The main scientific objective of the proposed project is to investigate and analyze the phenomena occurring during the process of rapid prototyping of test parts from stainless steel (as a model material), shape memory NiTi and heat resistant nickel alloy (Inconel 713) It is planned to apply two deposition technologies i.e. using a focused laser or electron beam. The main advantages of rapid prototyping (RP) using the concentrated energy of electrons or photons are related to the possibility of producing test parts of complex shape at a lower cost, lower power consumption, reduced greenhouse gas emissions and lower consumption of input material compared to other manufacturing technology, like for example, casting process. There is no complete description of the phenomena occurring during deposition of successive layers of material. The main difficulty is the fact that the process of crystallization takes place in a non-equilibrium conditions. Moreover, successively deposited layers induce heat treatment (thermal cycling) of the already deposited material. Therefore the materials for deposition has been chosen such to study various crystallization paths from the melt. Stainless steel has been chosen as a model material to estimate crystallization structure in well known material. Then, NiTi intermetallic shows very narrow solid-liquid range, so one would not expect segregation of elements, however due to possibility of martensitic transformation and precipitation of nonequilibrium phases it is important to determine structure resulting after RP. Finally heat resistant Ni alloy (Inconel 713) possess due to multiple elements including 5 % aluminum, a mixed solid solution and intermetallic structure, which is also important to determine after such deposition due to expected changes of structure and therefore effect on mechanical properties at high temperature.

Rapid prototyping of metals in many cases has no reliable alternatives. Thus, the idea of rapid prototyping of metals with wire and laser or electron beam as heat sources has opened up a research thread that is important to both scientific and manufacturing communities. The phenomena occurring during rapid prototyping of alloys from powder have been intensively investigated across the world in response to the demands of the manufacturing sector seeking a novel, efficient and environment-friendly producing technology. Presently, rapid prototyping of metals such as different stainless steel and nickel alloys, are of particular interest in aerospace and military applications. Therefore, identifying the rapid prototyping parameters that impact deposited layers' properties and understanding what kind of microstructure develops under these parameters is critical. Material deposition and microstructural evolution during the rapid prototyping with metallic powder are well understood. But, characterizing the microstructural evolution in the molten zones during deposition of metals and correlating its influence with physical properties would constitute a significant and fundamental contribution to the physical metallurgy of rapid prototyping. In spite of the advances in understanding of some phenomena occurring in rapid prototyping of metallic alloys, fundamental scientific understanding is still lacking, including the relationship between melt zone as well as heat affected zone microstructure and mechanical properties. A special problem arises in NiTi alloys where transformation in the solid state can affect resulting shape memory properties and temperature range. These phenomena has not been studied in detail, only preliminary experiments were reported in the literature.

The proposed research will follow world trends in the development of this unique and modern technique of metal parts manufacturing. It should provide a better understanding of the nature of metals deposited and help to implement this technology for future industrial applications. The proposed program sets forth the following objectives: (1): To characterize a microstructure of metal deposited by electron/laser rapid prototyping processes. (2) To establish a correlation between the microstructural characteristics and the mechanical behavior of alloys deposited by electron or laser rapid prototyping. The realization of this objective will allow for selection of rapid prototyping parameters that produce the desired mechanical performance particularly for shape memory effect in NiTi intermetallic alloy and heat resistant properties in parts produced using such technology from chosen Ni alloy.