# Institute of Education and Science in Engineering and Physics


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**Національний технічний університет «Харківський політехнічний інститут»**

# Institute of Education and Science in Engineering and Physics.

*The Institute was founded in 2018 but it has a history as a faculty since 1930*

*Nowadays, it consists of 10 departments 7 of which are graduates.*

*Every year our departments graduates more than 150 specialists.*

## Departments:

- *Dynamics and Strength of Machines*
- *Computer modelling of processes and systems*
- *Geometric modelling and computer graphics*
- *Continuum mechanics and Strength of Materials*
- *Theoretical Mechanics*
- *Applied mathematics*
- *Radioelectronics*
- *Physics of metals and semiconductors*
- *Materials for Electronics and Solar Cells*
- *Physics*

# Institute of Education and Science in Engineering and Physics.

*The Institute is one of the most active research center of the NTU KhPI and cover about 35% of all scientific activities of the University with the focus on applied mathematics, applied physics and physical electronics, applied computer science.*

## The main research directions

- ***Nonlinear dynamics***
- ***Theory of plates and shells***
- ***Computational modeling in mechanical engineering applications (strength, dynamics and reliability)***
- ***Computational analysis and synthesis of composites***
- ***Data-driven mechanics and applied computer vision***
- ***Navigation and control systems development***
- ***Computer engineering and radioelectronics***
- ***Physical-based material science (thin films for electronics and solar energy)***

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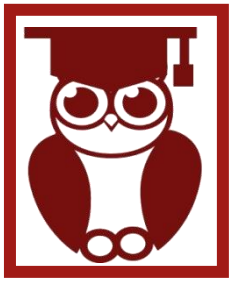


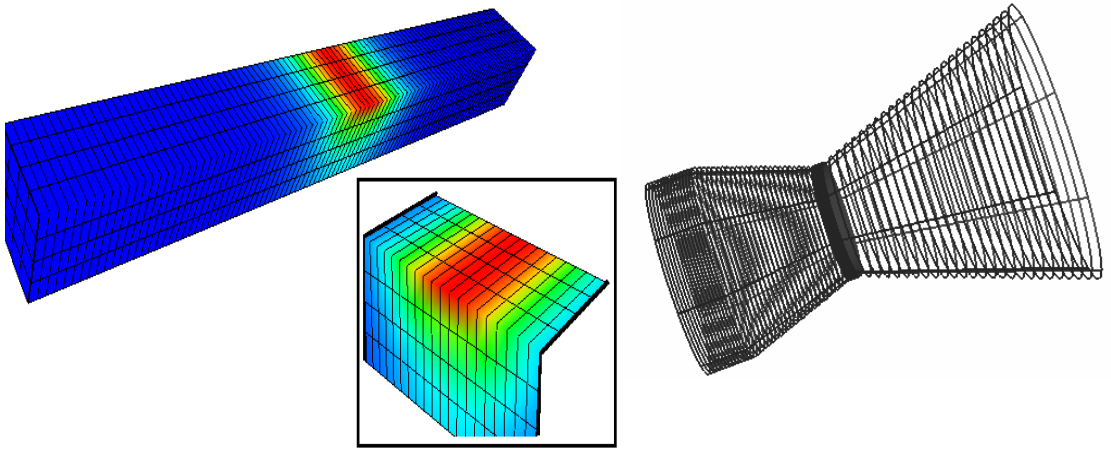
# COMPUTATIONAL MODELING IN MECHANICAL ENGINEERING APPLICATIONS


Національний технічний університет
«Харківський політехнічний інститут»

# Numerical modelling and software development for creep-damage processes in structural elements

Numerical modelling of creep and damage accumulation processes in structural elements and devices, which are subjected by complex action of cyclic loading and heating, can be done by use of developed software which

Include FEM programs for 2d, 3d problems and thin shells of revolution. Non-stationary heat expansion 3d problem is solved additionally. Original pre- and postprocessors are available



## Novelty and benefits

The developed approach for cyclic loading and heating in creep-damage conditions has been presented and published in scientific journals. One part of the project was awarded by CEGB prize (UK). Developed software was used for design and long term strength analysis of different structural elements and devices of turbines as well as space- and aircrafts.

## Outlook and perspectives

- Development of new commercial version of software
- Joint projects directed to estimation of long term strength of structural elements

## Contact

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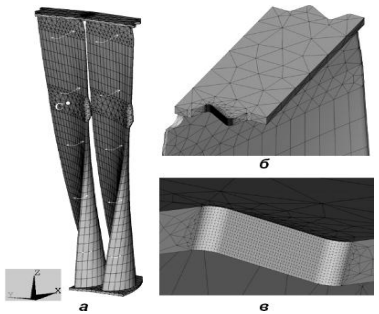
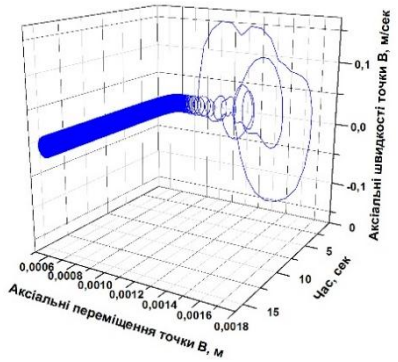
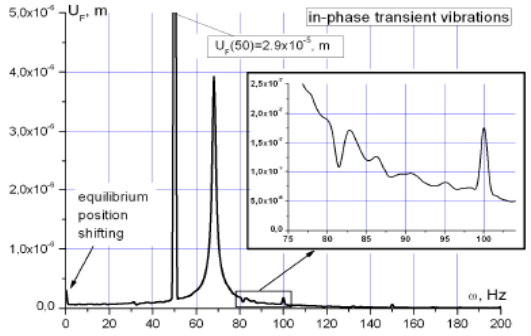
# Forced nonlinear vibrations of turbine blades package with dynamic contact in the shroud

Failures caused by the increased vibrations are widespread possible breakdowns occurring in steam and gas turbines. The blades assemblies are the most dynamically loaded units of the turbines. Inter-blades detachable joints are typically used for long blades stiffness magnification. Dynamic and strength characteristics of these designs essentially depend on the contact interacting peculiarities in such bandage. Vibrations of the blades assemblv become nonlinear under dynamic contact in the bandage and can be accompanied by the great number of the various phenomena. The work deals with the investigation of the forced nonlinear vibrations of blades package of turbine, taking into account the contact interaction in the shroud.




## Novelty and benefits

Analysis of the nonlinear dynamics phenomena in resonance and nonresponse regimes (a changing of resonance zones, sub and super harmonics, shifting of the system stability zone etc.).

## Outlook and perspectives

- Analysis of the process of shroud contact surfaces wear and bladed disks vibrational reliability
- Analysis of the nonlinear dynamics of the turbine blades taken into account a mistuning phenomenon.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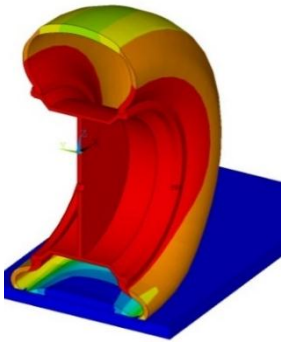
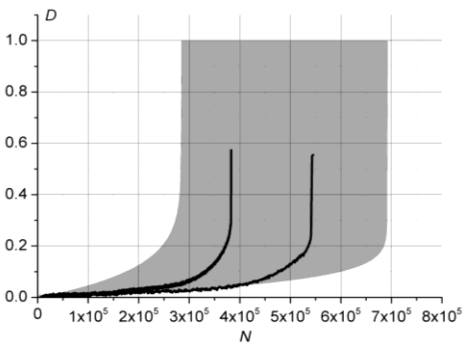
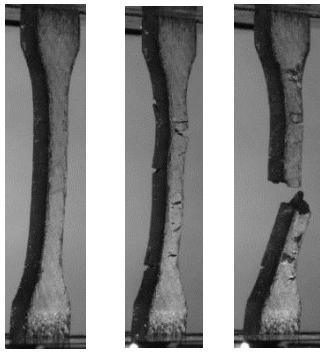
# Probabilistic modeling of structural failures for a prediction of mechanical engineering elements reliability

The work deals with a problem of the development of computational methods of determination of mechanical engineering elements life-time with random material characteristics and load. It is offered improved probabilistic models of the fatigue damage accumulation in the materials under cyclic deformation with finite strain amplitudes in the framework of continuum damage mechanics. The appropriate models take into account a random scatter of the material fatigue resistance characteristics, along with simultaneous passing of stochastic processes of material properties degradation caused by natural aging. The approaches are developed for the determination of the probability characteristics of the machine elements fatigue damage and lifetime considering the presence of possible operational random variation of the characteristics of the deformed state.





## Outlook and perspectives

- Analysis of the reliability of the elastomeric materials subject to the estimation of the influence of the self-heating process (the modelling of the self-heating of the elastomeric material under the cyclic load, analysis of cyclic heating of elastomers on their aging process)
- Development of the computational approaches for the estimation of the reliability of engineering designs considering simultaneous corrosion defects stochastic growth, material chemical degradation and the process fatigue accumulation

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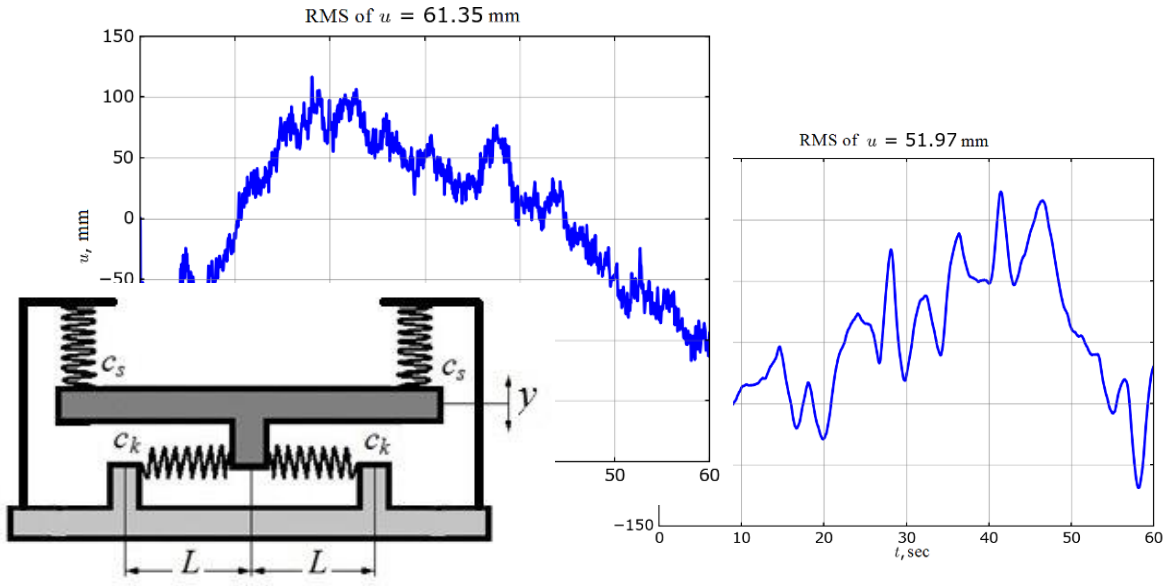
# Stochastic dynamics of the vibrational isolation systems with nonlinear suspension

At the present-day engineering practice, nonlinear stiffness or damping suspension is widely used for the reduction of the vibrations. A special attention here should be made on the systems with a quasi-zero stiffness because they can provide a vibro-isolation effect together with the efficiency of usage and compact size. This work deals with the theoretical modelling and experimental observations of the vertical dynamics of a cargo platform with the quasi-zero stiffness suspension under the operational random load. A discrete non-linear computational model has been developed and analysed within numerical simulations of the random vibrations. Dynamics of the system is analysed under a kinematic stochastic wide-band stationary load. A good comparative agreement is found between the numerical simulations and experimental data.




## Outlook and perspectives

- Analysis of the transient behaviour of the nonlinear vibration of such a system
- Development of the semi-active adaptive nonlinear suspension and the algorithm of its control
- Development of the genetic algorithms of optimal designing of the parameters of the nonlinear elastic and damping elements of a vibrational isolation suspension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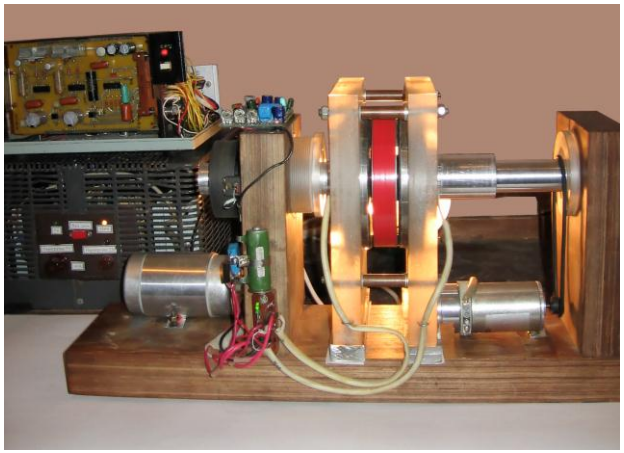
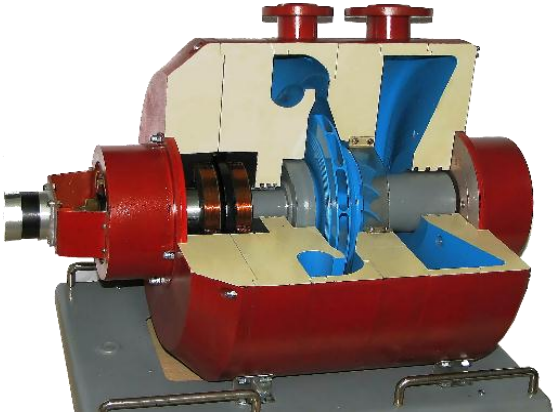
# Full combined magnetic suspension of shafts and rotors in passive and active magnetic bearings

Creating a method for constructing complete magnetic suspensions of shafts and rotors of various systems and machines. Development of new types of passive and active magnetic bearings based on a refined mathematical modeling for a calculation of force and stiffness characteristics, taking into account the laws and algorithms of the control. An introduction of passive-active magnetic suspensions for various systems and machines on a basis of carrying out various phenomena of the dynamics of rotors in magnetic bearings, considering a nonlinear interconnection of electrical, magnetic and mechanical processes.

**Outlook and perspectives**

- Creating the new types of active and passive magnetic bearings with a development of design solutions, laws, algorithms and control systems.
- A new type of passive magnetic bearings with a short-term variable stiffness to create competitive full passive-active magnetic suspensions.





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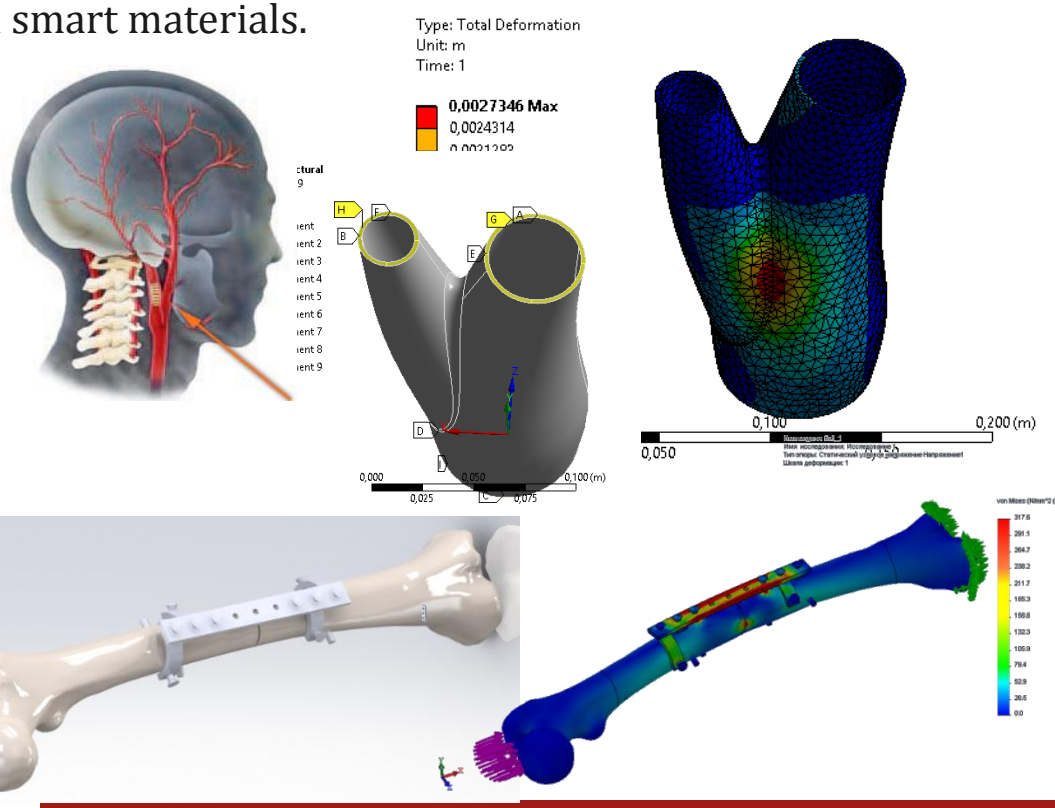
# Biomechanical computer-aided design and modeling

Theoretical (i.e. computer analysis (CAE)) of the stress state and deformation of biological bone tissues themselves and together with fixing system or implants require the development of complicated mathematical models. The main challenges here are following: complicated 3D geometry of the bone; multilayered internal structure; curvilinear orthotropy of the properties; nonlinearity of the mechanical behaviour; identification of material properties for a living tissue; specificity of the properties, geometry and loads from patient to patient; and implementation of new bio-neutral composite, functional and smart materials.




## Outlook and perspectives

- the methods for parametric modelling of fixation devices and their installation based on computer tomography data that will enable adaptation to specific clinical cases;
- new rheological models of materials reflected the heterogeneity of bone structure, anisotropy of mechanical properties.
- automated software systems oriented on general usage of computer-aided design in medical practice by a staff of clinical centers orthopedics and traumatology

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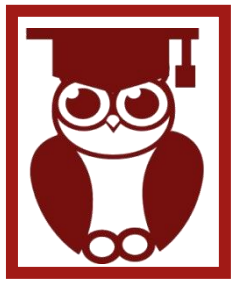

# COMPUTATIONAL ANALYSIS AND SYNTHESIS OF COMPOSITES

*Data-driven mechanics and applied computer vision*


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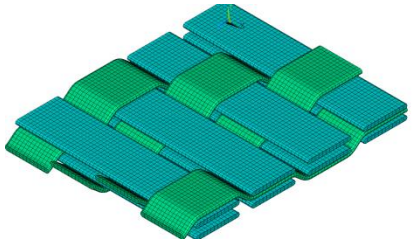
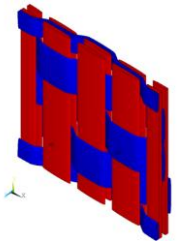
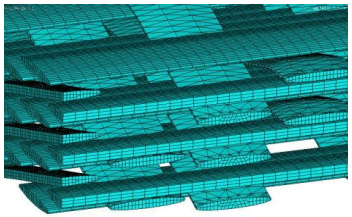
# Development of methods for designing functional anisotropic composite materials

Composite materials are widely used in various fields of modern technology due to the fact that their physical and mechanical properties allow to significantly improving the technical characteristics of products. The change in the structure of the reinforcement makes it possible to change in the desired direction the anisotropy parameters of the stiffness, strength, and thermal-physical properties of the composite materials. The control of anisotropy of complex modules





of polymer composite materials will increase the vibrational stability of structures and create effective noise absorbing materials. The creation of new materials with a given anisotropy of the properties of heat conductivity is necessary to improve the thermal insulation coatings of buildings and structures.



**Novelty and benefits**

New methods is being created for designing composite materials with the required parameters for the anisotropy of physical properties based on the combined use of numerical methods for analyzing the stressed state of structural elements and numerical methods for homogenization of composites.

**Outlook and perspectives**

The design of composites with the required anisotropy of mechanical properties is actualy in the manufacture of industrial wind turbine blades, elements of aircraft and space engineering structures. The creation of new materials with a given anisotropy of the properties of heat conductivity is necessary to improve the thermal insulation coatings of buildings and structures.

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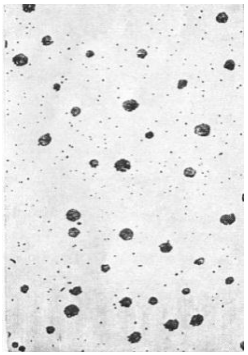
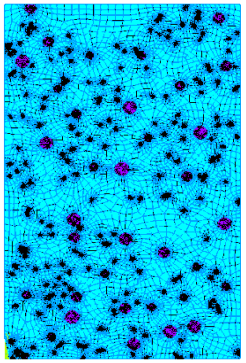
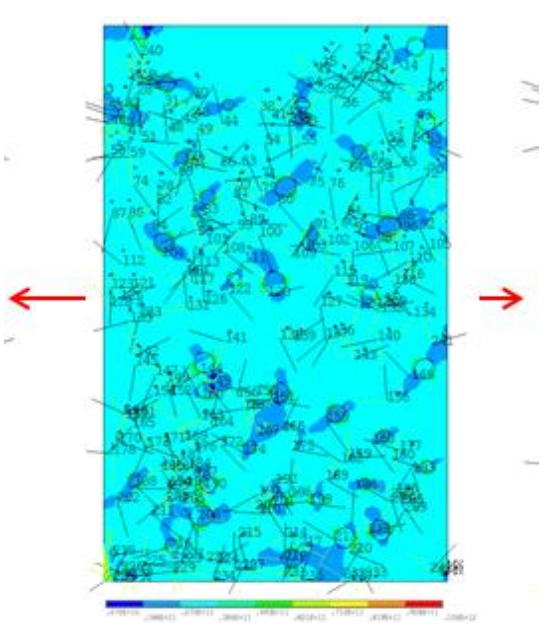
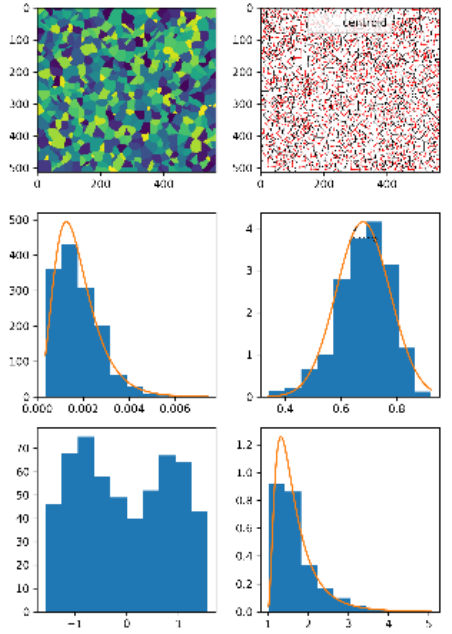
# IT for the analysis and synthesis of the structure of new materials for prediction of their physical properties

Modeling the mechanical behavior of materials at the micro level allows predicting the properties of the material at the macro level. This allows to significantly reducing the cost of testing, which is necessary to determine the mechanical properties. This is especially true for high cycle fatigue and creep testing. Computer simulation and modern information technologies allow virtually generate microstructures of materials and analyze their mechanical behavior. The most popular ways to virtually generate microstructures are the methods of cellular automata and the Voronoi tessellation. On the other hand, an important direction is the analysis of already existing microstructures and their properties.









## Outlook and perspectives

Today, work is being done on the modeling of simple materials; in the future, new, complex materials are of great interest

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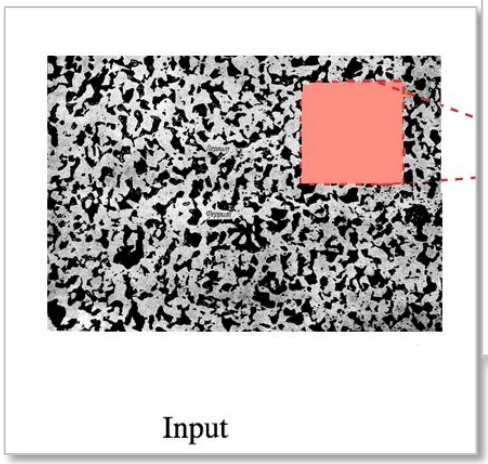
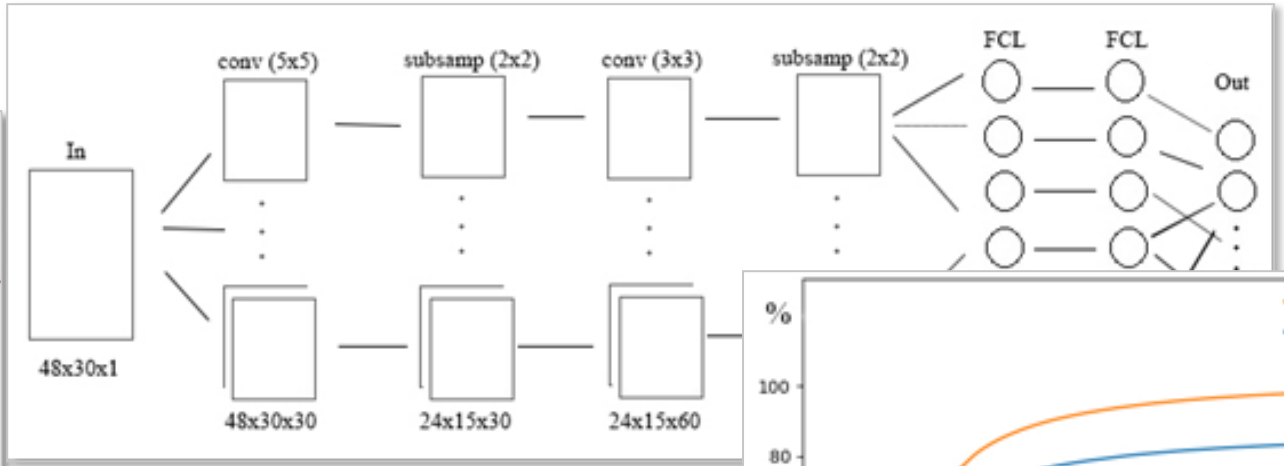
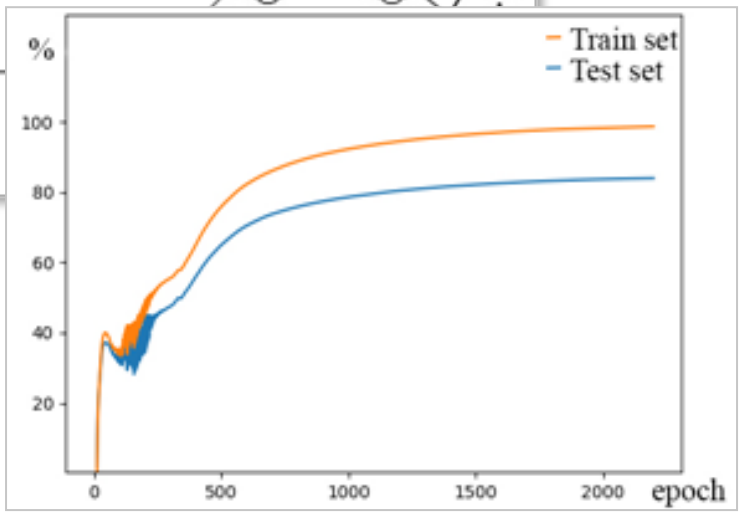
# Image microstructure estimation algorithm of heterogeneous materials for identification their chemical composition

Main objective — convolutional neural network (CNN) creation for definition of heterogeneous materials chemical composition: to create the database of images and percentage of the chemical elements corresponding to material; to develop an image recognition algorithm through programming of neural network; to estimate the received system




## Outlook and perspectives

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# NAVIGATION AND CONTROL SYSTEMS DEVELOPMENT

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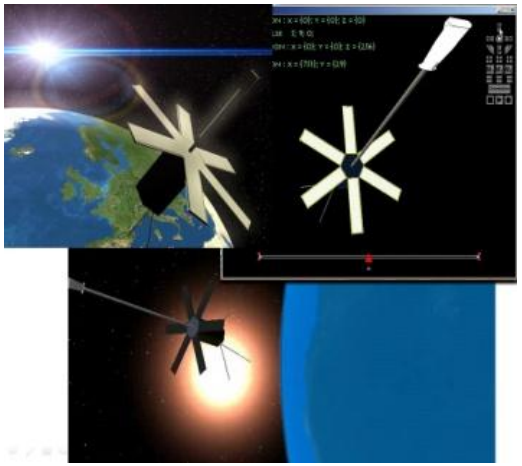
# Development of methods, algorithms and attitude control systems of artificial earth satellites

The attitude control system of the artificial Earth satellite incorporates measuring instruments and actuators of various types. For such systems there is experience of development:

- high-precision algorithms of orientation determination by use of the measurements of gyroscopes; technique of their efficiency assessment;
- calculation of the optimal configuration of quantitatively redundant system of actuators: gyrodynes, inertial flywheels;
- onboard algorithms of high-precision control of the artificial satellite reorientation for remote sensing of Earth with randomly specified boundary conditions and essential elastic structural elements ;
- algorithms of rational control of the redundant systems of gyrodynes or inertial flywheels;
- optimal unloading of the gyrodyne system or inertial flywheels with the help of gas-reactive engines;
- fault tolerance of the satellite control system at emergency situations;
- modeling of thermal processes in the satellite and its onboard subsystems at orbital motion around Earth.



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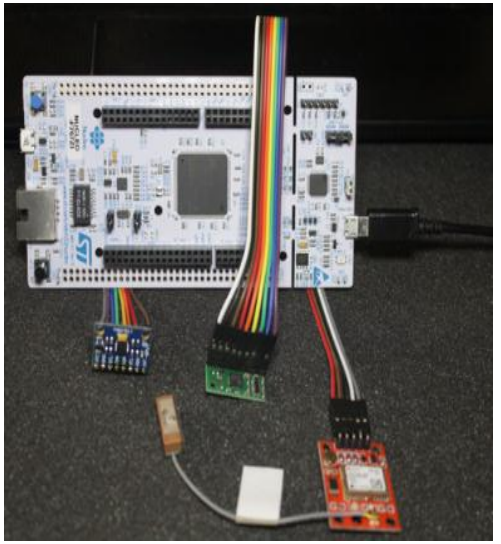
# Smart Quadcopter: Hybrid Drone for automatic monitoring, delivery of freights and safety control and security of technical objects

Our “hybrid drone” with unique “brains” navigation system is able to fly during a relatively long period of time (about 60-90 min) shipping the freight over 6 kg and due to “brains” of navigation system all proceed in autonomous mode according to a predetermined route and program of tasks. The problems our drone solves are mainly associated with agriculture: monitoring and aerial survey of forest plantations and farmland, chemical and biological treatment of agricultural land, protection and monitoring of fisheries waters. In the future it can be used in other areas, such as safety and security, search and rescue, monitoring systems etc.



**Outlook and perspectives**

Realization of our idea requires a tenancy and the test platform, transportation of the quadcopter on the platform and back.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# SANACAD: SAtellite NAvigation CAD

Such vehicles, as unmanned aerial vehicles, robots-transporters etc. require combined usage of the automatic control system (CS) and on-board navigation systems with special program-mathematical software (PMS). The use of budget mobile hardware in CS, for example the microelectrical electromechanical systems (MEMS), is desirable for mass user. Due to the special PMS, that has been developed within 10 years in the Department of Computer Modeling of Processes and Systems NTU «KhPI», the proposed computer-aided design system allows the user without special education to develop new and test existing PMS for integrated inertial-satellite navigation systems (IISNS) on the basis of this class of equipment.

## Outlook and perspectives

By use of the proposed system, the essential acceleration due to the possibility of usage the budget hardware in the process of development of motion control systems and essential cost reduction for a big class of objects will be possible.

There are known analogs of such complex software for other fields of activity, for example in design of electronic boards, elements of control systems, etc. but they are absent in the field of navigation equipment development.


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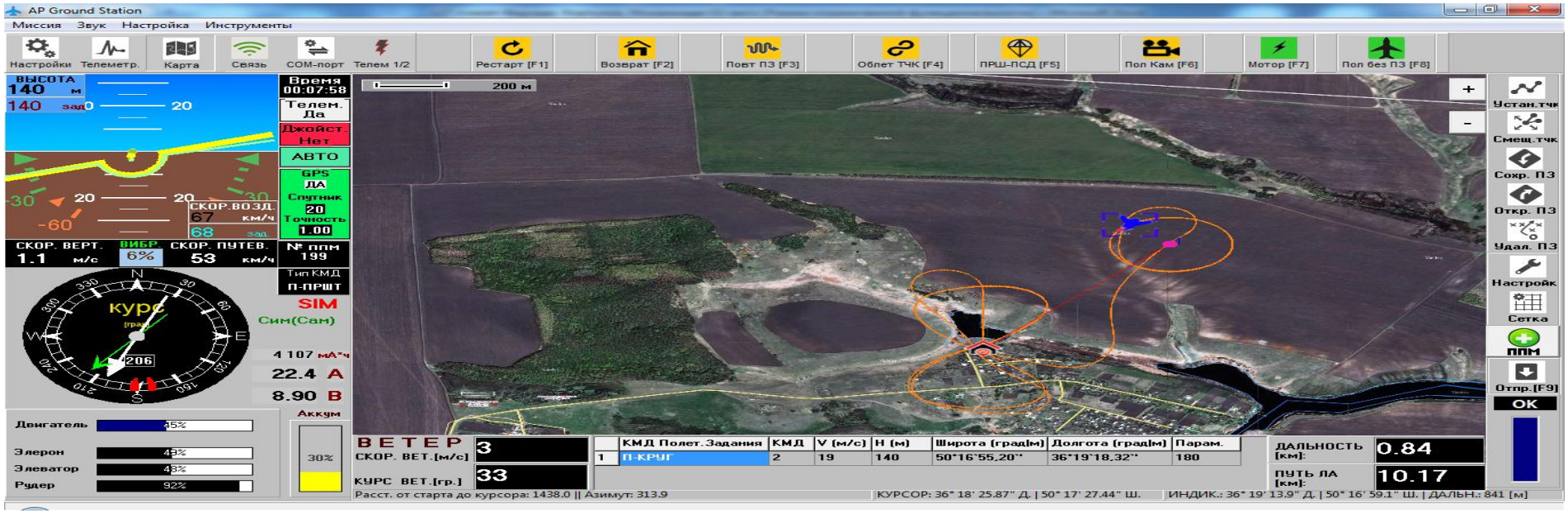
# ROBUST CONTROL OF THE UAV WITH MINI AUTOPILOT

roll channel nominal model and its uncertainties for the flight-wing UAV was found from several closed-loop flight-test data and then, a priori initial theoretical model and bounds of uncertainties were corrected and modified. Then robust control system for the roll channel was designed to increase the quality and robustness of the flight system during the system integration in the presence of uncertainties, disturbances, noise and actuator position and rate limits. It was shown that the designed robust control system can guarantee better quality for the UAV uncertain model than the PID controller in the presence of aileron angle and rate limits. Control system design is a compromise between contradictory requirements.

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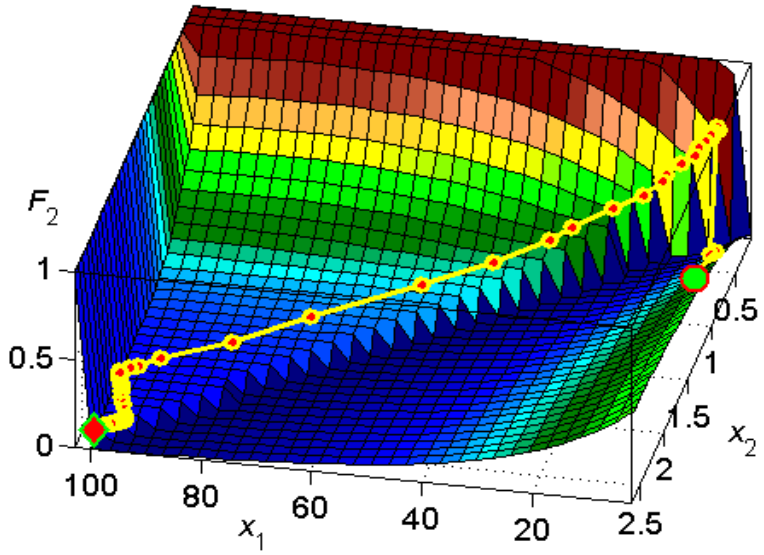
# Methods, algorithms and IT for multi-purpose optimization of radioelectronics and automated systems

For electronic and automated systems, quality criteria have been defined, vector objective functions have been introduced, mathematical methods and multi-purpose optimization algorithms have been developed. Based on optimization methods, an information technology has been created in the form of a computer lab, which includes databases of methods and tasks, subroutines of one-dimensional, multidimensional, unconditional, conditional, global and multi-criteria optimization methods, method utilities, tools for tabular and graphical representation of the optimization process. Multipurpose optimization of high-power electric pulse generators and automatic control systems of a nuclear power plant unit has been performed.

**Outlook and perspectives**

- Connection to the laboratory of other methods and models for solving multi-purpose optimization problems.
- Solving multi-purpose optimization problems for various existing and future objects and systems.

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