The origin of the modulated crystal structure of Ni-Mn-Ga alloys has been a matter of discussion at least for one decade. The disruption of long-range periodicity referred to as modulation often occurs in a variety of shape memory alloys (SMAs). What is more, its presence is usually combined with extremely low twinning stresses (even down to 0.05-0.5 MPa), low mechanical stabilization, and narrow hysteresis especially if compared with their unmodulated counterpartners. Such properties lie at the core of magnetic field induced strain (MFIS) and related phenomena. In fact, the extremely low twinning stress and MFIS observed in Ni-Mn-Ga-based single crystals make them unique systems and have raised great research interest both in terms of crystallographic nature of modulation, martensitic transformation and twinning mechanisms. Generally, two concepts are putting forward that attempt to explain the formation of small periodic atomic displacement in the form of modulation. The first one is related to nanotwinning. This approach is assumed to occur at the atomic scale and it is called the adaptive phase concept. The concept of adaptive martensite proposed more generally by Khachaturyan et al. and particularly to 14M Ni-Mn-Ga alloys by Kaufman et al. assumes that the lattice mismatch formed at a habit plane can be compensated by nanotwinned martensite formation. Elastic energy minimization is the basic and prime directive which is behind this concept. Furthermore, this concept seems to be very attractive since a number of functional materials including shape memory alloys have adaptive nature due to massive twin formation on different length scales. This property, known as the self-accommodation process, results in no macroscopic net shape change upon martensitic transformation and governs the formation of a hierarchical twin structure. Alternative concepts are based on Fermi surface nesting and hybridization of optical and acoustic phonon modes generally defined by the electronic band structure. In simple terms, this approach considers the modulated structures as independent crystal structures that may occur under certain thermodynamic conditions. However, the modulation nature and the mechanism or reason for extremely high twin boundary mobility in Ni-Mn-Ga alloys are still unknown. Therefore the main goal of the project is to answer the question what is the nature of modulation in 10M and 14M Ni-Mn-Ga martensites, and what is the mechanism for extremely low twinning stress. The second part of the project will deal with intermartensitic transformations and their role with respect to martensite stabilization and superelastic behavior in Ni-Mn-Ga SMAs. For example, in these alloys, depending on the chemical composition and combination of mechanical and thermal treatments, three different martensitic structures can be highlighted. To this group belong: five-layered (10M) martensite, seven-layered (14M) martensite (both monoclinic), and non-modulated (NM) tetragonal martensite. Unlike the classic martensitic transformation, the transitions between different martensitic structures demonstrate a wider thermal-stress hysteresis. It opens an opportunity to stabilize lower-temperature martensitic phases shifting the reverse start temperature to a higher temperature range. The third goal is to investigate the actuation kinetic at the microscale and to program functional properties to meet the expectations for micro- and nano-electro-mechanical systems. This objective will form part of a broader research program related to the so-called micro-functionality, actuation kinetic, size limitations both for field induced deformation and modulation stability. Depending on the twin configuration (parallel, perpendicular or mixed) different effects can be proposed e.g. magneto-elasticity, magneto-plasticity, and magnetically induced pseudoelasticity. The above-mentioned subjects will be studied with highly advanced research techniques including SEM/EBSD, HRTEM, and high energy synchrotron radiation along with *in-situ* (temperature and stress) observations and low temperature testing (up to 4 K) in order to follow the individual transformation steps during martensitic transformation making the complexity of thermally and mechanically induced martensitic transformation much better understood. Additionally, all discussed effects will be modeled on different length scales including non-linear continuum mechanics, Gautam-Howe (G-H) model and molecular dynamics.

Therefore, in light of the above, the main goals of the project will focus on three independent, but strictly related Work Packages dealing with (i) fundamental study to understand the modulation nature of the 10M and 14M Ni-Mn-Ga-based single crystals including twin mechanisms for different types of twin boundaries, (ii) mechanically induced martensitic and intermartensitic transformations and their role with respect to martensite stabilization along with superelastic behavior and finally (iii) the third part will deal with actuation kinetic at the microscale in order to program functional properties and to promote other magnetic field-assisted effects.