This dissertation thesis is concerned with developing a mesoscopic model for single crystalline shape-memory alloys including thermo-dynamically consistent thermo-mechanical coupling – here the term "mesoscopic" refers to the ability of the model to capture fine spatial oscillations of the deformation gradient by means of gradient Young measures. Existence of solutions to the devised model is proved in a "phase-field-like approach" by a scale transition from a microscopic model that features a term related to the interfacial energy; this scale transition from a physically relevant model justifies the mesoscopic relaxation. Further, existence of solutions is also proved by backward-Euler time discretization which forms a conceptual numerical algorithm. Based on this conceptual algorithm a computer implementation of the model has been developed and further optimized in the rate-independent isothermal setting; some calculations using this implementation are also presented. Finally, refinements s of the analysis in the convex case as well as a limit of the phase-field-like approach in this case are exposed, too.