towards MCC.

Astronauts mentioned, when asked about the positive moments, an unexpected delivery when they received a cargo with pudding which made them very happy and "cooking experiments" they have done in order to prepare nice meals.

When asked about negative moments, they have answered that it was an overreaction of the Flight director (FD) at certain moments of the mission which made

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[18] The "outside factors" that astronauts referred to were organizational issues which were unexpectedly affecting the overall realization of the project. Details cannot be provided due to confidentiality reasons.
[19] Scheduling was one of the aspects of the mission that were tested. MCC tried various ways of scheduling in order to find the most suitable way. The dissatisfaction of astronauts was known, MCC was opened to feedback thanks to which it was soon fixed.

them very angry and lowered their motivation. Additionally, they have mentioned organizational issues.

The most challenging period of the mission, as the crew concluded, was approx. the middle part of the mission when they perceived that time rapidly shifted[20], it led to lowered productivity and jet lag.

Each of the astronauts was asked about his or her favourite tasks and activities they have done during the mission. Those were: work on hydroponics; the longest EVA when the respective astronaut was taking pictures and also seeing how the crew works together; both of the women concluded that they have enjoyed sport activities that they were doing together; repairing of 3D printer which was repeatedly done with occasional success; repairing of a rover which he managed.

The next topic discussed was the different between LUNEX-0 and LUNEX-1. The crew concluded that the current mission was longer and better isolated, it gave them more time to accomplish all the mission tasks and experiments while the previous year they felt like there was lot of things to do. As the crew summarized, almost everything changed in the crew, they met just before the LUNEX-0, they were in touch in meantime therefore the relations between them developed. In contrary to LUNEX-0, there was the experiment including time shifts in LUNEX-1 which the crew did not like. Different were also schedules in the previous mission they had strict schedule while the current mission worked according to flexible schedule. The flexible schedules were appreciated, it allowed them to be more relaxed about time, however the time shifts led to lowered lower efficiency of the crewmembers' work.

The crew was asked whether they could imagine the mission last longer, the answer was that it highly depends on the schedule where they would prefer more experiments with more scientific content, similarly they would prefer better design of their EVAs, additionally the provided food was not balanced. Finally, they added that with the current crew it would not be a problem if the aforementioned would be all fulfilled because they feel that there is a lot of things that need to be improved, e.g. experiments did not always have a clear procedure *etc.*

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[20] This was just how the crew perceived the time shifts, the same time period was shifted each day.

The cooperation within the team was evaluated positively, they said they had a lot of fun, they enjoyed common meals and also yoga was fun, however sports were hard to perform.

The last topic discussed was the support from MCC. The issues with FD were mentioned again causing negative emotions to crewmembers and lowering their trust towards MCC. That was also the situation of the next issue connected to FD, saying that FD did not take seriously enough an injury of one of the astronauts[21]. Additionally, the crew was upset with the MCC support in terms of waiting for answers and feedback regarding reports. They had a feeling that MCC did not read all reports. They also questioned one mission event that according to the crew was not performed according to procedure.

The process of the interview was different than in the last mission. In this interview was a strong tendency of astronauts to allow to speak only the commander. Astronauts were frequently muting the call usually after a question was said. They switched to Polish, muted the call and discussed within the group before providing an answer. The only occasion when someone else than commander was speaking occurred when there was a question about favourite activities specifically targeted to each of the astronauts. There was a lot of laughing and joking within the crew even when serious topics were discussed.

The results of the GT of the individual interviews are described in *Table 19*. One of the main difficulties was caused, according to the crewmembers, by the time shifts[22] which resulted into problems with sleeping and lowered efficiency and productivity. On the other hand, the crew was referring to a great team with supportive crewmembers even though one of the crewmembers (astronaut *C*) was not well accepted by the rest of the crew, as also clearly visible in the results from the relational data of the questionnaire. There were several levels of this issue that were frequently mentioned by the crew. Astronaut *C* was perceived as having a different mindset, seeing the things differently, besides that he was not considered as a team player (as mentioned by all of the rest of the crew) notwithstanding 4 of the crewmembers mentioned that they were trying to be nice to him. However, couple of the

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[21] One of the astronauts injured his back during an EVA.
[22] Time shifts occurred due to an experiment investigating subjective time perception which was applied to this mission.

crewmembers mentioned they tried to avoid interactions with him. Astronaut *C* was aware that he was not fitting well into the crew and he mentioned some differences in his perspective in comparison to the perspective of the other crewmembers.

Another studied aspect of the mission was crew's satisfaction with MCC. There were complaints towards the work of Flight director mentioning certain moments of the mission consistently mentioned by crewmembers, leading to dissatisfaction and worsen trust to MCC. On the other hand, the work of CapCom work was appreciated.

The commander has received very positive feedback by the crew that appreciated his work for the team. The crew also highly appreciated experiments with cooking when some of the crewmembers tried to make innovative meals out of what was available in the habitat. The crew created internal jokes and experienced many funny moments. Astronauts were asked whether they could imagine the mission to last longer, all of them said that yes but under certain conditions. They mostly mentioned they could imagine the mission to last 1 or 2 months. Four of the crewmembers said that they were not satisfied with the mission as it was prepared and with the habitat which did not seemed fully prepared for the mission. Finally, all of the crewmembers mentioned they were happy for the overall experience of the mission.

Category	**Number of astronauts who mentioned it**	**Example(s)**	**Additional explanatory comments**
Tired and not enough sleep due to time shifts	All 6	*"Sleep was challenging with the jet lag. There were 2 or 3 days when the time was shifted and we could not do anything and we could not sleep either."* *"When the time was shifting, I went to sleep when I knew I should go to sleep but I couldn't especially when the time was getting back. (...) I did not sleep enough.*	All of the astronauts perceived certain difficulties due to time shifts. They mentioned tiredness, lowered efficiency and productivity *etc*.
Great crew	5 (all except astronaut C)	*"I think the best was our team. We did everything together; it was really nice."*	The five crewmembers were very satisfied with the team although they sometimes mentioned they did not count

			astronaut *C* among them.
Great, very patient commander	5, all of them mentioned repeatedly	*He is really calm and he knows how to talk with people he knows how to fist the situation if something is going on. He is a really great leader.* *"He did an amazing job as a team lead."* *"Really great. He is really calm and he knows how to talk with people."*	All 5 astronauts (not counting the commander himself) really appreciated the work of the commander that he has done for the crew.
Astronaut *C* had a different mindset (than the rest of the team)	5	*"We had many conflicts with astronaut C that was very problematic, yeah. Definitely different mindset than all of us."* *"…it is not only team mates that he doesn't care about it is also about some objectives. He seems them differently."*	Crewmates did not find astronaut *C* fitting in the team. They mentioned he saw many of the situations onboard differently than all other crewmembers; that he was having a different mindset *etc*.
Astronaut *C* was not a team player	5	*"I think he doesn't really understand what is the team spirit at all. He is really bad team player and I think this is the key aspect."* *"He was not a part of the crew anymore; he was not a team player. It can clearly destroy whole mission."*	Astronaut *C* was found a bad team player by all of his crewmates.
We were trying (to get along with astronaut *C*)	4	*"We did not want to separate him but as with these 4 we think alike."* *"I felt like he was not part of the team but of course, I was trying to make it not obvious. (…) I was always trying to be nice but it was just because I tried to be nice. I did not feel like."*	The crewmembers mentioned that they were trying to get along with astronaut *C*. Especially the commander who was repeatedly trying to mediate the problem.[23]

[23] Similarly, astronaut *C* to some extent wanted to help the situation as he said: "*It has been hard to fix. But I was working on that.*"

Trying to avoid astronaut C	2	*"I tried to avoid him [astronaut C] as much as I could."*	Two astronauts explicitly mentioned they tried to avoid astronaut C.
Crewmembers had different objectives (than astronaut C, from the perspective of astronaut C)	1 (mentioned in various occasions during the interview)	*"They cannot find the value in the things what was done."* *"I think also that the problem is they cared about the mission and I cared about the program. About future missions. About the habitat and what we can learn from now. Not to complain how bad it is, but what we can improve for the next mission. This is why we do not understand each other."*	In the first example he was referring to the organizational aspects and the preparation of the habitat and the mission itself, because he was helping with these aspects.
Insider behaviour	3	*"He had some kind of insider behaviour."*	Astronauts suspected their crewmate (C) that he had a secret communication channel with FD.
Injury taken too lightly by FD	5	*"I was really worried about him and I felt that MCC is not worried as much as I wished they were"*	Most of the crew mentioned they were worried about the injured astronaut. They felt FD took the situation too lightly.[24]
FD direct communication	5	*"FD was bypassing CapCom and went directly to us. I was really enjoying communication just with CapCom."*	The crewmembers did not like that FD in certain occasions communicated directly with the crew[25] and according to astronauts "overreacted"
CapCom appreciated	5	*"[CapCom] really did a great job (…)."*	The work of CapCom was appreciated.
Food experiments	All 6	*"It was actually nice when we started to do some experiments in kitchen with the food, it was quite nice."*	The crew started to experiment with ingrediencies and food they have had to make nice meals out of it. All

[24] However, the injured astronaut mentioned *"I hurt my back, but this was not serious."*
[25] The procedure is that all communication from MCC to a crew goes through CapCom except certain exceptional situations.

			crewmembers mentioned it positively.
Fun, internal jokes	5	*There were many funny moments.* *"…a lot of internal jokes were really funny; I know if I use it outside, I'd be really weird."*	Most of the astronauts mentioned they have experienced certain funny moments and they have had internal jokes.
Could stay longer but…	All 6	*"We definitely could without problem follow the mission but if we would be up to go for a longer mission it would definitely be better, much better if those issues would be solved."* *"Longer sure, but under one condition…"*	Astronauts were asked whether they could imagine the mission to last longer, all of them answered that yes, but with some certain conditions, they usually said 1 or 2 month they can imagine.
Not ready, not fully prepared	4	*"The mission was not fully prepared. It should be taken care much earlier."* *"Habitat was not ready."*	Four astronauts mentioned they expected the habitat and the mission prepared better, that it was not ready.
Overall satisfaction, happy for the experience	All 6	*"I had really great time inside the habitat"* *"I am happy I was there."* *"What was the best about the mission was the general feeling that we were doing this mission..."*	Despite some issues and complaints all of the astronauts were grateful for the experience thy have gained.

Table 19: The results individual interviews of LUNEX-1 crew.

III. DISCUSSION

7. Discussion and conclusion

There are many challenges linked to humans living in extreme environments. Research and design of psychological countermeasures is needed to minimize the risk associated with future long-term spaceflights. One example of such endeavours is a mission to Mars. From the psychosocial perspective the major issues include: the interactions among crewmembers, adjustment to the extreme environment of isolation and confinement, and the relationship between the crew and MCC. Moreover, there are also additional aspects to be addressed specifically for a mission to Mars. For instance, it is difficult to say what effect the distance from home planet might have on astronauts. They will reach a moment when Earth will be no longer visible – so called *Earth- out-of-view* phenomenon (Kanas, 2010). Additionally, there are two issues that are not new in the space environment, but have not attracted enough attention of researchers: space diet and sexual activity.

As already illustrated in the theoretical part (in section *3.1 Psychological and psychiatric symptoms and stressors*) certain aspects of diet such as insufficient amount of food, repetitiveness of meals, or dissatisfaction with flavour or consistency poses a stressor potentially causing a decline in individual well-being or even leading to interpersonal difficulties. On the other hand, as known from the ISS missions, re-supplies containing fresh food have a positive psychological effect on astronauts (Kanas, 2015). Unfortunately, during a mission to Mars, this is not going to be possible. The issue of food was mentioned by the analogue astronauts during both missions analysed as a part of this study.

Sexual activity in space is still considered a taboo topic in scientific literature (Suedfeld & Steel, 2000) despite being a natural need. However, it is known that sexual tension can happen and might cause significant interpersonal issues among crewmembers. This was part of the findings of the SFINCSS-99 experiment (Inoue et al., 2004; Sandal, 2004). Sexual needs in space need to be addressed to break the taboo and to provide solutions relevant for future long-duration space missions.

Another point of interest is the safety of the crew. Despite the aims of minimizing the risks of future long-term space missions, all risks cannot be eliminated. No one can guarantee that the first astronauts going to Mars will safely return back to Earth. Beside various potential technical issues, there exist considerable health and psychological risks that need to be addressed in the future research (Driskell, Salas, & Driskell, 2018; Goel et al., 2014; Horneck & Comet, 2006; Horneck et al., 2006; Kanas, 2014, 2016; Kanas & Manzey, 2008; Salotti et al., 2014; Salotti & Suhir, 2014).

One of the major pre-mission countermeasures is the crew selection. It is especially important in the case of long-term missions. Kanas (2010) highlights that not every astronaut will be willing to undergo a lengthy separation from family and friends while isolated with few crewmates. It might have consequences to the crew selection process. It raises a few questions: What kind of people will be selected to the crew? How compatible the crew will be? Moreover, there might be hidden issues related to the crew selection process: How difficult will it be to pass it?

Besides that, even the whole concept of sending humans to Mars can be questioned. Are there people resilient and motivated enough to undergo such a challenging mission without significant negative consequences? Humans on their way to Mars will be exposed to substantial risks which should be appropriately justified, otherwise the potential loss might be hardly accepted by public. As the consequence an interruption of further evolution of the future human spaceflights may occur. Moreover, one more question to be discussed: What would be defined as a success? - Even if the crew safely lands back on Earth, the astronauts might suffer from various health issues connected to long-term stay in space, or psychological/psychiatric issues caused by distress due to a long duration stay in isolated and confined environment with no possibilities of leaving for very long time period.

There are several options how to conduct a relevant research to study these issues, each of the options have certain benefits and limitations. For instance, it can be done on crews on ISS which would provide the closest conditions to a journey to Mars. However, as mentioned by London et al. (2018), astronauts on ISS have typically a very busy schedule which leaves them little time to participate on psychosocial studies. This can also be interpreted that psychosocial research was not acknowledged to make it higher priority. Nevertheless, a quality research can be conducted also on Earth as an analogue mission.

As already described in the theoretical part, analogues pose number of limitations. There are aspects that cannot be simulated, such as microgravity, no rescue in case of emergency *etc*. Moreover, there an important implication relating the psychological research of space. Generalization across environments might be difficult (Sandal, 2001, 2002). Moreover, the extent of the application to space could by hardly determined without conducting a comprehensive comparative research.

The analogue missions were applied to the current research thus these limitations have to be acknowledged also to the current study. The study focused mainly on the intra-team interactions among crewmembers. The knowledge known in this area was summarized above (in the section *3.2 Intragroup issues and their development over time*), This section provided an overview of the development of team relations in order to define what are the most difficult moments, what challenges occurs, and how to prevent them. Despite several papers approached this issue, no generally applicable approach was found.

One of the frequently mentioned findings is the *third quarter phenomenon* that was repeatedly reported from polar missions e.g. (Bechtel & Berning, 1991; Sandal et al., 2018; Stuster et al., 1999) but not from space or space mission simulations (Basner et al., 2014; Kanas, 2013; Kanas, Salnitskiy, Grund, et al., 2001; Kanas, Salnitskiy, Boyd, et al., 2007; Kanas et al., 2006; Kanas, Salnitskiy, Ritsher, et al., 2007; Šolcová et al., 2013; Wu & Wang, 2015). This area needs more research. It could be highly beneficial for design of countermeasures for future long-term space missions.

The current study was described in the second part (*II. Empirical part*) of the thesis. The study, by using multiple methods, investigated the psychosocial dynamics over the course of LUNEX-0 and LUNEX-1 analogue missions. It is unique for three reasons. Firstly, it provides results of two analogue missions that were both attended by the same crewmembers. Secondly, very similar research design was applied in both missions therefore a comparison is possible. And in third place, new visualization technique *Dotty Overview of Team Interactions* (DOTI) was introduced and tested.

The study provided detailed results relating the psychosocial aspects of human coexistence in space that were consistent across the applied methods. The current research designed proved to be effective in revealing underlying aspects of the crewmembers' relations.

The results show considerable difference in the team structure in LUNEX-0 and LUNEX-1. In the first mission were observed mostly very high scores in terms of both the frequency and quality of the interactions within the team. The crew was cohesive, none of the astronauts were avoiding any of their crewmembers, quite the contrary, the crewmembers were rating each other high in all of the data collections. There was only a slight indication of issues in interaction of *C* towards *D, E* and *F* although these relations were not symmetrical, *C* was well accepted by all of his crewmates. In contrary, LUNEX-1 crew indicated certain issues within the crew from the very beginning without any significant improvement until the end of the mission, showing clearly an incompatibility of one of the crewmembers (*C*) to the team. This finding was supported by the individual interviews. The astronauts reported that this crewmate was not a team player, some crewmates admitted they were trying to avoid C from interactions. On the other hand, the interactions among the rest five of the crewmembers were very good and satisfying for the respective astronauts.

There were many positive aspects reported by all of the crewmembers from both of the projects. The most significant of them represent the positive interactions among the crewmates and overall gratefulness for being part of the project that provided them valuable new experience.

The difficulties that occurred were in LUNEX-0 mission related to an organizational factors and issues with MCC. The relationship towards the MCC during the course of LUNEX-1 was studied separately for FD, scheduling officer and CapCom showing mainly some reservations towards the work of FD. This finding was supported by individual interviews that provided details of the problem.

The aspects of the delays in the crew-MCC communication are an important topic to be investigated further. It is important to add that the relationship between the crew and MCC will be very challenging in the future long-term space missions due to the communication delays. Some indications were made as a part of Mars 500 project, finding many difficulties including the information deficit, lack of opportunity to immediately increase reinforcement of one's opinion, difficulties on decision making, and worsen relationship towards MCC due to perceived insufficient contact (Ushakov et al., 2014).

The potential difficulties between the crew and MCC might be mitigated by common training of the crew and MCC personnel prior the mission. That can develop mutual trust and decrease the risks maladaptive communication and displacement tendencies during a space mission (Gushin & Yusupova, 2012; Kanas, Salnitskiy, Boyd, et al., 2007; Kanas et al., 2006, 2009; Kanas, Salnitskiy, Ritsher, et al., 2007).

Next paragraphs will include recommendations for future research based on the indications of the current study. The relations between the crew and MCC needs to be investigated in details to analyse the respective relations of crewmembers towards the MCC personnel and preferably also interactions from MCC to the crewmembers because negative feeling of MCC members can contribute to issues with crewmembers and *vice versa*. From this reason there should be mission psychologist that can provide mediation between these two groups. For that is necessary to gain trust of the members of both of these groups prior the experiment and to have a private communication loop with astronauts.

Beside that there is one more topic linked to MCC. It is a work of CapCom. In spite of CapCom being *just* a communicational link between the crew and MCC, he can significantly affect the quality of mutual crew- MCC communication, mutual trust between them, and information sufficiency of provided and received information.

There are several remarks and comments relating the current study that will be discussed in the next paragraphs. The study would not be possible without good cooperation and mutual trust with the crew. It is beneficial to get to know the crew prior the mission and to be a part of the project. Being present in MCC provided additional context and understanding of events in both MCC.

It would be greatly beneficial to obtain video recordings from the habitat to make a detailed observation for research purposes. That could add an objective data into the research design. However, obtaining video recordings is very difficult from ethical reasons. Astronauts value their privacy and refuse to allow such research.

There are several limitations of the current study. The missions were only a week and 2 weeks long. On the other hand, the same crew after a year might be considered interesting by showing a development of the relations also after a longer non-mission period.

The LUNEX-0 was demo mission where the best fitting solutions were searched in various aspects. This is a limitation but also an advantage because there was a lot of testing of procedures providing valuable lessons learned. For instance, the communication between the crew and MCC was in the beginning of the mission tried without CapCom. In both teams – the crew and the MCC everybody could speak during the briefings and debriefings. After switching to the procedure of CapCom and one of the crewmembers who is responsible for communications the briefings and debriefings were significantly more effective. They were clearer and faster.

The organizational aspects of analogue missions indicated organizational difficulties that led to last minute changes in both, the organizational aspects as well as in the mission schedules and procedures. The lessons learned from these aspects include the need of clearly defined and complied - time line; list of people and their roles in project; defined tasks and deadlines *etc*. Nevertheless, in scientific missions that are conducted by team of volunteers working on a project in their free time, it is difficult to maintain all of the above-mentioned.

8. Summary

The theoretical part of this thesis provides a literature review of the psychosocial aspect of crewed space missions. The first chapter is devoted to the challenges of living in extreme environments. It includes a brief overview of past projects of crewed space missions as well as the future ones – a base on the Moon and mission to Mars. Additionally, the extreme conditions related to space research are described.

The second chapter summarizes the risks and psychological countermeasures linked to a crewed spaceflight. Two of the pre-mission countermeasures are described in more details – the crew selection and astronaut training.

Third chapter consists of characterization of the psychological, psychosocial, and psychiatric symptoms and stressors as well as other challenges that are typical for a stay in space. The additional stressors defined for future long-term missions are also discussed. This section is followed by a summary of intragroup issues and their development over time, with an emphasis on finding the most difficult parts of the missions. Additionally, the relationship between a crew and MCC is addressed.

The empirical part provides the description and results of a study performed as a part of this thesis, during two analogue missions: Lunar Expedition-0 and Lunar Expedition-1. This study addressed mainly the development of the relations between the crewmembers. The research design consisted of a questionnaire, an interview with the whole crew, and the individual interviews with all respective astronauts. Moreover, observation from the MCC was conducted in order to gain additional context and background of the crew-MCC interactions. This contributed to the adjustment of the questionnaires and interviews. Additionally, a new visualization method, called DOTI, was created and described as a part of this research. DOTI was used to visualize the data relating mutual interactions among the crewmembers.

During the first mission, high scores were observed in the terms of both frequency and quality of the interactions within the team. In most cases, the crewmembers did not know each other before the mission and were keen to get to know each other. The crew was cohesive, with a relatively stable team structure. There was only a minor indication of issues in interactions of *C* towards *D, E* and *F.* Interestingly, these relations were not symmetrical, *C* was well accepted by all of his crewmates. None of the astronauts were avoiding any of their crewmembers, quite the contrary, the crewmembers were rating each other high in all of the data collections.

In contrary, during LUNEX-1, the crew indicated certain issues from the beginning, without any significant improvement until the end of the mission. This manifested itself by an incompatibility of one of the crewmembers to the team. It was astronaut *C* who already indicated slight issues in the previous mission. This finding was supported by the individual interviews as well as DOTI plots. The astronauts reported that this crewmate was not a team player and that they were trying to avoid interactions with *C*. The interactions amongst the other five crewmembers were very good and satisfying from their perspective.

The crew ratings of the MCC varied over time, pointing out problems with trust and insufficient support during LUNEX-0. During LUNEX-1 the crew was asked to provide a more detailed scoring to the respective roles in MCC personnel. Due to some of their actions, FD has been rated relatively low in the second half of the mission. It's worth noting that the issues with MCC had implications on astronauts' well-being, which has been highlighted by the crew in open questions of the questionnaire.

Several challenging, discomforting, but also positive situations were reported from both of the missions. The most significant positive factors represent the positive interactions among the crewmates and overall gratefulness for being part of the project that provided them valuable new experiences.

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IV. Appendices

Appendix 1	The history of crewed space missions
Appendix 2	LUNEX-0 results
Appendix 3	LUNEX- results

Appendix 1 The history of crewed space missions

This appendix is a continuation of the section *1.1 Brief history of past crewed missions*. It is presented separately because it is not essential for the topic of this thesis, however it provides a valuable historical context and continuation of the discussed topic.

Before sending humans to space, the important part of the research was testing on living organisms. Robots and animals became space travellers. Americans were sending monkeys, Soviets dogs. The most famous were Soviet dog Laika and Mercury's chimpanzee Ham. Laika died aboard Sputnik 2 in 1957, Ham returned to Earth to a comfortable retirement at the National Zoo in Washington, D.C. (Dohrer, 2017; National Geographic, n.d.). However, the first mammal in space became Albert II, a Rhesus monkey in 1949. Previous Albert I's mission was not successful. Albert II was anesthetized during flight and implanted with sensors to measure his vital signs. He died upon impact at re-entry (Dohrer, 2017).

The NASA's human spaceflight program started with Project Mercury. This project was launched in 1958. About a year after the U.S.S.R. had signified the start of the Space Age with the successful launch of their satellite Sputnik 1 (National Geographic, n.d.).

The Cold War between the United States and Soviet Union started the space race, an unprecedented program of space exploration and crewed space missions. The Soviets sent Yuri Gagarin, the first person in space on 12th of April, 1961. In response to that, President John F. Kennedy challenged the U.S. by saying: "*To achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to earth.*" Eight years and three NASA's programs - Mercury, Gemini and Apollo later, it was achieved (NASA, n.d.-e).

About a month later upon Yuri Gagarin's spaceflight, Alan Shepard, Jr. became the first American in space (May 5, 1961) aboard Mercury-Redstone 3. Between 1961 and 1963, six manned one-man missions went to space as part of the Mercury project. In February 1962 John Glenn became the first American who orbited the Earth (National Geographic, n.d.).

The following NASA's Gemini program (Gemini in Latin means "Twins") was a series of 12 two-man spacecraft launched into orbit around Earth by the U.S. between

1964 and 1966. The Gemini program was designed to test the ability of astronauts to manoeuvre the spacecraft by manual control. The Gemini series, helped to develop the techniques for orbital rendezvous and docking with a target vehicle. During the Gemini 4 mission (June, 1965), astronaut Edward H. White performed the first American spacewalk. Gemini 5 (Aug., 1965) completed an eight-day mission, the longest spaceflight undertaken up to that time (Britannica, n.d.-b; National Geographic, n.d.).

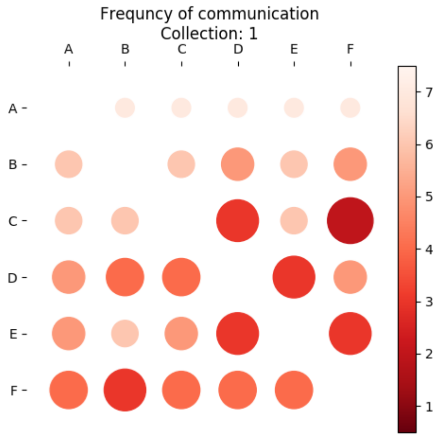
In meantime, Soviet cosmonaut Aleksei Leonov (Алексей Архипович Леонов) became the first person to exit an orbiting spacecraft Voskhod 2 in March 1965. He got into critical situation when he could not fit into airlock hatch due to his inflated spacesuit (Britannica, n.d.-a; Иванов, Аносов, Квасников, Розенблюм, & Столовски, 2009).

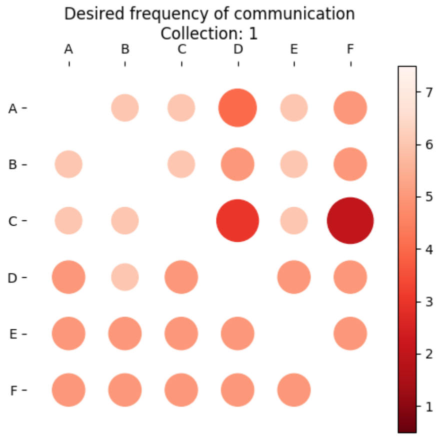
Before the first Apollo flight astronauts Virgil Grissom, Edward White, and Roger Chaffee died in a launchpad fire during training. After several of Apollo speceflights, Apollo 11 with commander Neil Armstrong, Command Module Pilot Michael Collins and Lunar Module Pilot Edwin "Buzz" Aldrin became the first mission to reach the Moon when they landed in the Sea of Tranquility on July 20, 1969. Before Apollo program ended on 1972 five more missions flew to Moon (NASA, 2017; National Geographic, n.d.).

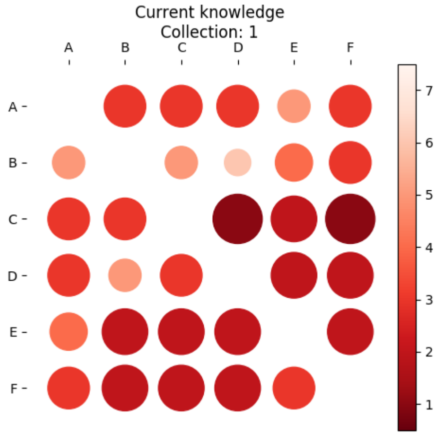
After the end of the Apollo project, Skylab expeditions were paving the way for the collaborative ISS project. One of the Skylab’s primary achievements was observations of the Sun. The US-Soviet political tensions that had accelerated the space race was slowly dropping in 1970s. Apollo-Soyuz Test Project gave way to cooperation between them. The political tensions that had accelerated the space race began to thaw. International collaboration became the norm during the space shuttle era and current cooperation with the International Space Station which includes many nations (NASA, n.d.-e).

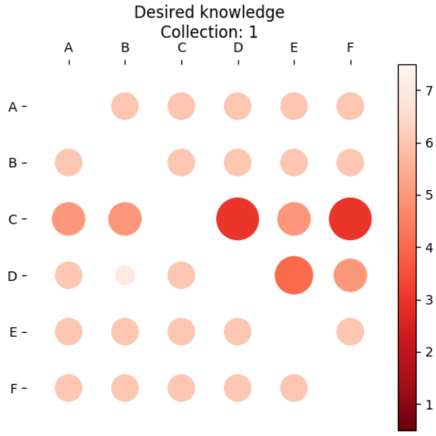
Space shuttle, officially called the Space Transportation System (STS), became the first reusable spacecraft transporting humans. There was six Space shuttles Enterprise, Columbia, Challenger, Discovery, Atlantis and Endeavour that together flew 135 missions and carried 355 different people to space during over 30 years. Enterprise was the first of space shuttles but it never flew in space, only made tests. First STS in space was Columbia (April, 1981). Space shuttles launched, recovered and repaired satellites and built the largest structure in space, the ISS. Two crews of seven astronauts died tragically during the era of Space Shuttle - Challenger accident in 1986 and Columbia accident in 2003 (NASA, n.d.-h, n.d.-i, n.d.-e, n.d.-j).

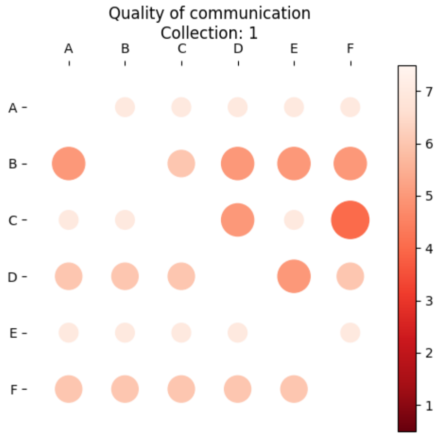
Appendix 2 LUNEX-0 results

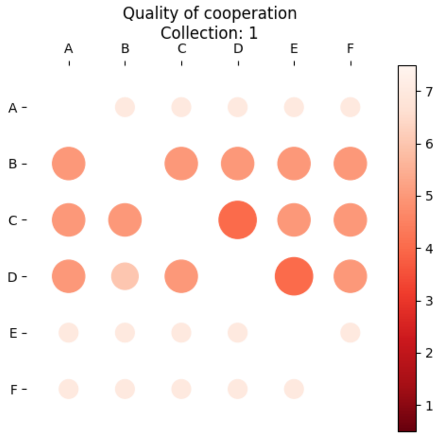


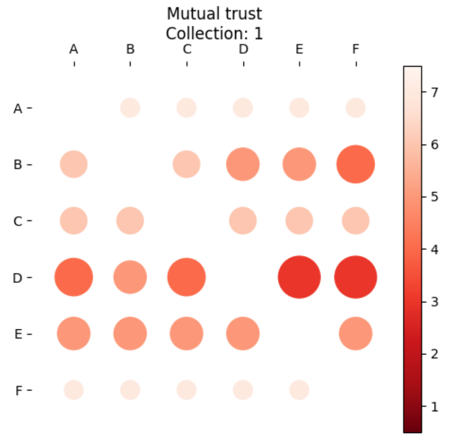




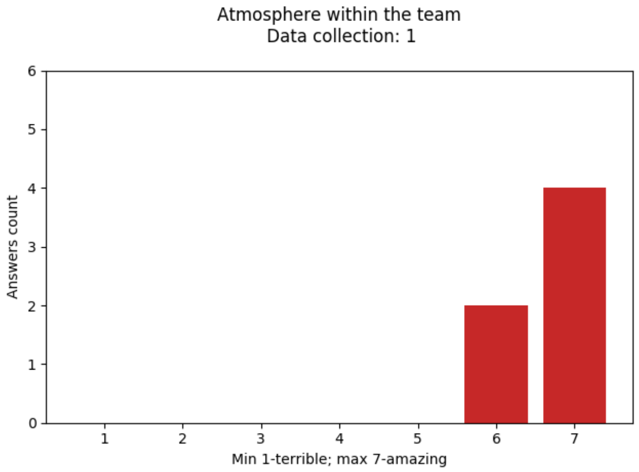




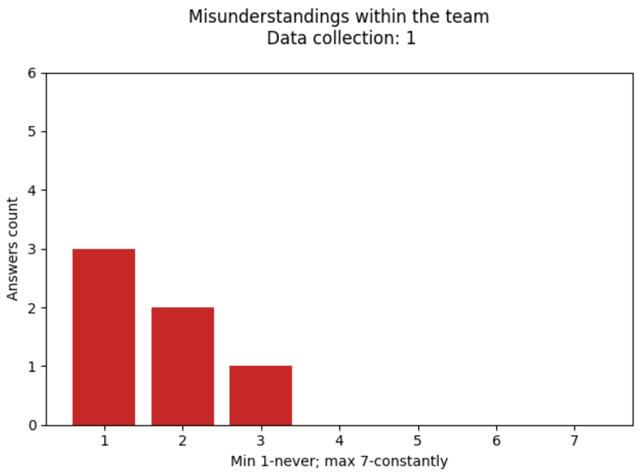




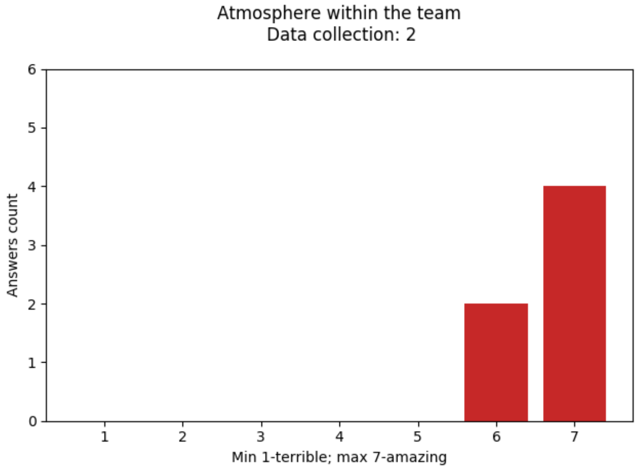
Mutual trust
Collection: 1
A
B
C
D
E
F
A
B
C
D
E
F
7
6
5
4
3
2
1

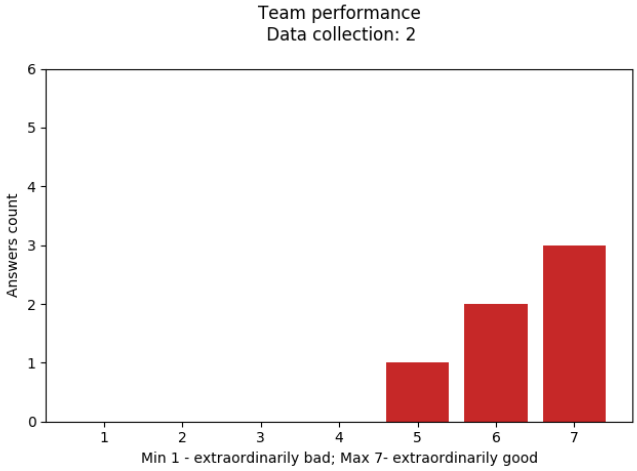


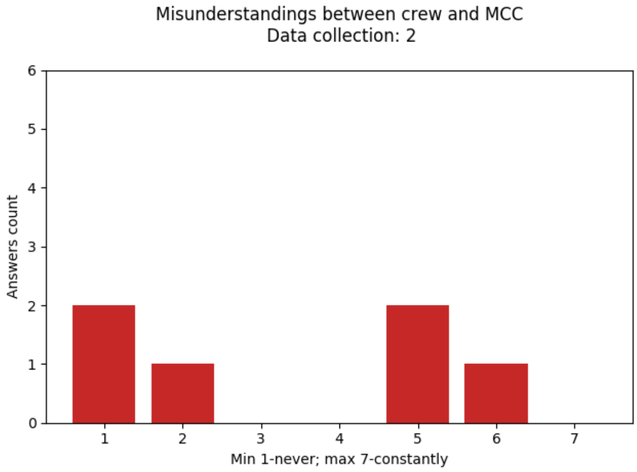
Atmosphere within the team
Data collection: 1
Answers count
0
1
2
3
4
5
6
1
2
3
4
5
6
7
Min 1-terrible; max 7-amazing

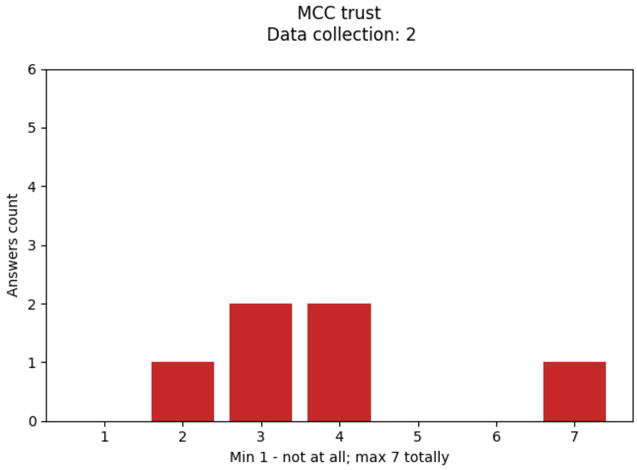


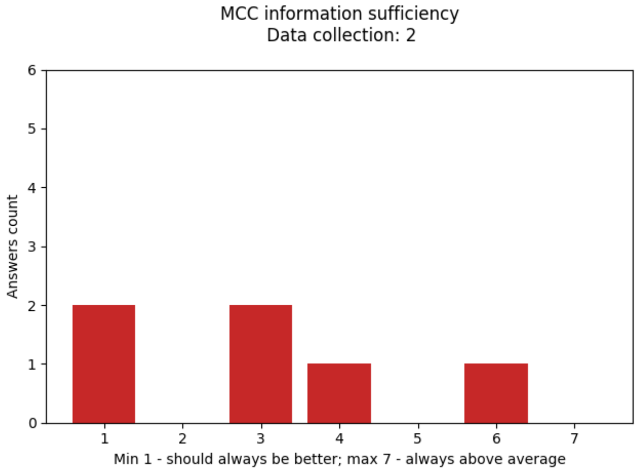
Misunderstandings within the team
Data collection: 1
Answers count
0
1
2
3
4
5
6
1
2
3
4
5
6
7
Min 1-never; max 7-constantly

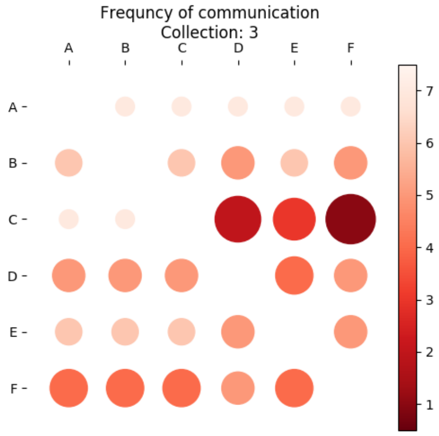

Atmosphere within the team
Data collection: 2
Answers count
Min 1-terrible; max 7-amazing

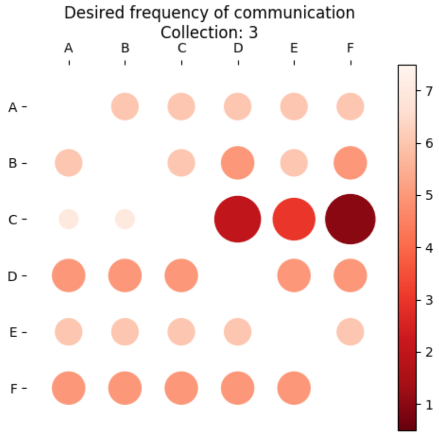

Team performance
Data collection: 2
Answers count
Min 1 - extraordinarily bad; Max 7- extraordinarily good

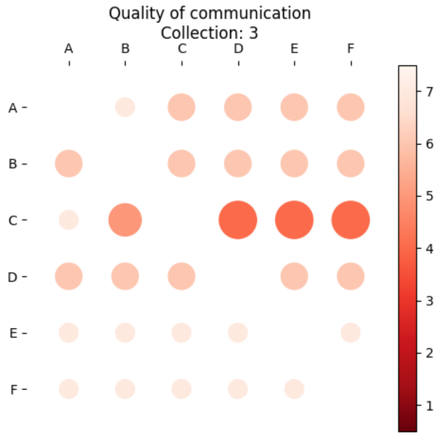

Misunderstandings between crew and MCC
Data collection: 2
Answers count
Min 1-never; max 7-constantly

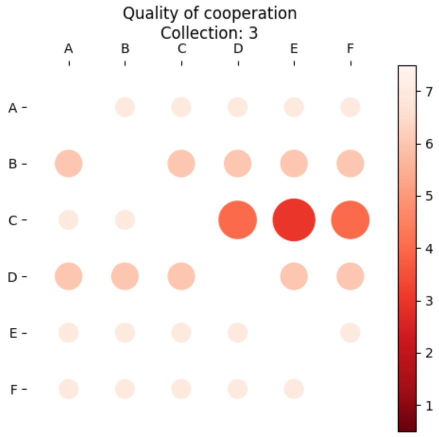

MCC trust
Data collection: 2
Answers count
0
1
2
3
4
5
6
1
2
3
4
5
6
7
Min 1 - not at all; max 7 totally

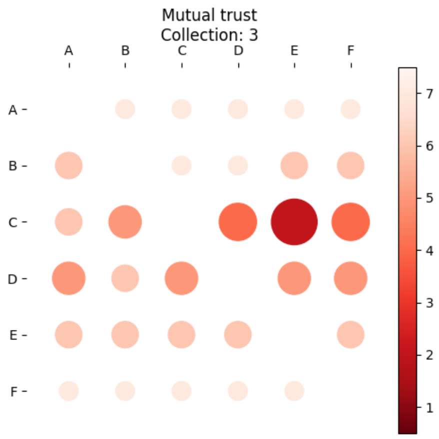

MCC information sufficiency
Data collection: 2
Answers count
0
1
2
3
4
5
6
1
2
3
4
5
6
7
Min 1 - should always be better; max 7 - always above average

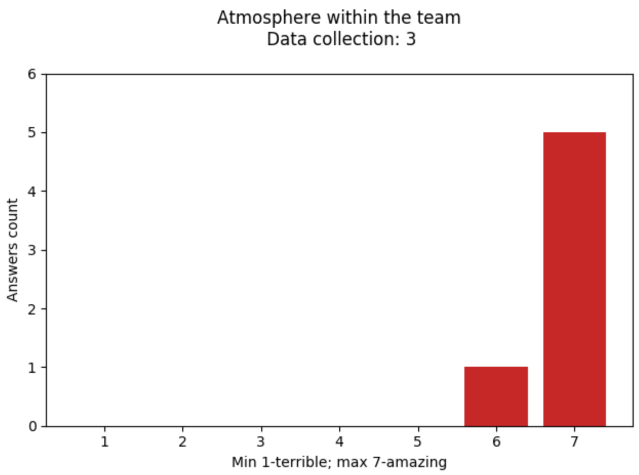

Frequncy of communication
Collection: 3
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Desired frequency of communication
Collection: 3
A B C D E F
A B C D E F
1 2 3 4 5 6 7

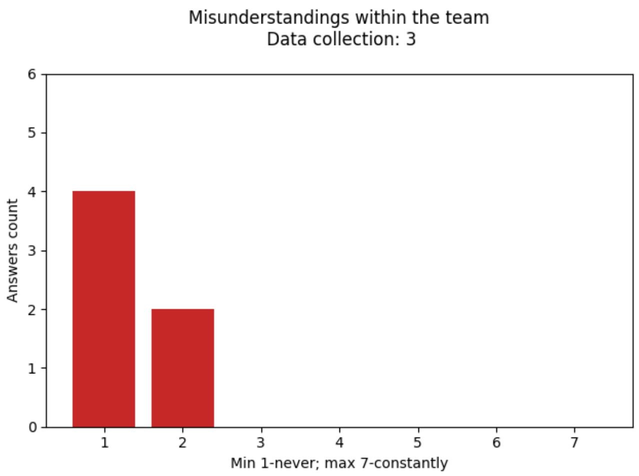

Quality of communication
Collection: 3
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Quality of cooperation
Collection: 3
A B C D E F
A B C D E F
1 2 3 4 5 6 7

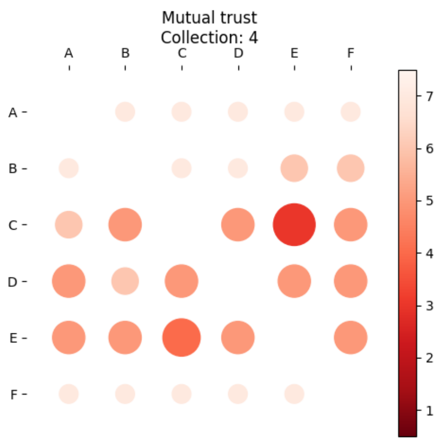

Mutual trust
Collection: 3
A B C D E F
A B C D E F
1 2 3 4 5 6 7



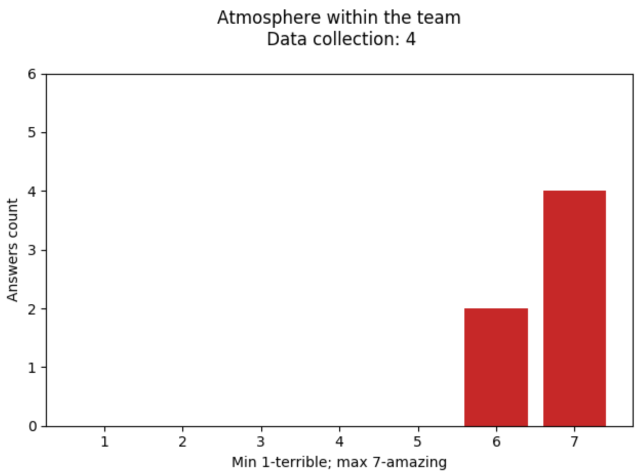
Atmosphere within the team
Data collection: 3
Answers count
0
1
2
3
4
5
6
1
2
3
4
5
6
7
Min 1-terrible; max 7-amazing

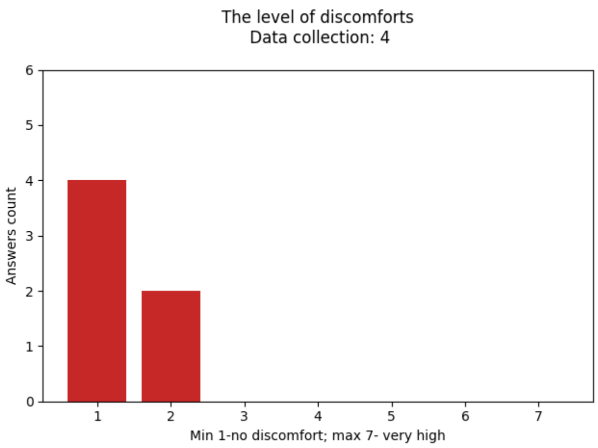


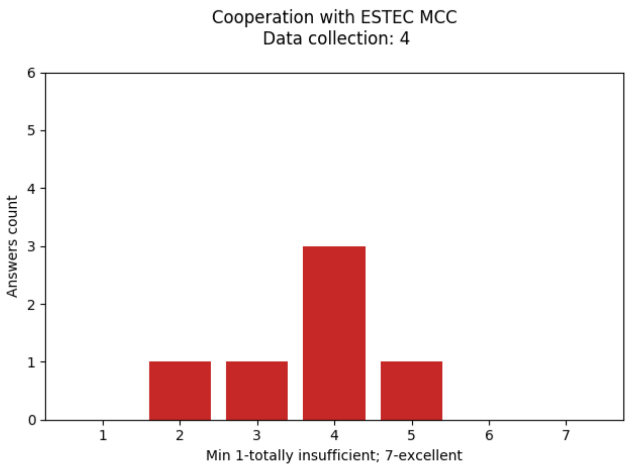
Misunderstandings within the team
Data collection: 3
Answers count
0
1
2
3
4
5
6
1
2
3
4
5
6
7
Min 1-never; max 7-constantly

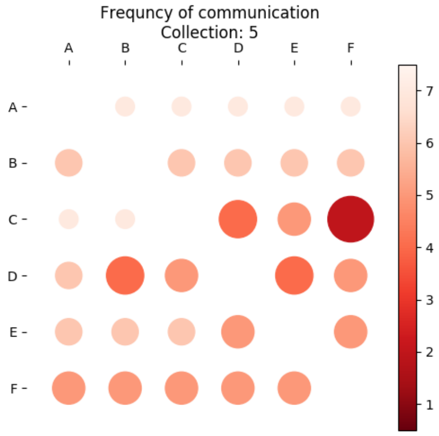


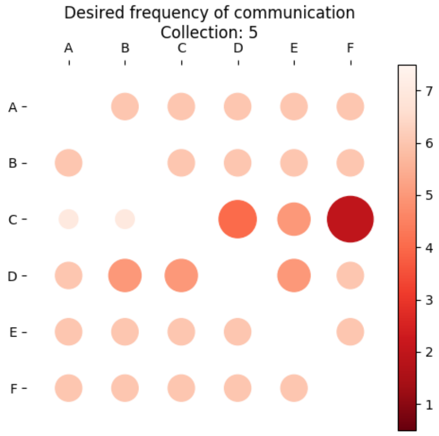
Mutual trust
Collection: 4
A
B
C
D
E
F
A
B
C
D
E
F
7
6
5
4
3
2
1

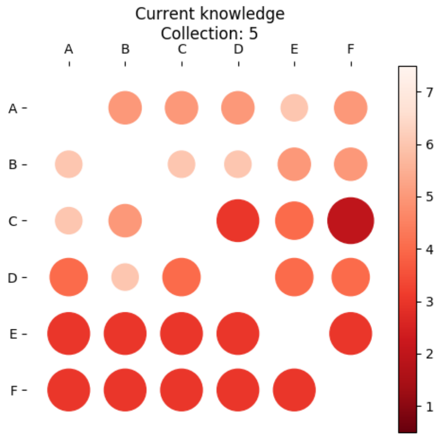

Atmosphere within the team
Data collection: 4
Answers count
Min 1-terrible; max 7-amazing

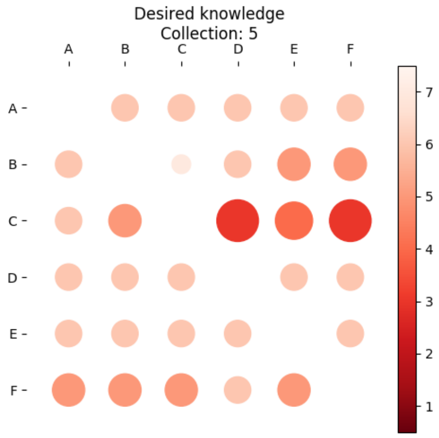

The level of discomforts
Data collection: 4
Answers count
Min 1-no discomfort; max 7- very high

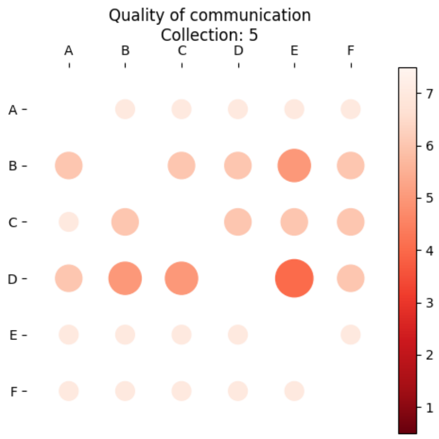

Cooperation with ESTEC MCC
Data collection: 4
Answers count
Min 1-totally insufficient; 7-excellent

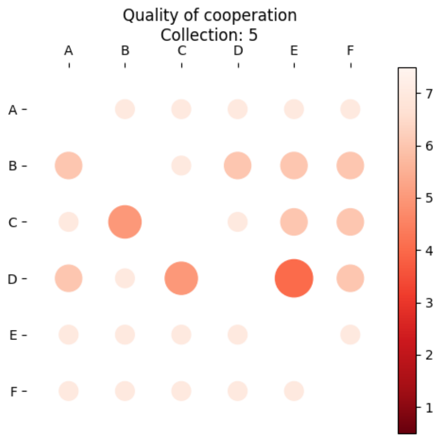

Frequncy of communication
Collection: 5
A B C D E F
A B C D E F
1 2 3 4 5 6 7

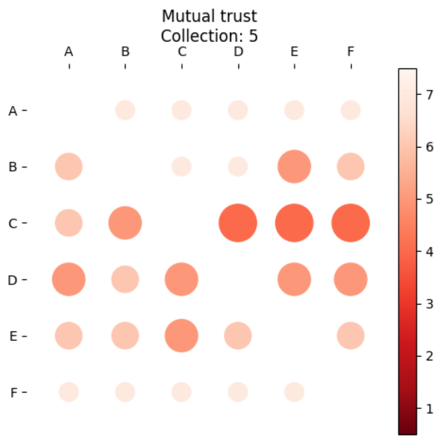

Desired frequency of communication
Collection: 5
A B C D E F
A B C D E F
1 2 3 4 5 6 7

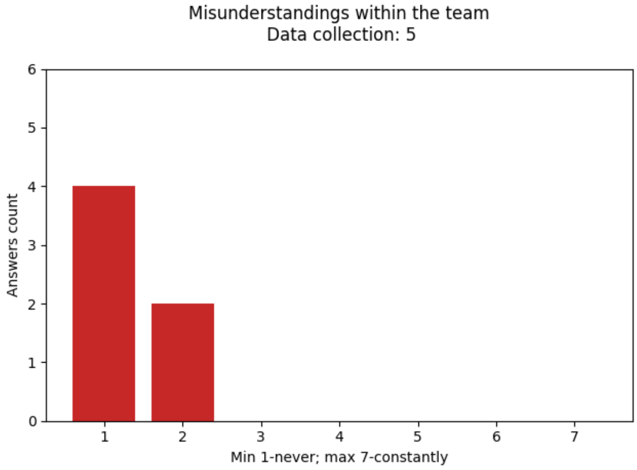

Current knowledge
Collection: 5
A B C D E F
A B C D E F
1 2 3 4 5 6 7

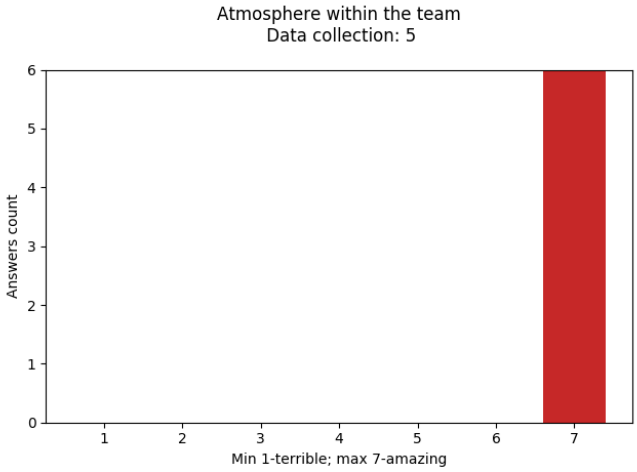

Desired knowledge
Collection: 5
A B C D E F
A B C D E F
1 2 3 4 5 6 7

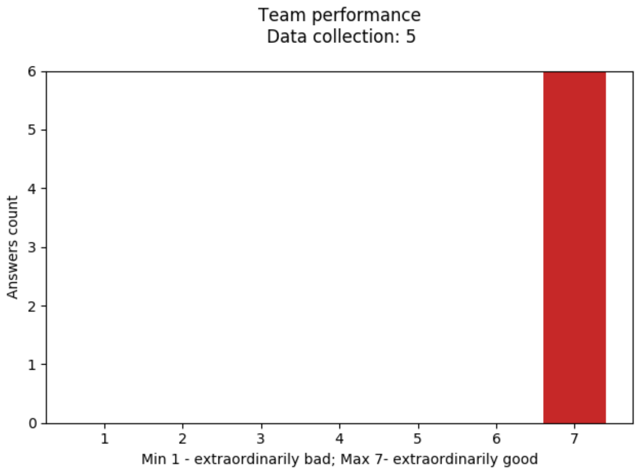

Quality of communication
Collection: 5
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Quality of cooperation
Collection: 5
A B C D E F
A B C D E F
1 2 3 4 5 6 7

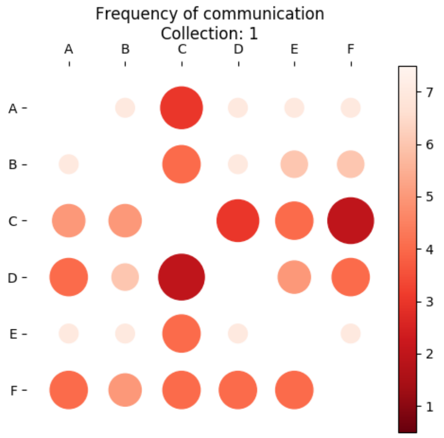

Mutual trust
Collection: 5
A B C D E F
A B C D E F
1 2 3 4 5 6 7

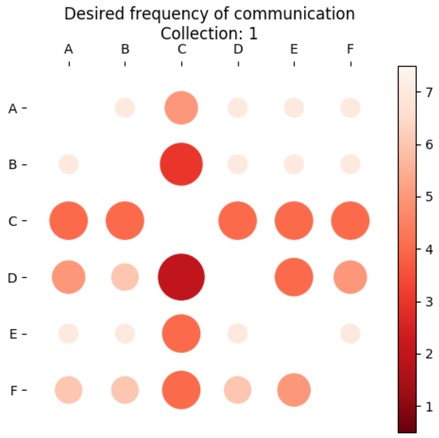

Misunderstandings within the team
Data collection: 5
Answers count
Min 1-never; max 7-constantly

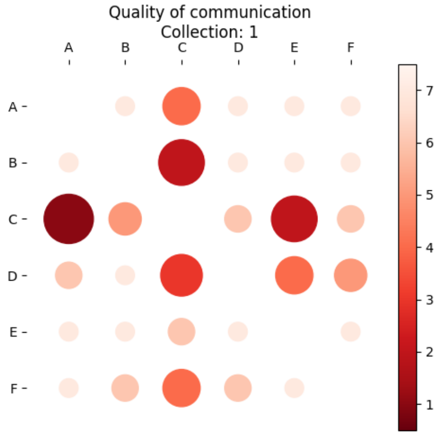

Atmosphere within the team
Data collection: 5
Answers count
Min 1-terrible; max 7-amazing

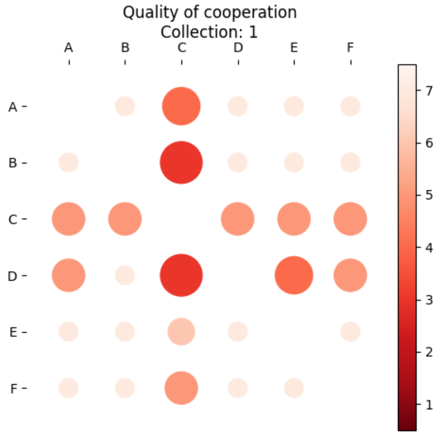

Team performance
Data collection: 5
Answers count
Min 1 - extraordinarily bad; Max 7- extraordinarily good

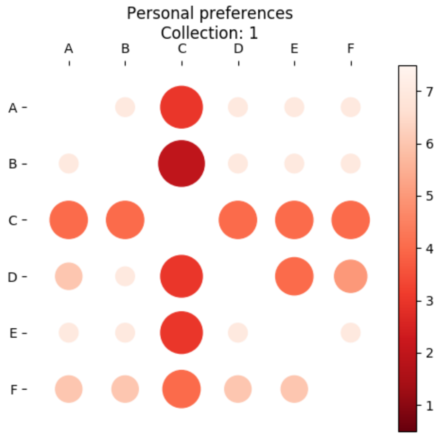
Appendix 3 LUNEX-1 results



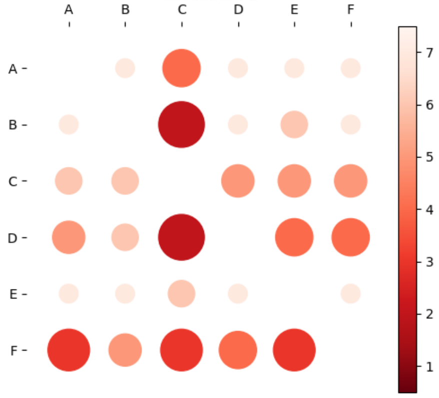




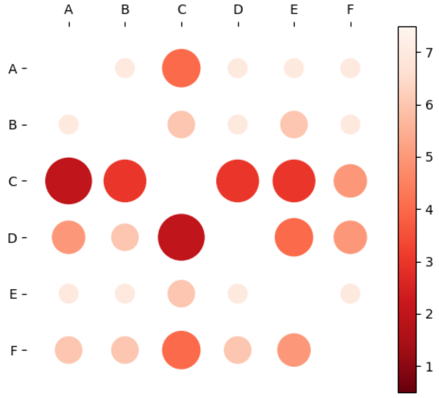




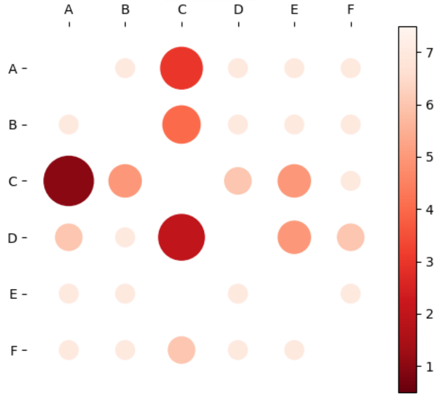
Frequency of communication
Collection: 2



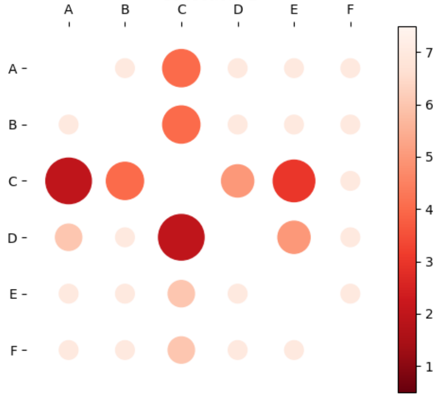
Desired frequency of communication
Collection: 2



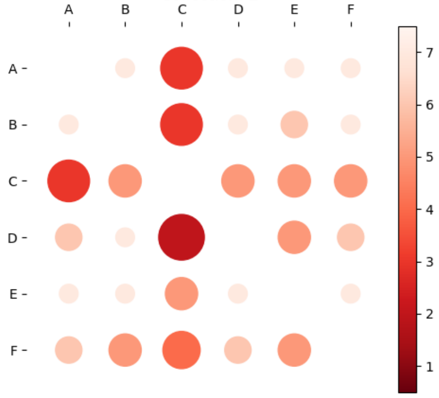
Quality of communication
Collection: 2

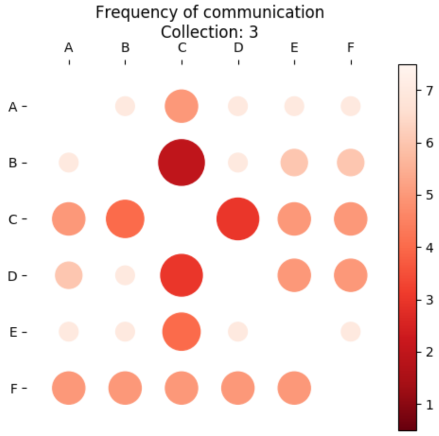


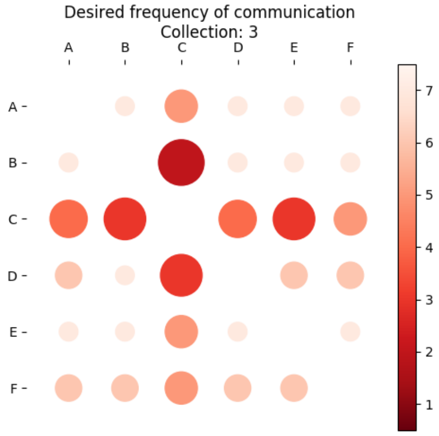
Quality of cooperation
Collection: 2

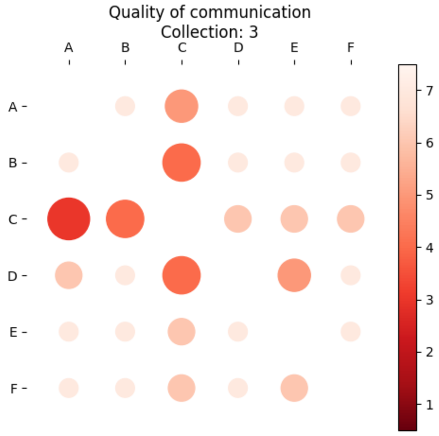


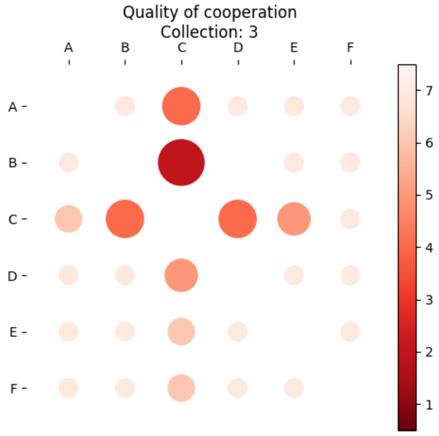
Personal preferences
Collection: 2

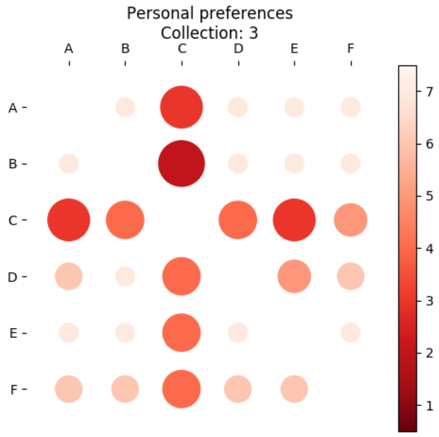


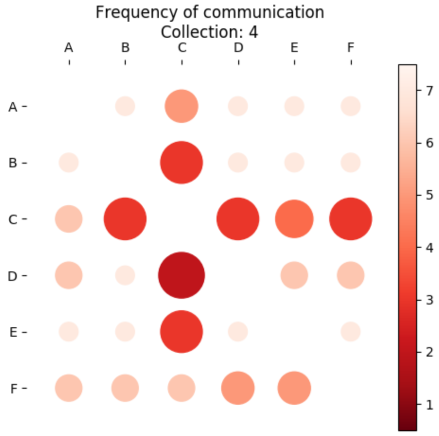

Frequency of communication
Collection: 3
A
B
C
D
E
F
1
2
3
4
5
6
7

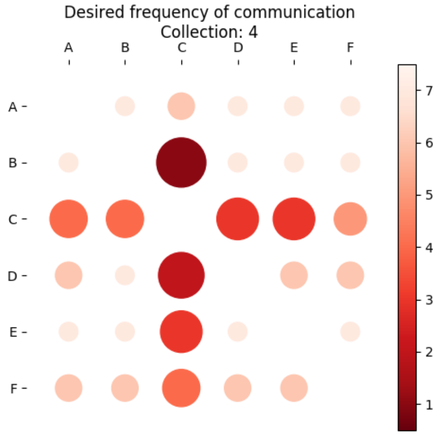

Desired frequency of communication
Collection: 3
A
B
C
D
E
F
1
2
3
4
5
6
7

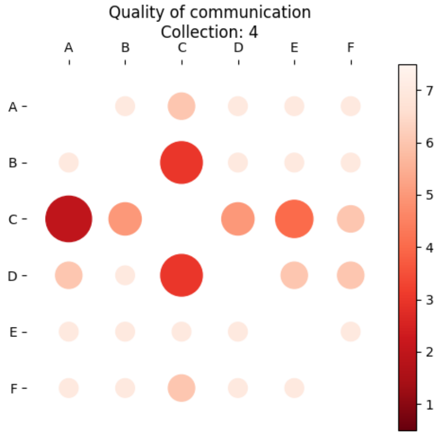

Quality of communication
Collection: 3
A
B
C
D
E
F
1
2
3
4
5
6
7

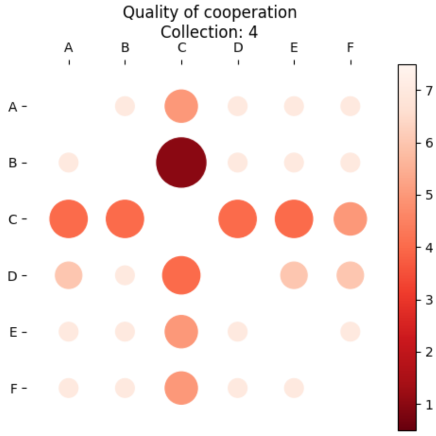

Quality of cooperation
Collection: 3
A
B
C
D
E
F
1
2
3
4
5
6
7

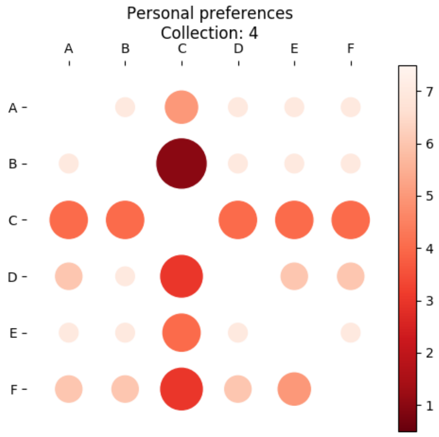

Personal preferences
Collection: 3
A
B
C
D
E
F
1
2
3
4
5
6
7

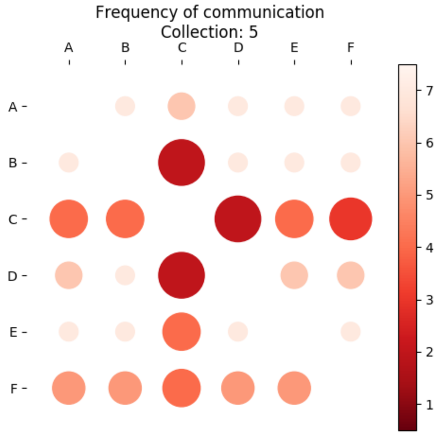

Frequency of communication
Collection: 4
A B C D E F
A B C D E F
1 2 3 4 5 6 7

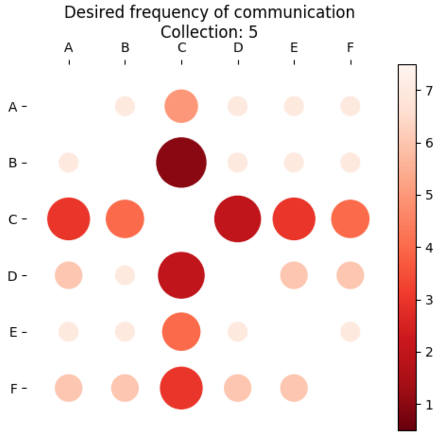

Desired frequency of communication
Collection: 4
A B C D E F
A B C D E F
1 2 3 4 5 6 7

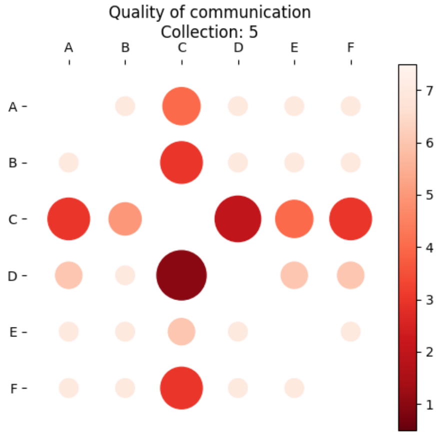

Quality of communication
Collection: 4
A B C D E F
A B C D E F
1 2 3 4 5 6 7

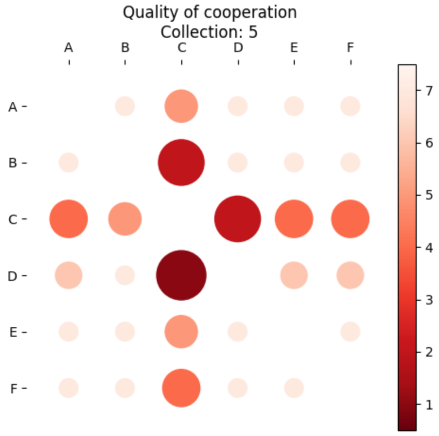

Quality of cooperation
Collection: 4
A B C D E F
A B C D E F
1 2 3 4 5 6 7

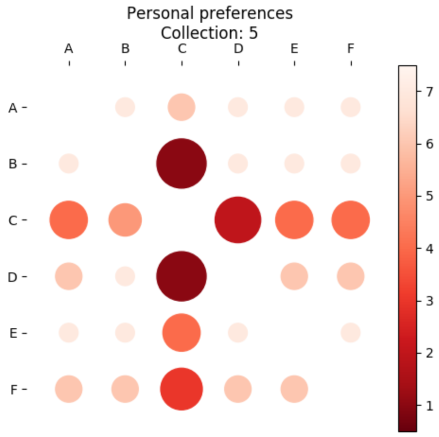

Personal preferences
Collection: 4
A B C D E F
A B C D E F
1 2 3 4 5 6 7

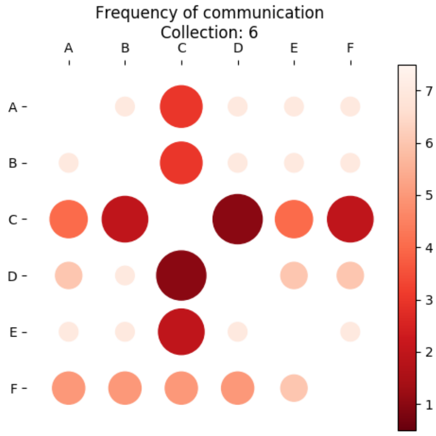

Frequency of communication
Collection: 5
A
B
C
D
E
F
A
B
C
D
E
F
7
6
5
4
3
2
1

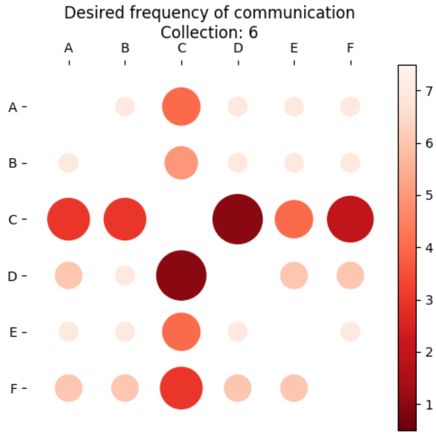

Desired frequency of communication
Collection: 5
A
B
C
D
E
F
A
B
C
D
E
F
7
6
5
4
3
2
1

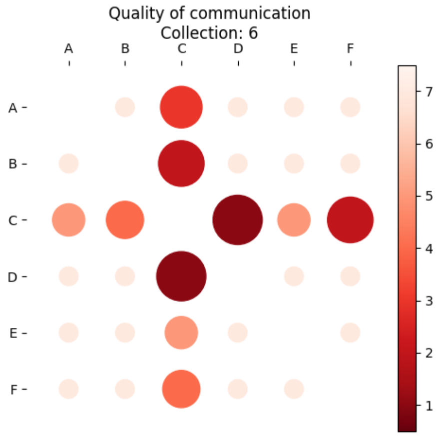

Quality of communication
Collection: 5
A
B
C
D
E
F
A
B
C
D
E
F
7
6
5
4
3
2
1

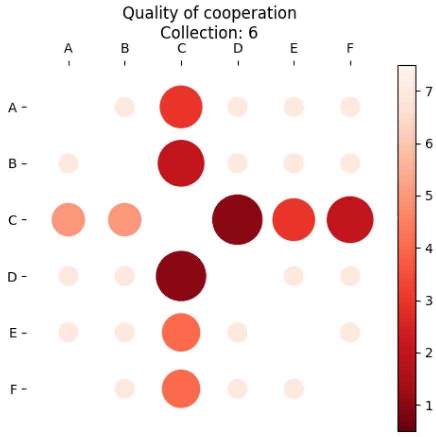

Quality of cooperation
Collection: 5
A
B
C
D
E
F
A
B
C
D
E
F
7
6
5
4
3
2
1

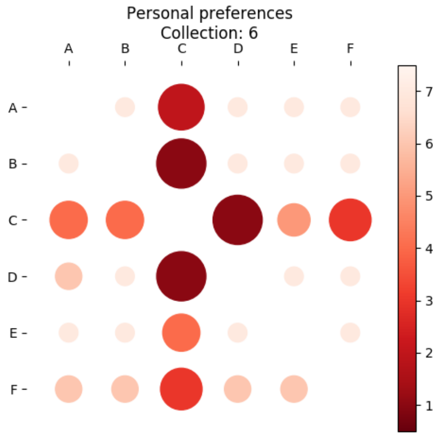

Personal preferences
Collection: 5
A
B
C
D
E
F
A
B
C
D
E
F
7
6
5
4
3
2
1

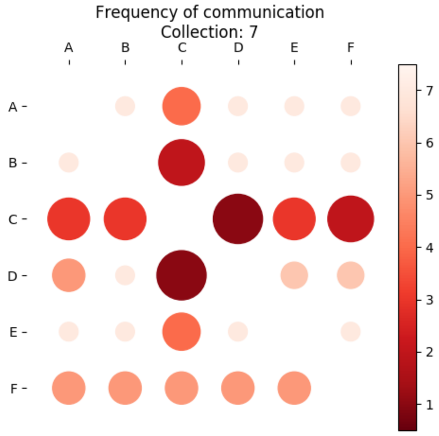

Frequency of communication
Collection: 6
A B C D E F
A B C D E F
1 2 3 4 5 6 7

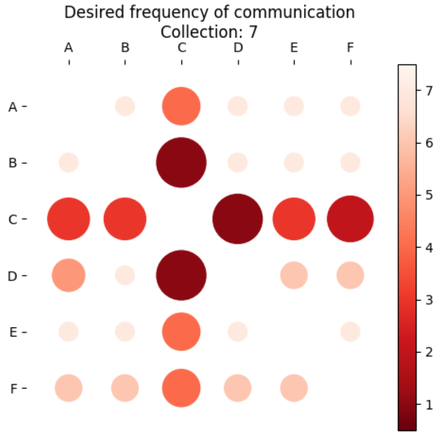

Desired frequency of communication
Collection: 6
A B C D E F
A B C D E F
1 2 3 4 5 6 7

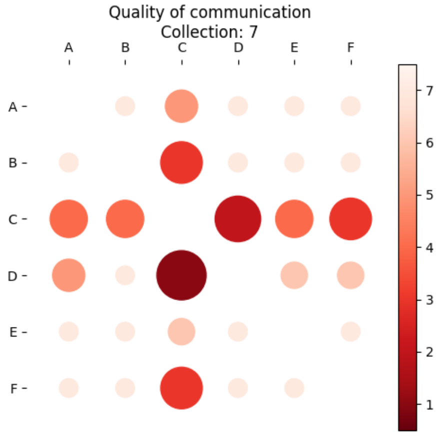

Quality of communication
Collection: 6
A B C D E F
A B C D E F
1 2 3 4 5 6 7

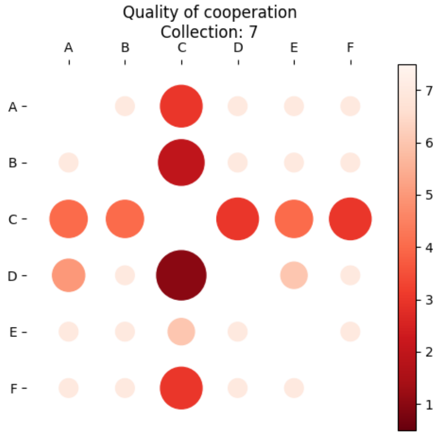

Quality of cooperation
Collection: 6
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Personal preferences
Collection: 6
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Frequency of communication
Collection: 7
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Desired frequency of communication
Collection: 7
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Quality of communication
Collection: 7
A B C D E F
A B C D E F
1 2 3 4 5 6 7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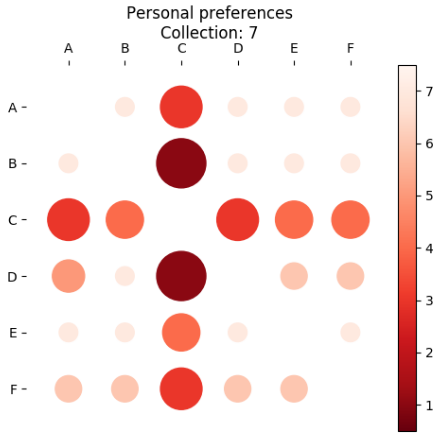
1 2 3 4 5 6 7


Personal preferences
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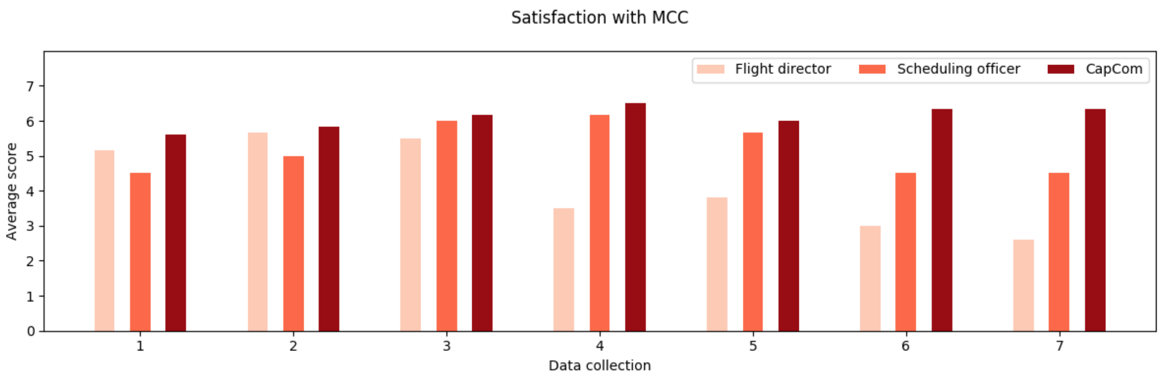
A B C D E F
A B C D E F
1 2 3 4 5 6 7


Satisfaction with MCC
Flight director
Scheduling officer
CapCom
Average score
0 1 2 3 4 5 6 7
1 2 3 4 5 6 7
Data collection