The miniaturization of sensors and instruments to a nanoscale has led to the need to identify and study the patterns that determine the processes occurring in these devices. Nanoelectromechanical (NEMS) devices have unique properties which determine their relevance for practical application. Among such properties, it is possible to distinguish low mass, high electric strength, high frequencies of a mechanical resonance, potentially larger effects of quantum mechanics, or a large surface-area-to-volume ratio. These properties are important for sensing elements of some types of sensors such as, for instance, pressure sensors. Nanosensors and nanoactuators find application in physics, biology, chemistry, medicine (diagnostics, cellular nano- and microsurgery, drug delivery) or industry. The operating conditions of NEMS sensors largely coincide with those for microelectromechanical sensors (MEMS). However, due to the ultra-small size of NEMS, the disturbing factors have a greater impact on NEMS devices than on MEMS.

The novelty of the proposed research project will comprise: (i) construction of new mathematical models of NEMS components by using the methods of nonlinear dynamics and taking into account the small size and operating conditions of NEMS sensors; (ii) development of new algorithms, advanced system software and new methods of the analysis of data; (iii) application of a more complex theory, for example, the modified couple stress theory, taking the account of the von Kármán geometric nonlinearity. Overall, the abovementioned methods will be used to solve the scientific problem of creating new approaches to the design, manufacturing and materials of NEMS components in the form of nanoplates and nanoshells.

Another important aspects of the study are the choice of a temperature effect model and taking into account the influence of white additive and color noise and the mutual action of the deformation and temperature fields. It should be noted that modeling of nonlinear vibrations of structural members is deeply simplified to studying one- or two-degree-of-freedom systems. Consideration of such reduced order systems leads to the analysis of coupled nonlinear second-order differential equations, but it does not allow one to accurately describe the nonlinear processes occurring in the original system of an infinite dimension. In this project, a continuous system is considered as a system of an almost infinite number of degrees of freedom, which describes the real structure most accurately. Hamilton's principle will be used to obtain nonlinear partial differential equations of different types and dimensions as well as boundary and initial conditions. The qualitative study will be carried out by means of experiments implementing various numerical methods. The reliability of the study will be verified by reducing the systems of partial differential equations to ordinary differential equations (by the 2nd and 4th order finite difference method, Faedo-Galerkin method) as well as solving the Cauchy problem using the Newmark methods and the Runge-Kutta method of the 4th and 2nd orders. The Runge-Kutta methods provide an automatic step change and allow one to control the integration error, which together ensures a reliable signal. In addition to the well-known approaches, it is proposed to analyze chaotic dynamics by using the wavelet analysis with Morlet, Haar, Daubechies, and Gauss wavelets. As for the problems of nonlinear dynamics, the spectra of Lyapunov exponents will be estimated by several methods, including Wolf, Kantz, and Rosenstein methods and the modified method of neural networks. With the help of modified known methods of nonlinear dynamics and author's approaches, the following topics will be investigated: scenarios of transition from periodic to chaotic vibrations, the character of a chaotic state (chaos, hyper-chaos, hyper-hyper chaos, deep chaos), the influence of size-dependent parameters as well as temperature and noise fields on the vibration modes of mechanical structures. The main task of the project is the development of a research methodology, new software and algorithms for designing nanoelectromechanical devices with the required characteristics as well as the improvement of characteristics of the currently existing NEMS sensors.

All of the above leads to the conclusion that this problem is relevant and has a scientific novelty. The foundations of the study are the experience of the project participants in this field, accompanied by their active publishing activities, created methods, approaches, algorithms and software systems. The significance and relevance of investigating the nonlinear dynamics of geometrically nonlinear components of NEMS at the presence of temperature and noise fields is confirmed by the conducted review of the current research on the project subject.