Institute of Aeronautics and Applied Mechanics

Prospectus

PW-ZOOM during its Antarctic mission (MONICA project)
photo Pawel Kusidel

Warsaw 2020

The history of **the Institute of Aeronautics and Applied Mechanics (IAAM)** continues the traditions of the oldest Polish institution that offers education in the field of aeronautical engineering. In the academic year 1922/1923, the Faculty of Mechanics of Warsaw Uiversity of Technology opened the Aeronautical Group, later called the Division of Aeronautical Engineering. The aeronautical study was conducted on semesters 5 to 8. Students were admitted after the so-called half-diploma, i.e. after passing the first four semesters. That was the beginning of aeronautical studies at Warsaw University of Technology for engineers of Polish aviation companies, research units and the army.

An important stage of the development of the IAAM was the erection of the Institute of Aerodynamics in 1925-1928, where theoretical and experimental work was conducted, contributing to the development of the Polish aviation industry. It was this Institute that created designs of engines and famous constructions of Polish aircrafts; their innovative and perfect design secured Warsaw University of Technology a prominent place among the world best research units dealing with aircrafts construction and design.

During the Second World War the University activity was to a great extent limited to underground education. After the Second World War, the situation of the Institute was very difficult. The building of the Institute of Aerodynamics had been burnt down, the laboratories destroyed, there was also a shortage of research and teaching staff.

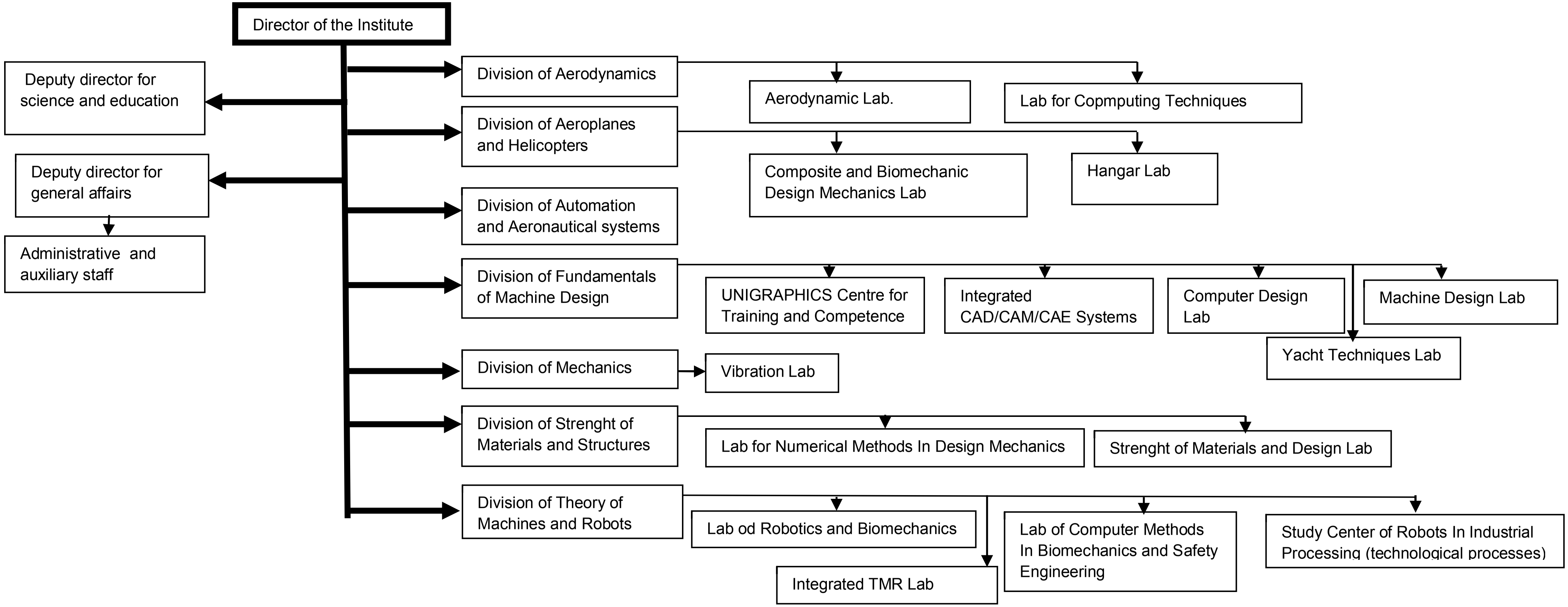
1951 was a special year in the history of the Institute. Then, the University was reorganised by merging the Wawelberg-Rotwand School with Warsaw University of Technology. The Institute of Aerodynamics was dissolved and the Faculty of Aeronautics was established. Also in 1951, construction of two new buildings - of Aeronautics and of Heat Engineering, began.

In 1960, the Faculties of Mechanics and Design and of Aeronautics were merged and the Faculty of Power and Aeronautical Engineering was founded, known under this name until today. In 1970/1971, due to the intention of shutting down the Polish aviation industry, education in the field of aeronautics was suspended and the Faculty was renamed the Faculty of Mechanics and Power Engineering (FPAE). The change was temporary, though and soon the name - Faculty of Power and Aeronautical Engineering come back.

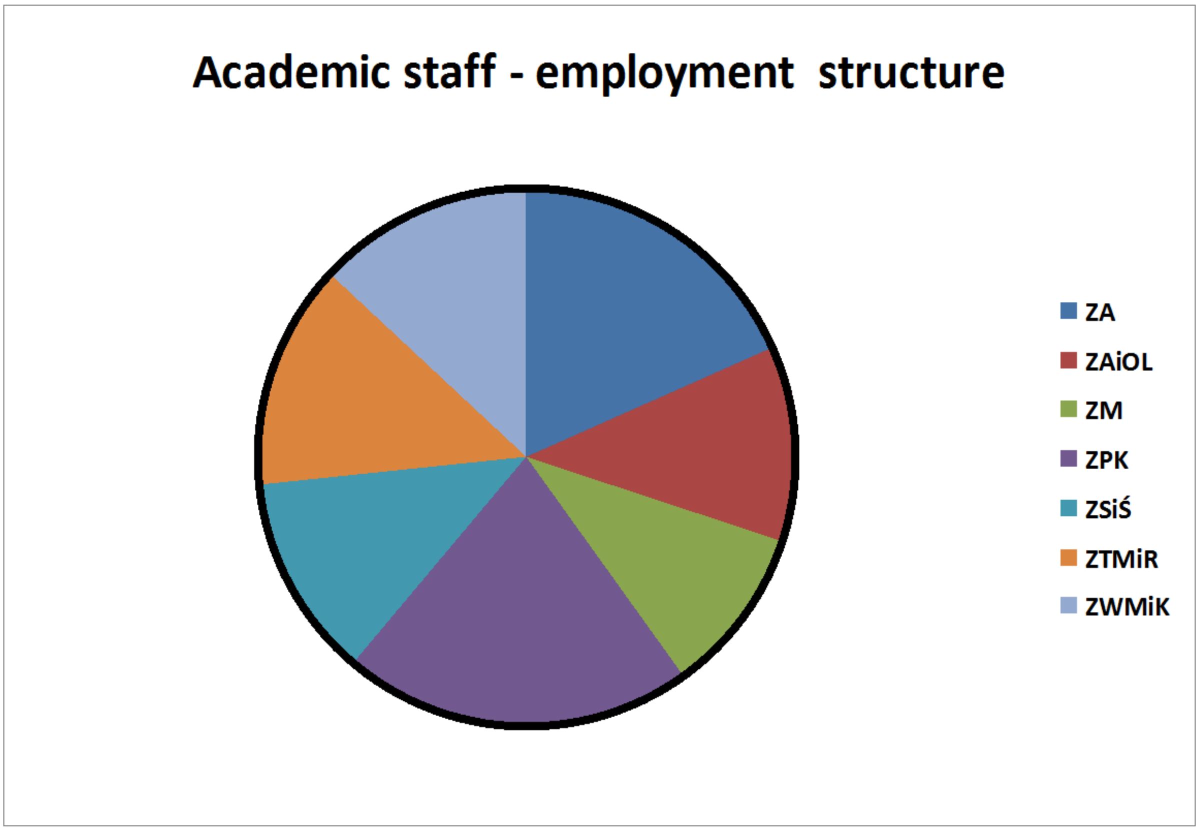
The Institute of Aeronautics and Applied Mechanics beeing the follower of the Institute of Aerodynamics, and the Faculty of Aeronautics was established in 1975 as one of the two institutes of FPAE. IAAM and the Faculty Dean's Office are located in Aleja Niepodległości. The buildings of the Institute create the research and teaching base .

Institute of Aeronautics and Applied Mechanics consists of:

- Division of Aerodynamics
- Division of Automation and Aeronautical Systems
- Division of Mechanics
- Division of Aeroplanes and Helicopters
- Division of Fundamentals of Machines Design
- Division of Theory of Machines and Robots
- Division of Strength of Materials and Structures

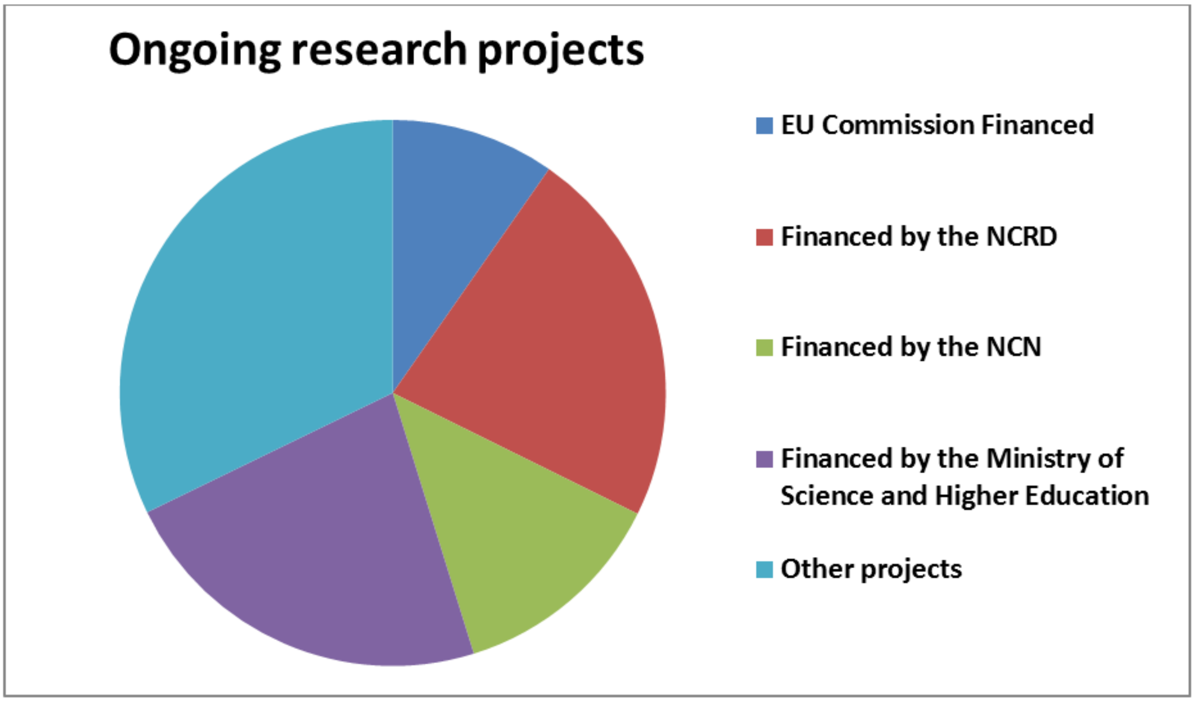


Director of the Institute
Deputy director for science and education
Deputy director for general affairs
Administrative and auxiliary staff
Division of Aerodynamics
Aerodynamic Lab.
Lab for Copmputing Techniques
Division of Aeroplanes and Helicopters
Composite and Biomechanic Design Mechanics Lab
Hangar Lab
Division of Automation and Aeronautical systems
Division of Fundamentals of Machine Design
UNIGRAPHICS Centre for Training and Competence
Integrated CAD/CAM/CAE Systems
Computer Design Lab
Machine Design Lab
Yacht Techniques Lab
Division of Mechanics
Vibration Lab
Division of Strenght of Materials and Structures
Lab for Numerical Methods In Design Mechanics
Strenght of Materials and Design Lab
Division of Theory of Machines and Robots
Lab od Robotics and Biomechanics
Integrated TMR Lab
Lab of Computer Methods In Biomechanics and Safety Engineering
Study Center of Robots In Industrial Processing (technological processes)



List of divisions

- **ZA –** Aerodynamics
- **ZAiOL –** Automation and Aeronautical Systems
- **ZM –** Mechanics
- **ZPK –** Fundamentals of Machine Design
- **ZSiŚ –** Aeroplanes and Helicopters
- **ZTMiR –** Theory of Machines and Robots
- **ZWMiK –** Strenght of Materials and Structures

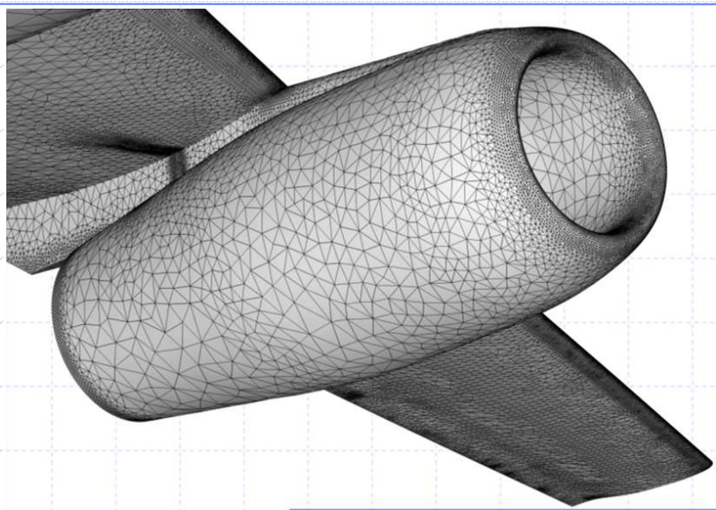


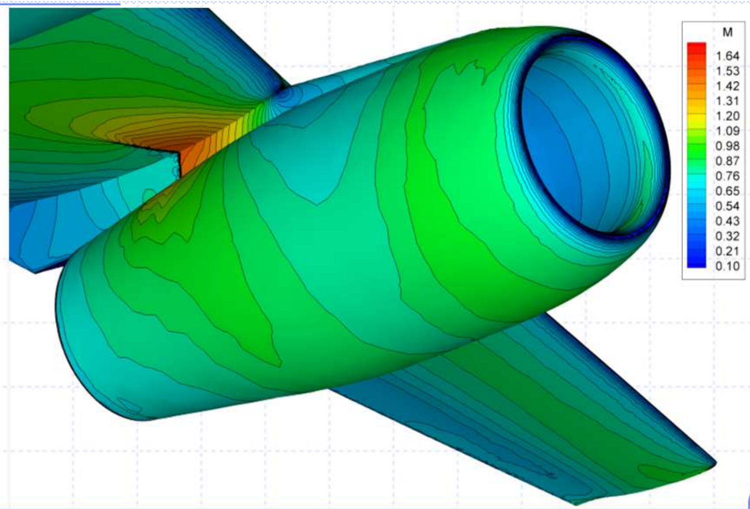
Presentation of IAAM divisions

Division of Aerodynamics
Warsaw University of Technology

Jacek Szumbarski

Institute of Aeronautics and Applied Mechanics
Faculty of Power and Aeronautical Engineering
Nowowiejska 24, 00-665 Warsaw
Warsaw University of Technology

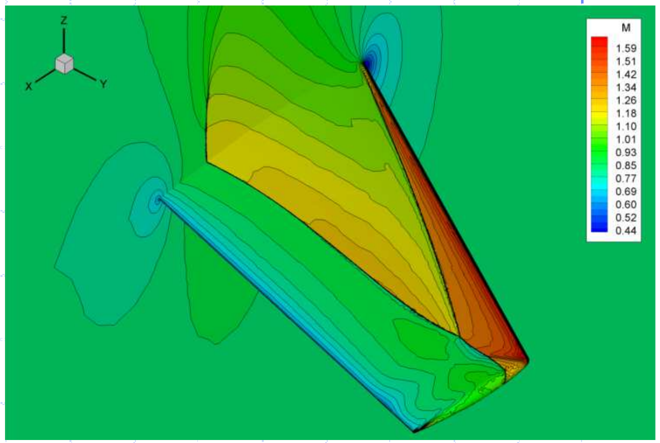




Division of Aerodynamics

Research:

- Computational Fluid Dynamics
- High and Low Speed Experiments
- Aerodynamic Design and Optimisation



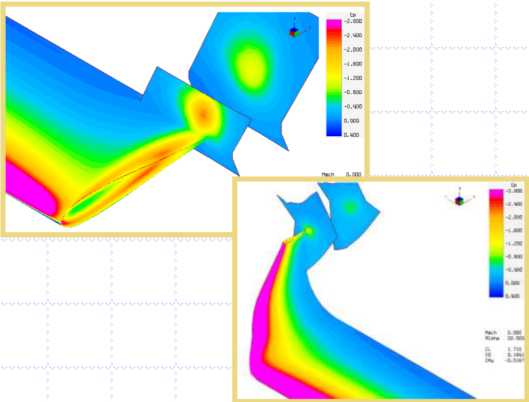
Equipment

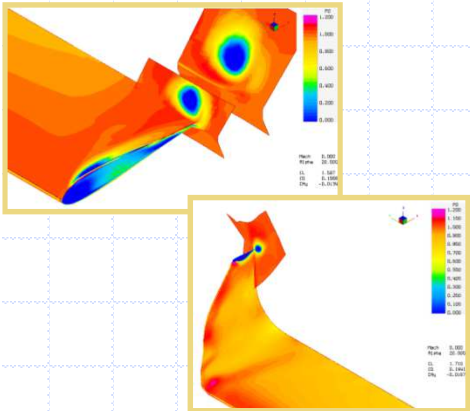
- Range of Wind tunnels (subsonic, laminar, transonic, ...)
- New laminar and new transonic wind tunnels (2016)
- Own computing centre (3 HP clusters – 900 cores)
- In-House codes (Residual Distribution Compressible, Spectral, Lattice-Boltzmann)

ACTIVITIES

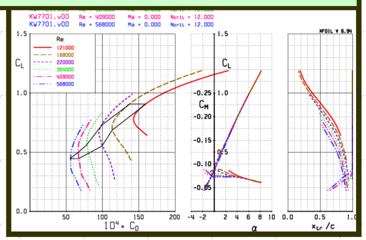
(EXAMPLES)

Fixed Wing Aerodynamics

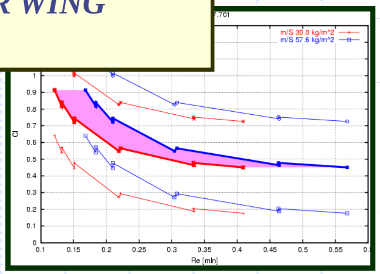


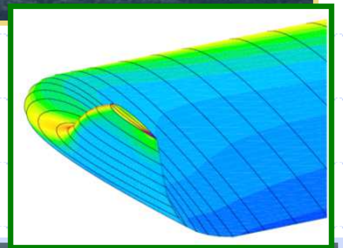


OPTIMIZED AIRFOIL FOR WING STATION

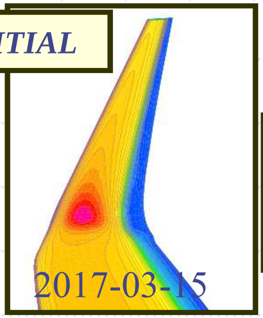


REQUIREMENTS FOR WING SECTION

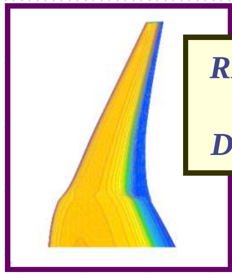




INITIAL



→ 3D - DESIGN PROCESS →

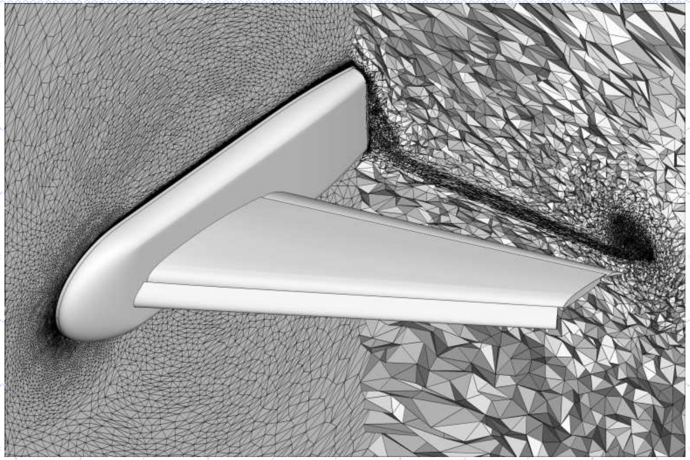


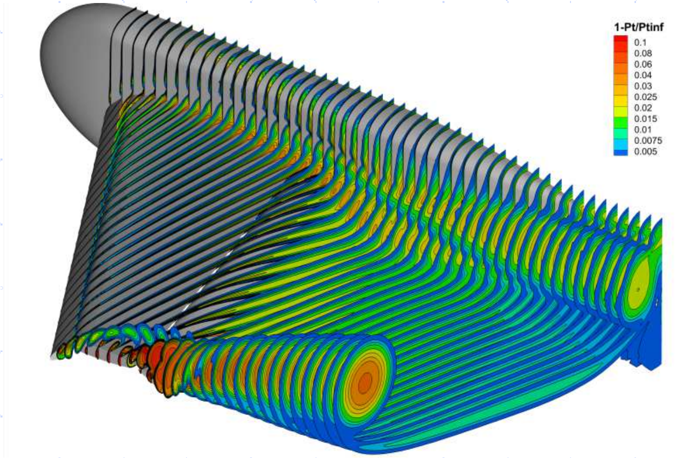
REQUIRED = DESIGNED

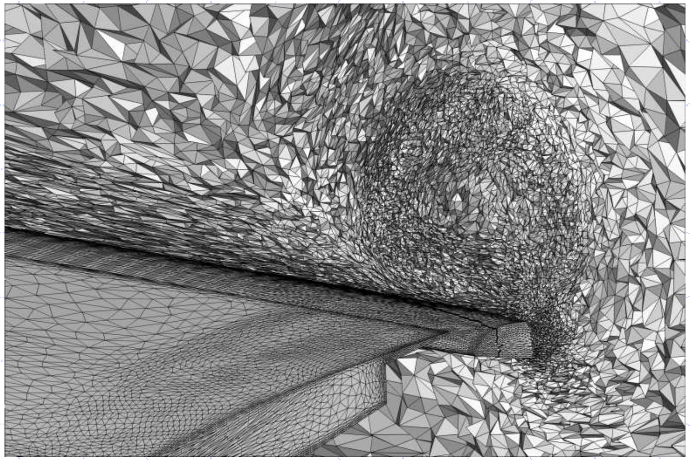
Mesh Generation and Adaptation

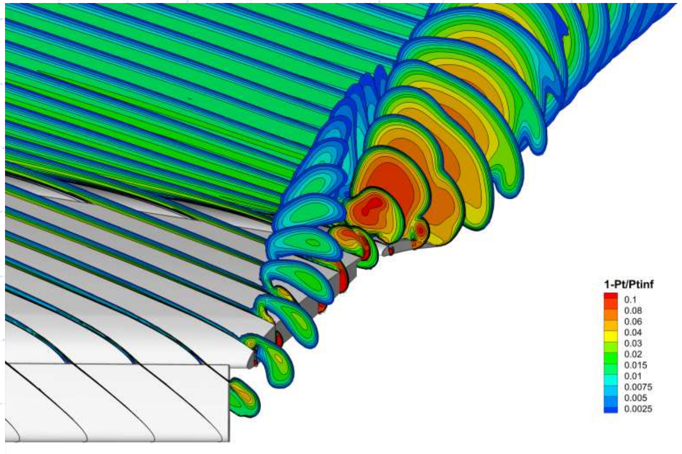
High Lift Prediction Workshop 1 Trap Wing

Mesh adaptation for wing-body configuration (turbulent flow, M=0.2, Re=$4.3 \cdot 10^6$, α=13)





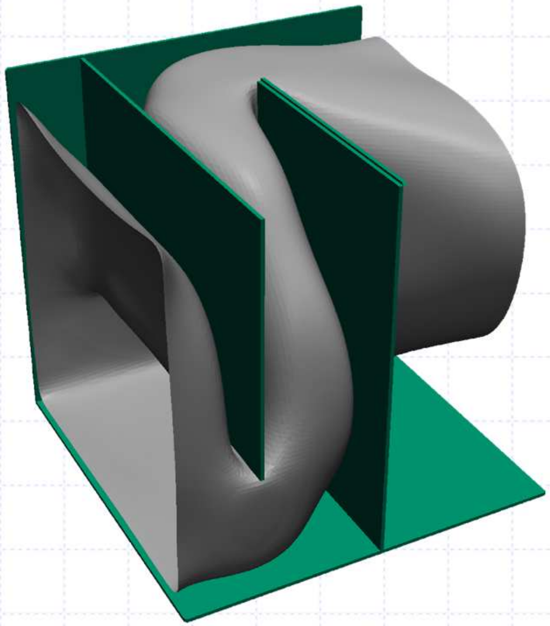




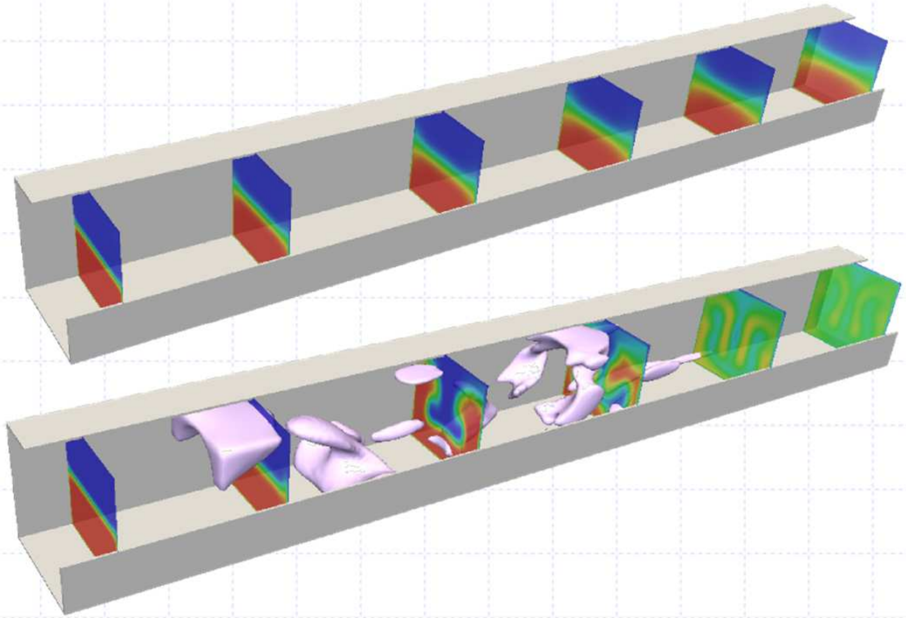
Fast optimisation in aerodynamics

- Topological optimisation

Lattice Boltzman Method implementation for hybrid CUDA+MPI architectures.
Capable for automatic generation of adjoint formulation and topology optimisation.



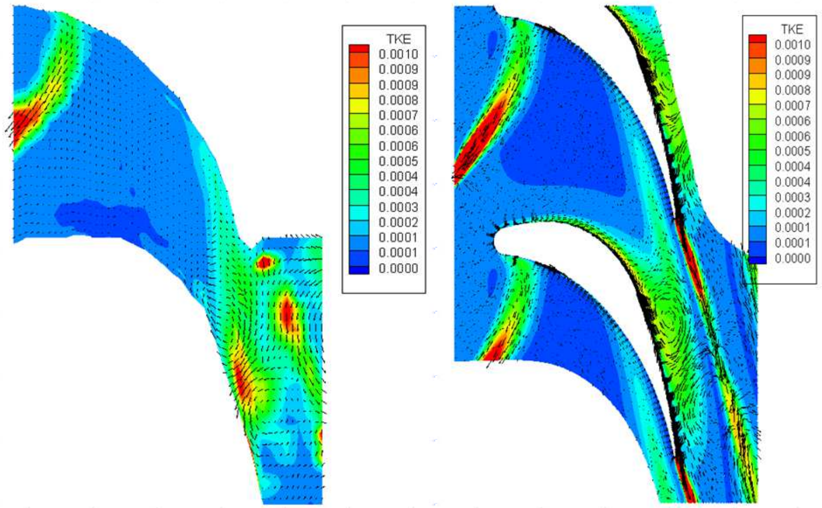
Optimisation of pressure loss in a flow around two obstacles



Optimisation of pressure loss in a flow around two obstacles in a square duct

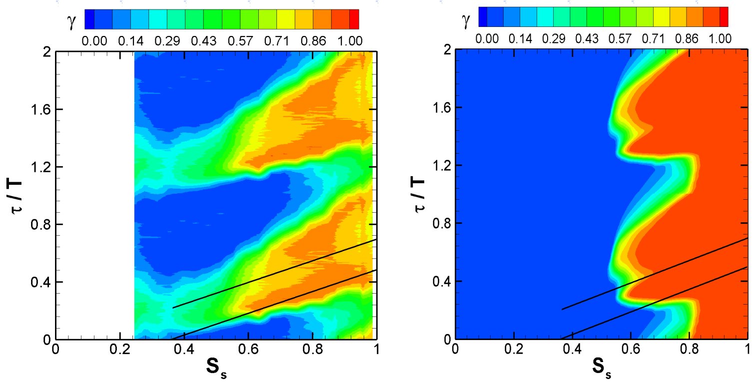
Transition modelling

- RANS-based techniques
  - Present approach: Correlation-based Dynamic Intermittency Model (reliable for wake-induced transition in boundary layer in attached and separated state)
  - New approach – Laminar Kinetic Energy-based model (under development)



Flow with moving wakes (N3-60 profile). Contours of turbulent kinetic energy and perturbation vectors in the blade passage. left : experiment, right: simulation.

Near-wall intermittency

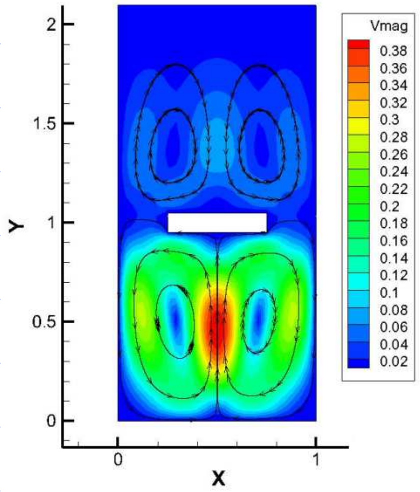


Experiment

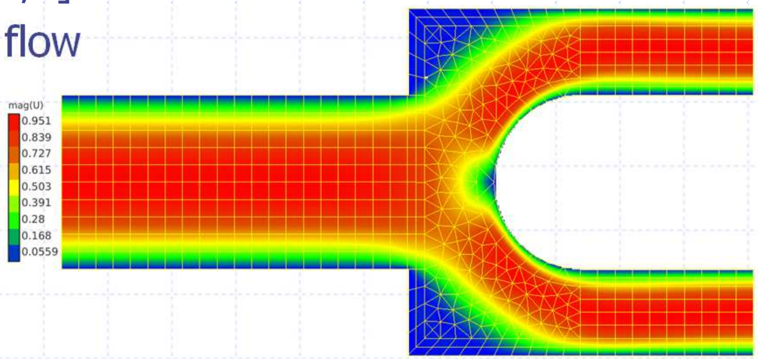
Simulation

Numerical Methods for Incompressible Flows

- **Main objective:** development of accurate, robust numerical methods and their efficient implementations to simulate unsteady incompressible flows

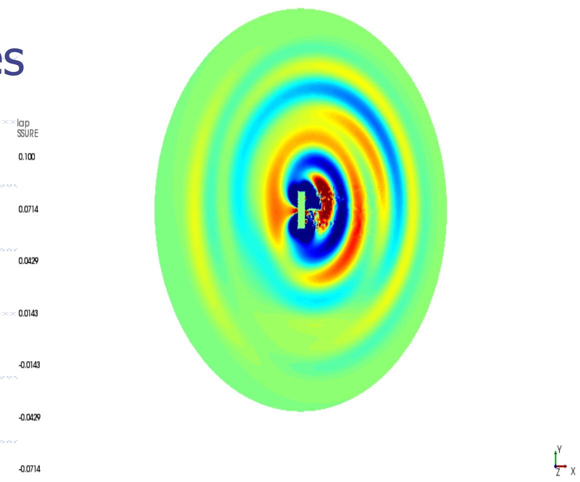


- Numerical algorithms and computer codes:
  - 2D and 3D spectral element methods (SEM) with mixed flow-rate/average-pressure conditions at inlets and outlets [1, 2]
  - design of PPE-based SEM codes using various spllitting approaches and do-nothing inlet/outlet conditions
  - parallel and GPU implementation
  - SEM code for thermal convection flows [6,7]
  - hybrid-mesh SEM codes for thermal and flow simulations



Computational AeroAcoustic (CAA)

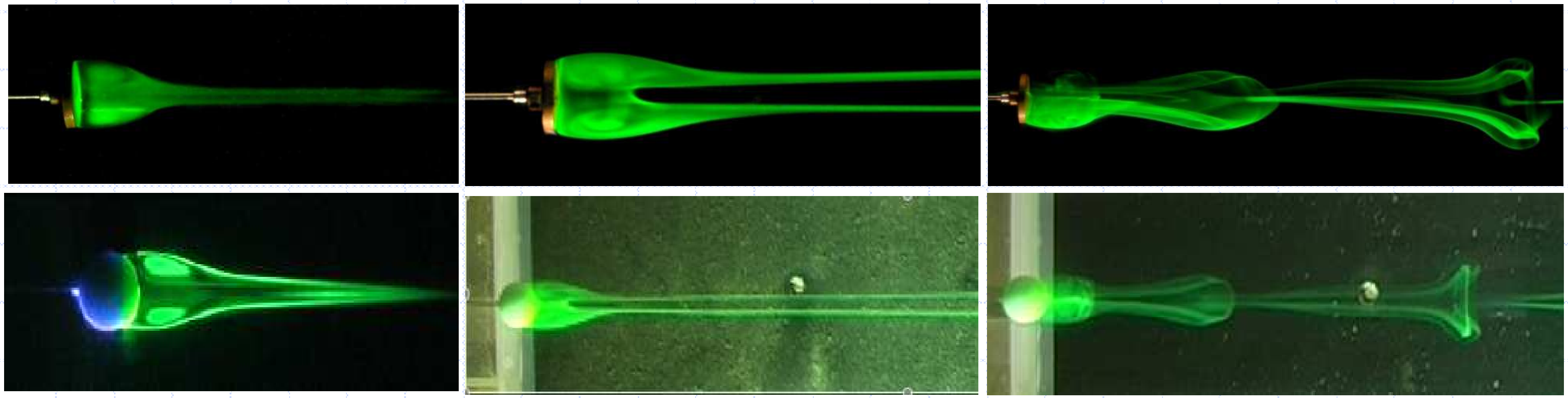
- CFD calculations and CFD/CAA coupling schemes to obtain acoustic sources
- Frequency domain methods based on the convected Helmholtz equation to simulate acoustic propagation
- Time-domain Discontinuous Galerkin Methods (DGM) for solving linearized Euler equations to simulate acoustic propagation

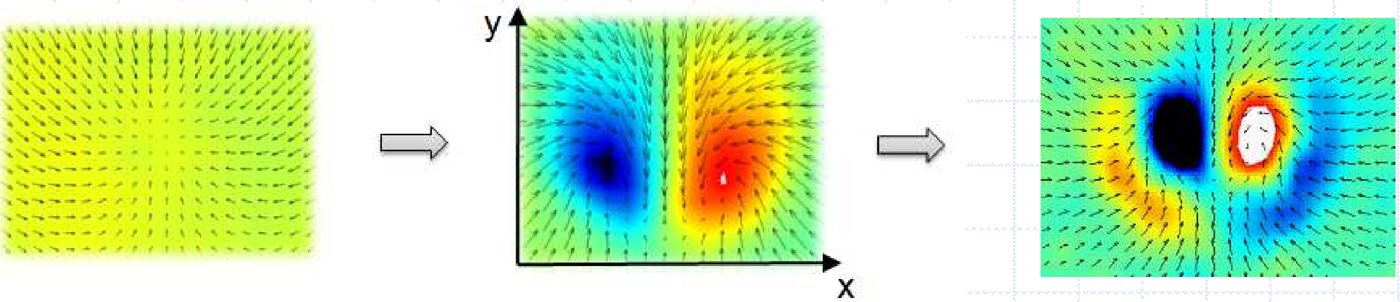


- Simulations of sound attenuation by liners and absorbing materials
- Ffowcs-Williams and Hawkings (FWH) method for far-field acoustic predictions
- Development of novel approaches to reduce tonal and broadband noise generated by airfoils

Industrial research project: Development of a family of quiet blades for large industrial fans

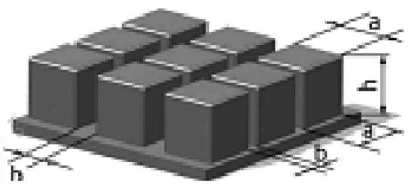
Low Reynolds number flows

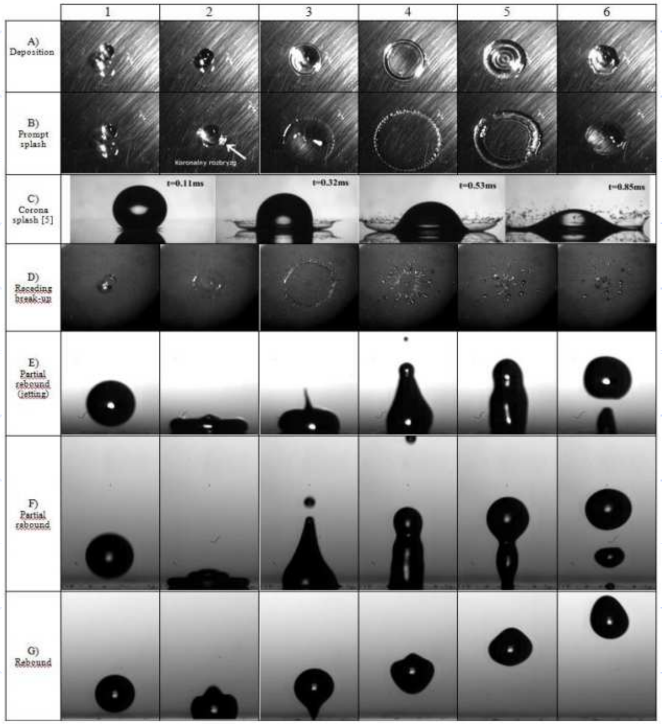




Droplet impact

- Research on dynamic contact of water droplet on hydrophilic, hydrophobic and superhydrophobic surfaces
  - With various topography
  - Chemically modified



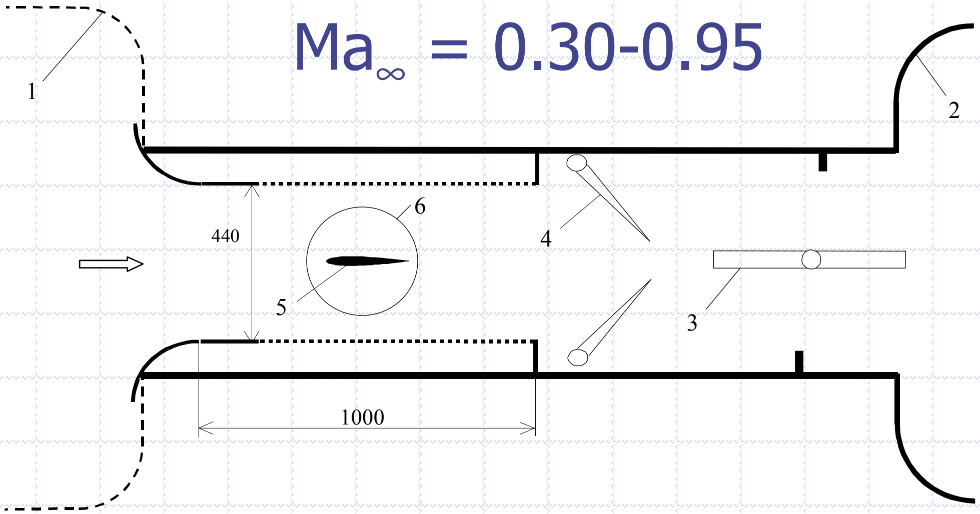


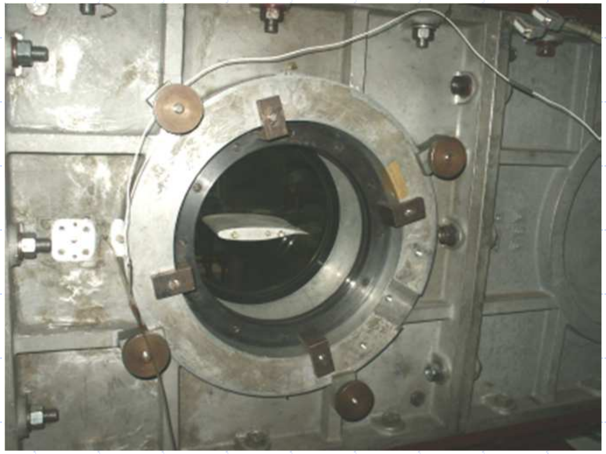
Surface with microstructure (up)

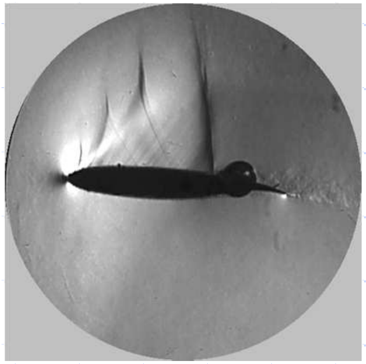
Various phenomena during drop impact (right)

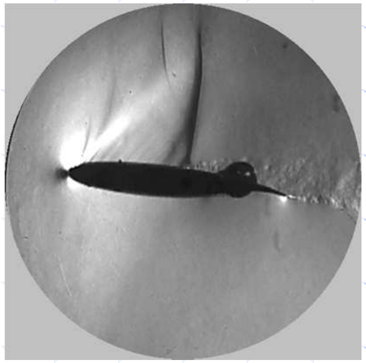
- (A, B, D ,E , F, G) own pictures, C - [1]

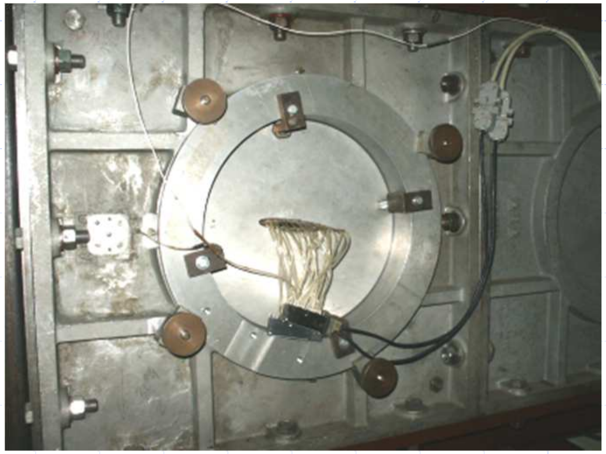
Transonic experiments (old WT)





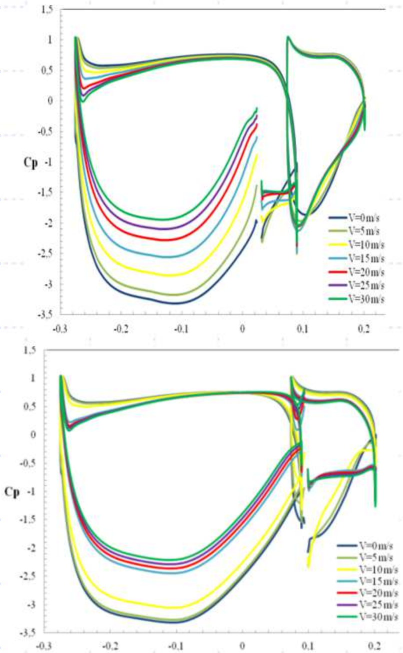


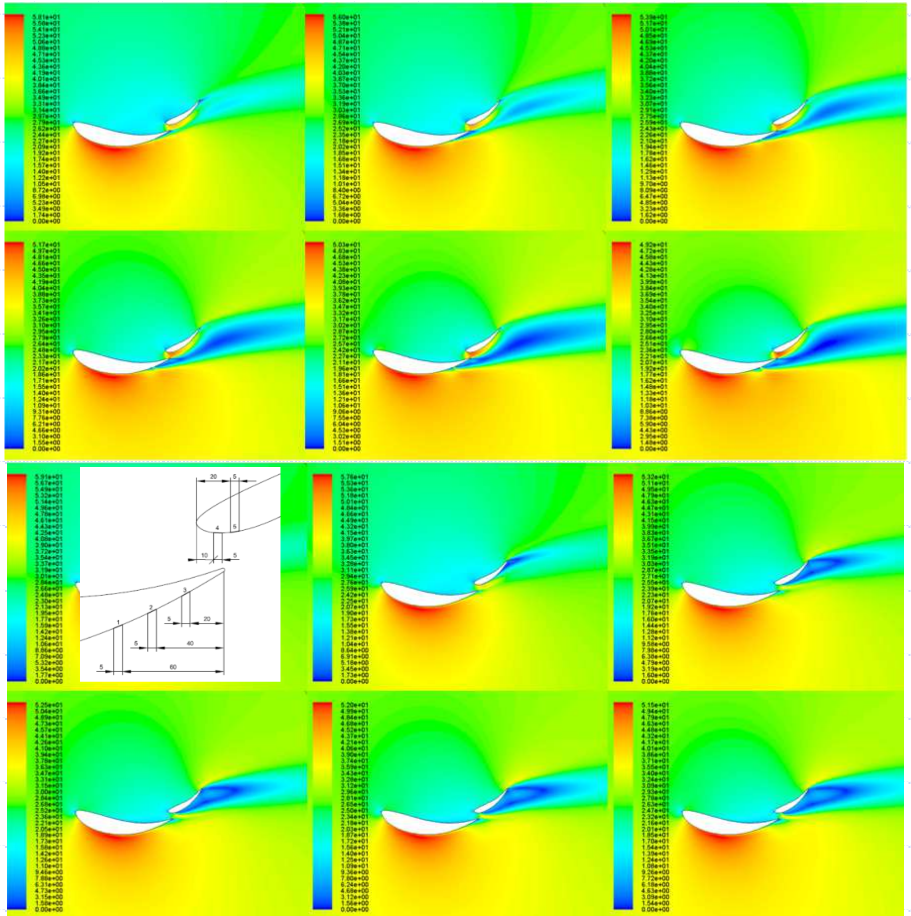




Fast car active aerodynamics

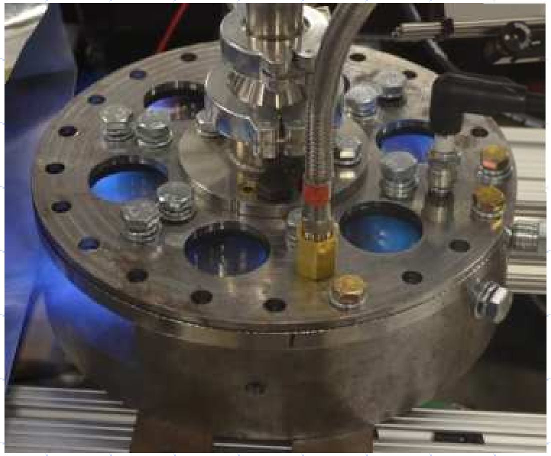
- Drag and lift controlled by the forced separation

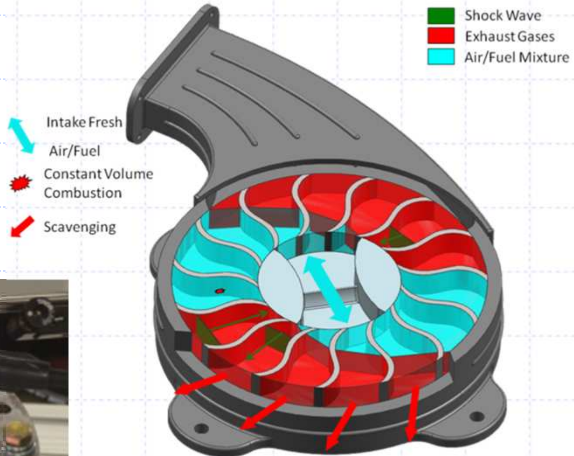


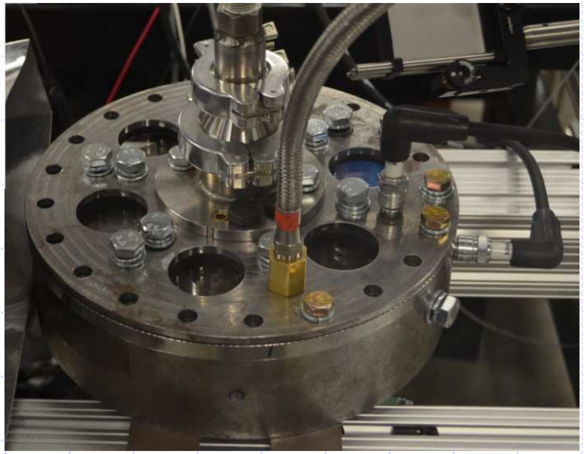


Wave engines

- Scheme of wave engine and prototype operation before and after optimisation at MSU



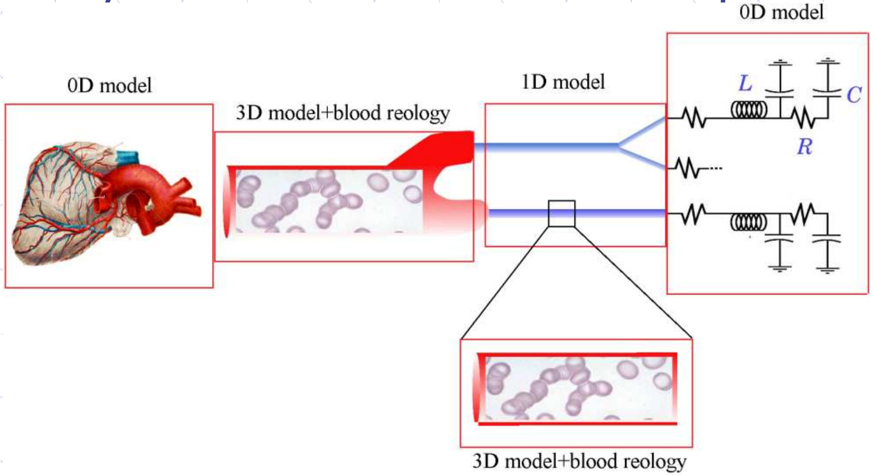


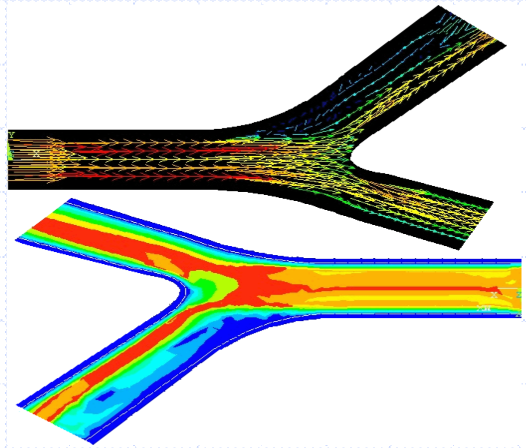


Numerical Methods in Cardiovascular Biomechanics

- The validated model is used for computations of the

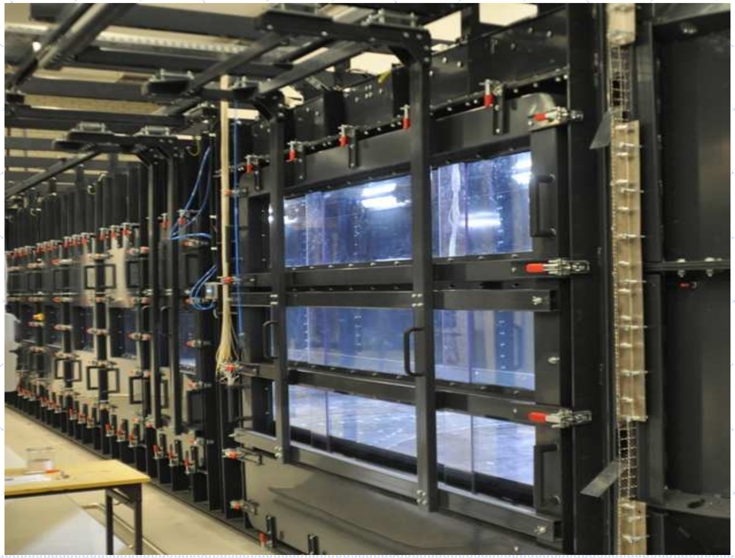
- blood flow distribution between inner organs; modeling of the 'blood steal' phenomena, e.g. 'coronary steal';
- pressure wave evolution along the systemic tree in normalcy and pathology, pulse wave analysis;
- peripheral P(t) and P(V) patterns; biomechanical substantiation of the pulse wave diagnostics;
- patient-based *in silico* planning of the cardiovascular surgery, quantitative analysis of the outcomes of therapeutic and rehabilitation procedures.

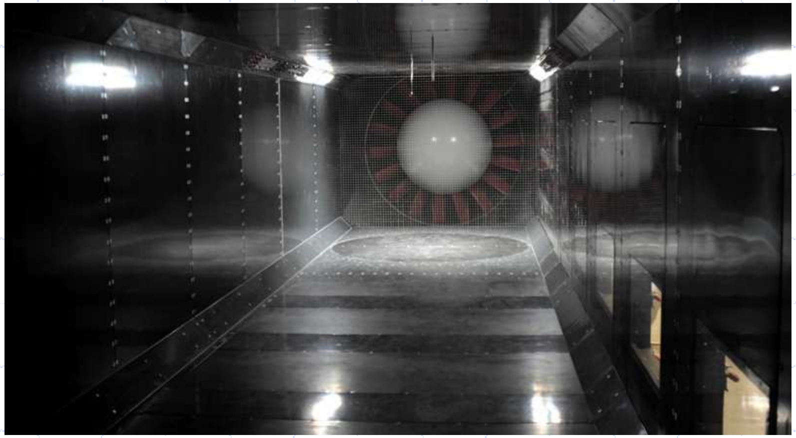




WIND TUNNELS

LATiS laboratory – wind tunnel





Test section 2,5x 2 m

Max flow velocity 25 m/s

Own computing resources

Hyperion cluster:

- –16 Computing Nodes
  - •36 Intel cores, 128GB RAM per node
  - ***•Total: 546 cores & 2TB RAM***
- – 4 GPU nodes
  - ▫Nvidia Tesla K40, 128GB RAM per node
- –Parallel in-cluster storage, up to 10TB
- –Infiniband interconnection

Tachion cluster:

- –22 Computing Nodes
  - •10 x 8 AMD cores, 16GB RAM per node
  - •6 x 16 AMD cores, 64GB RAM per node
  - •6 x 32 AMD cores, 128GB RAM per node
- –One GPU node, 2 x NVIDIA GPU
- –Parallel in-cluster storage, up to 3TB
- –2 x Gigabit Ethernet interconnection

Institute of Aeronautics and Applied Mechanics
Faculty of Power and Aeronautical Engineering

Division of Automation and Aeronautical Systems

Expertise in DAAS

- **Simulation of air, ground and water vehicles**
  - performance and control analysis
  - computer models of various air, ground and water platforms: airplane, helicopter, tilt-rotor, car, ship, etc. various complexity of models with control modules.
- **Control and navigation**
  - methods and algorithms for signal processing
  - transferring expertise in navigation systems to ground and water platforms
- **Integration of navigation sensors for mobile platforms**
  - sensors: GPS, INS, magnetic compass, laser range finders, camera, odometers
  - filtering methods: Kalman, Julier - Uhlmann
- **Autopilots and control systems for mobile platforms**
  - fly-by-wire systems
  - unmanned systems
  - autonomy
- **Human factors**
- **Security and Defense Systems Research**
  - Flight control systems for rockets and missiles
  - Guidance systems
  - UAV, UGV systems
  - Autopilots for airplanes and rotorcrafts

Equipment in DAAS

Software

- ✓ Matlab/Simulink
- ✓ Flightlab
- ✓ C/C++

Hardware

- ✓ sensors
    - ✓ GPS,
    - ✓ IMU/INS,
    - ✓ digital compass,
    - ✓ video cameras,
    - ✓ actuators,
- ✓ mobile platforms
    - ✓ mobile robots
    - ✓ airplanes
    - ✓ helicopters
    - ✓ quadrotors
- ✓ research simulator

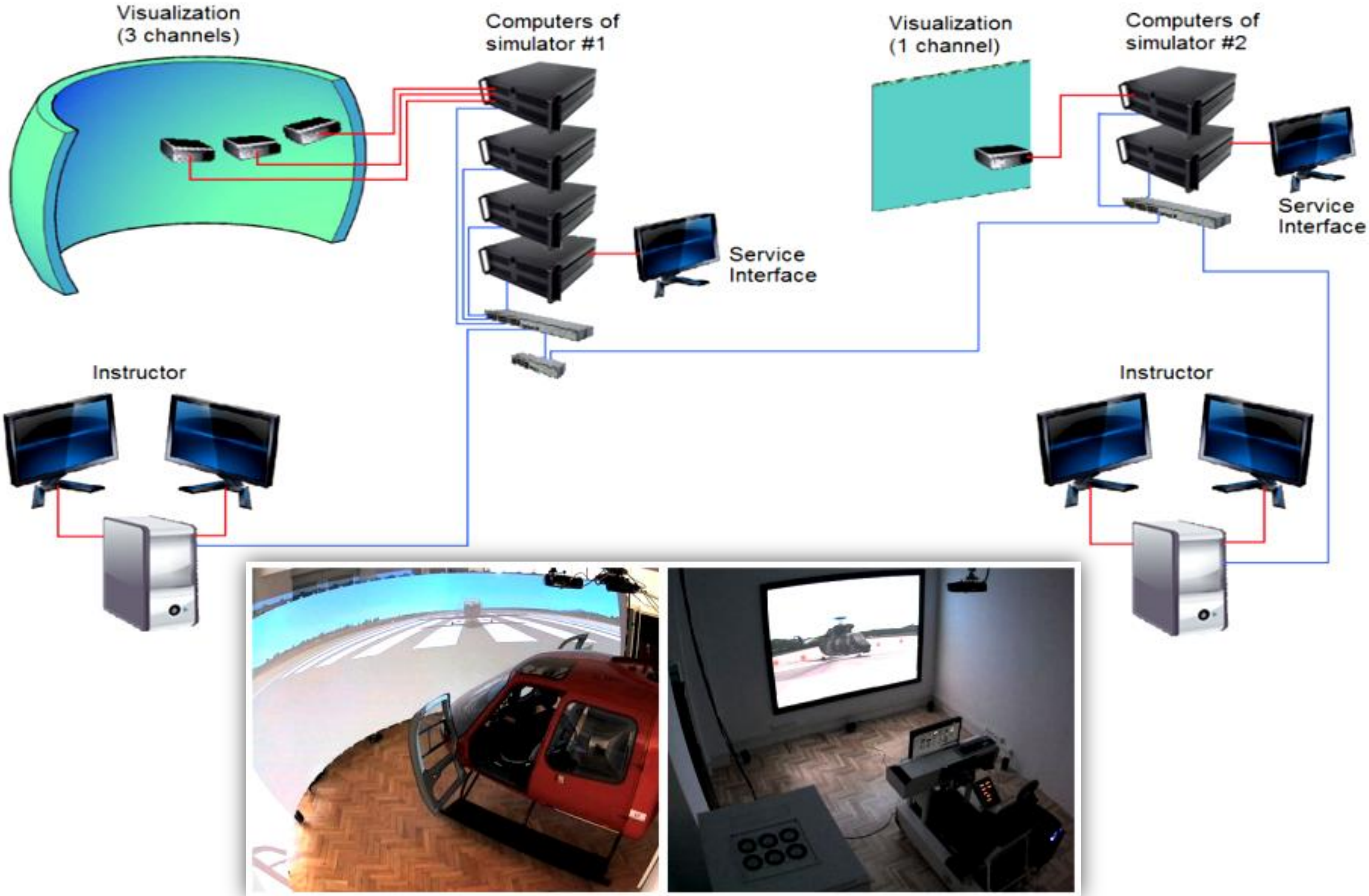
DAAS - mobile robots

Rotorcraft

UAV

Simulator Laboratory

Simulators


Visualization
(3 channels)
Computers of
simulator #1
Service
Interface
Visualization
(1 channel)
Computers of
simulator #2
Service
Interface
Instructor
Instructor

FLIGHTLAB

Advanced Rotorcraft Technology INC.

FLIGHTLAB, a software environment to support modeling of dynamic systems from a predefined library of physically based modeling components.

Helicopters

FLIGHTLAB

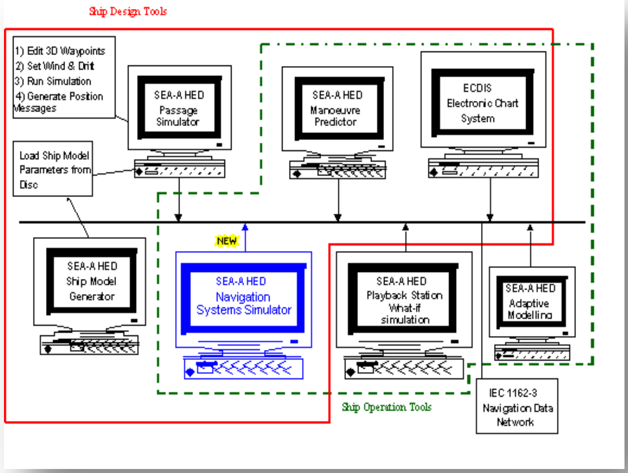
Simulation Environment

Airplanes

Other vehicles

SAE-AHEAD - Simulation Environment and Advisory system for on-board Help, and Estimation of maneuvering performance during Design

Projects EU

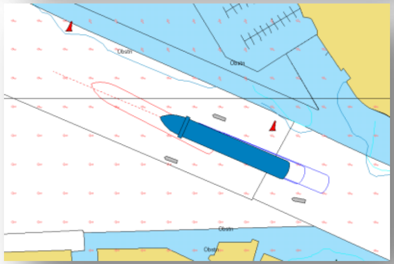


Objectives:

prediction of ship motion in future (within the prescribed time horizon) based on the identified vessel model,

DAAS tasks:

- system for navigation data acquisition and processing (Kalman filtering)
- on-line identification of ship parameters (Julier-Uhlman filter)
- prediction of ship motion in the nearest future



NACRE - New Aircraft Concepts Research

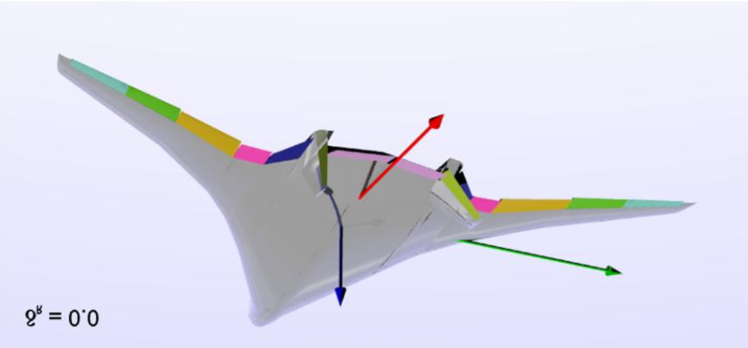
Projects EU

- ACROSS
- ADFCS II
- TALOS
- NACRE
- NEFS
- NICE TRIP
- CAPECON
- SAE-AHEAD

DAAS tasks

Simulation of Flight Control Laws for Flying Wing configuration

- Aircraft model
- Trim calculation
- Stability investigation
- Flight control methods and algorithms



CAPECON - Civil UAV Applications & Economic Effectivity of Potential Configuration solutions

DAAS tasks

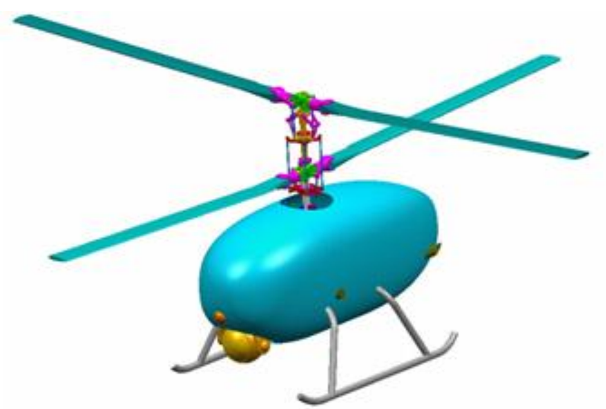
Two configurations selected: single rotor and coaxial.

Single rotor was modeled using FLIGHTLAB software.

For coaxial rotor configuration, the dedicated model was developed

Simulation of hover and forward flight conditions for evaluating control requirements

Calculated: trim conditions, state and control matrices, stability and control



TALOS - Transportable Autonomous Patrol for Land Border Surveillance System

Projects EU

- ONION
- ACROSS
- TALOS
- NACRE
- NEFS
- NICE TRIP
- ADFCS II
- CAPECON
- SAE-AHEAD

Objectives:
to develop and field test the innovative concept of a mobile, modular, scalable, autonomous and adaptive system for protecting European borders

Description:
the complete system applies both aerial and ground unmanned vehicles, supervised by command and control centre,

DAAS tasks:

-UGV subsystems design, implementation, integration and tests (navigation systems)

-dissemination & exploitation-(website, workshops)

NEFS - New Track integrated Electrical Single Flap Drive System

Projects EU

- ONION
- ACROSS
- TALOS
- NACRE
- NEFS
- NICE TRIP
- ADFCS II
- CAPECON
- SAE-AHEAD

Objectives:

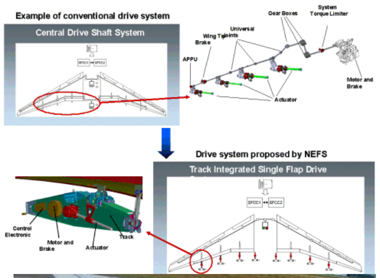
- distributed electrical flap drive system (fault tolerant),
- integrated into the flap support structure in the very limited space,
- increased the availability and reliability, additional functionalities, simplify installation,

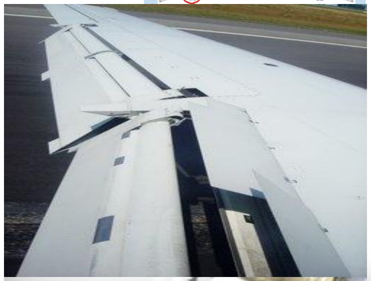
DAAS tasks:

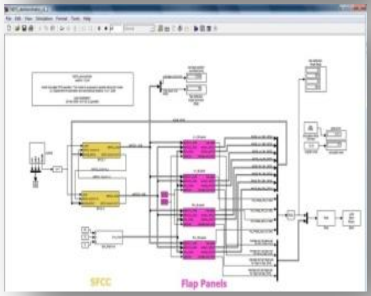
- to develop a comprehensive model of an aircraft with integrated model of differential flap system to evaluate the functions and performance of an aircraft with differential flap system (DFS),

Results:

- model system architecture, model of elements, models integration, implementation of diagnostic functions and failure simulation.







NICE TRIP - Novel Innovative Competitive Effective Tilt Rotor Integrated Project

Projects EU

ONION
ACROSS
TALOS
NACRE
NEFS
NICE TRIP
ADFCS II
CAPECON
SAE-AHEAD

Objectives:

- acquisition of new knowledge,
- development of appropriate technologies,
- integration of these technologies with other technologies developed in preceding projects,
- testing at reduced scale in wind tunnels, and at full scale on the ground,
- all main tiltrotor elements and systems designed,

DAAS tasks:

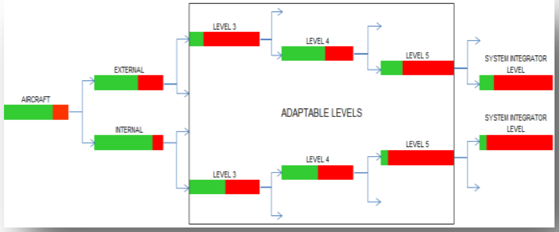
- definition of an operational concept of use of the tiltrotor in the European ATM system and definition of an operational scenario for civil tilt rotor applications,
- tiltrotor flight control system modeling and simulation (Flightlab and Simulink),
- modeling of actuators dynamics,

Projects EU

ONION
ACROSS
TALOS
NACRE
NEFS
NICE TRIP
ADFCS II
CAPECON
SAE-AHEAD

ACROSS – Advanced Cockpit for Reduction of Stress and Workload

Objectives:
development of avionics systems architecture that will facilitate the work of the crew in case of large psycho-physical load as well as in the event of an unexpected reduction of the crew



DAAS tasks:
development of the supervision system that allows to quickly and clearly (in quantitative way) identify the aircraft and its systems failures and the place of its occurrence. The system uses information from internal sources (systems of the aircraft), external (eg. Air Traffic Control), and also monitors the behavior and health of the crew. What is more, the system works with developed at DAAS simulation model of the Airbus A320, which is a source of reference of the correct flight parameters of the aircraft.

ONION – Operational Network of Individual Observation Nodes

Projects EU

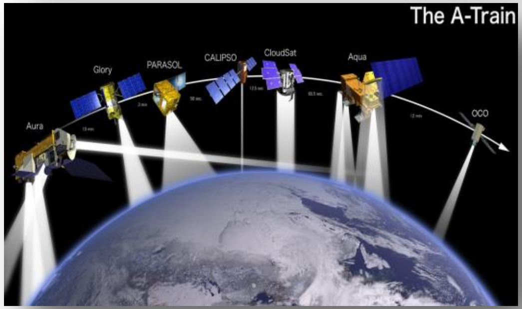
- ONION
- ACROSS
- TALOS
- NACRE
- NEFS
- NICE TRIP
- ADFCS II
- CAPECON
- SAE-AHEAD

Objectives:

To investigate the distribution of spacecraft functionalities into multiple cooperating nodes, leveraging on the emerging fractionated and federated satellite system concepts. The proposed concept provides augmentation, supplementation, and possibilities of new mission for future EO Missions (for science and commercial applications).

DAAS tasks:

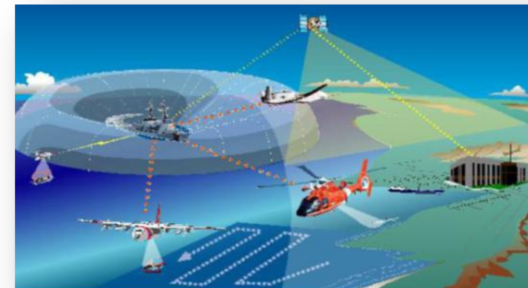
Review of the emerging fractionated and federated observation system concepts related for nanosatellites, validation of observation needs with the respective user communities to be fit for purpose in terms of scientific and commercial applications for nanosatellites, development of the formation flying simulation models for nanosatellites



Projects
US

OpUSS

OpUSS- Optimization of Unmanned System of Systems



Objectives:

Optimization of unmanned aerial system of systems

DAAS tasks:

The use of the „system of systems" concept to analyze a UAV fleet flight.

Maximising the effectiveness of the fleet operation for the assumed mission.

Possibilities of indication of gaps and / or ways to improve the operation effectiveness.

Mission software - Locate / Identify / Track.

Flight demonstration of optimized fleet flight for three different aircraft

LOCKHEED MARTIN

PROTEUS - Integrated mobile system for counterterrorism and rescue operations

Projects
PL

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

MISSILES CONTROL

ROTORCRAFT

FLIGHT CONTROL

Objectives:

- development integrated mobile systems to respond to terrorist thread and/or crisis.
- development of new technologies and new methods of research in: mobile robotics, aerial objects, telecommunications, information technology, materials, and sensors,
- mobile robots (and UAV) used to support the evacuation of people, removal or neutralization of dangerous/hazardous materials, overpower attackers,
- integrated command center for an effective intervention management ,

DAAS tasks:

- simulator development to verify the design of mobile robots (at the time of the project and after its completion),
- training of the operators both of robots and other elements of the system (after the implementation of the system),

APN - Autonomous Water Surface Platform

Projects PL

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

MISSILES CONTROL

ROTORCRAFT

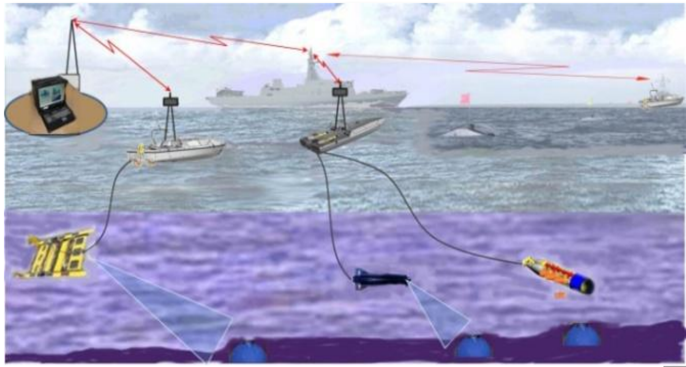
FLIGHT CONTROL

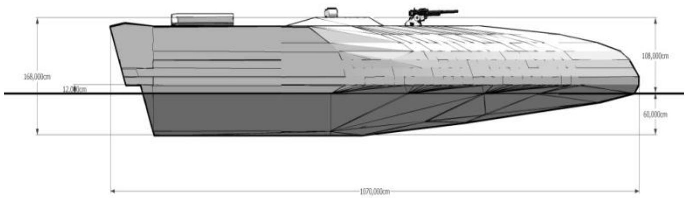
Objectives:

Construction of the autonomous boat used to patrol the maritime areas, in order to detect, classify and rapid neutralization of naval mines

DAAS tasks:

- design and implementation of an advanced, long distance, high precision navigation system,
- integration of signals from various sensors,
- development of the sea boat simulation model,
- development of the automatic control systems,
- development of the autonomous functionalities (obstacles avoidance, patrolling, following the path),
- integration with other systems of the platform.





APN-R

APN-I/N

Impulsive Control of Small Smart Missiles Flight with Control Laws Based on Artificial Neural Networks

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

MISSILES CONTROL

ROTORCRAFT

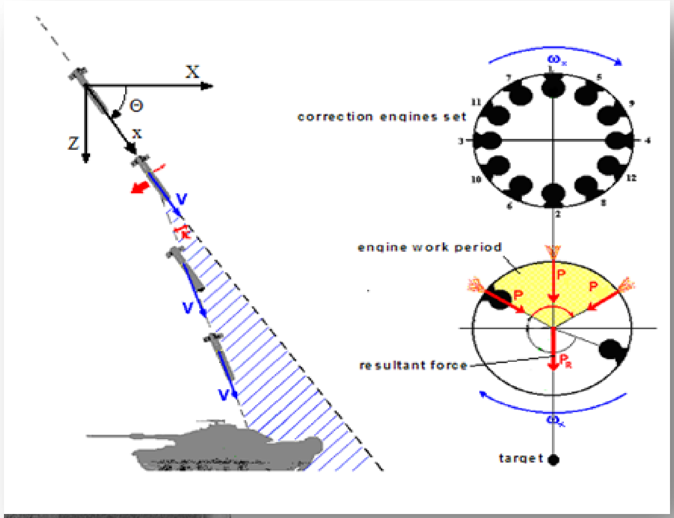
FLIGHT CONTROL

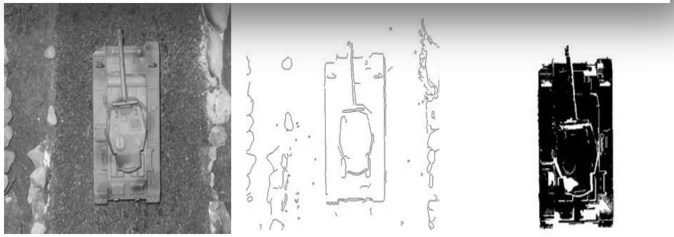
Objectives:

flight control systems for small rockets and missiles with impulsive propulsion for control

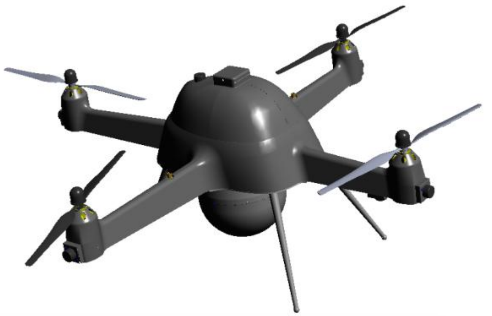
DAAS tasks:

- control by rocket correction engines located around its centre of gravity
- computer model of the rocket and control algorithms developed
- application of visual navigation methods for simple sensor device (Image processing methods applied to missile guidance to hit the target)
- missile attitude determination using artificial neural networks algorithm





Development of Mini Class (R)UAV



Industrial leader WB Electronic

Project objective:
design and build small rotorcraft for military application TRL9

DAAS contribution:
design and build simulator for operator training and research simulator

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

MISSILES CONTROL

ROTORCRAFT

FLIGHT CONTROL

MYSTERY - Methodology of Synthesis of the Aircraft Control System in Emergency Situations

Projects PL

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

MISSILES CONTROL

ROTORCRAFT

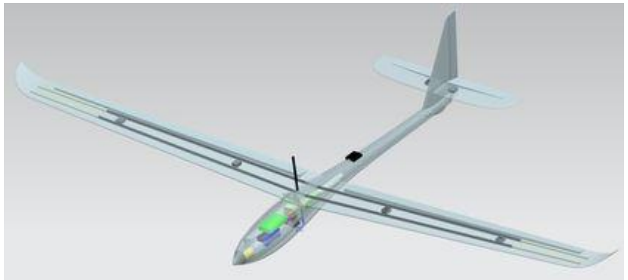
FLIGHT CONTROL

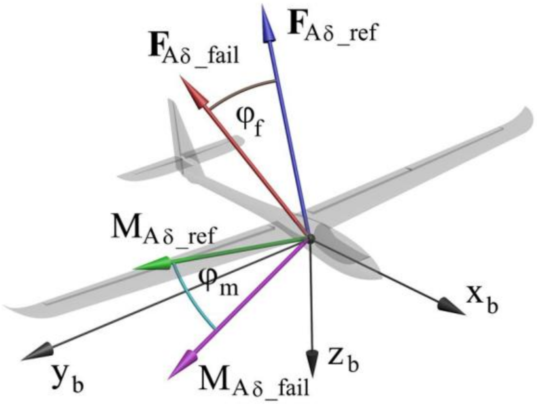
Objective:

develop methods, equipment and control system of UAV for emergency situation

DAAS contribution:

- design of UAV aircraft model for control system (failure) analysis and synthesis
- design of reconfiguration of UAV flight control system
- design of algorithms for integratet navigation system
- design research simulator for hardware-in-the-loop tests

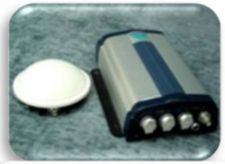




Application of Attitude and Navigation Systems in Evaluation of Helicopter Flying Qualities

Projects PL

PROTEUS
WATER SURFACE
LAND PLATFORMS
NON-METAL MINES
TILTROTOR CONTROL
HELICOPTER NAVIG.
IMAGE NEVIGATION
MISSILES CONTROL
ROTORCRAFT
FLIGHT CONTROL

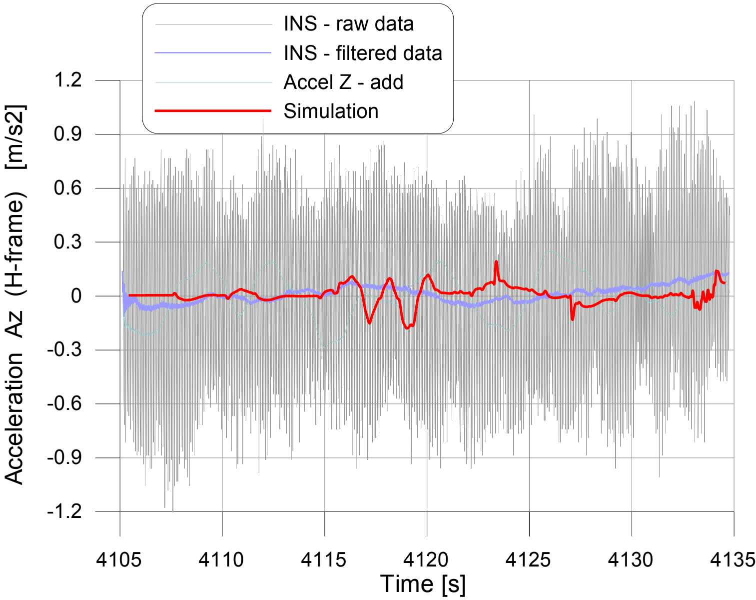


Objectives

Integrated INS-GPS measurement system developed

System used in flight tests as autonomous measurement unit

Results compared with other sensors and simulations



Helicopter Control in Landing

Projects PL

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

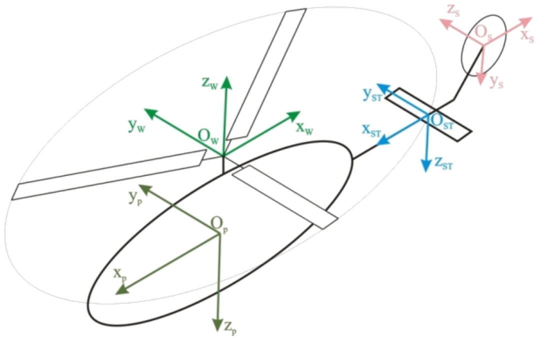
MISSILES CONTROL

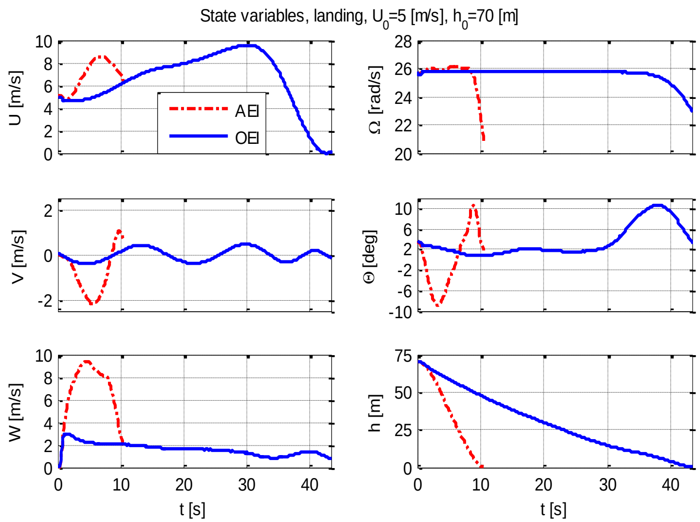
ROTORCRAFT

FLIGHT CONTROL

Objectives:

- to investigate and develop optimal control methods for helicopter landing (autonomous), possibility of avoiding H-V zone
- simulations (FLIGHTLAB and dedicated Matlab model)
- development of optimal control method





Investigation of the influence of lifting surface disturbances on aircraft performance

(Coordinated by Institute of Aviation)

Projects
PL

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

MISSILES CONTROL

ROTORCRAFT

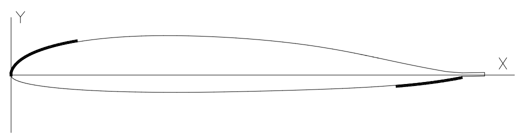
FLIGHT CONTROL

Objectives:

- explore possible disturbances of the rotor blade airfoil and their influence on the rotor performance,
- wind tunnel test
- calculation of disturbed airfoil performance
- calculation of rotor loads in FLIGHTLAB

DAAS contribution

- calculations of rotor loads for different lifting surface disturbances
- FLIGHTLAB model of the main rotor



Methods and algorithms in integrated navigation and control systems

Projects PL

PROTEUS

WATER SURFACE

LAND PLATFORMS

NON-METAL MINES

TILTROTOR CONTROL

HELICOPTER NAVIG.

IMAGE NEVIGATION

MISSILES CONTROL

ROTORCRAFT

FLIGHT CONTROL

Objectives:

Various control methods were developed and implemented on-board of various moving platforms:

- Filtering: Kalman, Joulier-Uhlman
- Navigation algorithms
- Control methods: linear and nonlinear, error function based, reconfiguration based and for autonomous flights
- Investigations: laboratory and in field experiments

Supported by simulations (FLIGHTLAB and dedicated software)

Contact

- **Head:** Prof. Janusz Narkiewicz
  jnark@meil.pw.edu.pl

- **Address:** Nowowiejska 24, 00-665 Warsaw, POLAND

- **Phone:** (+ 48 22) 234 74 45
- **Fax:** (+ 48 22) 622 38 77

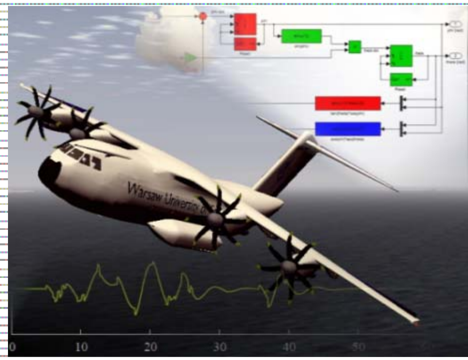
- **E-mail:** **zaiol@meil.pw.edu.pl**

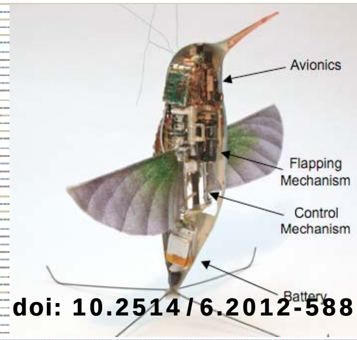
- **Website:**
  - Polish: http://zaiol.meil.pw.edu.pl
  - English: **http://daas.meil.pw.edu.pl**

Division of Mechanics

Division of Mechanics – Research Areas

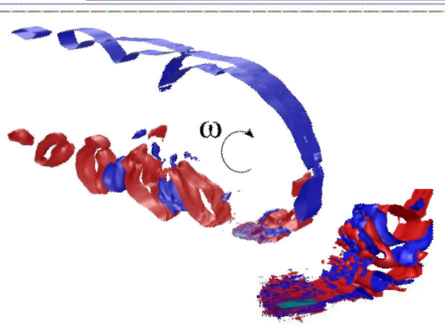
Flight dynamics
- aircraft accidents investigation
- aircraft and spacecraft control
- aircraft system identification
- aeroelasticity
- flight simulators
- nonlinear flight dynamics

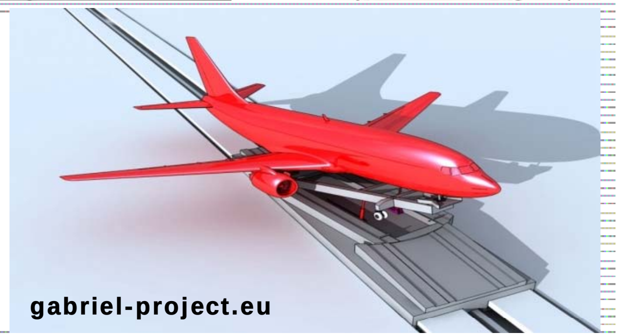




Biomechanics
- optimal strategies
  in sports and medicine
- animalopters

Wind turbines
- turbine modelling





Division of Mechanics – Grants, Patents

Projects participation

- Egzoskeleton (NCBiR)
- MYSTERY (NCBiR)
- Butterfly Motion Analysis (NCN)
- Vortex Generators (ICM)
-

Patents

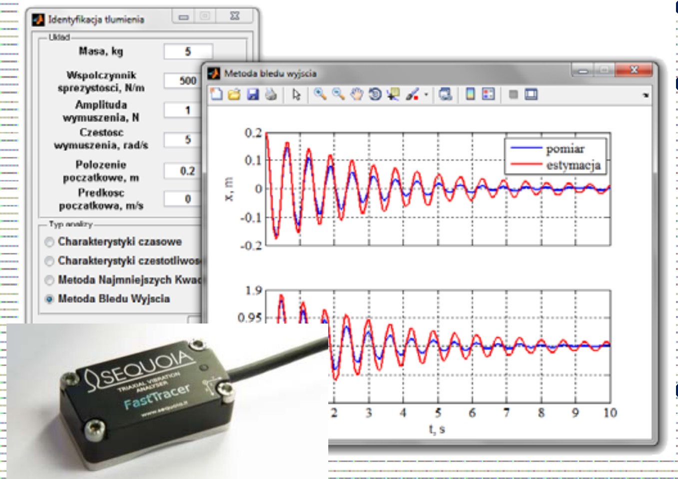
- Ultrasound Signals Identification (application)

Scientific cooperation

- Deutsches Zentrum für Luft- und Raumfahrt (DLR)
  - Simultaneous Flight Control Deflections for Syst.
- Technical University of Denmark (DTU)
  - Darrieus Wind Turbines
- Universidad de San Buenaventura – Bogotá
  - New Methods for Multisine Inputs Design
- Jan Kochanowski High School in Radom„Olim
  Wiedzy Technicznej" 2nd stage

Division of Mechanics – Lab

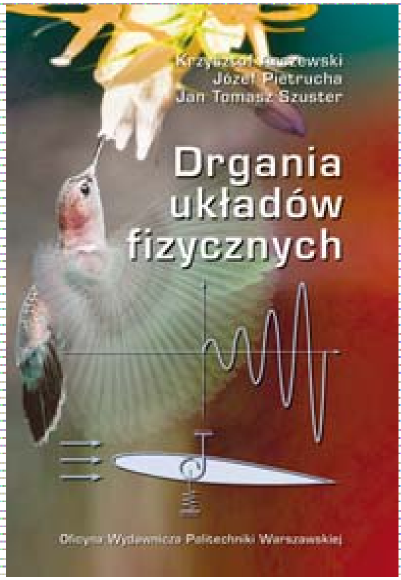
Vibrations Lab

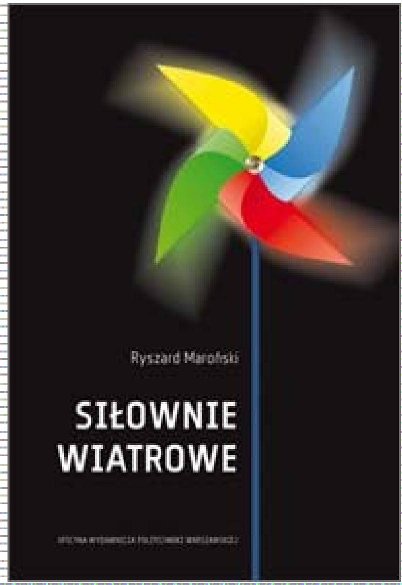


- tilting wind tunnel (flutter, spin)
- Mi-2 helicopter blade
- measurement equipment:
  - accelerometers, anemometer, vibration shakers, camera
- computer lab

Books

- R. Maroñski: Wind Turbines, 160 pages, Oficyna Wyd. PW, 2016.
- R. Maroñski: Optimal Strategies in Flight Mechanics and Biomechanics, 112 pages, Oficyna Wyd. PW, 2016
- K. Sibilski (ed.): Mechanics in Aviation ML-XVII, 2 vol., PTMTS, 2016
- M. Lasek, K. Sibilski: Micro-UAV Flight Dynamics, Oficyna Wyd. PW, (submitted)





Aircraft Design Division

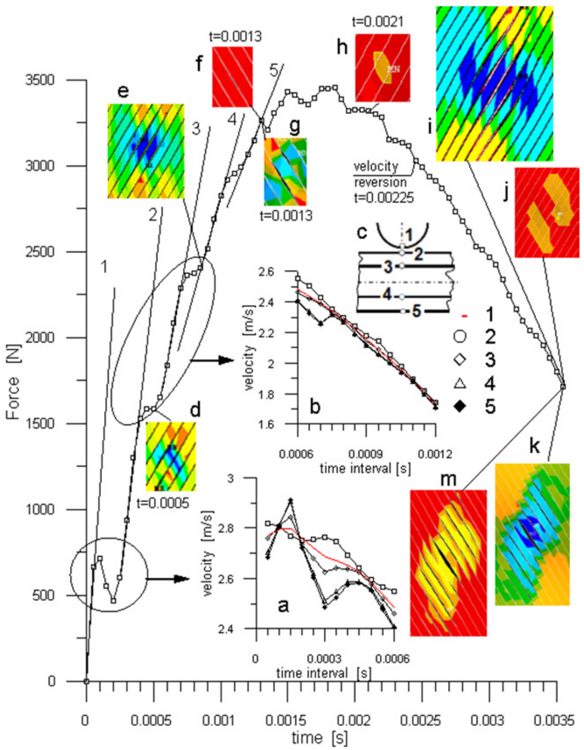
Institute of Aeronautics & Applied Mechanics, Faculty of Power & Aeronautical Engineering, Warsaw University of Technology

Overview of Research & Design Activity

prepared by **Zdobyslaw Goraj**

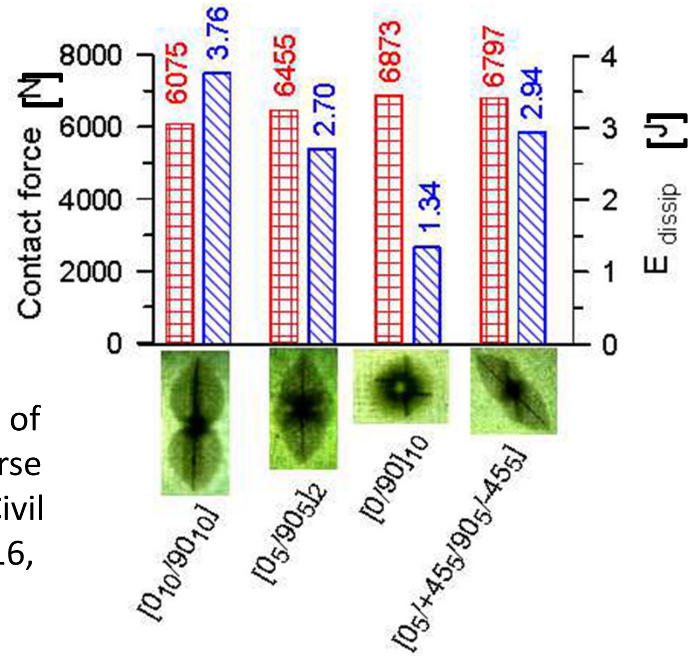
Damage tolerance of composite structures

- damage caused by low energy impacts, damage formation mechanisms and their outcomes
- delamination growth under quasi-static and cyclic loading



growth stages of delamination resulting from impact

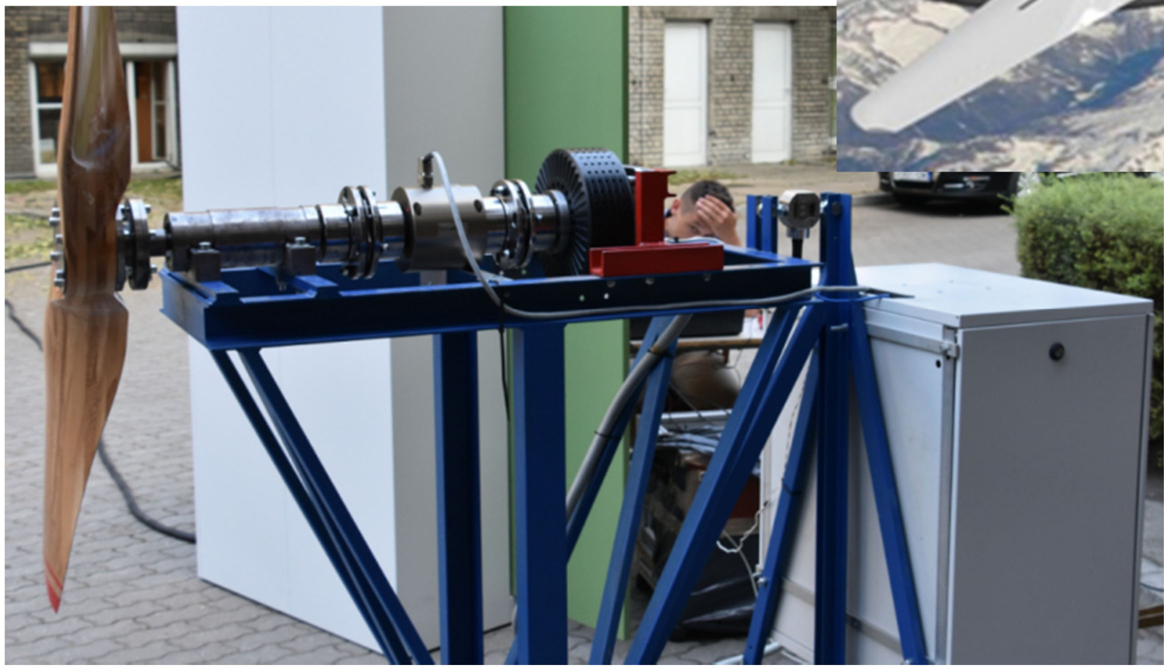
P. Czarnocki, T. Zagrajek, „Sequence of damage events occurring in the course of low energy impact", Archives of Civil and Mechanical Engineering, 16,2016, pp.825-834



Delamination Resistance of Laminates with Various Stacking Sequences against Low Velocity Impacts

2016/17

Hybrid propulsion system with fuel cells for a light aircraft - AOS-H



Dynamically similar demonstrator of the inverted joined wing airplane MOSUPS

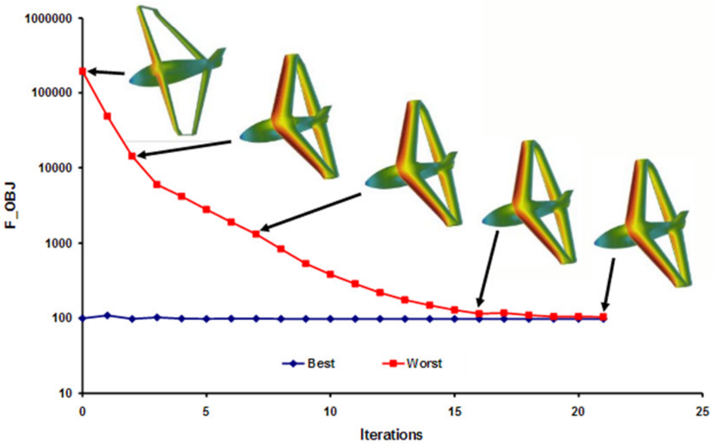
Aerodynamic optimisation

$$F_{obj} = 1000 \cdot C_D / C_L$$

constraints:

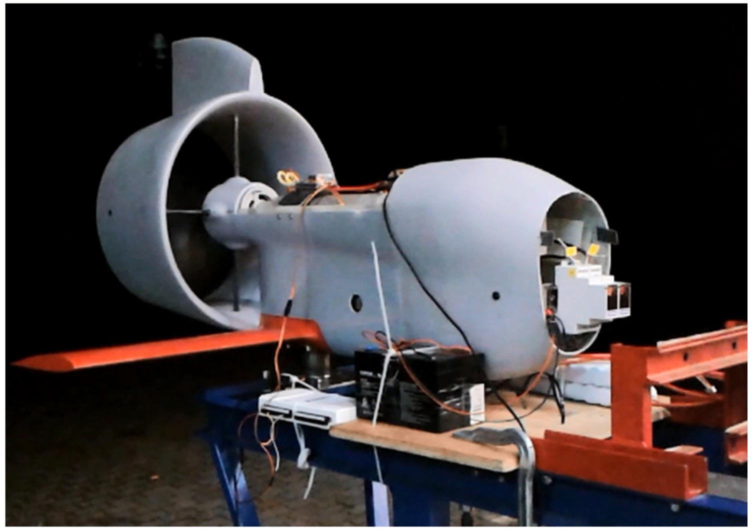
$$mg = L$$

$$\sum M_{CG} = 0$$



variables: 15 (50)

algorithm: Swarming

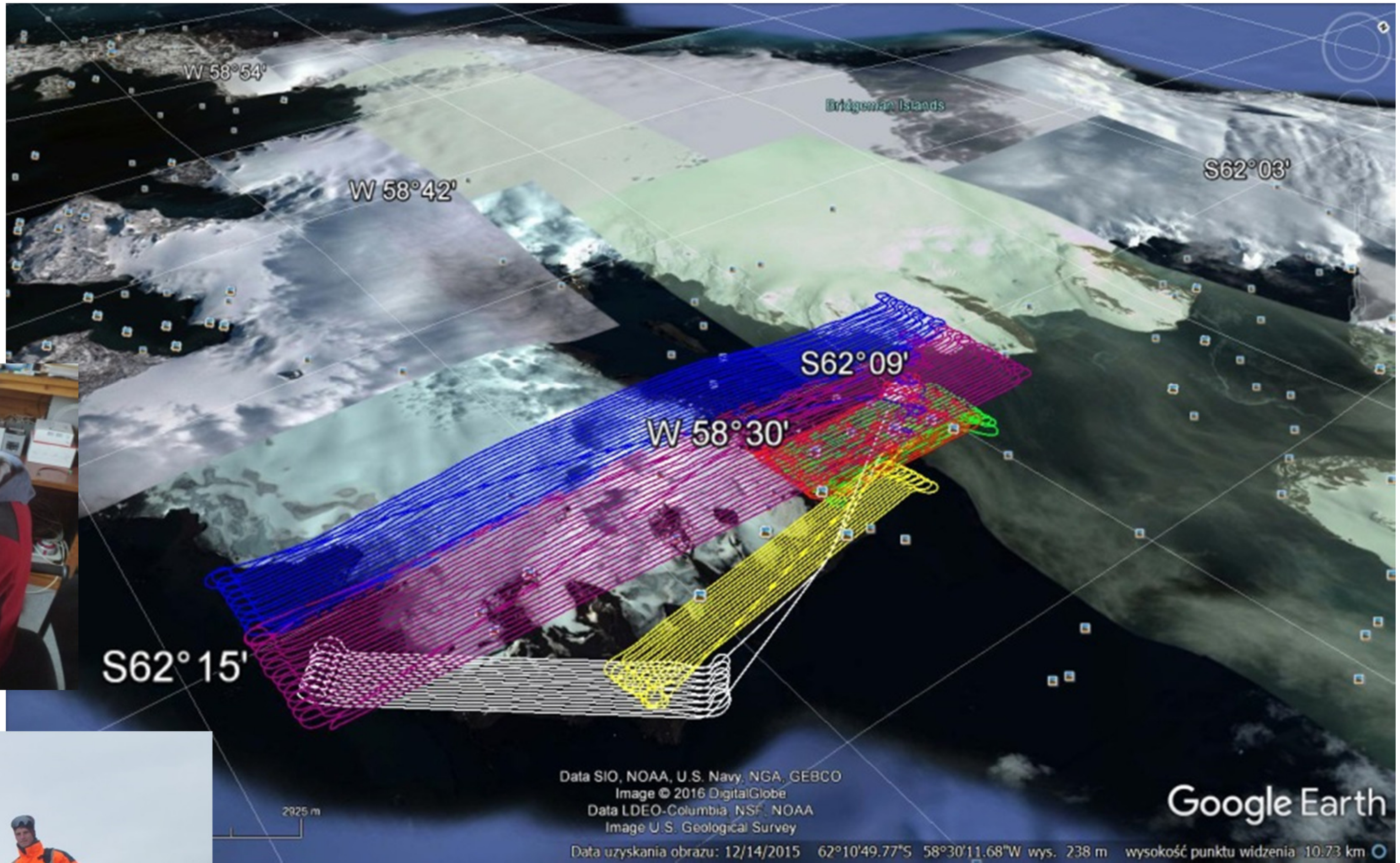


Tasks performed by the AIRCRAFT DESIGN DEPARTMENT of the FACULTY of POWER and AERONAUTICAL ENGINEERING:

1. Design and Optimization of Low Speed Ducted Fan
2. Developement the tools for Multicriterial optimization

Project POL-NOR/197810/84/2013): A novel approach to monitoring the impact of climate change on Antarctic ecosystems, MONICA (1/2)

Project POL-NOR/197810/84/2013): A novel approach to monitoring the impact of climate change on Antarctic ecosystems, MONICA (2/2)



Tasks performed in a current 41-th Polish Antarctic Expeditiontion (up to 17 Nov 2016):

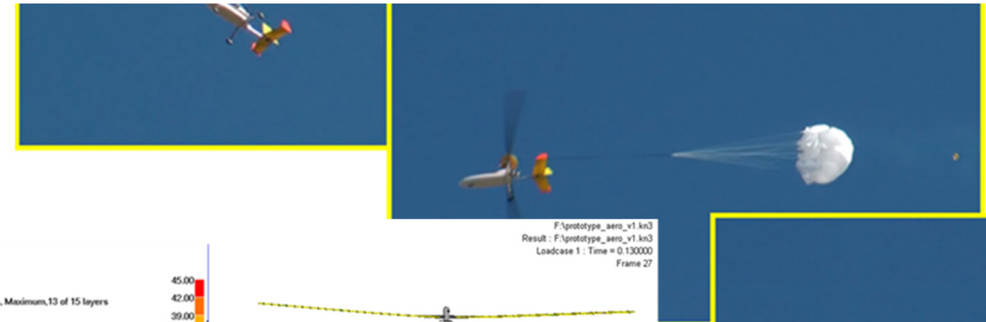
Distance flown: 1600 km

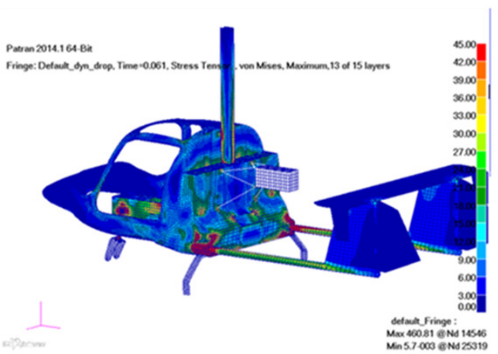
Total time of flight: 16,3 hours

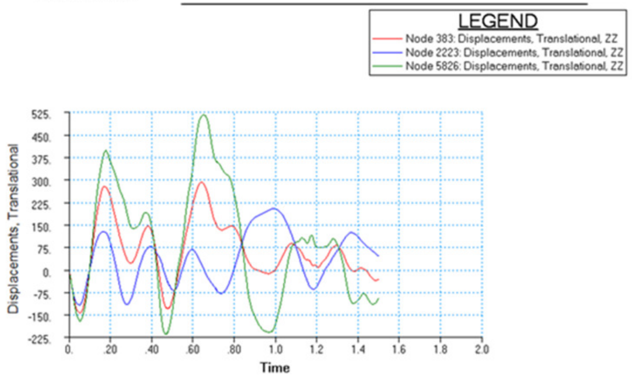
No of collected orto-photos: 15 447

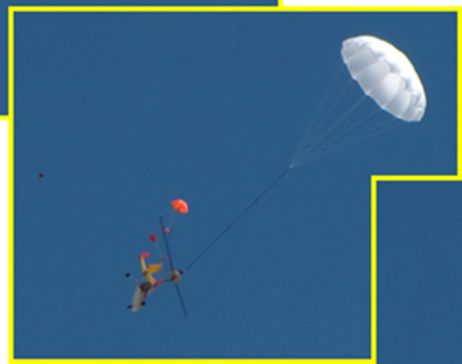
Project INNOTECH-K3/IN3/29/227736/NCBR/14: Rescue system for light gyrocopters

Aim:
elaboration of parachute rescue system (PRS)
& study the dynamic phenomenon occuring during PRS use



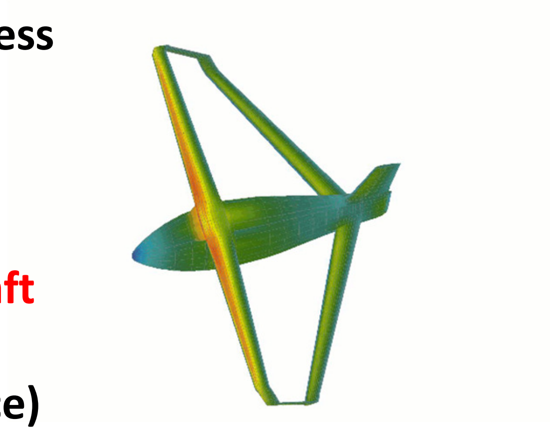


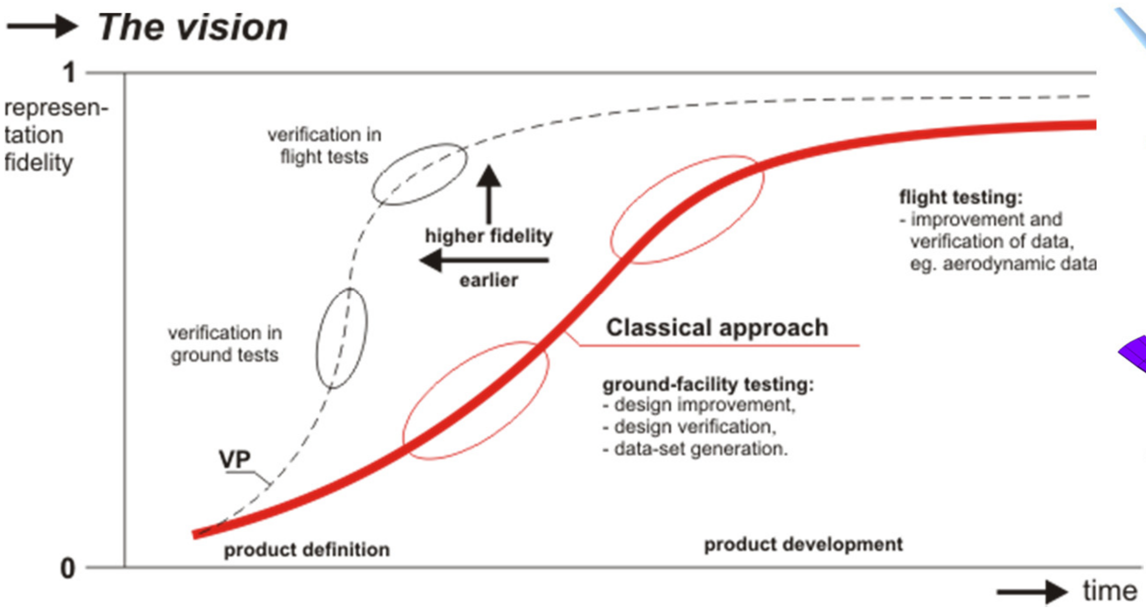


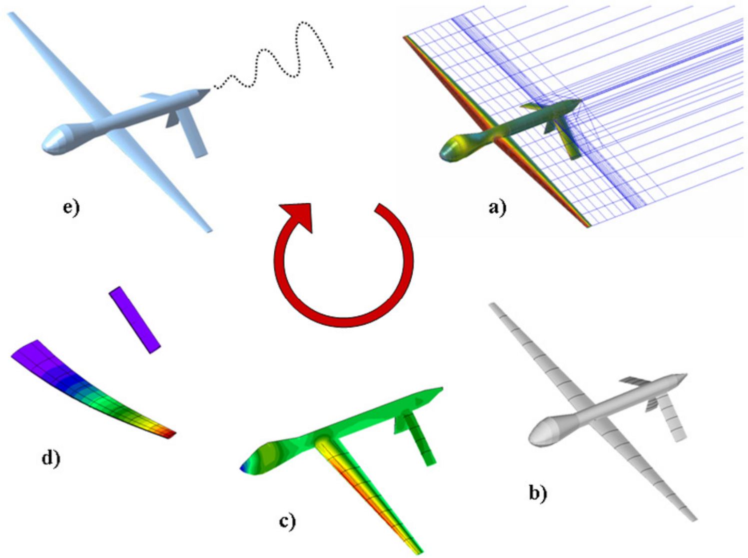


Optimization in Aircraft Design

- **Application of optimization methods** into aircraft design process
- **Linking of many disciplines**: aerodynamics, flight qualities (trimming, stability, controllability), performance and stress analysis) within processes of multidisciplinary optimization
- Development of the software **reducing time and cost of aircraft design** (OptiM – optimization algorithms, PANUKL – aerodynamic analysis, SDSA – flying qualities and performance)



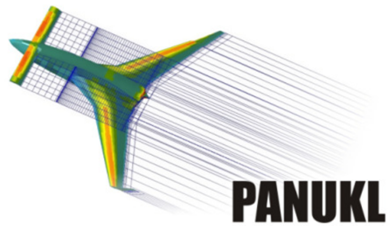




Aided Design of aircraft

- ______________________________

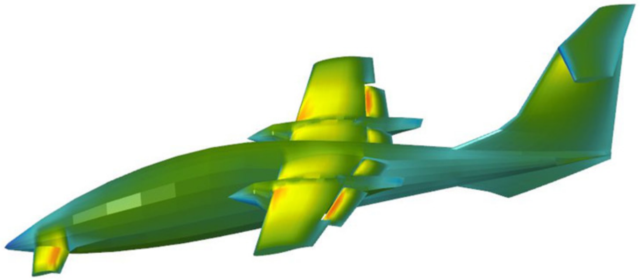
  The specialized software,
  which is used within following stages of aircraft design,
  is developed and validated.

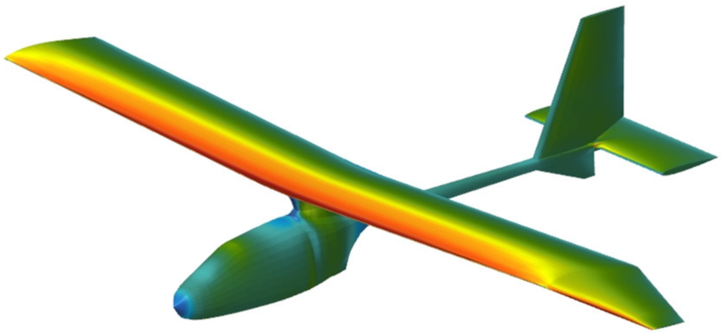


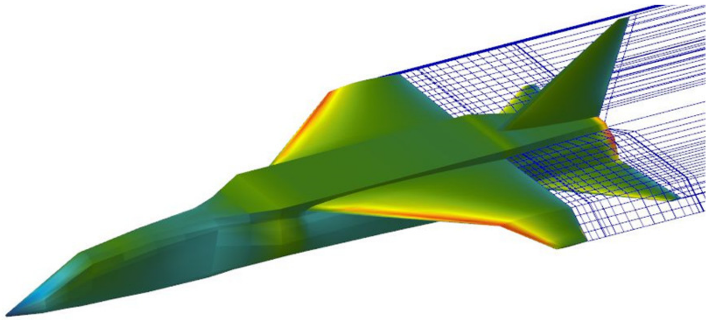
- **Software developed in Aircraft Design Department:**
  - **PANUKL – panel method – started within project (KBN PB0044/56/93/04) supported by Polish Committee of Scientific Research - „The study of the stability of the complex aerodynamic configuration”**

  - **SDSA – Package for dynamic stability analysis and performance computation – developed within FP6 project: Simulating Aircraft Stability and Control Characteristics for use in Conceptual Design, SimSAC**
  - **Optim – software system to solve optimization problems partly developed within MOUSPS project supported by The National Centre for Research and Development**

Projects using PANKUL

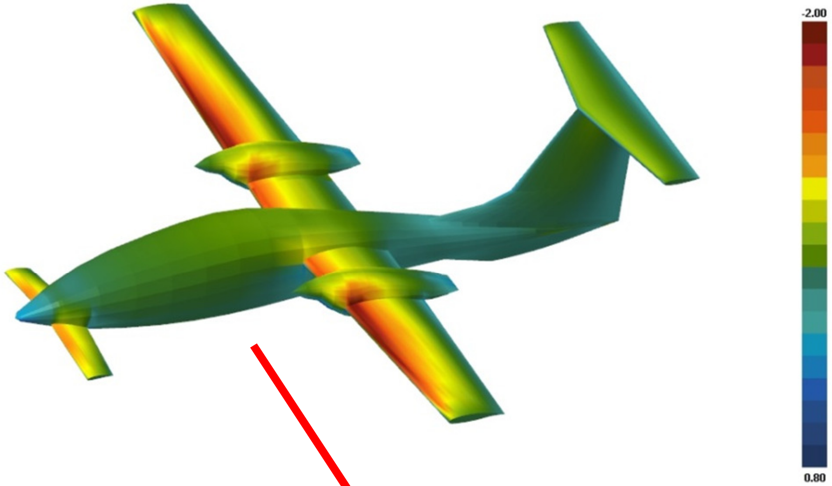


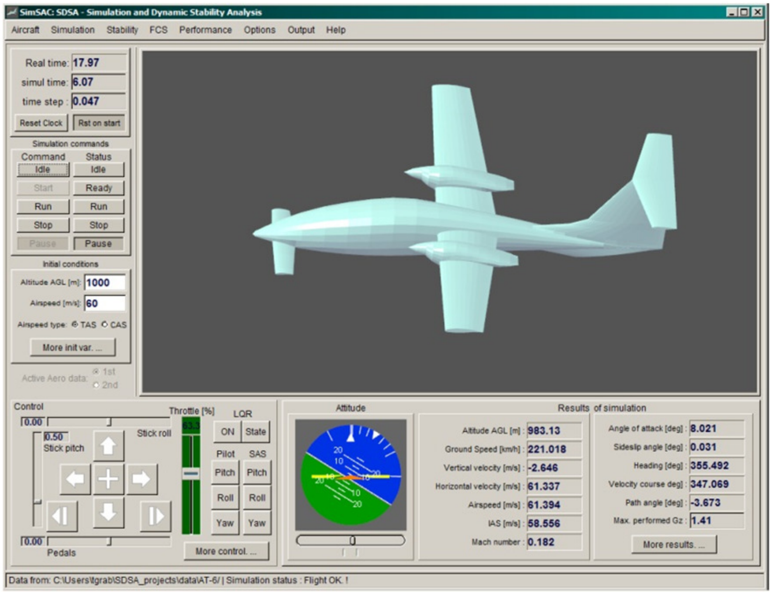


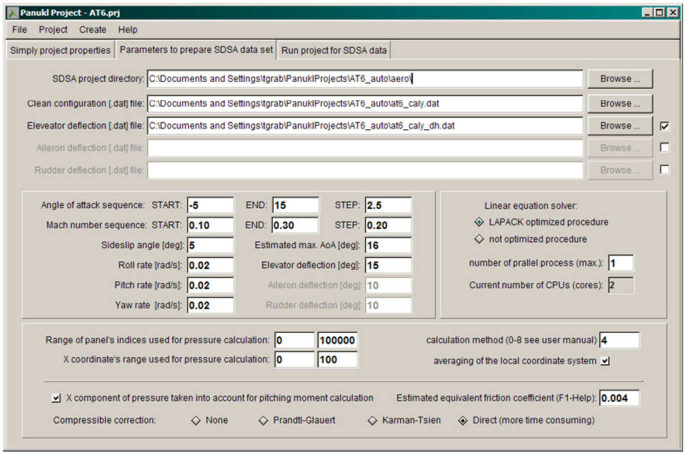


The data flow between different disciplines is very important within design process

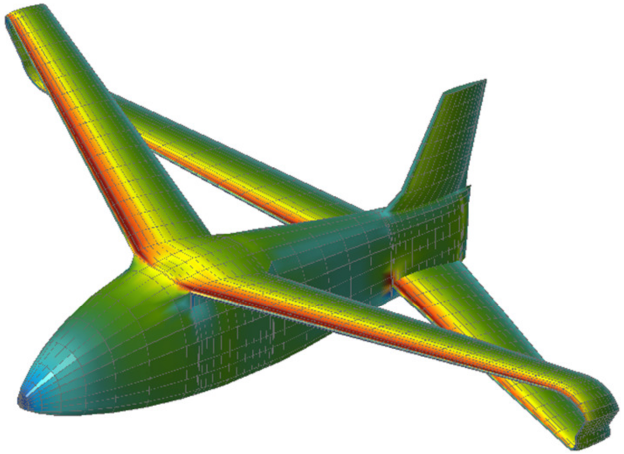
Exchange of PANUKL and SDSA





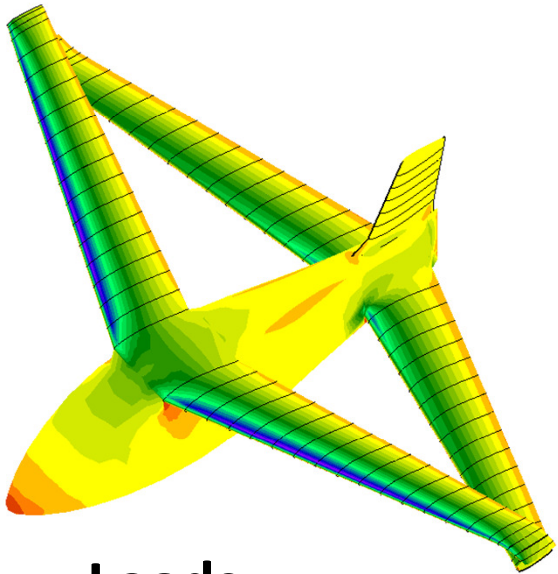


Export of data and results from PANKUL package to CalculiX



PANUKL

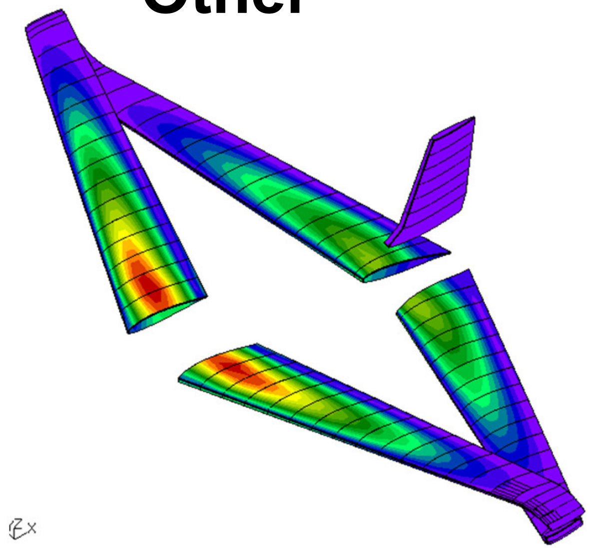
- Geometry
- Pressure distribution



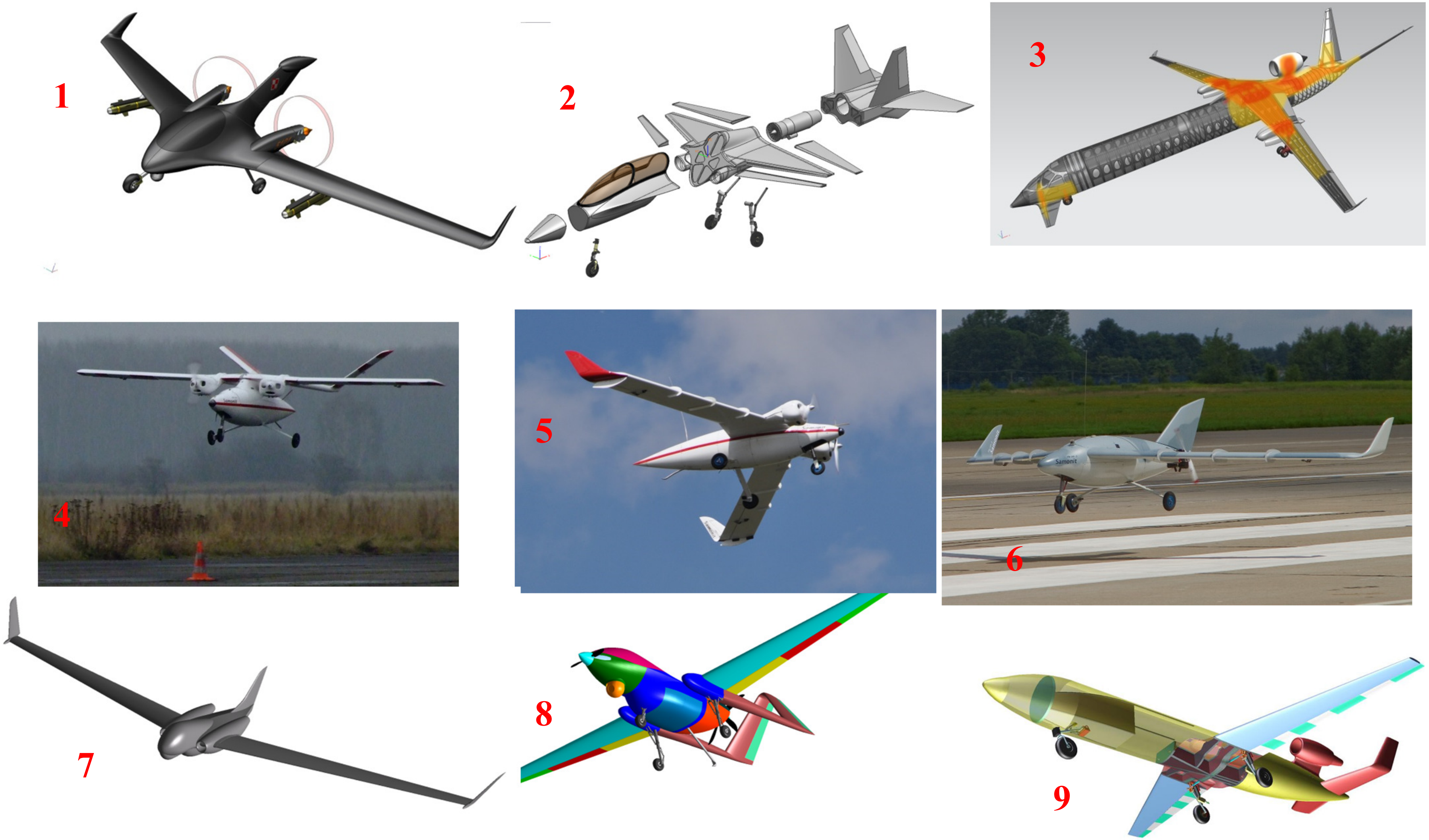
- Loads
- Constrains
- Material
- Other

CalculiX

- Stress
- Deflection
- Other

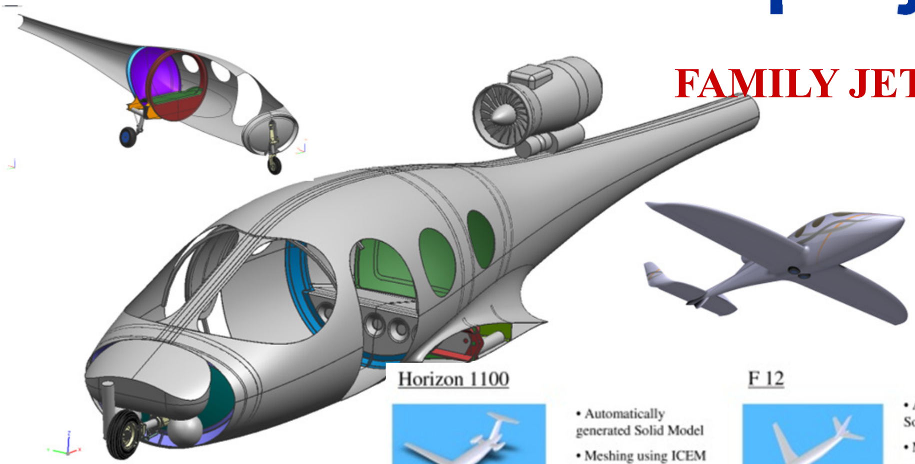


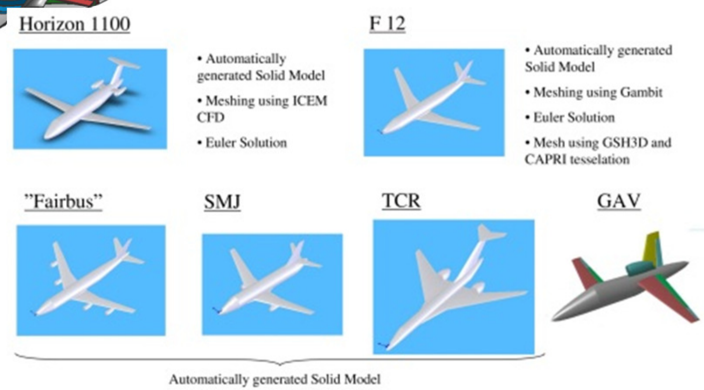
Experience - Selected projects



Selected projects

FAMILY JET





SimSAC: *Simulating Aircraft Stability and Control Characteristics for Use in Conceptual Design*

AEROVAN

- STOL passenger airplane

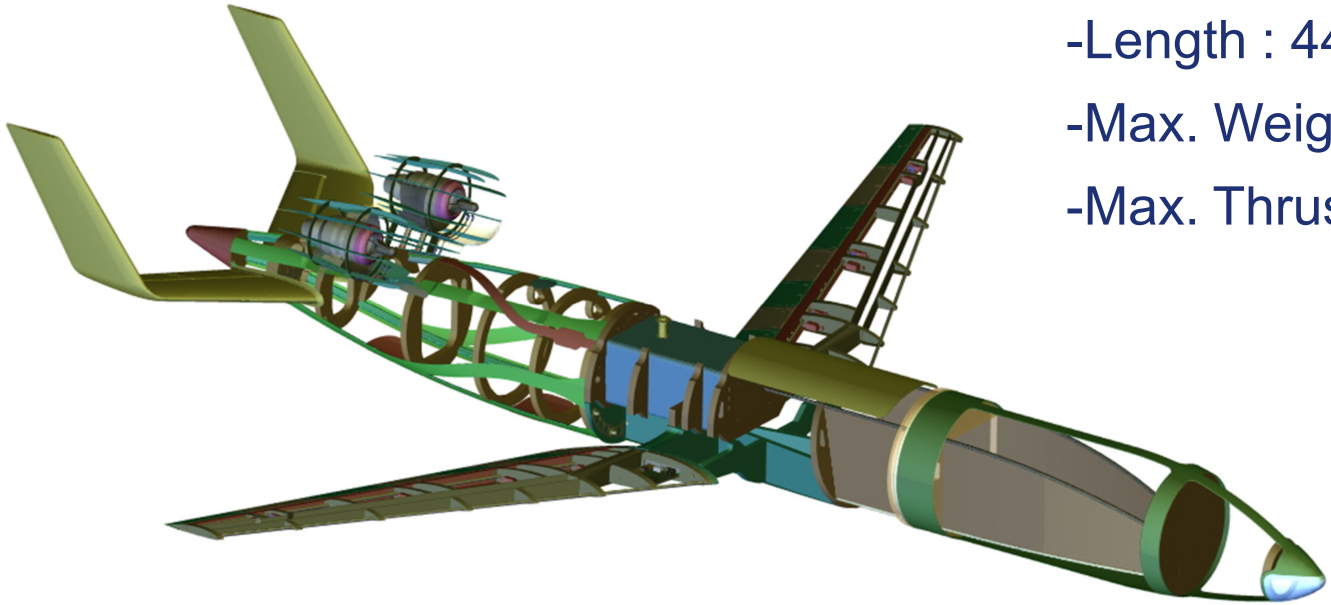
B2 - Long Range Business Jet

EFFICIENT SYSTEMS AND PROPULSION FOR SMALL AIRCRAFT

ESPOSA

Innovative Evaluation Platform (IEP) Design

- Preliminary Design and Detailed design :
  - Modular Flying Platform Airframe



<u>Main characteristics</u>

Property of NACRE consortium

-Span : 4160 mm

-Length : 4445 mm

-Max. Weight : 100 kg

-Max. Thrust : 400 N

<u>Sizing is based on</u>:

-Froude Similarity

-Operational aspects

-Available engines

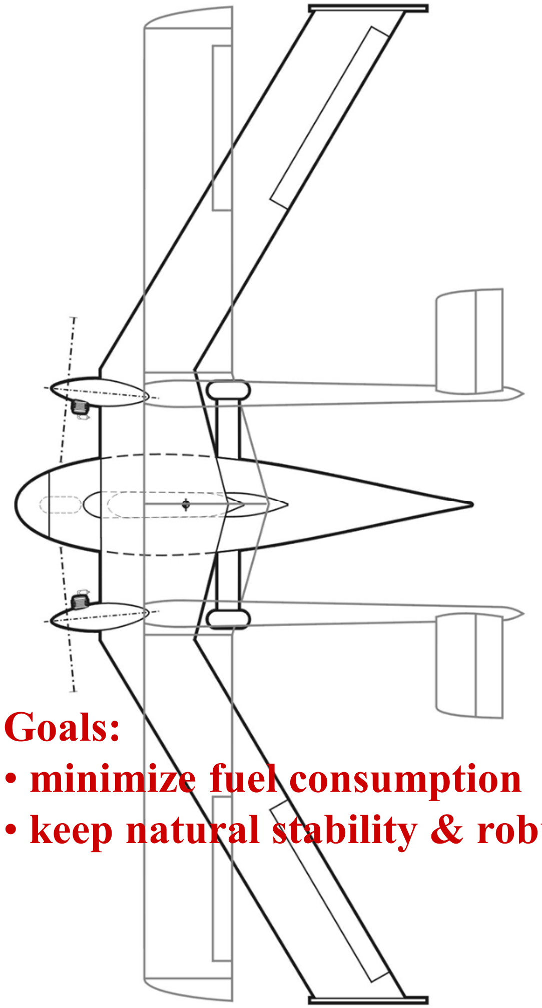
  - Modular Flying Platform Systems (FMCS, Autopilot)
  - Ground Segment

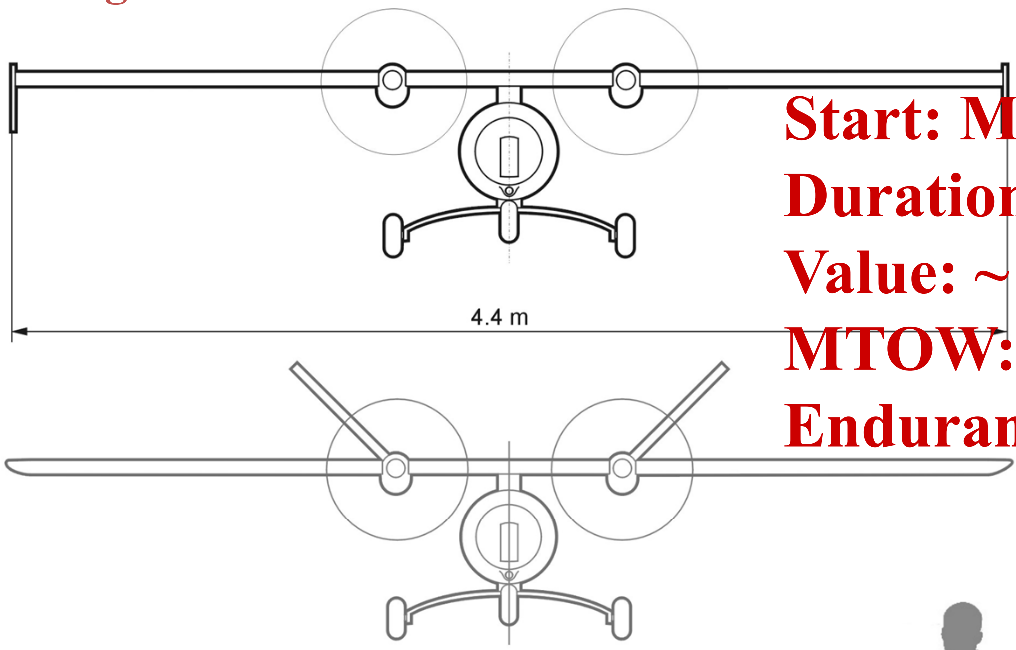
Taxi tests, Bemowo

Taxi tests in Modlin

SAMONIT - Polish Research Program For Development of an Advanced Aerial Surveillance System

Classical and tailless configurations under consideration





Start: May 2007

Duration: 3y

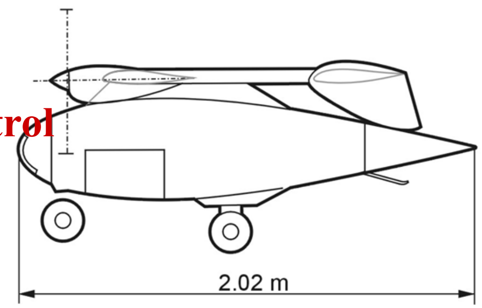
Value: ~ $ 0.9 mln

MTOW: 90 kg

Endurance: 24 h

Goals:

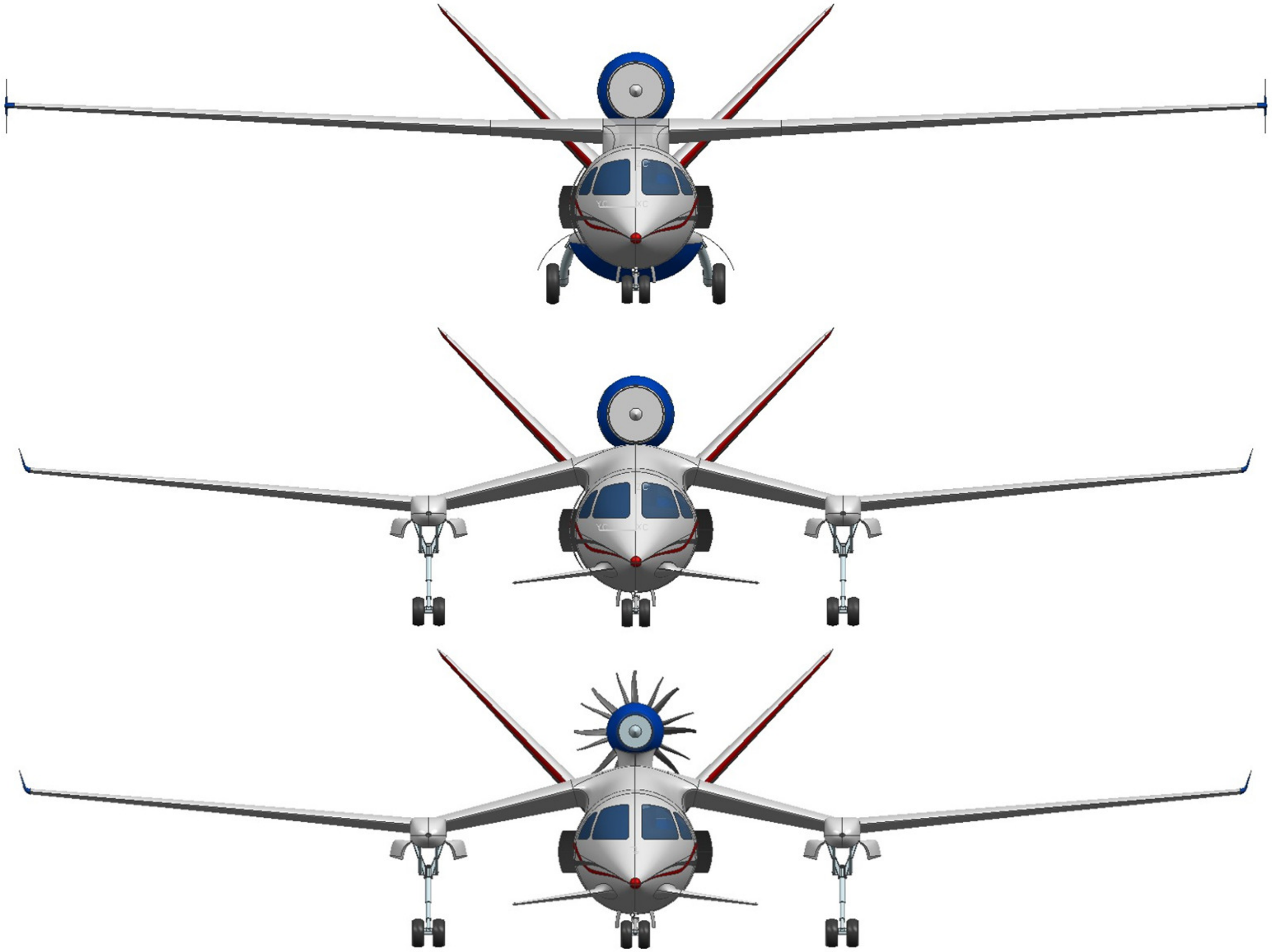
- **minimize fuel consumption**
- **keep natural stability & robust control**



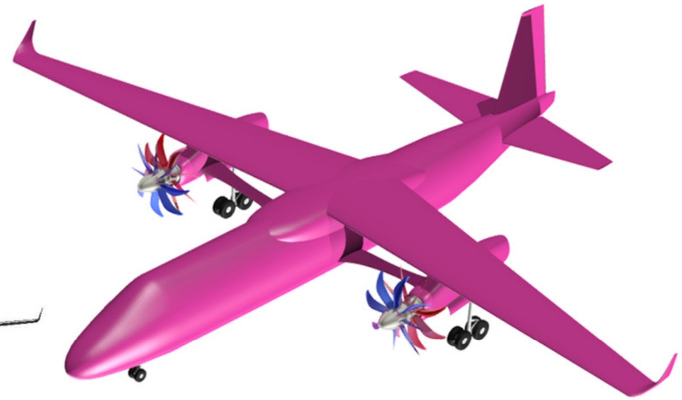
Flight tests

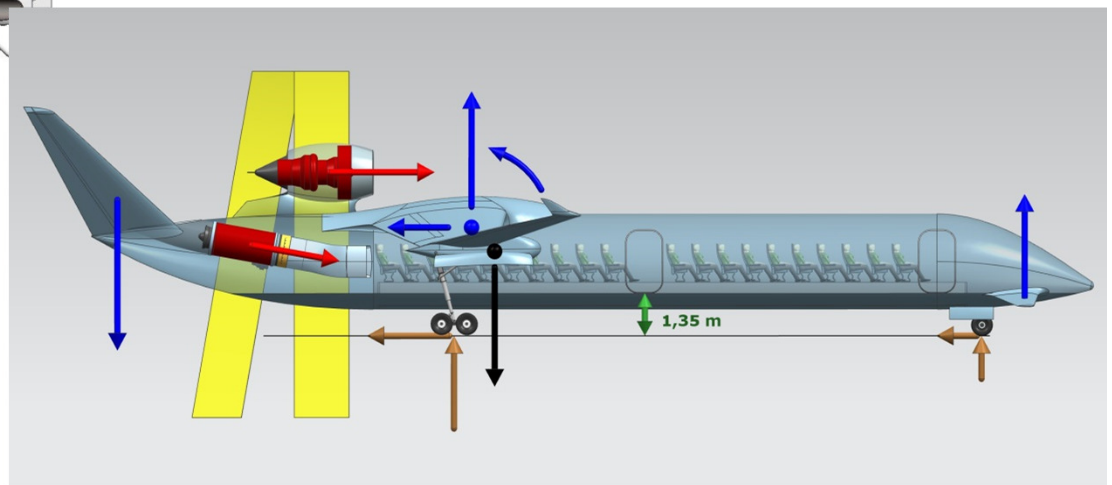
Flight tests

Polish Regional Jet Concepts – starting point for structure analysis

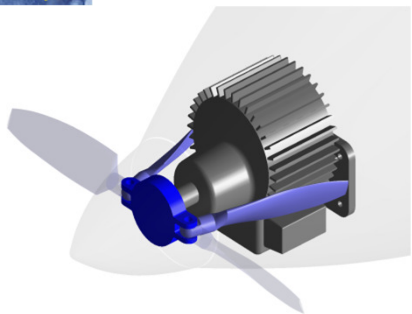


Central European Jet Demonstrator



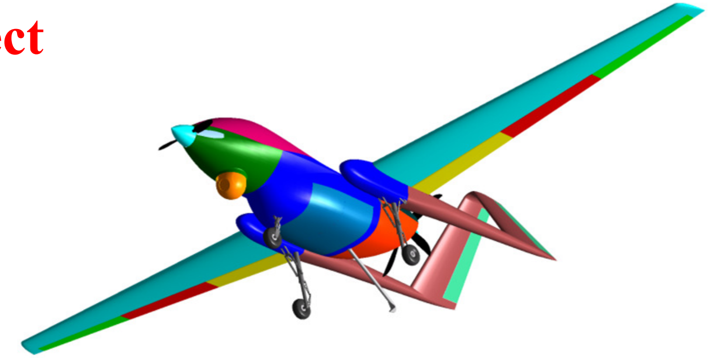


Push-pull-redundant engine design

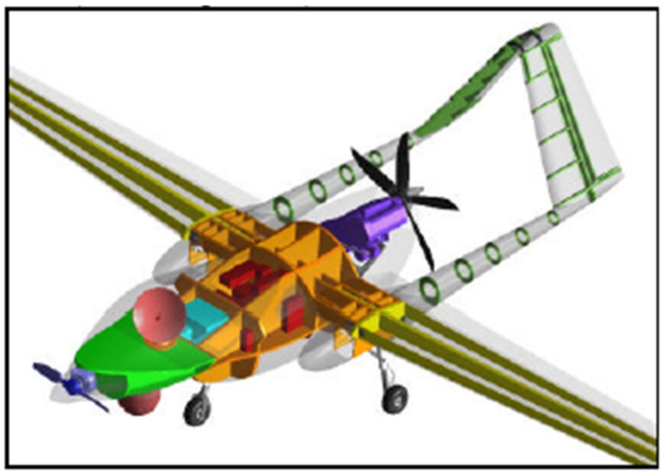


CAPECON Project

Maximum Takeoff Weight	930kg
Basic Empty Weight	488 kg
Fuel Weight	225 kg
Payload Weight	*217* kg
Span	12.6m
Reference Area	10.22m^2
Propulsion Type	Piston
Propulsion	TAE 125
Flight Altitude	***20*** kft
Total Endurance	*42* hr

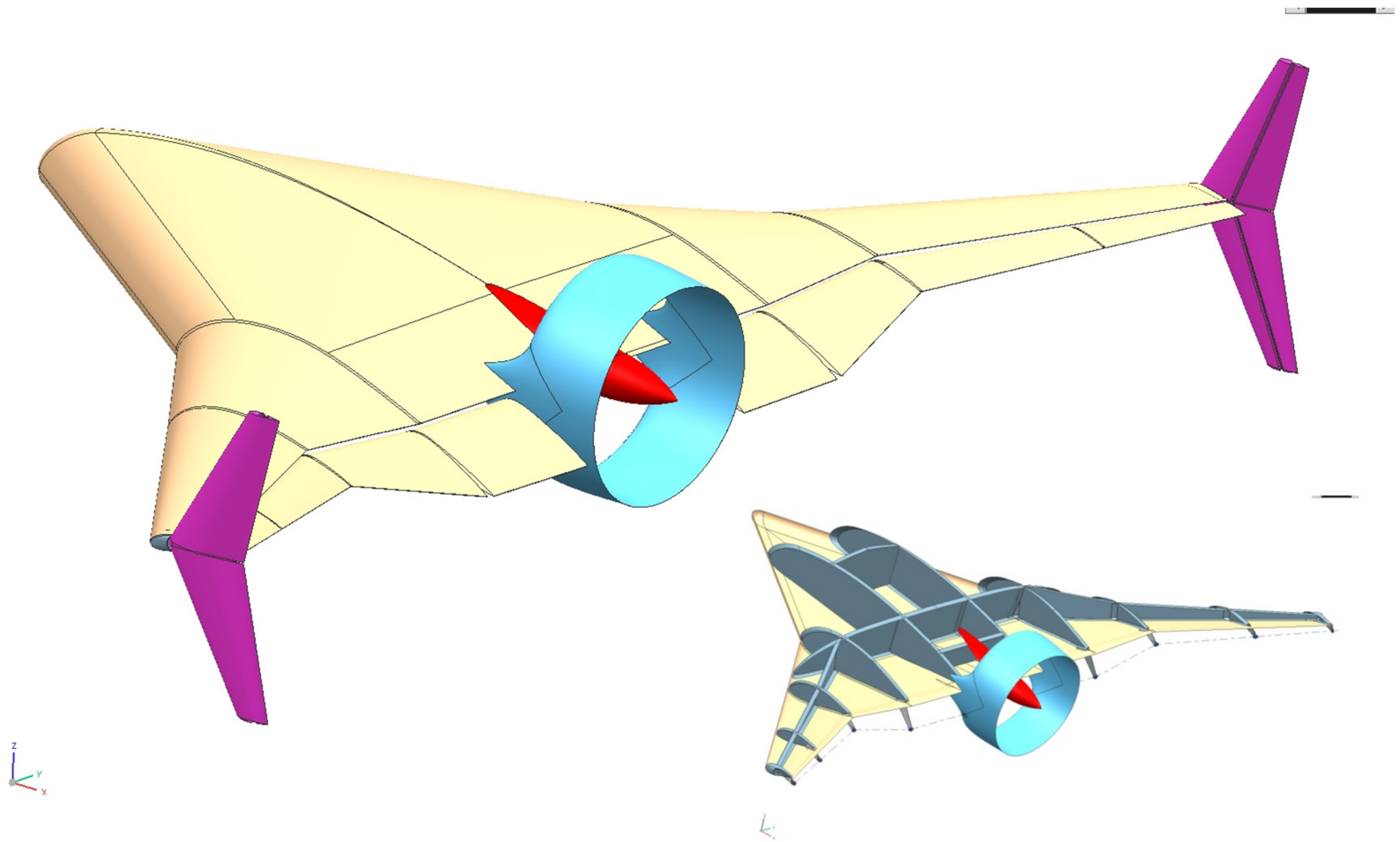


WUT PW103 Configuration

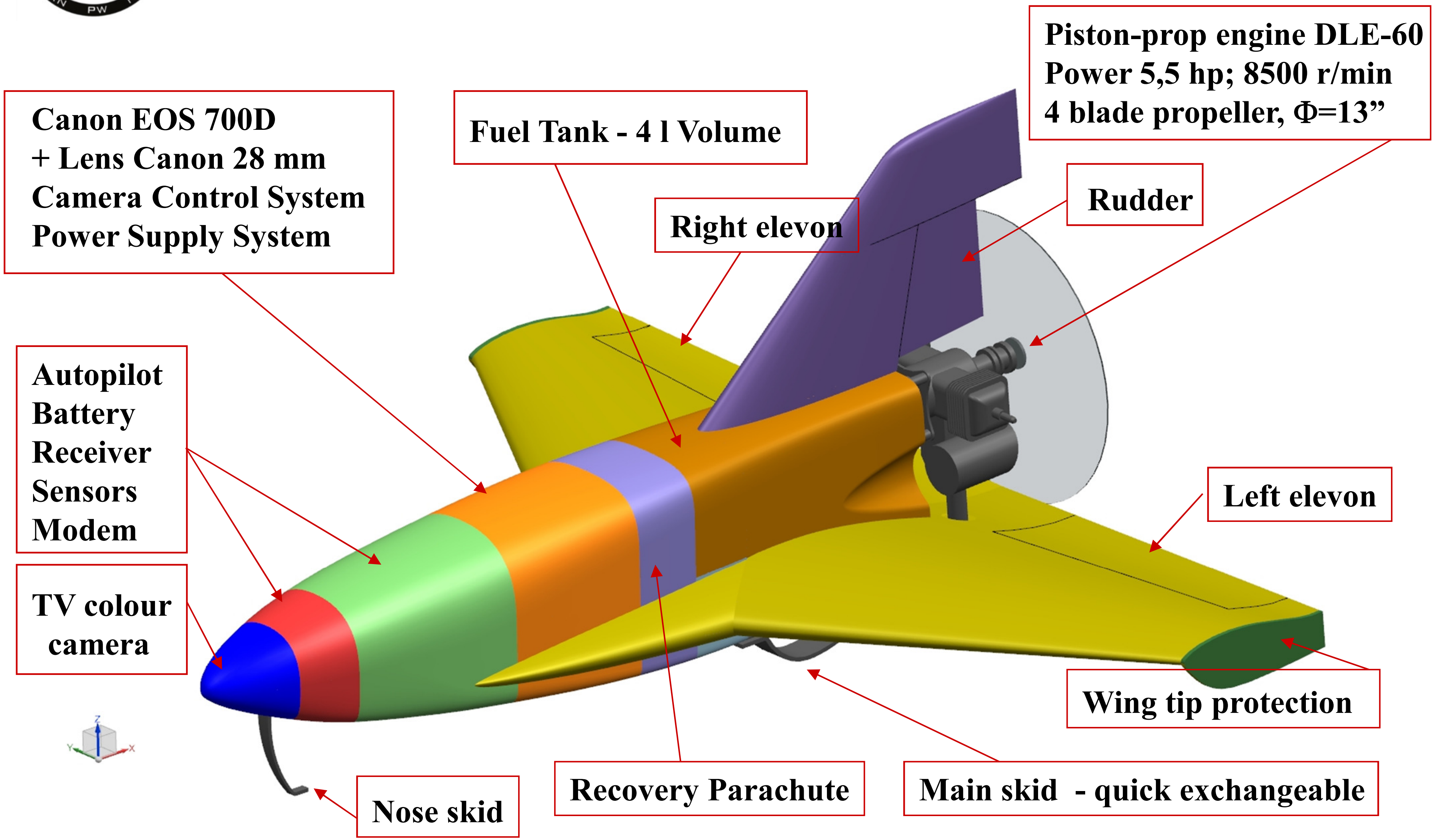


WUT PW103 Internal Layout

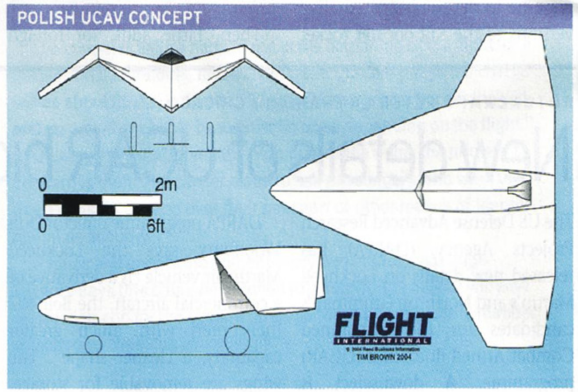
Penguin - High wing loading UAV for surveillance in windy, turbulent environment – now in progress



MONICA_2 – more classical & lighter version



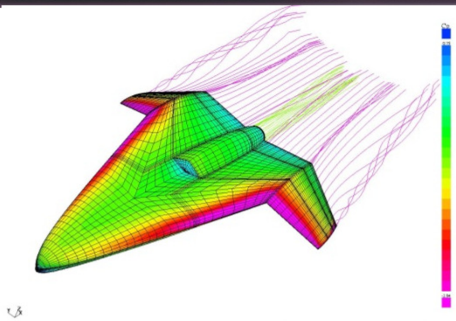
PW-124 – UCAV (Unmanned Combat Air Vehicle)



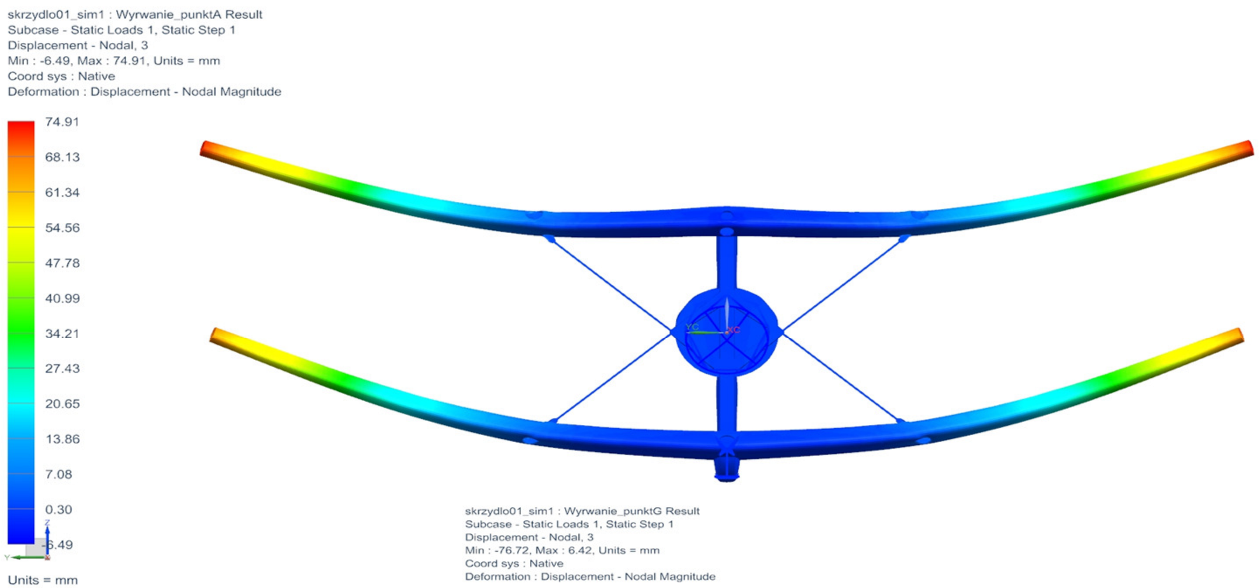
RESEARCH

Polish university reveals concepts for UCAV

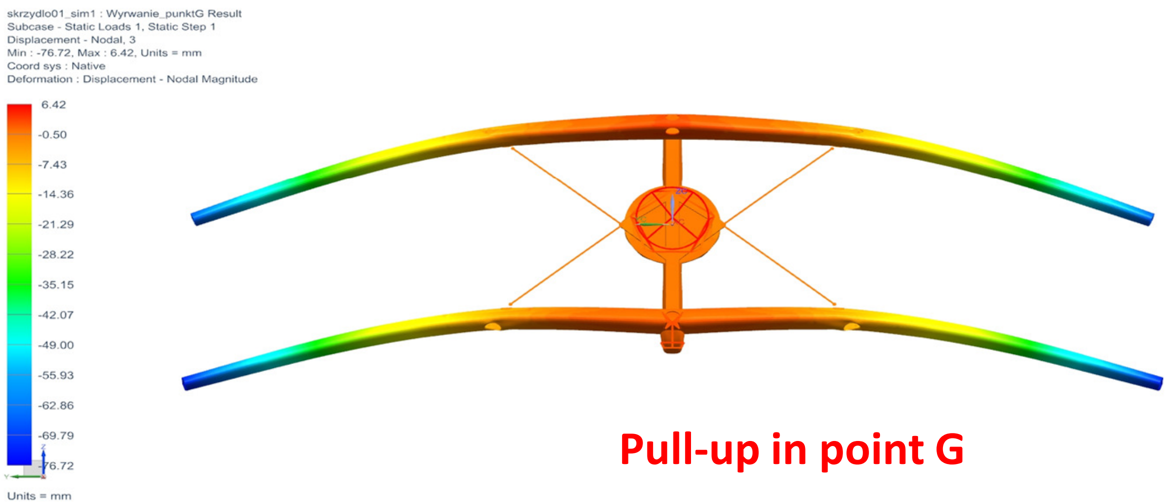
The Warsaw University of Technology has unveiled concepts of what it hopes will be a Polish unmanned combat air vehicle (UCAV). Initial design work has been carried out on an air vehicle designated PW-124 which is proposed as a 700km (380nm) maximum range, high subsonic speed ground-strike system with an endurance of 2.5h. The UCAV would be powered by a Microturbo TRI 60-5 turbojet engine.



Displacements of nodes [mm]



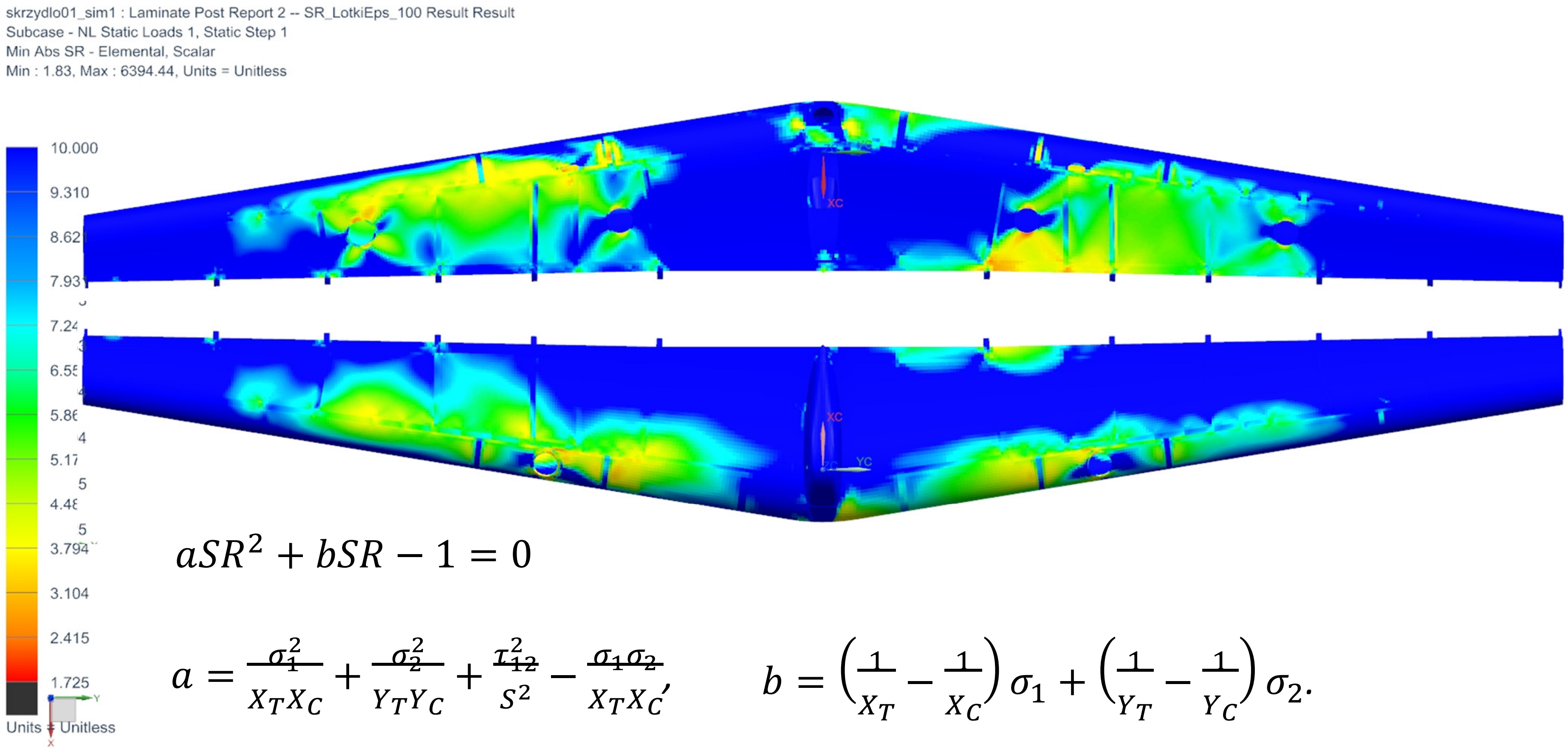
Pull-up in point A



Pull-up in point G

PC-NASTRAN; ~ 1,5 mln degrees of Freedom

Lower wing – **Sizing of structure through the loading** (Envelope of minimum strength ratio SR in case of brutal aileron deflection (100% of ultimate loading) – nonlinear analysis. Top view in upper figure, bottom view in lower figure)



$$aSR^2 + bSR - 1 = 0$$

$$a = \frac{\sigma_1^2}{X_T X_C} + \frac{\sigma_2^2}{Y_T Y_C} + \frac{\tau_{12}^2}{S^2} - \frac{\sigma_1 \sigma_2}{X_T X_C}, \qquad b = \left(\frac{1}{X_T} - \frac{1}{X_C}\right)\sigma_1 + \left(\frac{1}{Y_T} - \frac{1}{Y_C}\right)\sigma_2.$$

SR is inversely proportional to the effort of structure (and to coefficient of safety)

AFLoNext **Active Flow- Loads & Noise control on next generation wing**

WP1.2.4 DAMAGE ASSESSMENT and TEST

Specification of benchmark impact tests

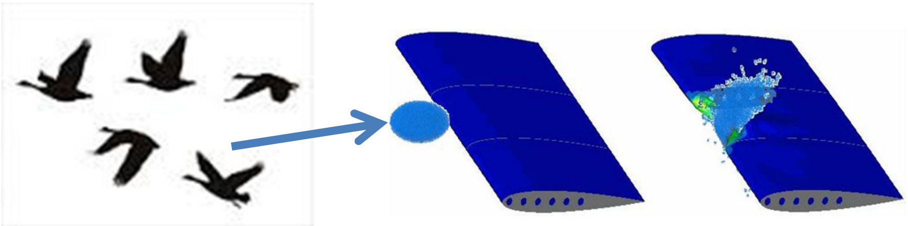
Requirements on PW:

- Manufacturing of 5 flat composite test specimen 440 x 425 mm (2 x sandwich, 3 x sheet)
- Manufacturing of 10 flat composite test specimen 150 x 100 mm
- Specification of hail impact speed (analysis of airworthiness requirements)
- Specification of other requirements on measurement (piezo sensors, SHM etc.)

Simulation model (equations + constant coefficients) will be useful for certification procedure of the new wing (wing must withstand the impact of 4 lb bird)

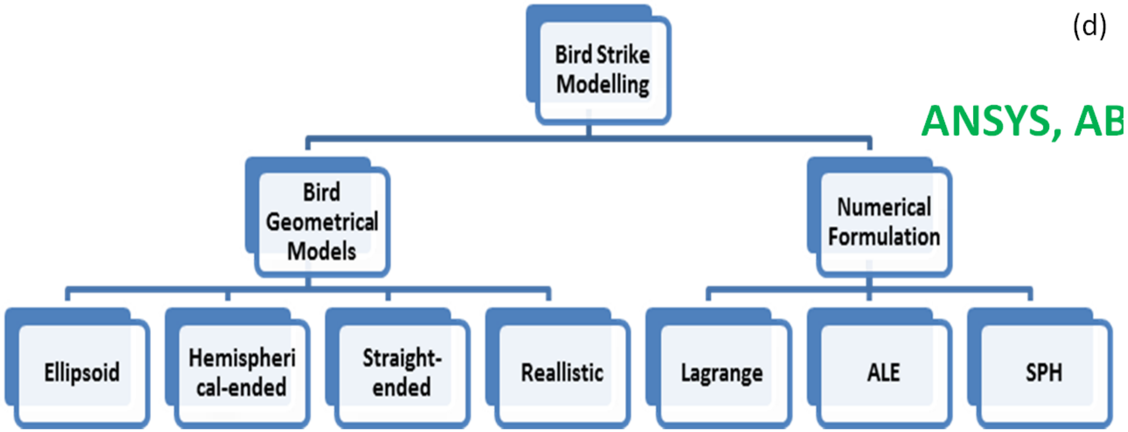
AFLONEXT - Bird strike & hail impact (photos after AFLONEXT DoW)

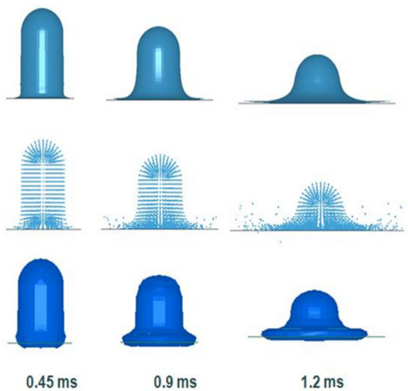
SOURCES OF UNCERTAINTIES FOR BIRDSTRIKE & HAIL IMPACT MODELLING

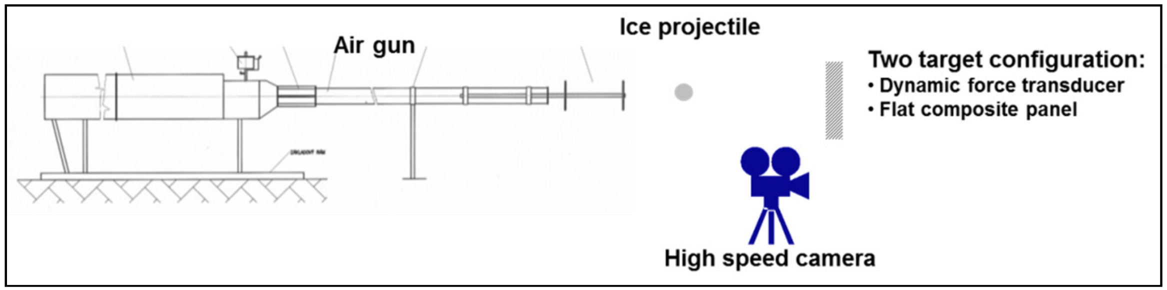


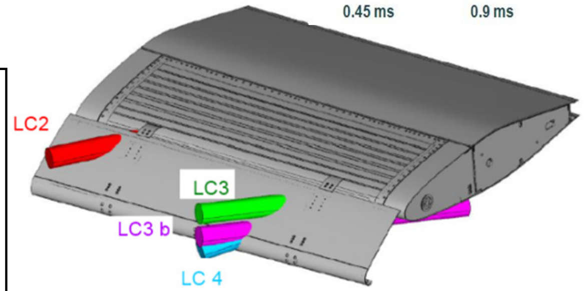
(d)

ANSYS, AB





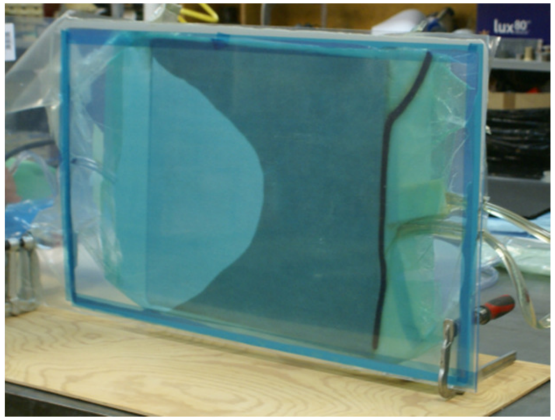


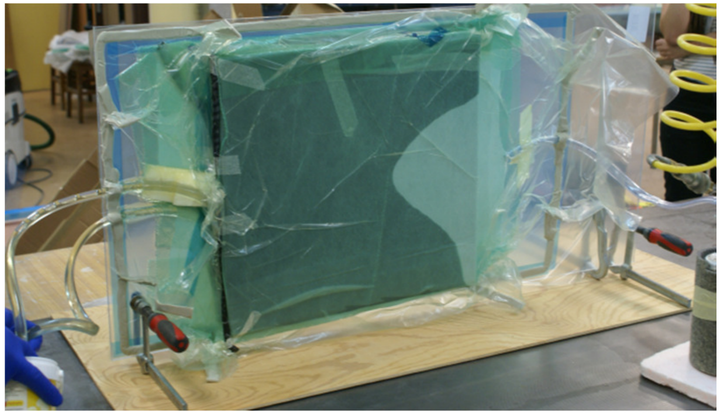


Manufacturing process (Silesian Research Centre & Aircraft Design Lab (PW))

Process

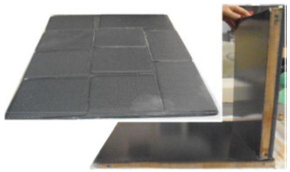
1. Injection process
   vacuum infusion





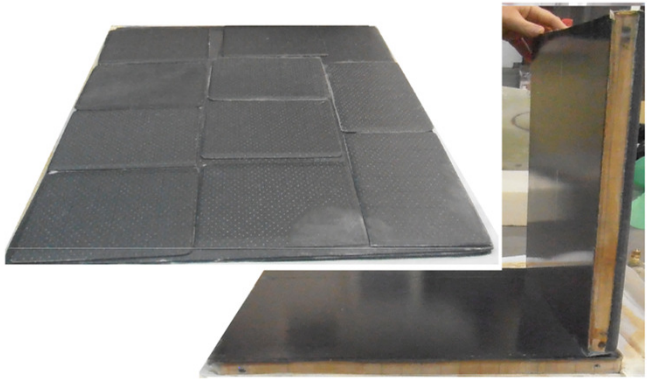
2. autoclave curing 270 min at 120°C, applied pressure 3 bar
3. post cure for 480 min at 140°C

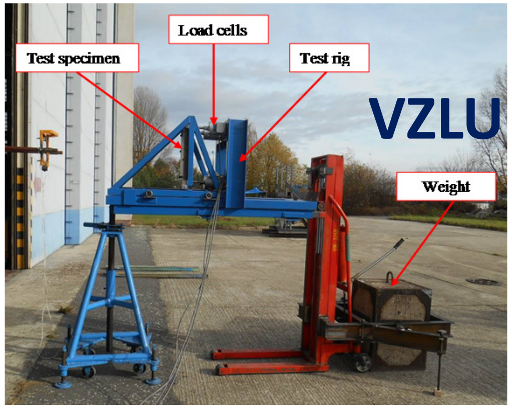
- 13 face sheet samples
  - 3 - 440 x 425 mm
  - 10 - 150 x 100 mm

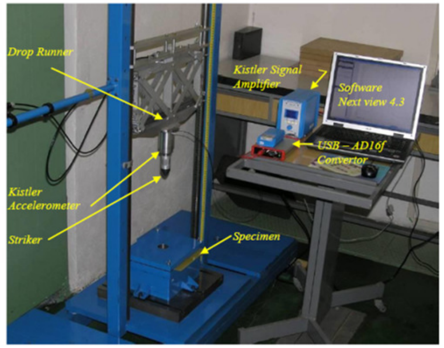


- 2 sandwich panels
  - 440 x 425mm
  - 2 CFRP face sheet 2 mm, 10 layers $(45,0,45,0,45)_s$ and foam 30 mm

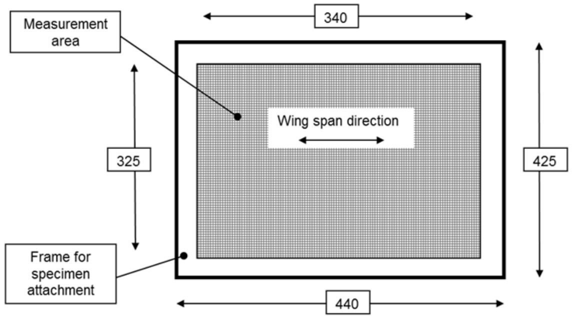
DAMAGE ASSESSMENT & TEST - Hail strike test on composite skin







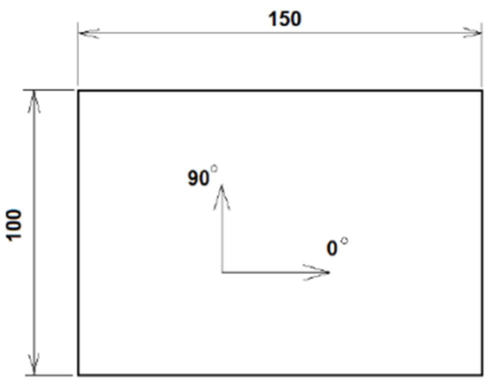
Test arrangement



Measurement and inspected data:

- ✓ Reaction force – time
- ✓ High speed camera picture
- ✓ Depth of impact after test
- ✓ NDT – A scan, C-scan

Number of test specimen = 3



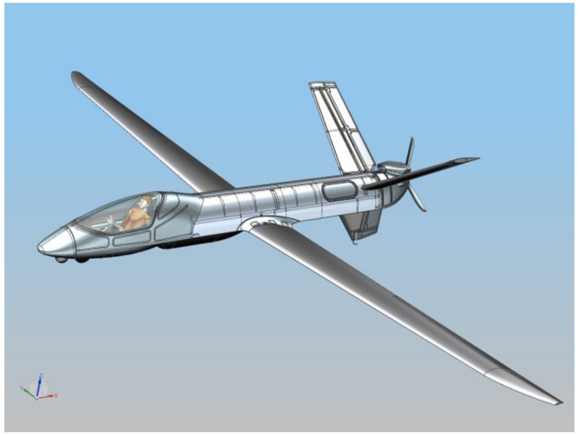
Online measurement data:

- ✓ Impact force – time
- ✓ Impact energy – time
- ✓ Impact speed – time
- ✓ Displacement – time
- ✓ Impact force - displacement

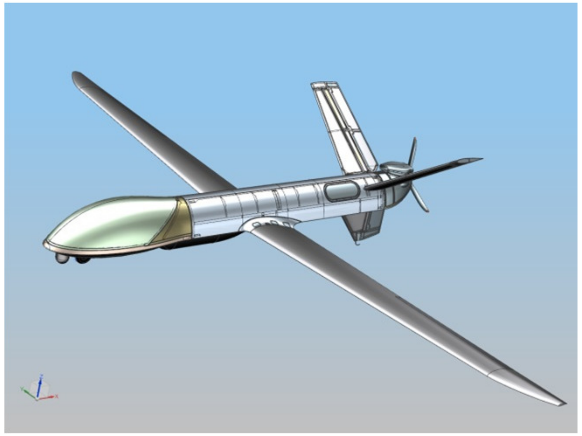
Number of test specimen = 10

PW-100A – the first public presentation -2016

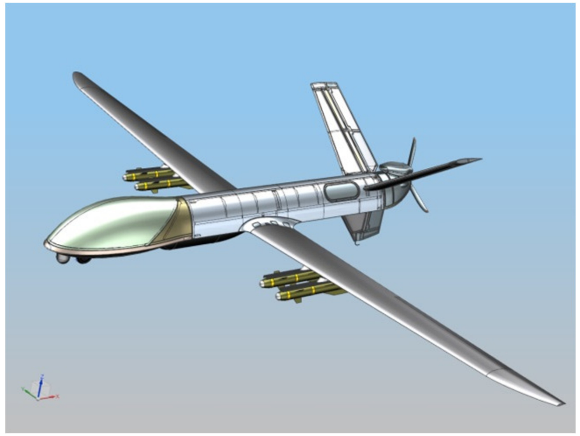
Phases of future development & main parameters



Phase I: manned version, MTOW=600 kg



Phase II: unmanned version, MTOW=600 kg



Phase III: unmanned version, MTOW=1200 kg

Parameters	PW-100C	MQ-1 Predator	Hermes 900
Wing span	15 m	17 m	15 m
Take-off weight	1100 kg	1043 kg	1100 kg
Power unit	Rotax 912 iS	Rotax 940 turbo	Rotax 914
Fuel mass	660 kg	286 kg	300 kg
Payload	300 kg	300 kg	300 kg
Endurance	75 h	40 h	36 h
Max flight speed.	230 km/h	250 km/h	222 km/h
Loiter speed	110 km/h	120 km/h	111 km/h
Max flight altitude	9000 m	8000 m	10000 m

Institute of Aeronautics and Applied Mechanics

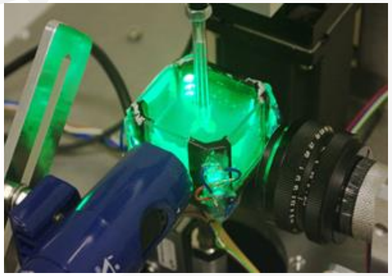
Division of Machine Design

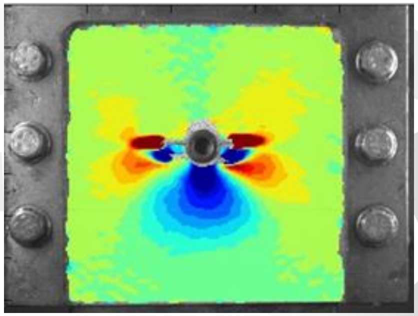
Head of Division

Marek Matyjewski

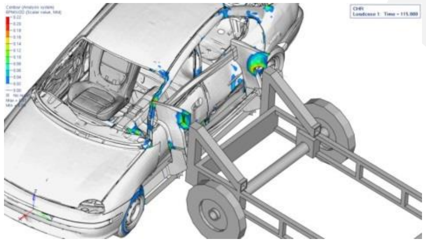
Research Areas

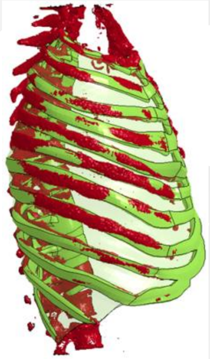
- Experimental mechanics

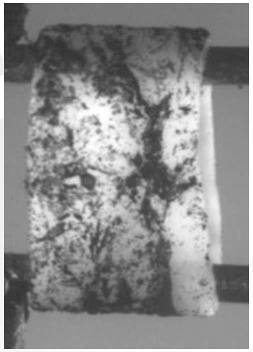




- Biomechanics

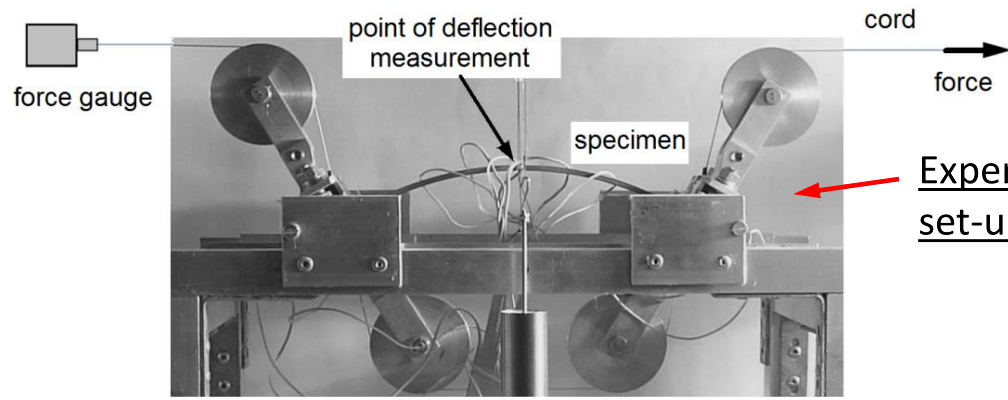




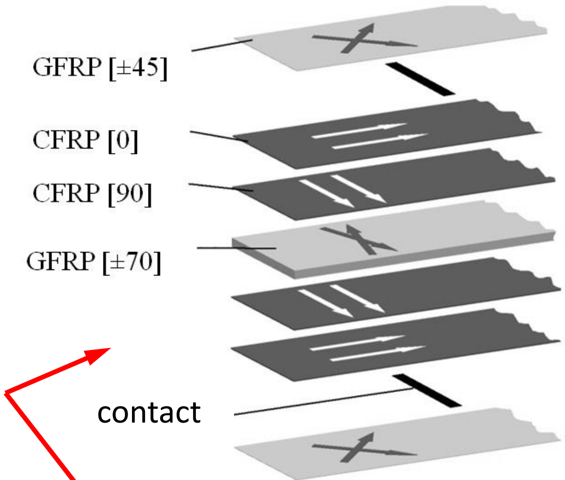


- Safety analysis

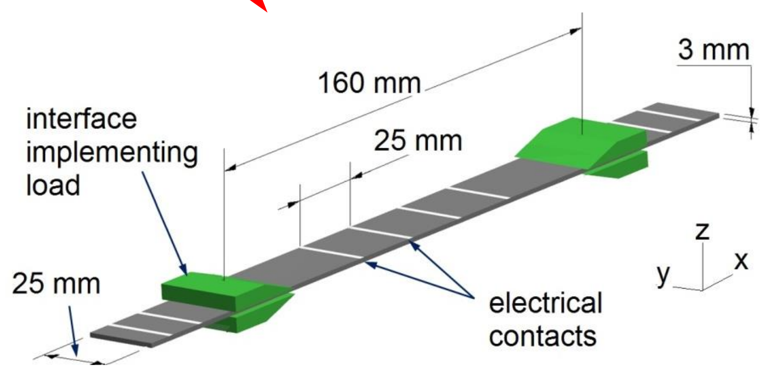
Experimental investigation of fatigue destruction of CFRP using the electrical resistance change method



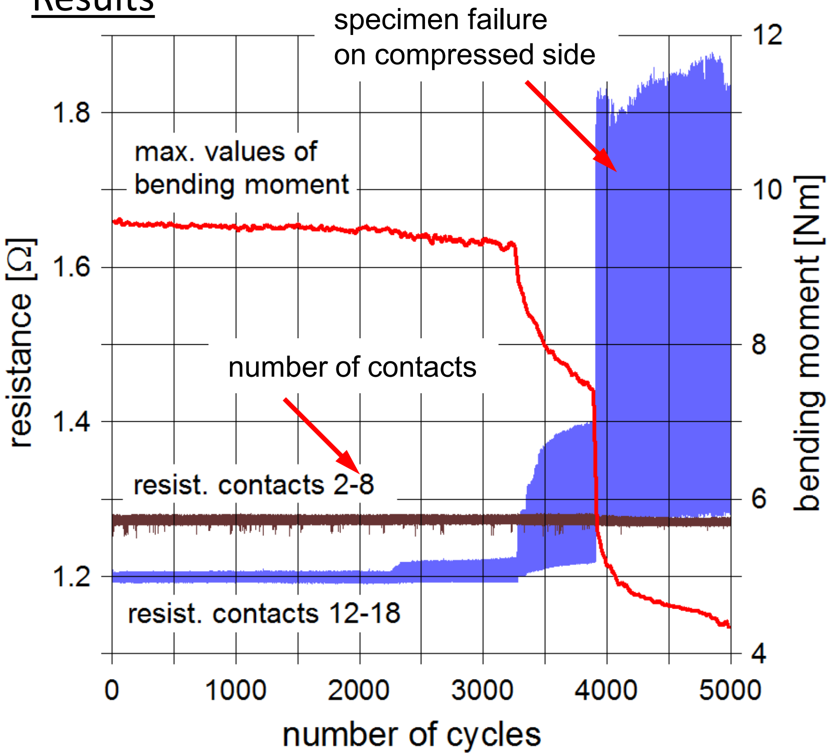
Experimental set-up



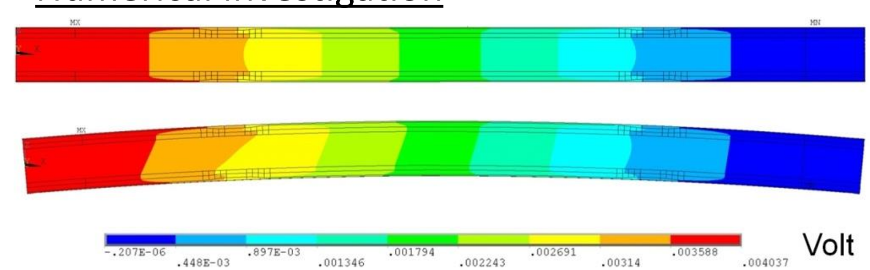
Specimen



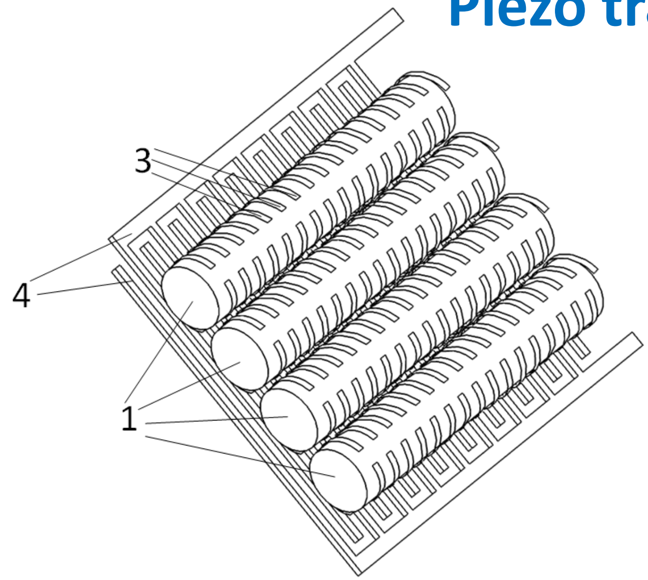
Results



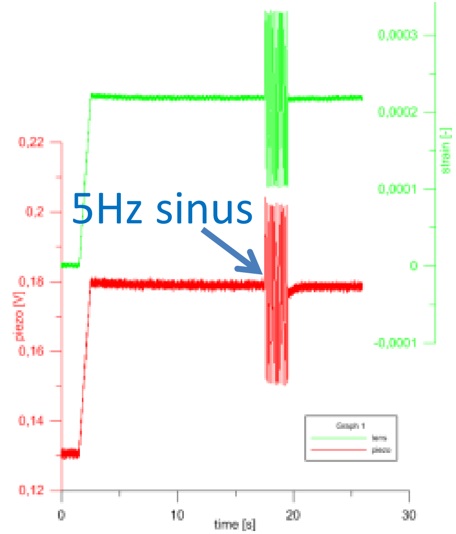
Numerical investigation

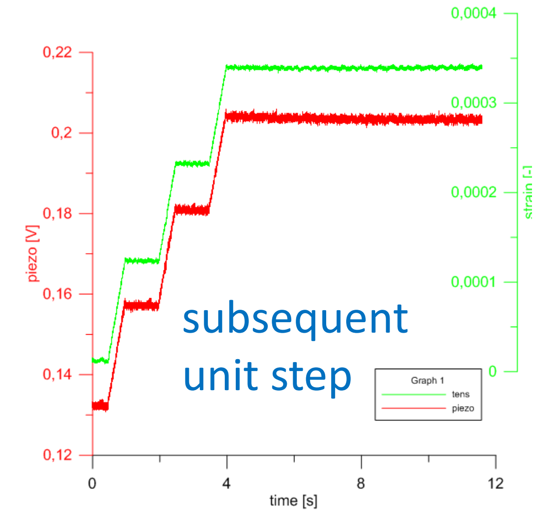


Piezo transducer with spiral electrodes



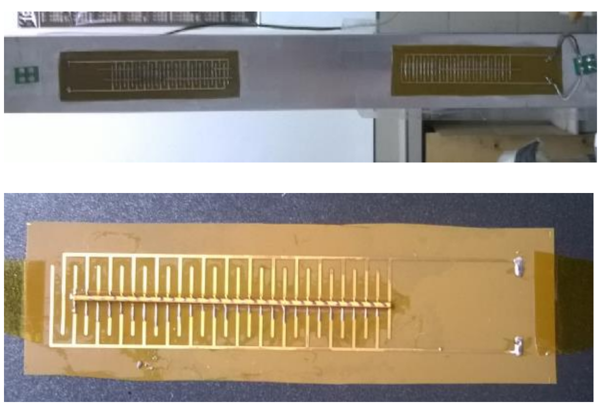
Transducer scheme





High compatibility of the obtained results

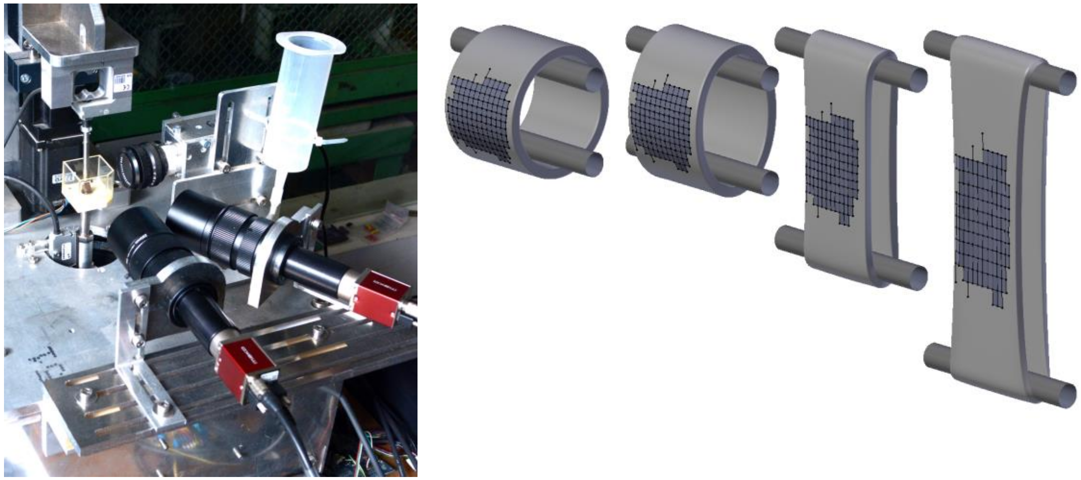
Patent Protection **No. 225481**



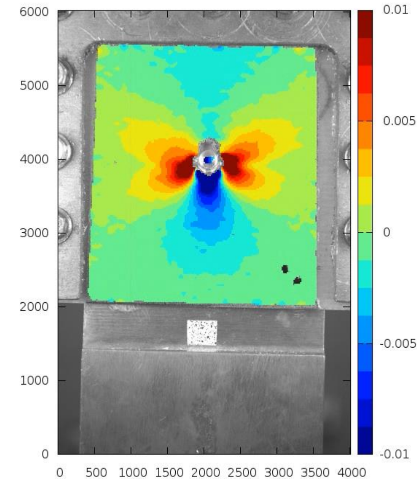
Existing single fiber prototypes

- New sensor has good accuracy in the study of deformation
- possibility of using it to study low-frequency waveforms, using the new charge amplifier with high impedance input

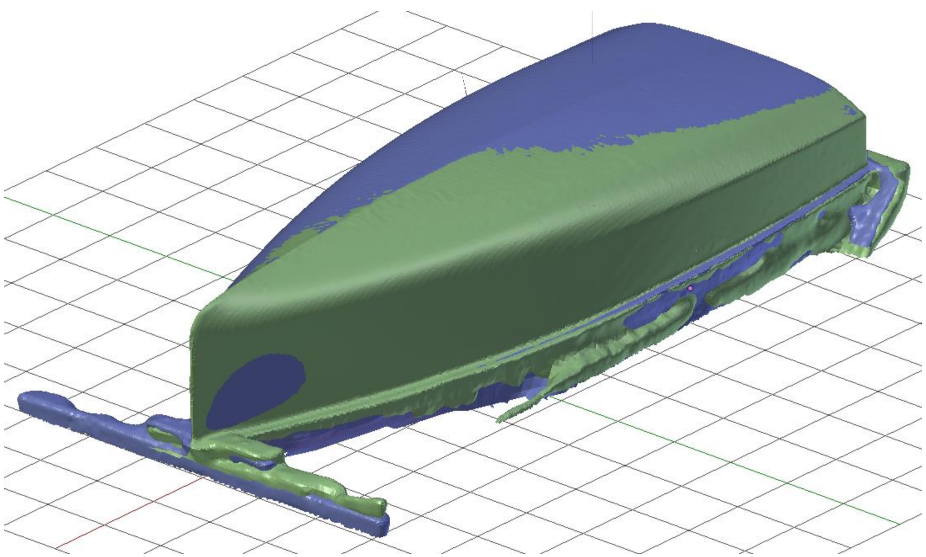
Measurement of deformation using 2D and 3D Digital Image Correlation



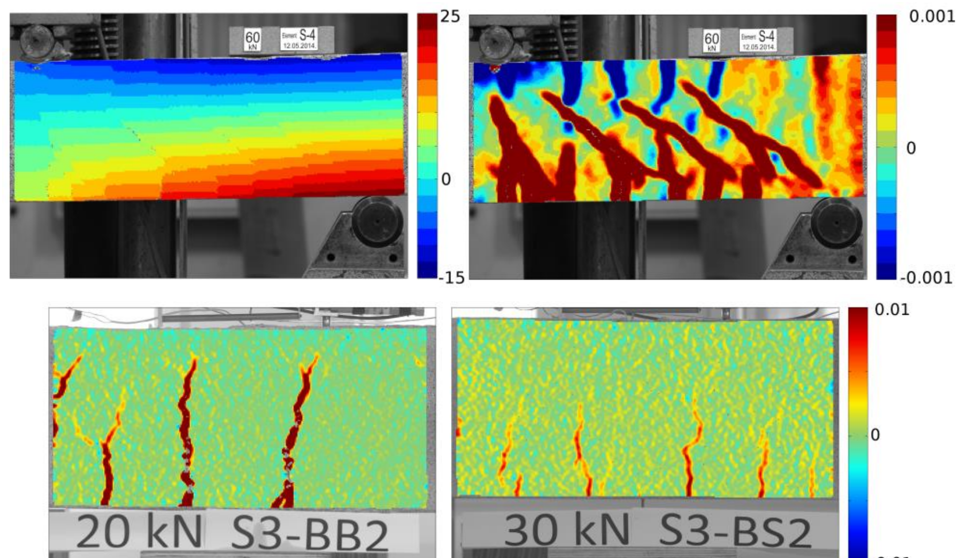
In biomechanics



For composite structures

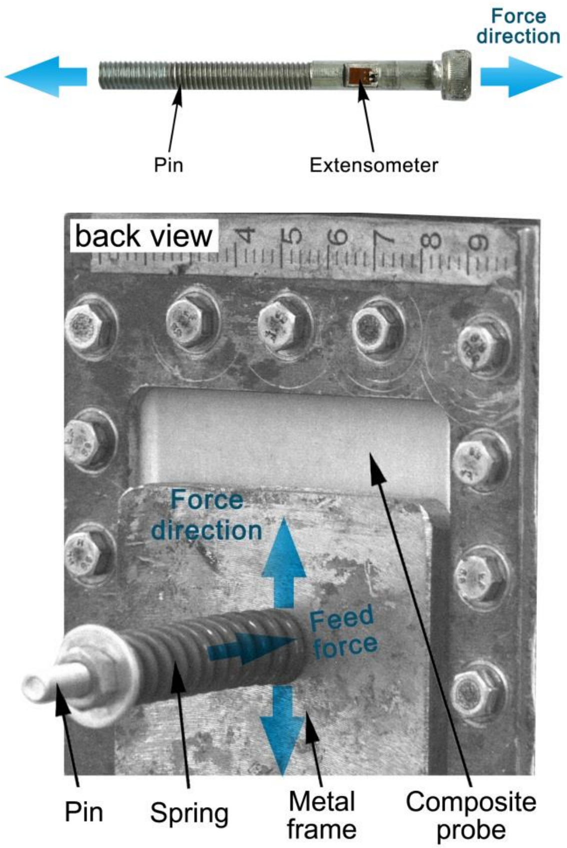


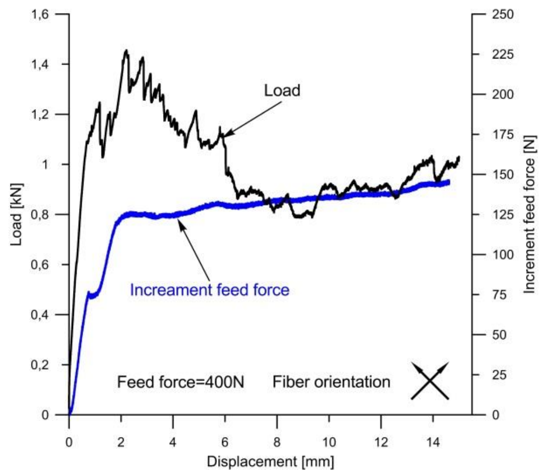
For complex shapes

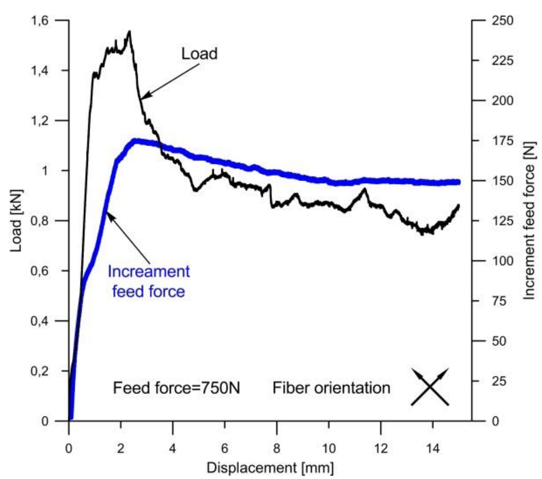


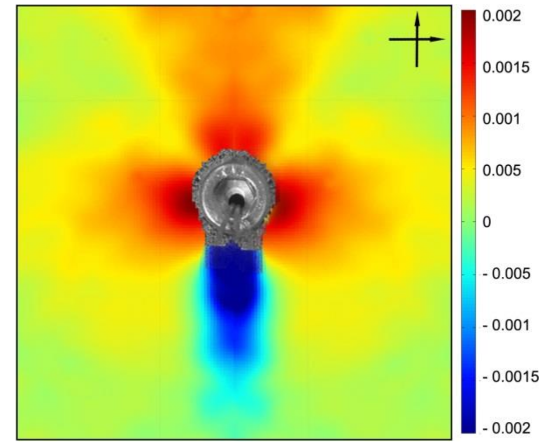
For reinforced concrete structures

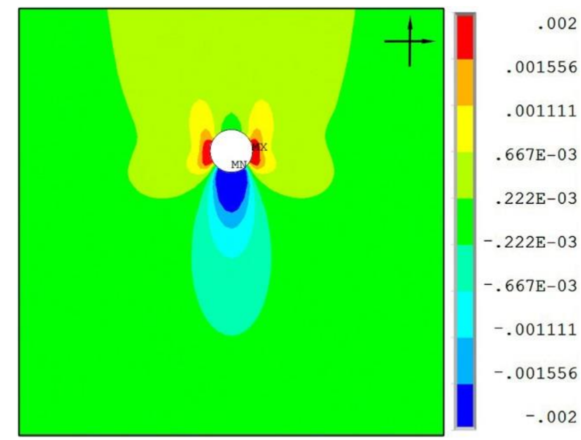
Research of riveted joints in aircraft composite structures









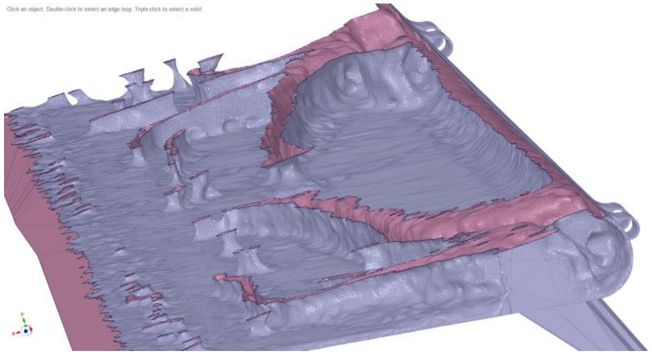


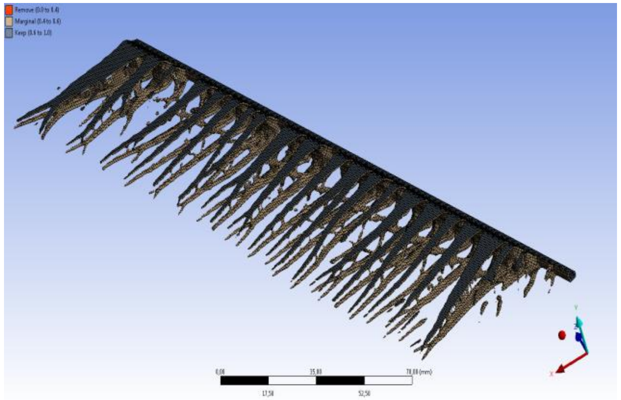
Specimen with strain gauge

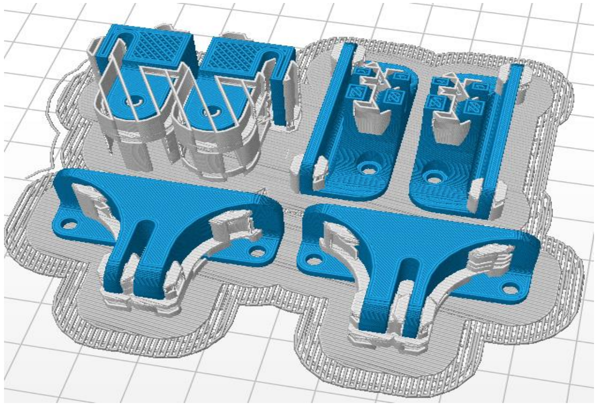
Results – load and force

Results – strain from DIC and FEM

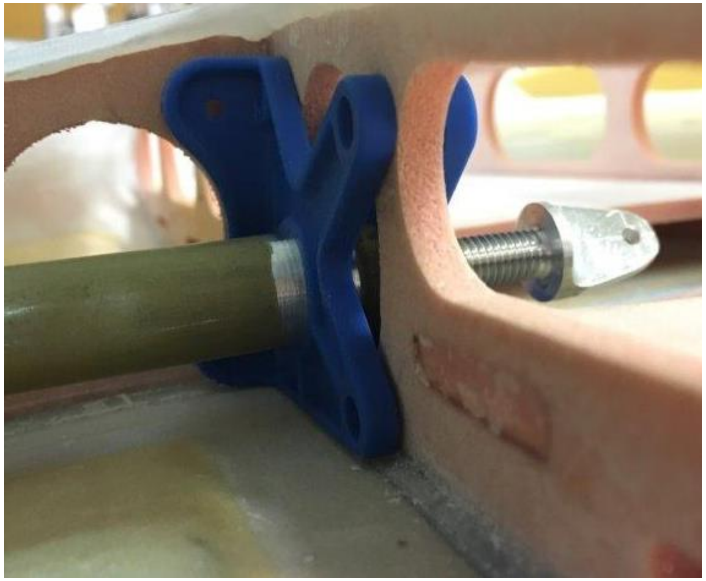
Additive manufacturing



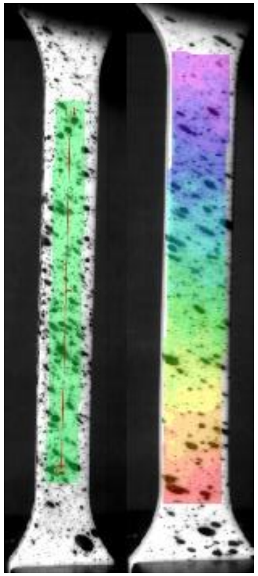


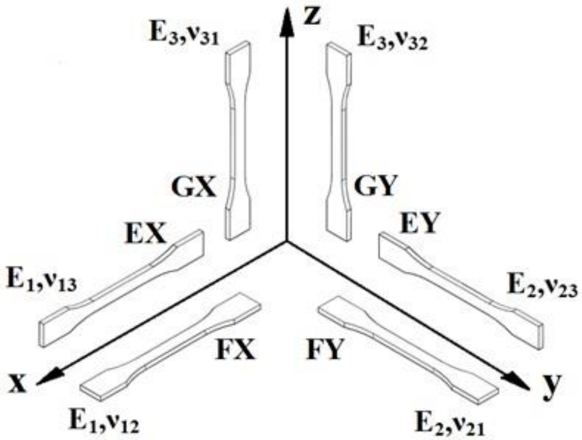


Topology optimization



Parts for UAV





Material testing

Yacht laboratory

Remote controlled sailing boat

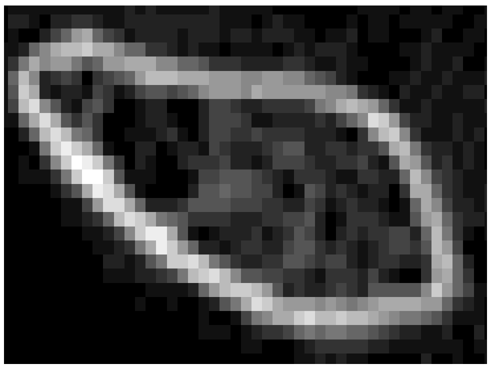

Forces and velocity measurement

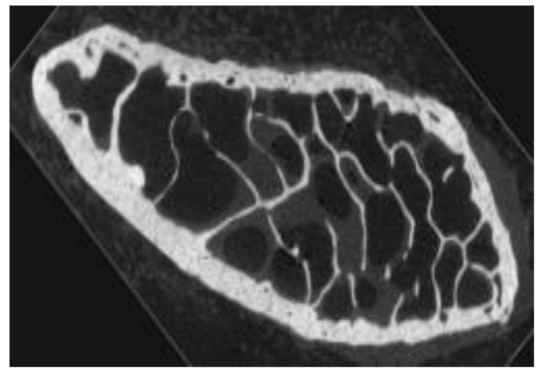
Sail shape registration

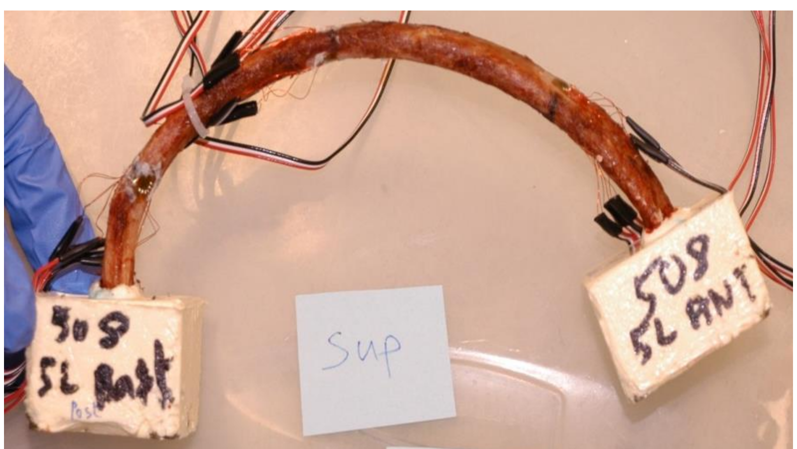
1:5 scaled hull of the OPEN 30

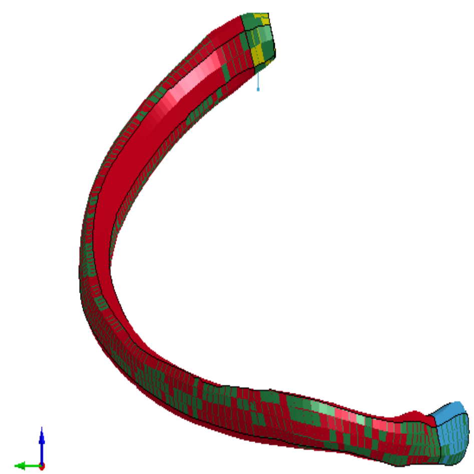
Development and validation of the human ribs FE models based on different X-ray imaging techniques

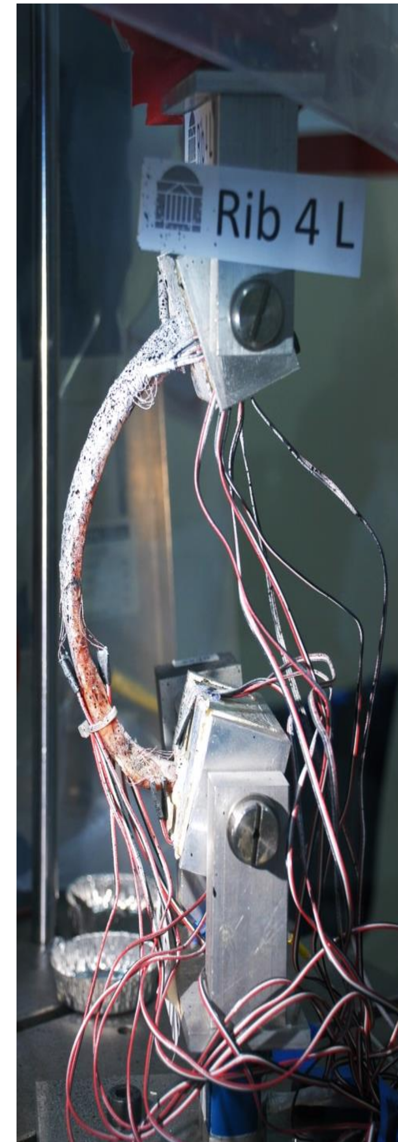
Clinical CT **?** **Micro CT**



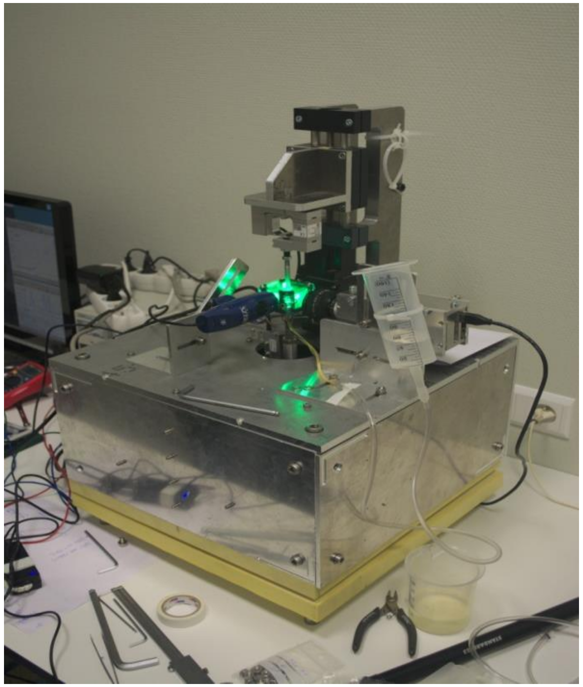


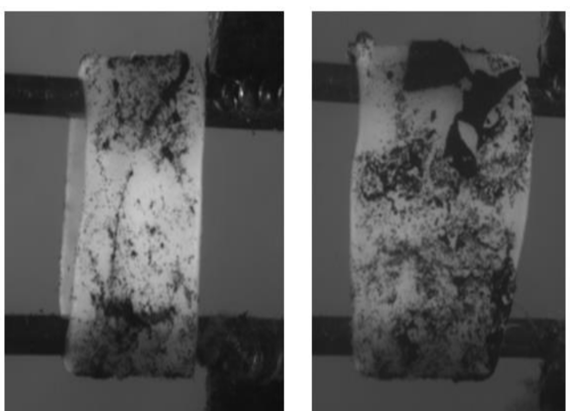




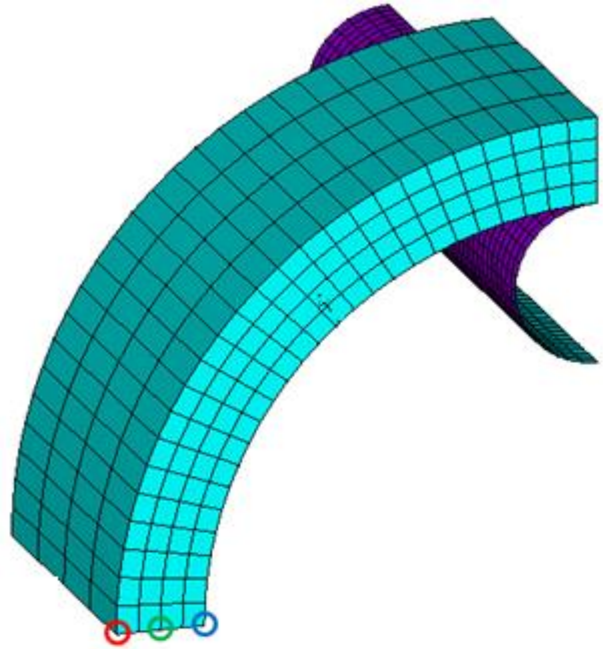


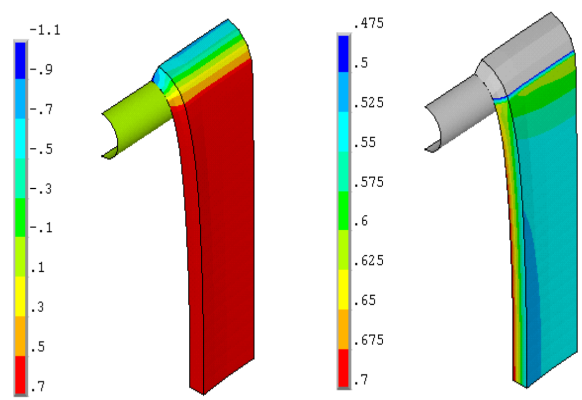
Mechanics of soft tissues



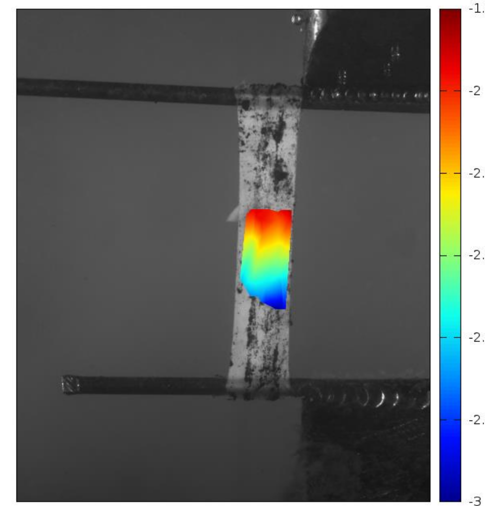


Experimental testing

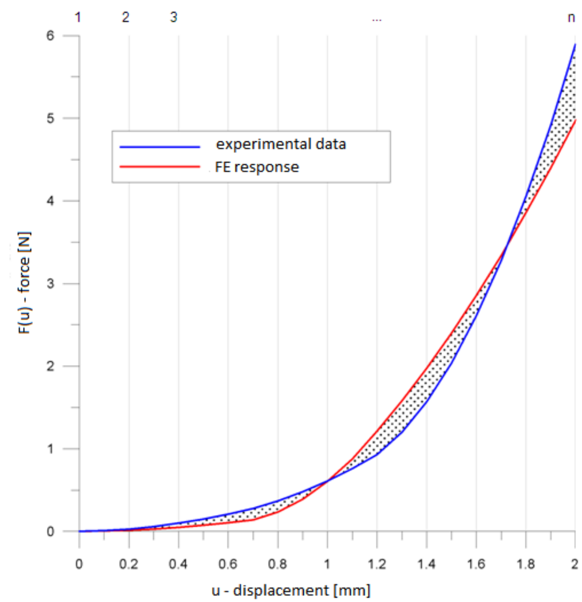




FE modeling

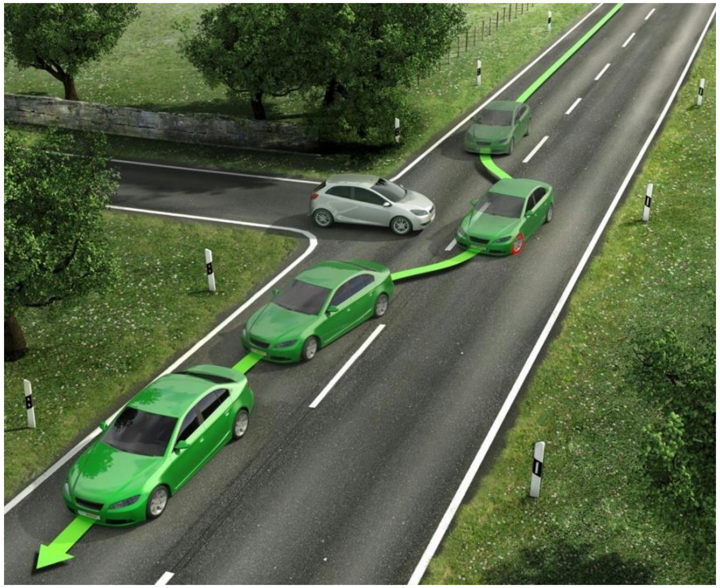


DIC strain measurement



ADAS - Advanced Driver Assistance Systems

Pedestrian crossing scenario
in PreScan environment
a vehicle equiped with AEBS.



Sensor systems

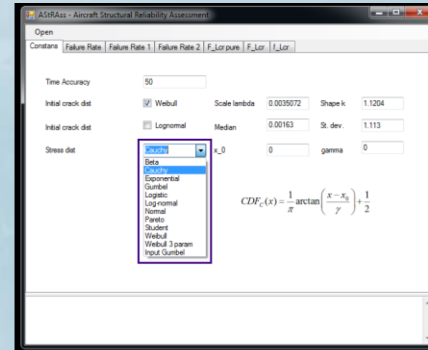
Acceleration-breaking control

Steering control

Narodowe Centrum Badań i Rozwoju
PBS Program Badań Stosowanych
The project is a part of the III Applied Research Program of the National Research and Development Centre (Contract No. PBS3/B6/28/2015)
SEARCH SAFETY ENGINEERING RESEARCH

Reliability analysis of the aircraft PZL-130 Orlik TC-II airframe under real operating conditions

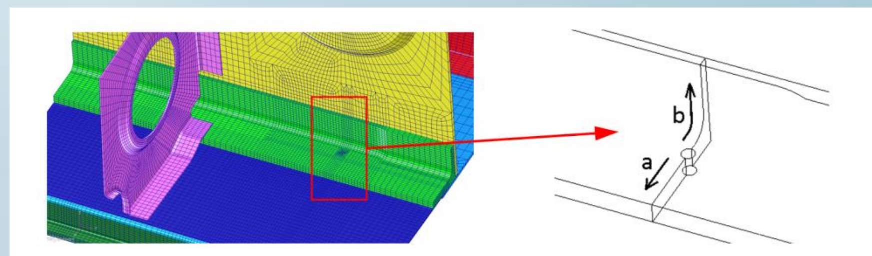
The theme is to present development of new methods for assessing the reliability of the aircraft structure. Based on the mathematical models, the author developed the "Aircraft Structural Reliability Assessment" (AStRAss) computer software, which implements the realized mathematical model. The aim of the software is calculation of aircraft structure reliability.
The failure rate of the selected location within the structure of the PZL-130 Orlik TC-II under real operating conditions were calculated. For the chosen control point within the structure the sensitivity of failure rate to the input data was investigated.

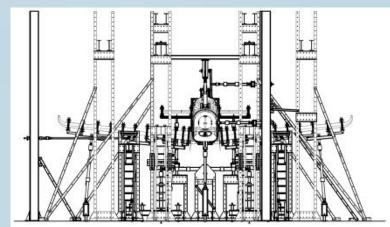


The probability of component failure during a time period (0,t) caused by exceeding the allowable crack length can be described as:

$$F_{\mathrm{Lcr}}(t) = 1 - F_A(a^*(t_{\mathrm{cr}} - t))$$

where: F_A – the distribution function of the initial crack length, $a^*(t)$ –function of crack length corresponding to the time to the occurrence of failure $t_f = t_{cr} - t$, t_{cr} – the time, when crack size will reach the predefined crack size a_{cr}

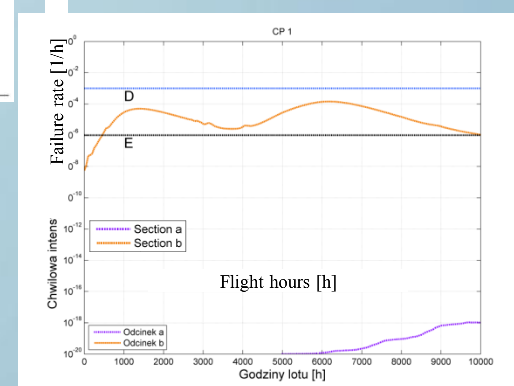




The probability that the stress value will cause a failure during a flight at time t for cracks smaller than a_{cr} can be calculated with the following equation:

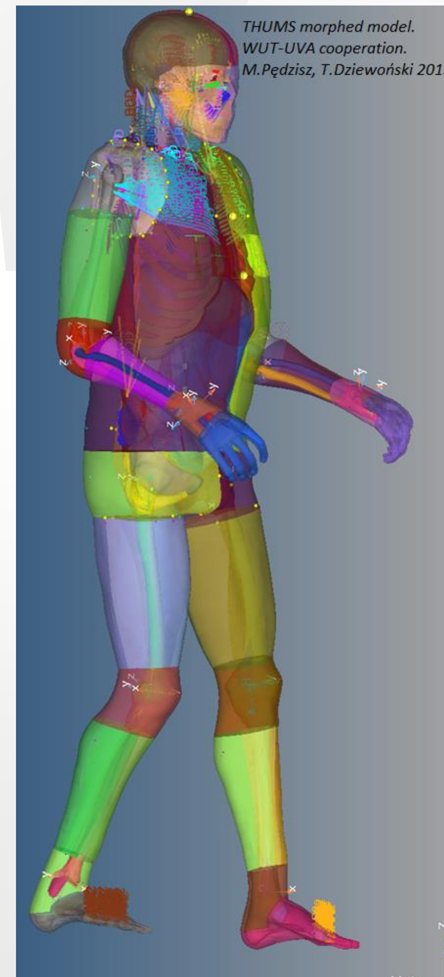
$$P_N(t) = \int_0^{\infty}\int_0^{a_{cr}} \hat{H}(\sigma_{cr}(a,k_c))\, f_A(a)da \cdot f_{K_c}(k_c)dk_c$$

where: $H\hat{}$ is the exceedance probability for the peak load per flight, $f_A(a)$ is the density of the flaw size distribution at time interval t, f_{Kc} *(kc)* is the density distribution of fracture toughness.

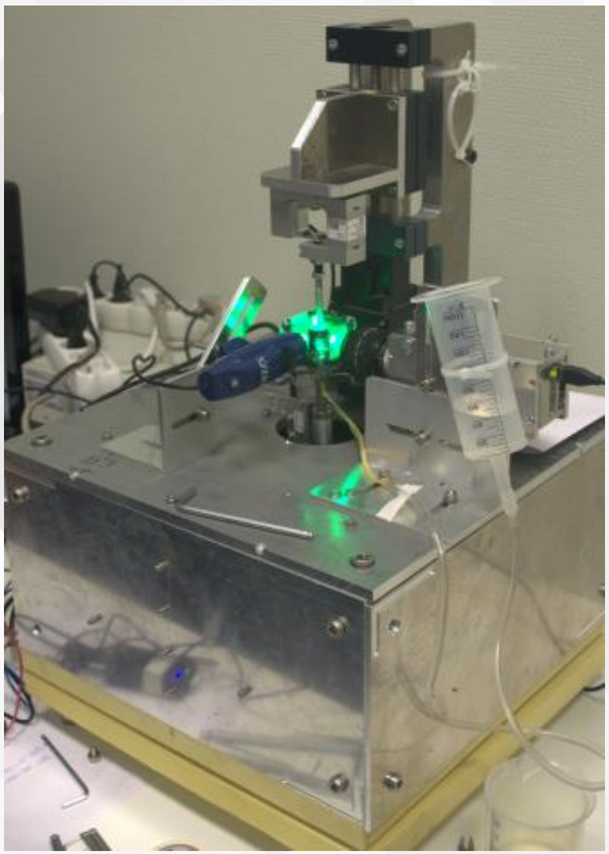


Research Achievements

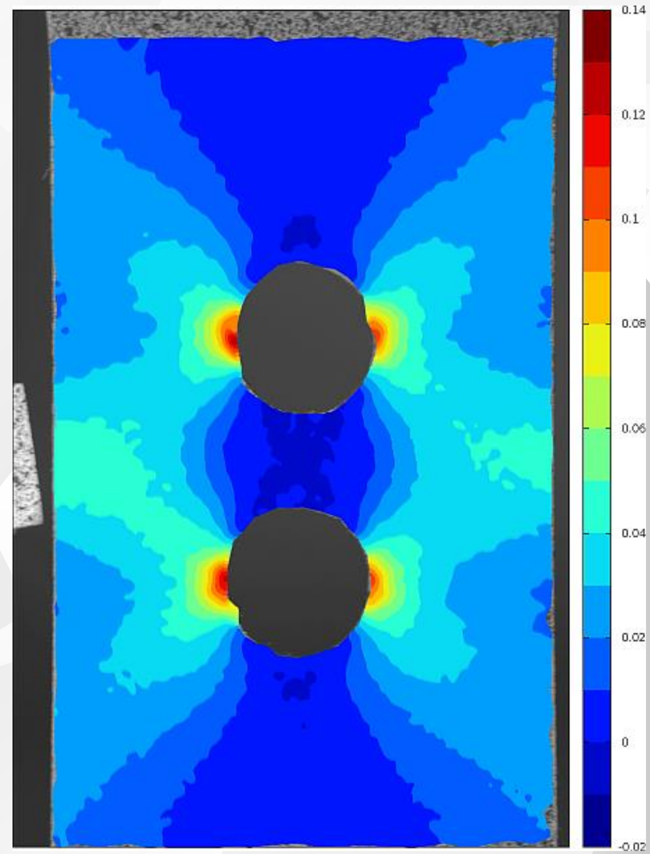
- Piezoelectric sensor process and piezoelectric sensor, Patent No: 225481,
Date of granting: 07-11-2016;
- Scaling and morphing of the Pedestrian THUMS model, carried out for University of Virginia;
- Testing of wood composite materials
– application for ski, snowboard and skateboard



Research Laboratories

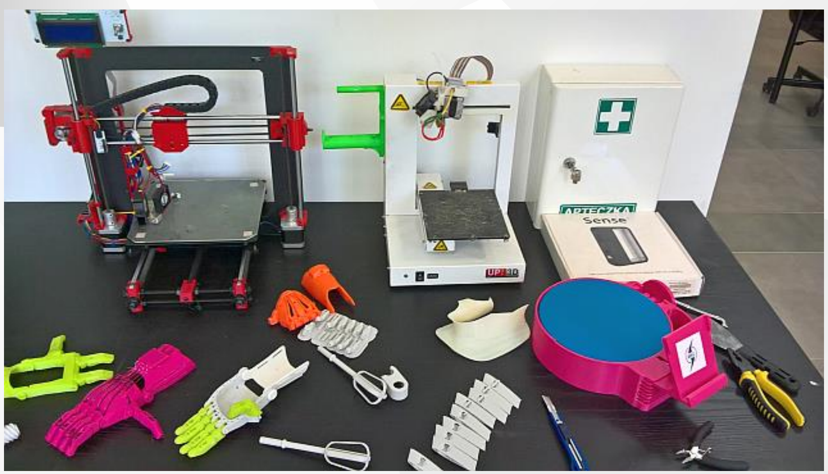


Artery mechanical properties testing machine



Digital Image Correlation
DIC

Research Laboratories



3D printing laboratory

Advanced Driving Assistance Systems

Mini-simulator stand

Research Projects

Innovative simulation technologies for evaluating vehicle automation systems in terms of road traffic safety.

NCBIR - PBS3, grant No PBS/B6/28/2015, 2015-2017

Consortium:

- Motor Transport Institute - ITS;
- Warsaw University of Technology; IAAM;
- SEARCH – Safety Engineering Research

Division of Theory of Machines and Robots

Institute of Aeronautics and Applied Mechanics

Faculty of Power and Aeronautical Engineering

Warsaw University of Technology

Research interests in brief

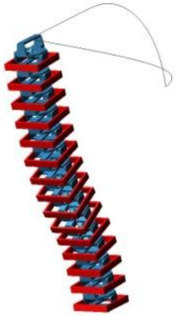
– Biorobotics & humanoid robots

– Biomechanics & passive safety

– Medical & rehabilitation robotics

– Mechanical design of robotic systems

– Mobile robotics



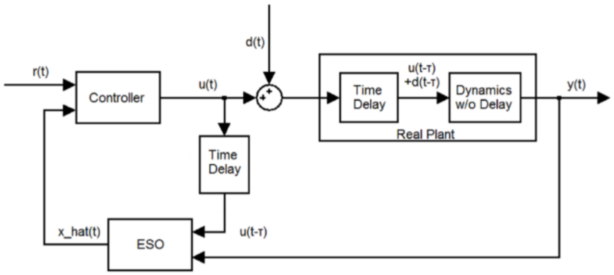
– Multibody dynamics

Research interests – examples

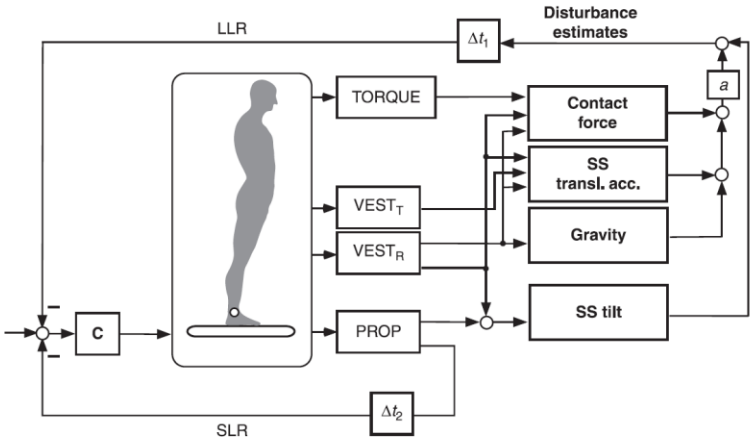
Biorobotics & humanoid robots

– postural stabilization

cooperation with Freiburg Uni.



Lucy (Freiburg Uni.)

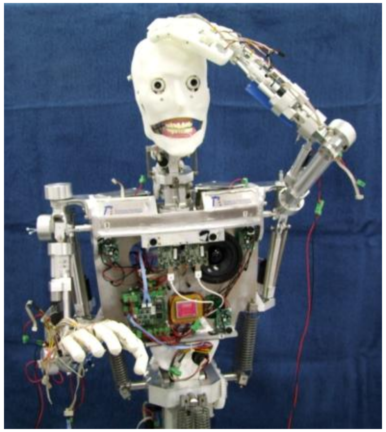


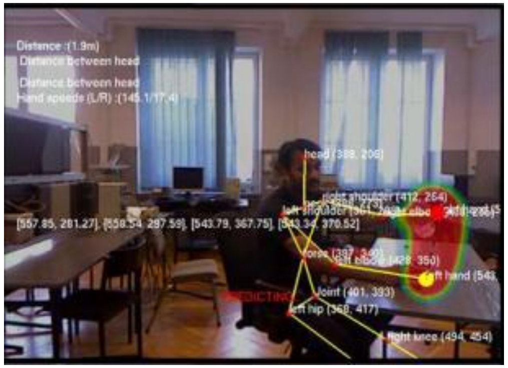
ADRC (Active Disturbance Rejection Control) vs. DEC (Disturbance Estimation and Compensation)

– human-robot interactions

Robot Roman interacts by expressing emotions

cooperation with TU Kaiserslautern



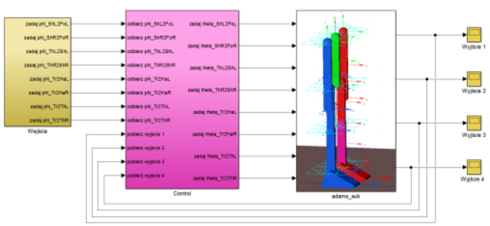


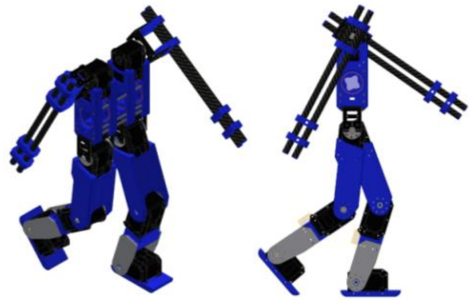
Predicting the intentions of human activities

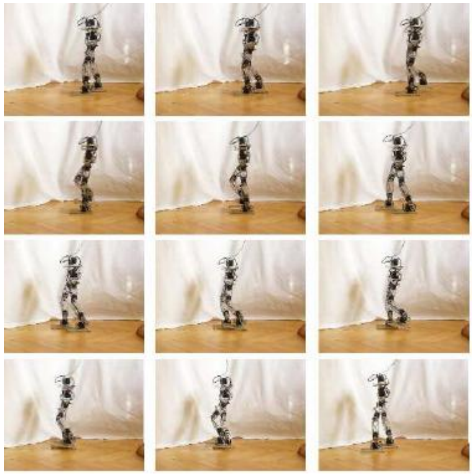
Research interests – examples

Biorobotics & humanoid robots

– humanoids: design and motion synthesis

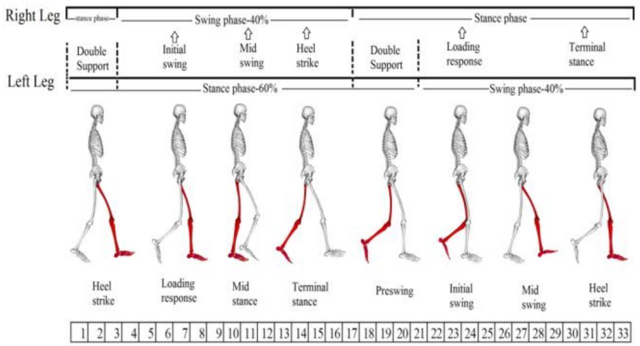


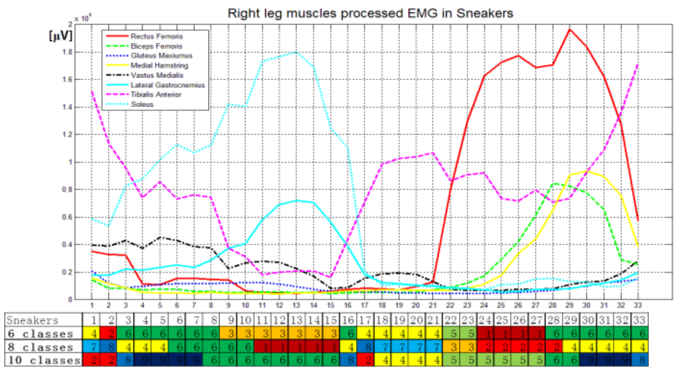




motion planning and simulation – stabilization (incl. active arms) – biologically inspired design & control

– classification and analysis of EMG





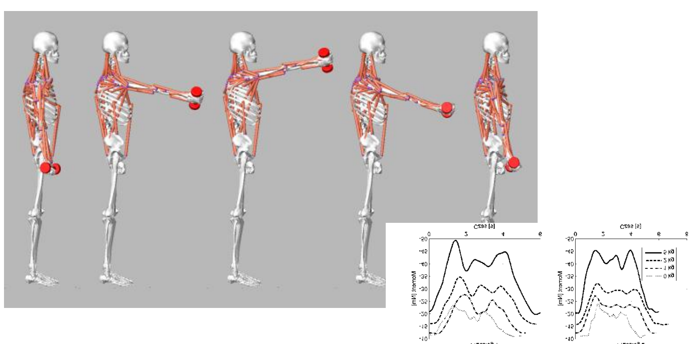
Research interests – examples

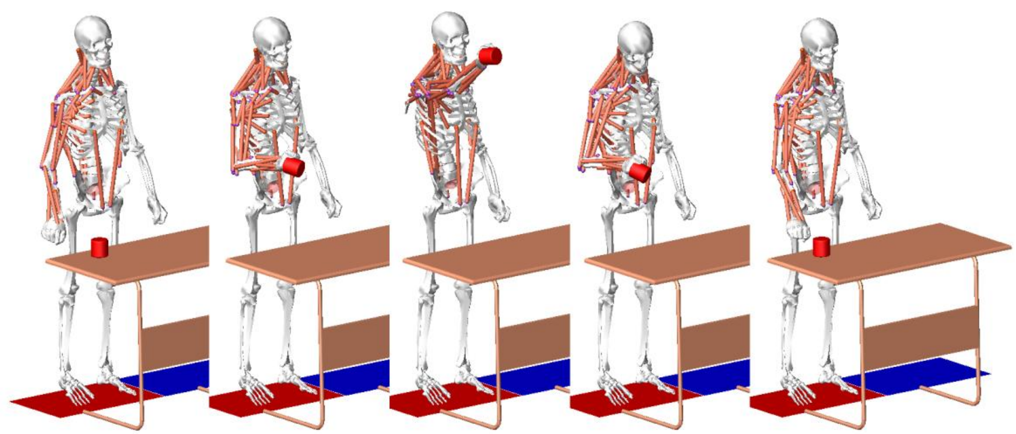
Biomechanics & passive safety

– development of a finite element model of the human thorax and upper extremities

- validation of the reference – 50-percentile *male* – model;
- scaling (50-percentile *male* to 5-percentile *female* and 95-percentile *male*) and personalization methods.

– occupational biomechanics



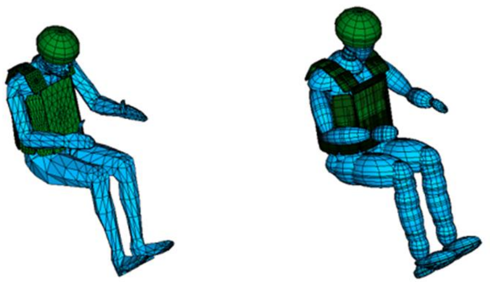


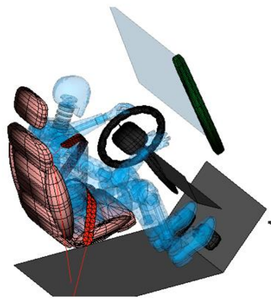
Analysis of load distribution, muscles activity, ergonomy, asessment of changes due to surgery, …

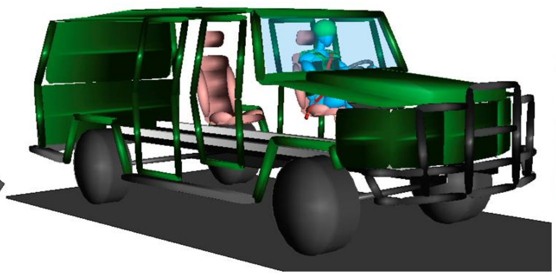
Research interests – examples

Biomechanics & passive safety

– crew safety

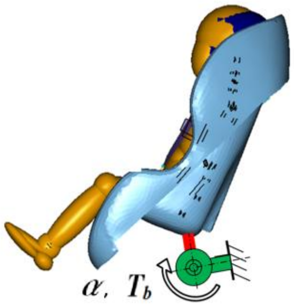


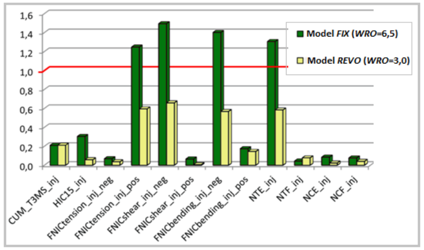




Experimental and simulation investigations and the assessment of improving possibilities of both crew safety and robustness of patrol and intervention vehicle when ramming into barriers

– children safety



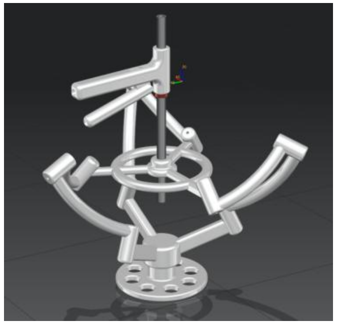


An analysis of the possibilities of improving the safety of children transported by cars thanks to special articulated child seats

Research interests – examples

Medical & rehabilitation robotics

– surgical manipulators

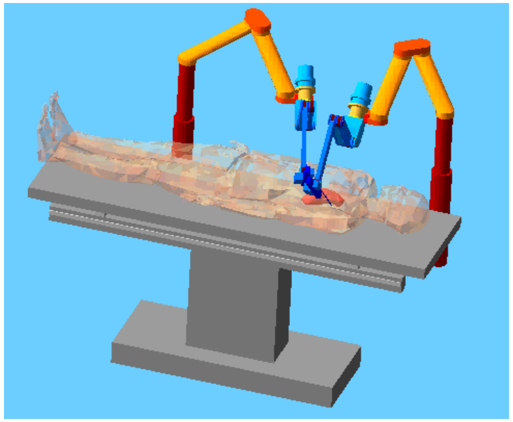


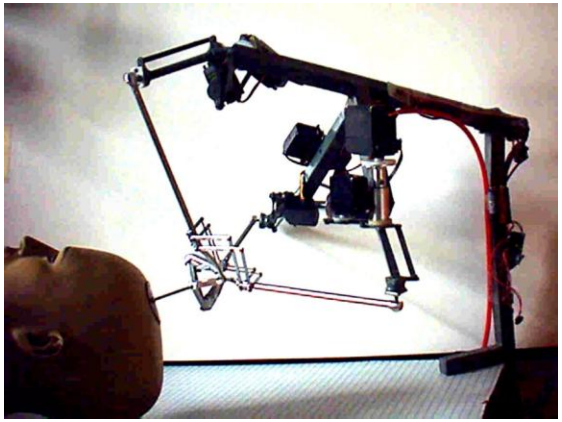
Spherical manipulators – minimally invasive surgery

Cardiac surgical manipulator *RobIn Heart 2*

– rehabilitation devices

Spine rehabilitation device

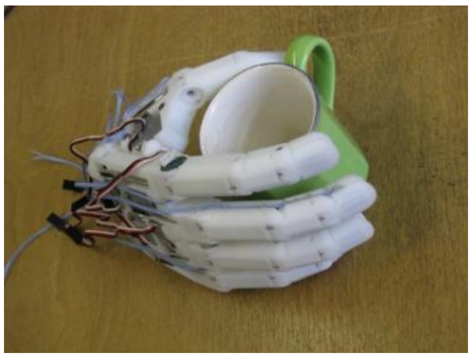




Serial and parallel manipulators for surgical purposes

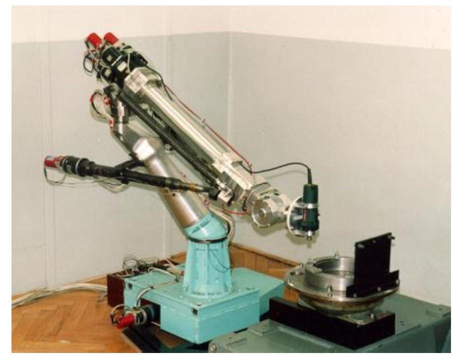
Research interests – examples

Mechanical design of robotic systems



Biomimetic hand

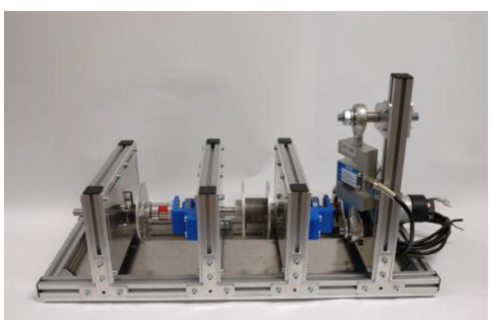
Parallel manipulator



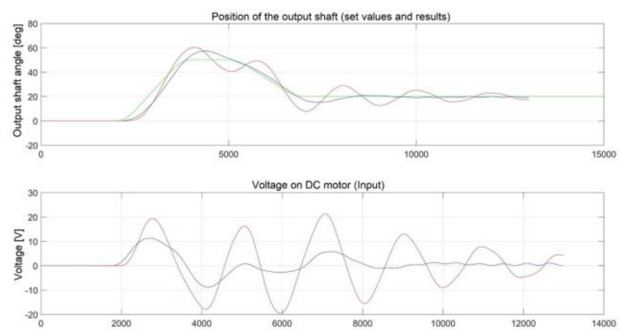
Robot *RNT*

Robot *POLYCRANK*

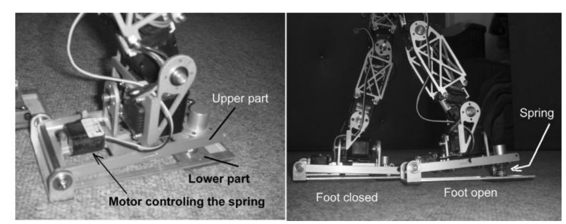
– compliant actuators; compliance in locomotion



Testbed for Parallel-Series Elastic Actuators (PSEA)



Model Predictive Control of Elastic Actuators

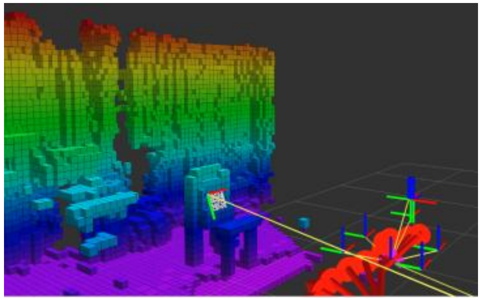


Compliant foot

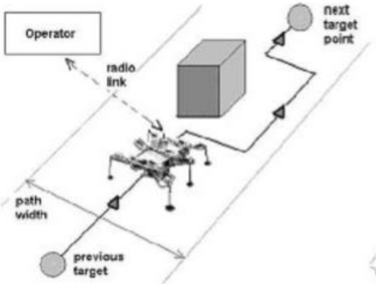
Research interests – examples

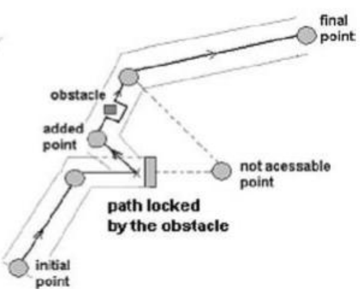
Mobile robotics

– SLAM (Simultaneous Localization And Mapping)
– obstacle recognition
– sensor fusion

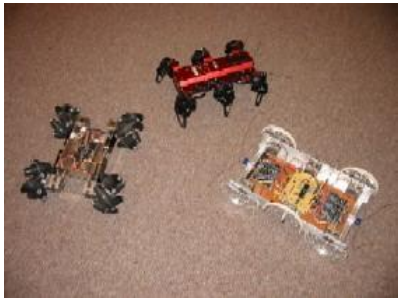


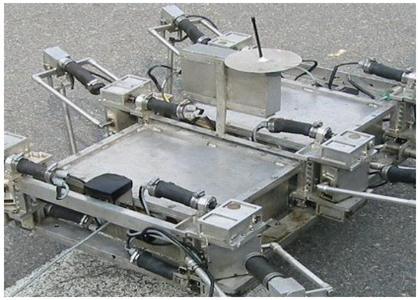
– path planning
– autonomous navigation





– real-time control of robotics systems
– walking machines
– optimization of energy expenditure





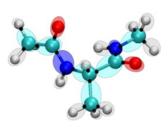
Research interests – examples

$$\mathbf{M}\ddot{\mathbf{q}} + \mathbf{\Phi}_{\mathbf{q}}^{T}\boldsymbol{\lambda} = \mathbf{Q}(\mathbf{q},\dot{\mathbf{q}},t)$$
$$\mathbf{\Phi}(\mathbf{q},t) = \mathbf{0}$$

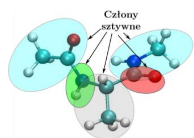
Multibody dynamics

– Divide and conquer algorithms (DCA)

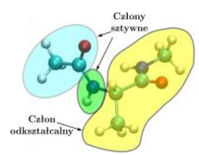
- algorithm based on augmented Lagrangian
- highly parallelizable formulation
- simulation of large systems on parallel computing platforms



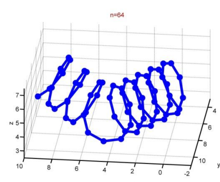
Atomistic models



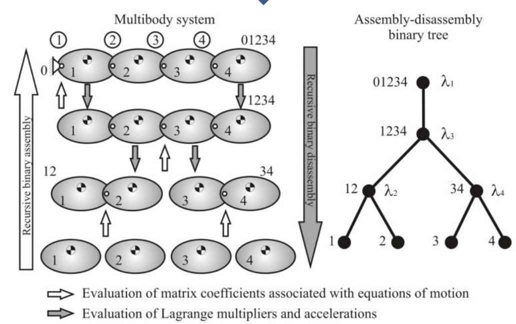
Rigid bodies



Rigid and flexible bodies



Simulation of helix formation

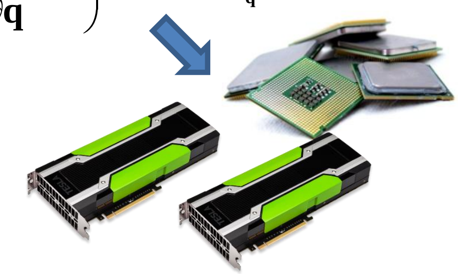


Interesting application: molecular dynamics

– Hamiltonian based DCA

- superior numerical properties compared to acceleration based counterparts
- many applications of the approach in multibody system dynamics and beyond, e.g. in port-Hamiltonian approach, in passivity based control or in optimal control, and optimal estimation

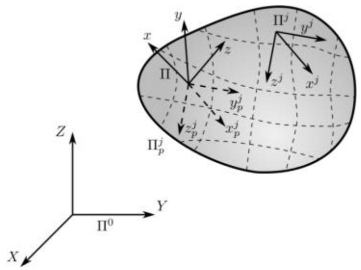
$$\dot{\mathbf{q}} = \left(\frac{\partial \mathrm{H}(t,\mathbf{q},\mathbf{p})}{\partial \mathbf{p}}\right)^{T}$$
$$\dot{\mathbf{p}} = -\left(\frac{\partial \mathrm{H}(t,\mathbf{q},\mathbf{p})}{\partial \mathbf{q}}\right)^{T} + \mathbf{Q} - \mathbf{\Phi}_{\mathbf{q}}^{T}\boldsymbol{\lambda}$$
$$\mathbf{\Phi}(\mathbf{q},t) = \mathbf{0}$$

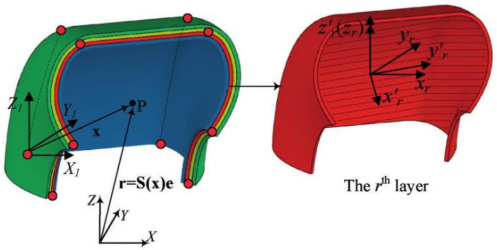


Research interests – examples

Multibody dynamics

– Flexible multibody systems
- floating frame formulation
- absolute nodal coordinate formulation (large deformations, exact kinematics)
- new elements, new material models

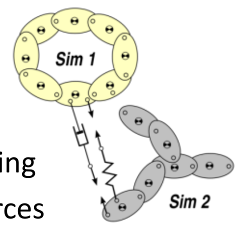




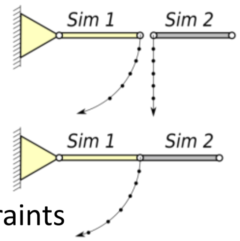
ANCF – tire modeling

– Co-simulation methods
- coupling through forces
- coupling through constraints
- waveform-Newton algorithm

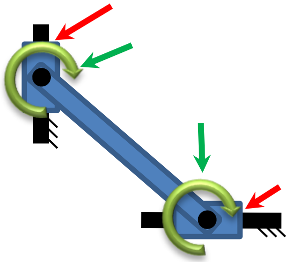
Coupling via forces

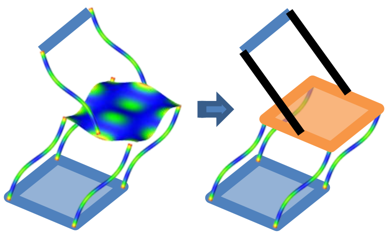


Coupling via constraints



– Redundantly constrained or actuated MBS
- redundant constraints handling methods
- solvability and uniqueness problems
- reactions in partially flexible systems



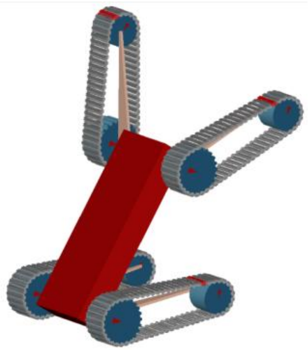


– Friction in MBS
- non-uniqueness due to frictional locking
- multiple solutions and paradoxes

– Multibody methods in robotics
- identification and simulation
- model-based controllers

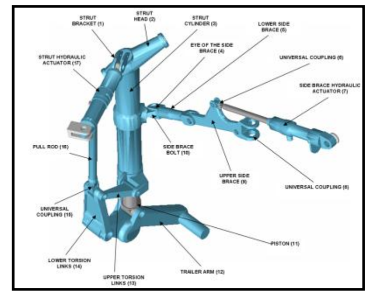
Research interests – examples

Multibody dynamics



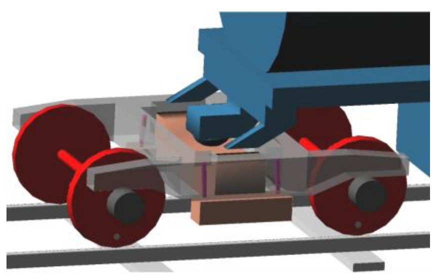
Mobile robot analysis

Cooperation with PIAP

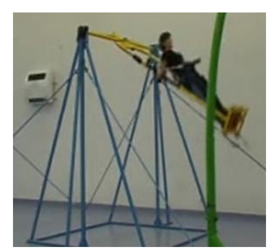


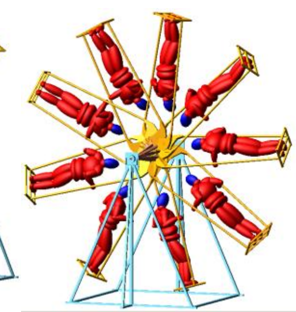
Multibody model of the main landing gear of Su-22 military aircraft

Cooperation with the Air Force Institute of Technology



Multibody analysis of a bimodal train derailment



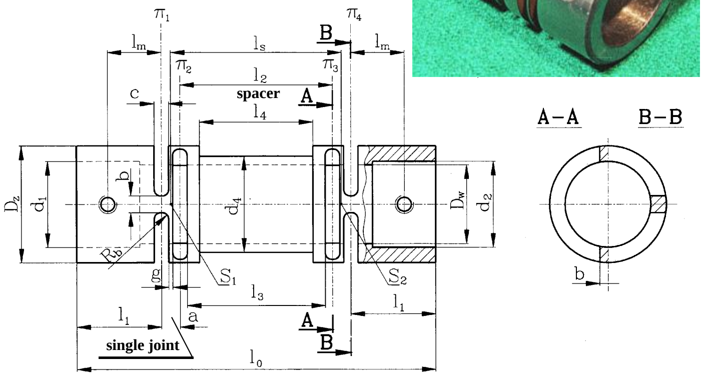


„Looping" device analysis

Selected achievements

Patents granted (selection)

Development of original design of
a membrane coupling



- a new concept of a steel cross–slotted coupling called SM-PW^{TM} devised at DTMR
- the construction combines positive features of one–piece flexible joint and classical membrane coupling

Device for spine correction
with measuring system

Selected achievements

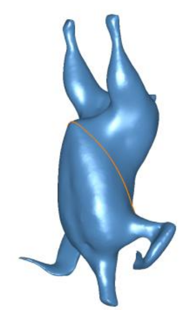
Patent applications in processing

A device for enforcing GSM equipment to broadcast in order to enable its localization

A device for localization of short-term broadcasting GSM equipment

---

A method for using a 3D scanner for determining the weight of thighmuscles in chicken carcasses

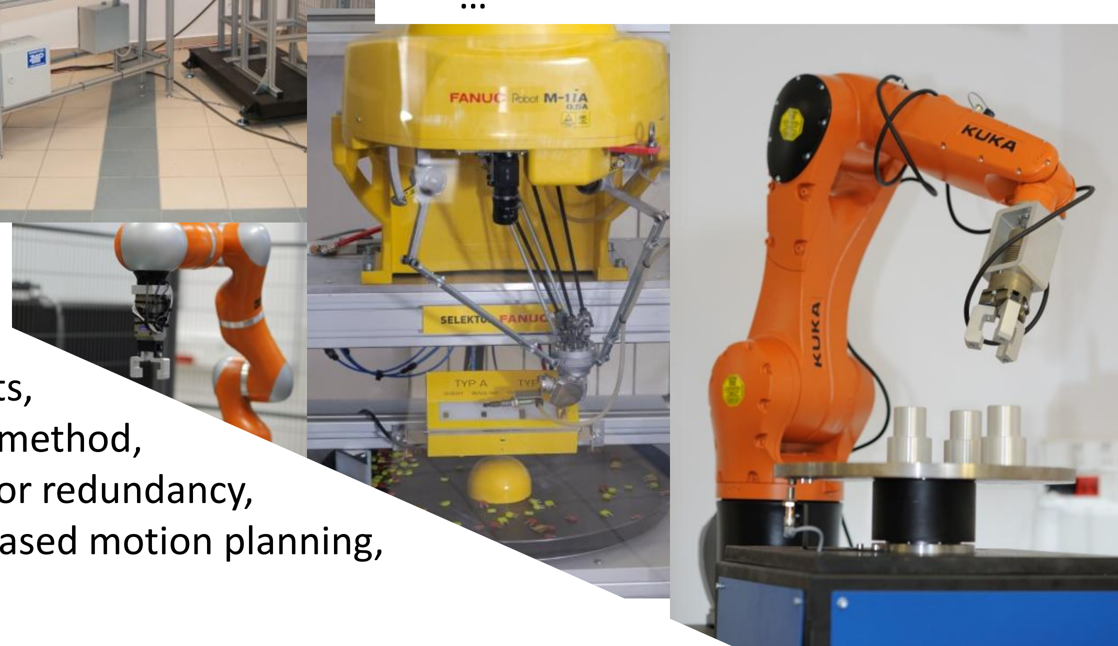


Laboratories

Laboratory of Robotics

– Industrial robots tutorials

- basic robot programming
  (tool definition, path planning,…),
- sensors and vision systems,
- grippers, positioners, conveyors,
- force control capabilities,
- robot cooperation,
- …



– Research on robotics

- model-based control,
- dynamic characteristics of robots,
- sensor-based motion synthesis method,
- methods of handling manipulator redundancy,
- vision based and force-sensor based motion planning,
- …

Laboratories

Laboratory of Mobile Robots

– Research on

- SLAM,
- machine intelligence and autonomy,
- sensor fusion,
- robot cooperation,
- motion synthesis and navigation,
- humanoid robots design,
- humanoid robots motion generation,
- human-inspired control techniques,
- …

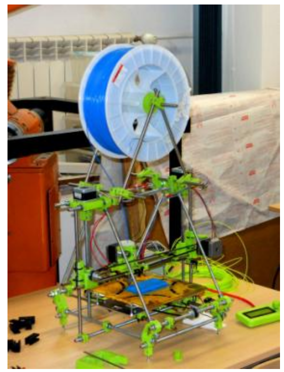
– On-board equipment

- control computer,
- manipulator,
- stereo-vision (movable camera),
- laser distance scanner,
- Wi-Fi and GPS module,
- inertial measurement units,
- bumper sensors,
- …

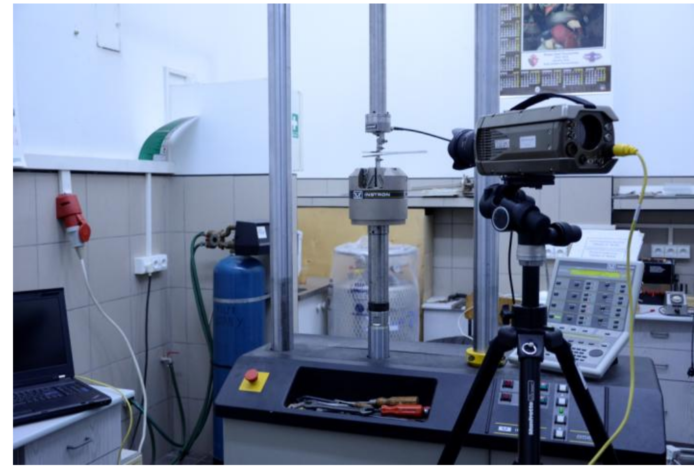
Laboratories

Other equipment

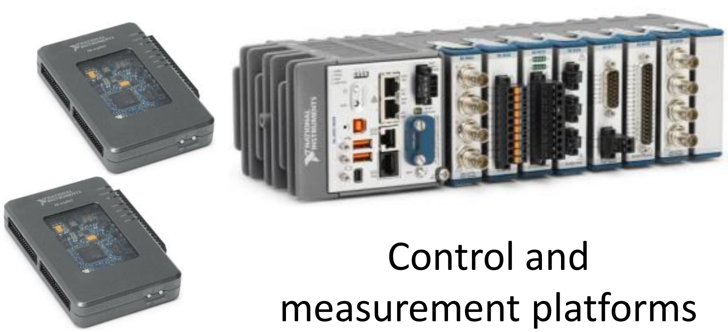
3D printing



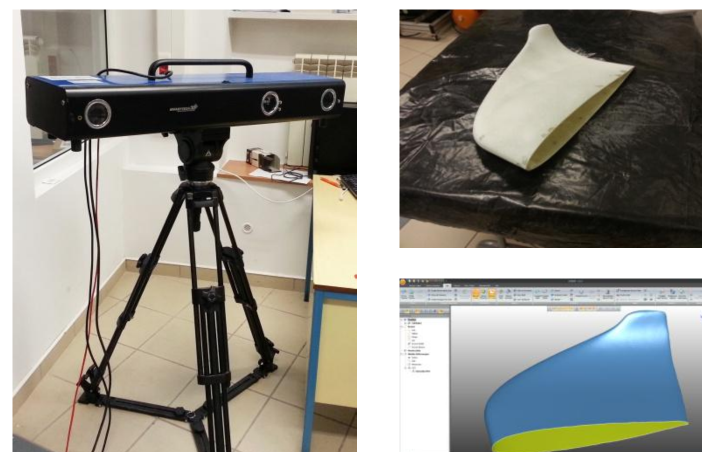
Workshop for Student Research Group on Robotics



High-speed cameras



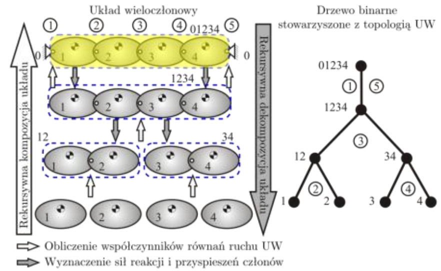
Control and measurement platforms



3D scanner

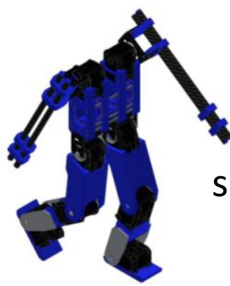
Exemplary projects

- *Modeling of Flexible and Redundant Multibody Systems Using Sequential and Parallel Computing*, OPUS, National Science Centre

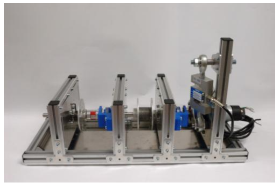


see slides 15, 16

- *Development and testing of dynamic motion synthesis with the use of own construction robot*, Diamond Grant, Ministry of Science and Higher Education

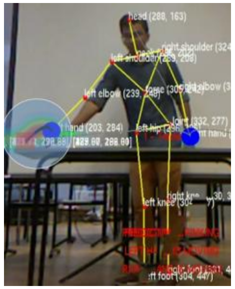


see slides 9, 13



- *Predicting the intentions of human activities for human-robot interaction (elderly, children with autism)*, PRELUDIUM, National Science Centre

see slide 8



Exemplary projects

Finalized projects (selection)

- *APROSYS—Integrated Project on Advanced PROtection SYStems*, FP 6, (with Divsion of Aerodynamics).
- *THOMO—Development of a Finite Element Model of the Human Thorax and Upper Extremities*, FP 7
- *PROTEUS—Integrated mobile system for supporting anti-terrorist and crisis management operations*, Innovative Industry (EU Structural Funds),
- *Swarm-it-Fix: Self Reconfigurable Intelligent Swarm Fixtures*, FP 7
- *Robotic Applications for Delivering Smart User Empowering Applications*, FP 7

Exemplary projects

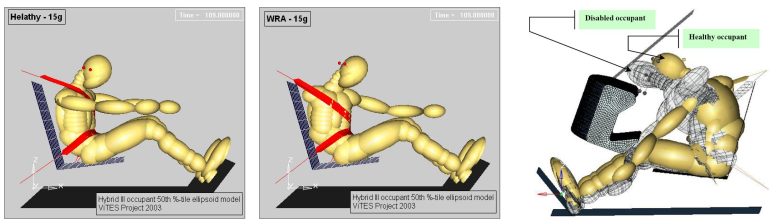
Finalized projects (selection)

- *Modeling of Spatial Mechanisms Using Parallel and Distributed Computing*, Ministry of Science and Higher Education
- *Modeling of Spatial Flexible Mechanisms Using Multibody System Method and PC Clusters*, Ministry of Science and Higher Education
- *Analysis of the possibilities of improvement of safety of children transported in passenger cars using special fixed rotationally safety seats*, Ministry of Science and Higher Education,
- *Stabilization mechanisms in two-legged locomotion*, Ministry of Science and Higher Education

- Educational projects: *Erasmus Mundus*, *Funded specialization*

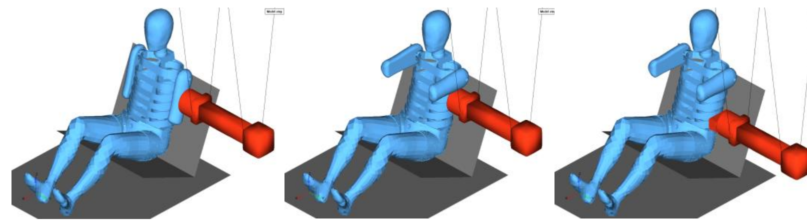
Exemplary projects

VITES—Virtual Testing for Extended Vehicle Passive Safety



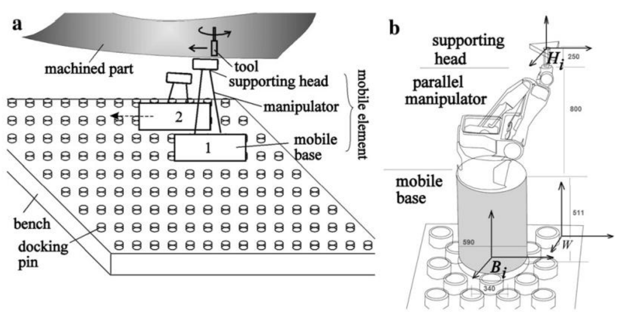
Study of impact of car users' disabilities on effectiveness of restraint systems

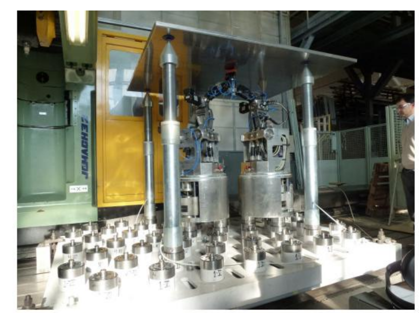
SIBER—Side Impact Dummy Biome-chanics and Experimental Research



FEM modeling of the WorlSID 50-percentile male dummy

SwarmITFix





Self reconfigurable intelligent swarm fixtures for machining flexible aircrafts parts (implemented in Piaggio)

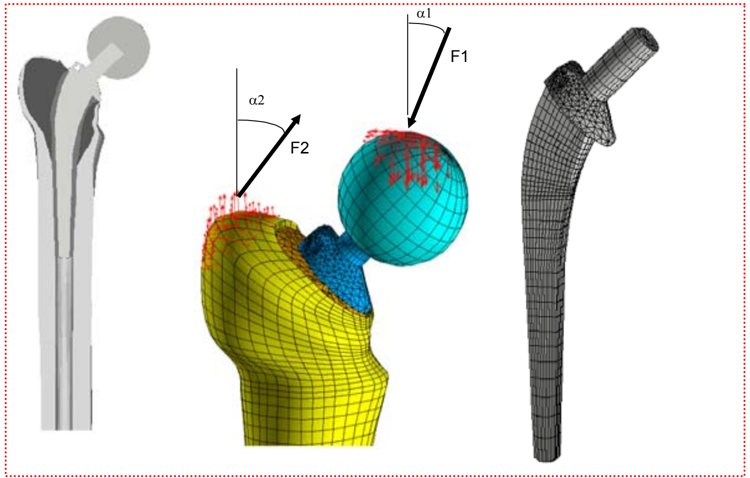
Division of Strength of Materials and Structures

Division of Strength of Materials and Structures – Research Areas

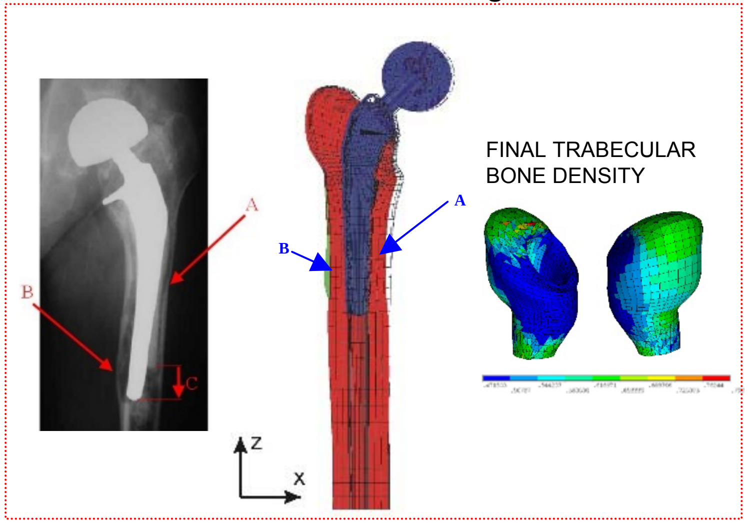
Biomechanics

- **IMPLANTS AND BONE REMODELING (SPINAL DISC IMPLANTS, HIP IMPLANTS)**

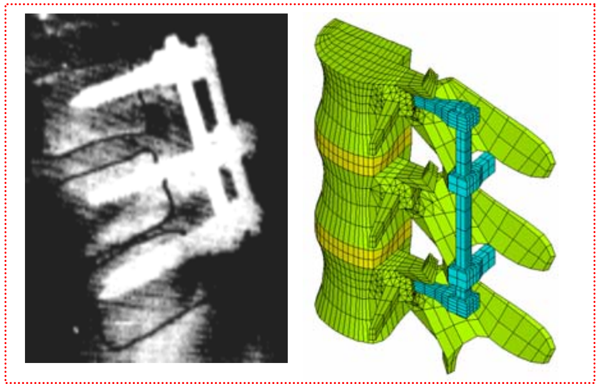
Hip implants



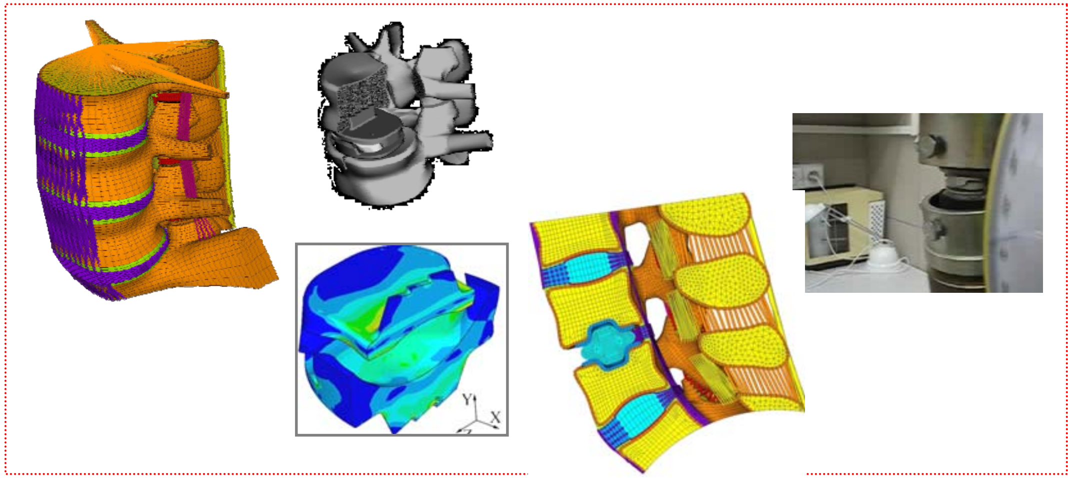
Bone remodeling



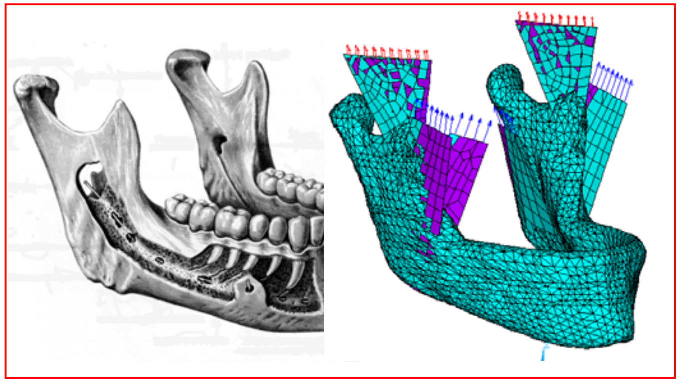
Spine stabilization



Disc implants (NCBiR, 2010 – 2013)



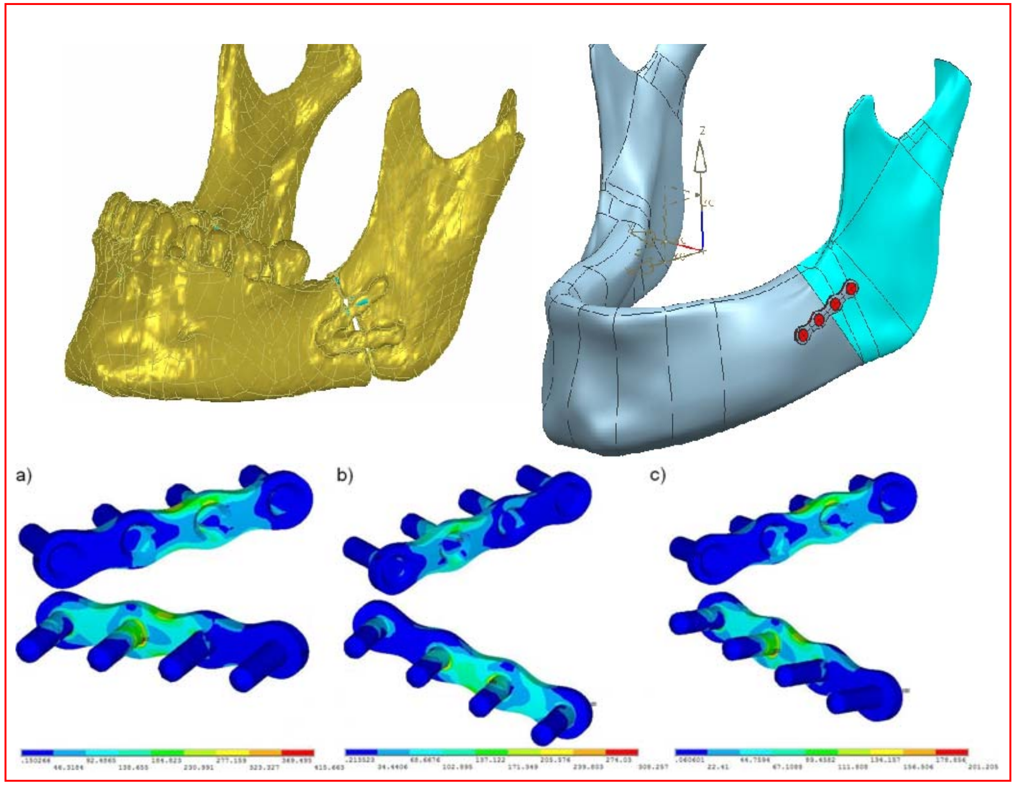
Biomechanics



- **IMPLANTS AND BONE REMODELLING (DENTAL IMPLANTS)**

- **FINITE ELEMENT MODELS FOR NUMERICAL SIMULATION OF PLATE STABILIZATION OF MANDIBLE FRACTURE**

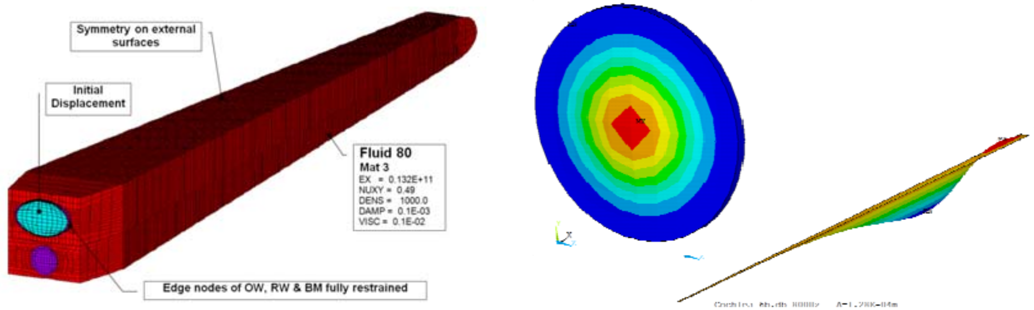
- Optimization of the stabilization technique and procedure
- Simulation of the behaviour of the bone tissue during healing period
- Cooperation with Medical Univeristy of Warsaw



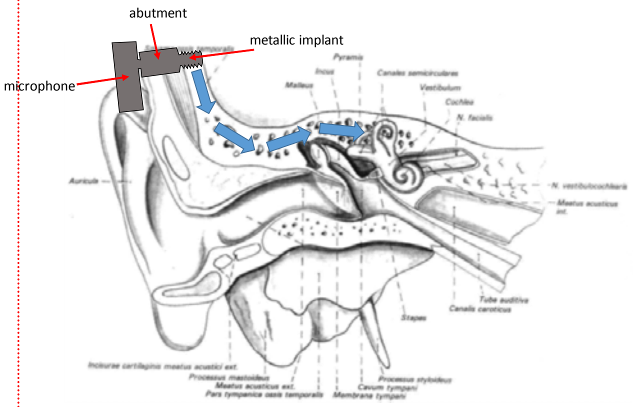
Biomechanics

- **INNER EAR BIOMECHANICS AND BONE CONDUCTION IMPLANTS**

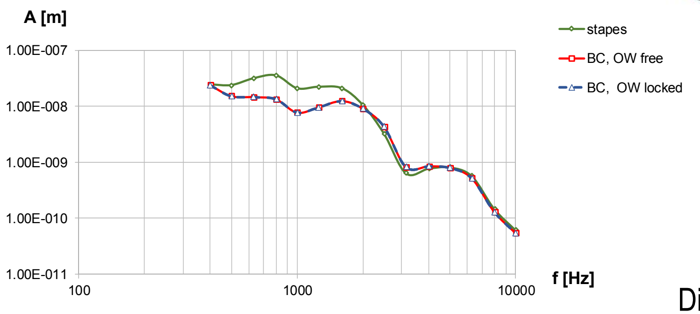
Biomechanics of Stapedotomy Surgery – Model and Experiment (2013-2016)

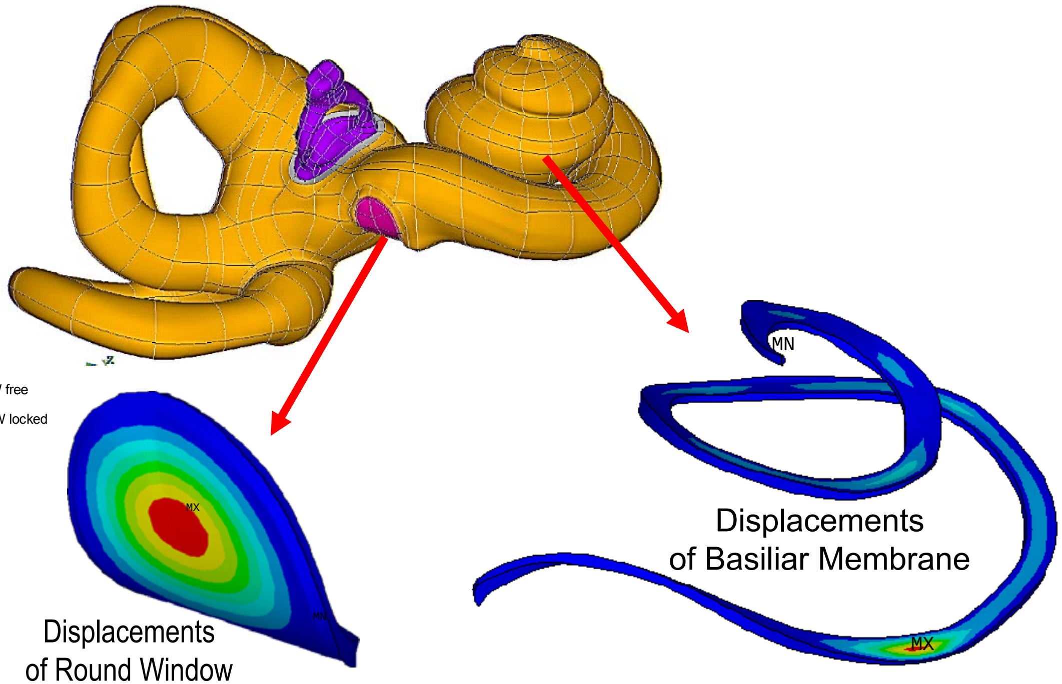


A new innovative method for direct stimulation of inner ear structures via bone conduction (2015-2018)



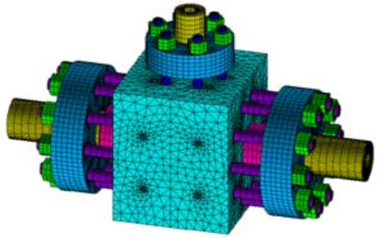
[Bochenek A., Anatomia człowieka]

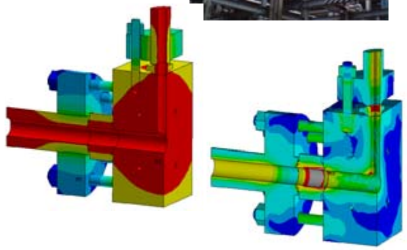




Power engineering

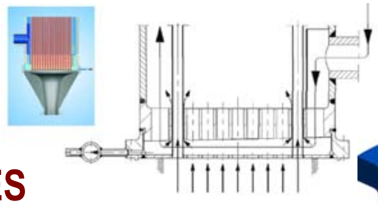
- **FE ANALYSIS OF A HIGH PRESSURE T-CONNECTION**

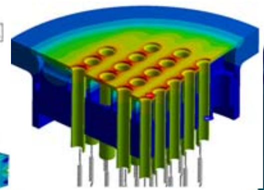


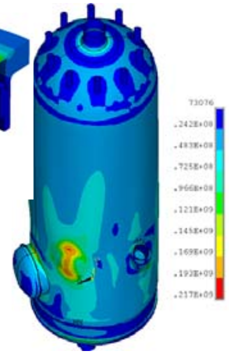


- **FATIGUE LIFE DEVICES IN CONDITIONS OF CYCLIC PRESSURE CHANGES**
  (HOG -ORLEN S.A.)

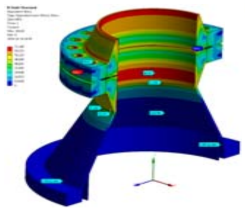
- **LOW CYCLE FATIGUE PROBLEM FOR DOUBLE TUBESHEET OF QUENCH HEAT EXCHANGERS FOR ETHYLENE CRACKING FURNACES**
  (Olefins II PKN ORLEN S.A.)



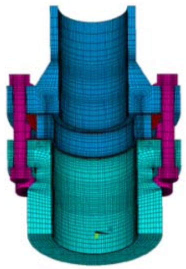




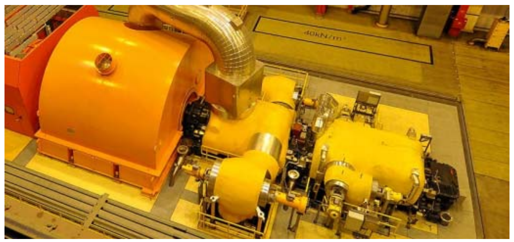
- **TIGHTNESS ANALYSIS FOR QUENCH HEAT EXCHANGERS FOR ETHYLENE CKRACKING FURNACES** (PKN ORLEN S.A)

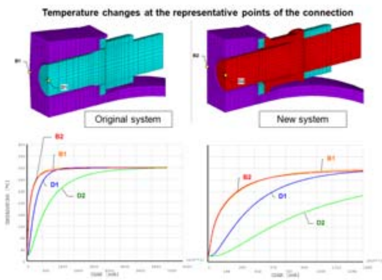


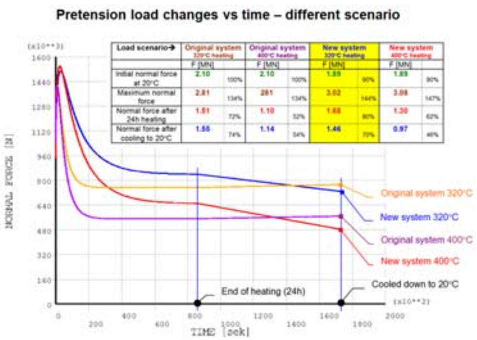
- **ANALYSIS OF FLANGE CONNECTIONS UNDER VARYING THERMAL CONDITIONS**



- **ANALYSIS OF STEAM LEAKAGE IN THE FUSELAGE OF WP TURBINE** (ALSTOM)

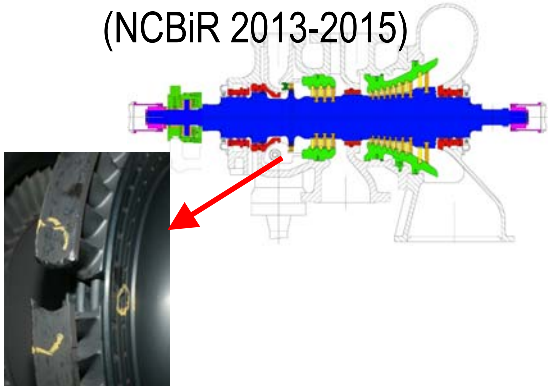


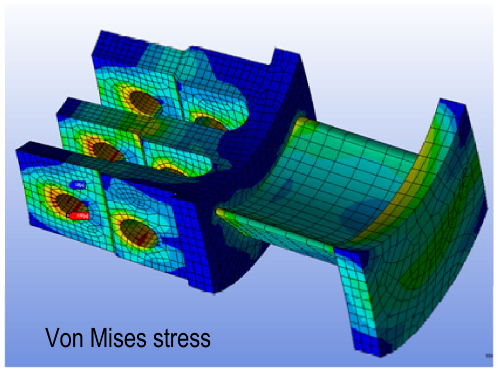


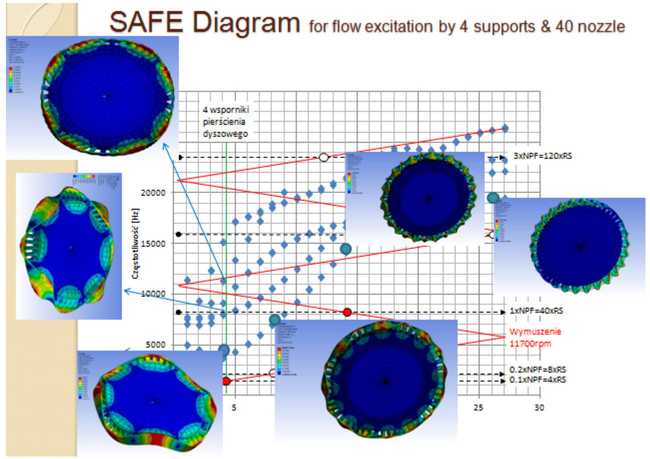


Power engineering

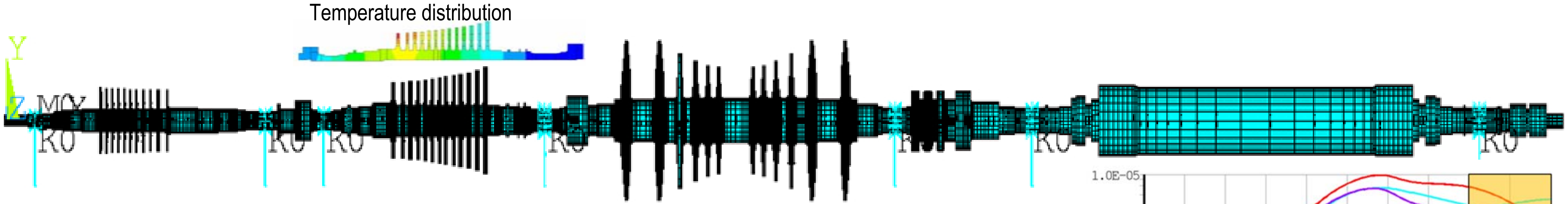
- **PROBLEMS OF STRENGTH OF ROTATING TURBOMACHINERY** (NCBiR 2013-2015)

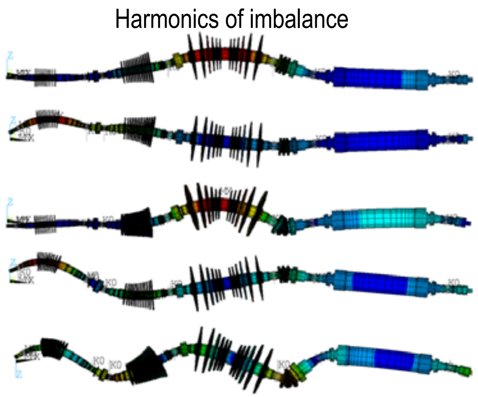


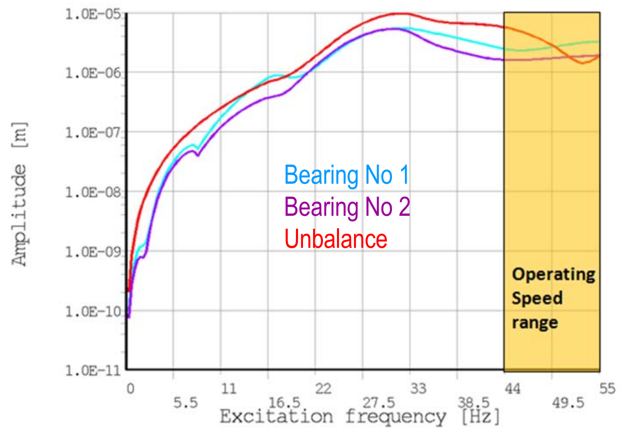




- **ANALYSIS OF THE DYNAMICS AND STRENGTH OF THE ROTORS** (NCBiR 2013-2015)

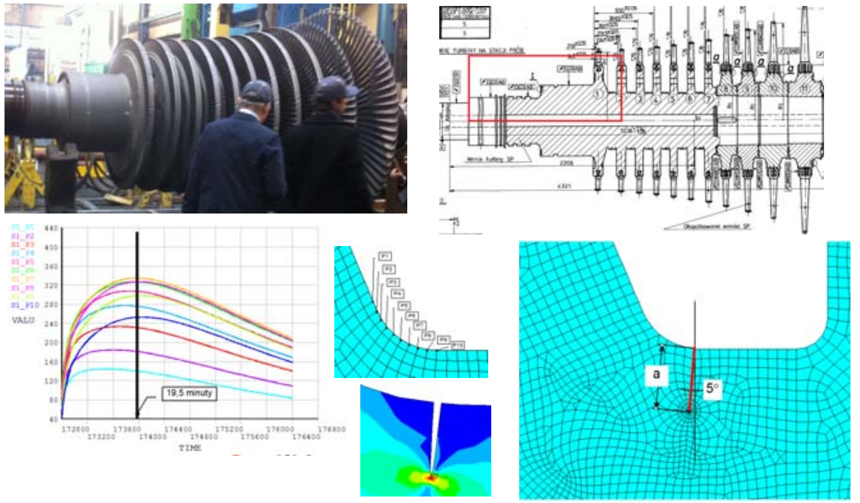


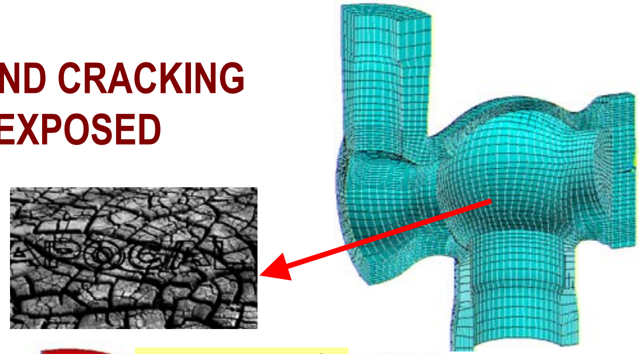


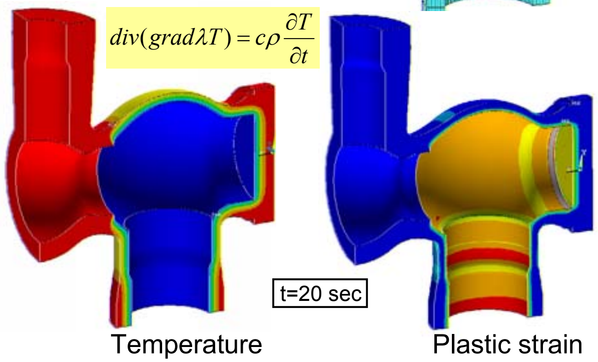


Power engineering

- **FINITE ELEMENT MODELING OF MATERIAL FATIGUE AND CRACKING PROBLEMS FOR STEAM POWER SYSTEM HP DEVICES EXPOSED TO THERMAL SHOCKS** (2014-2015)

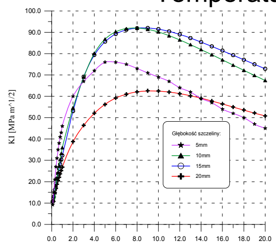






$$div(grad\lambda T) = c\rho \frac{\partial T}{\partial t}$$

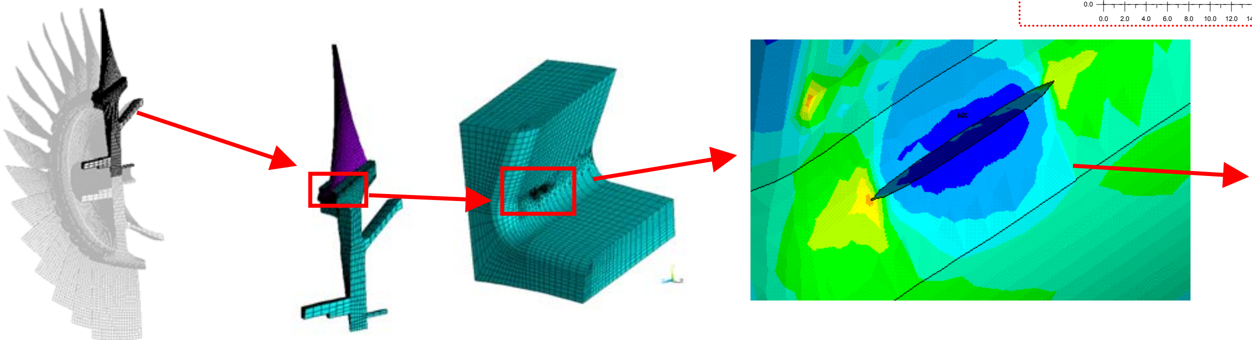
$\varepsilon_{pl}^{max}=8‰$

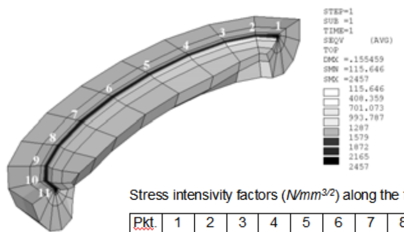


Low cyclic fatigue:

Cracking: $\frac{da}{dN} = C_e \quad N^k \Delta\varepsilon_{pl} = C$

- **FE ANALYSIS OF THE TURBINE BLADE LOCKING PIECE DEFECTS**





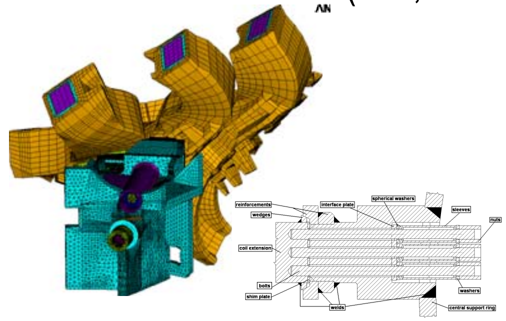
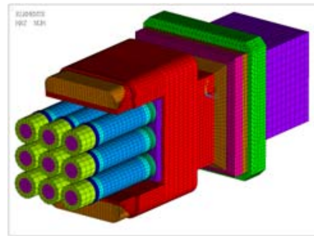
Stress intensivity factors ($N/mm^{3/2}$) along the front of the crack

Pkt.	1	2	3	4	5	6	7	8	9	10	11
K_I	410	421	442	453	465	472	476	462	455	455	450
K_{II}	81	59	38	8	12	28	44	50	52	66	76
K_{III}	30	42	64	73	78	78	72	62	48	29	25

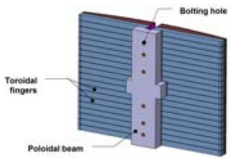
Power engineering

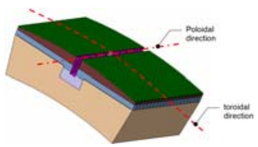
- **FINITE ELEMENT ANALYSIS OF CRITICAL CENTRAL CONNECTION ELEMENTS OF W7-X STELLATOR COIL SUPPORT SYSTEM** (IPP, Greifswald, 2005-2011)

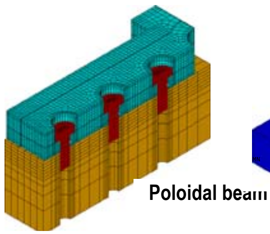


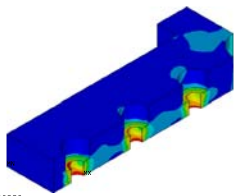
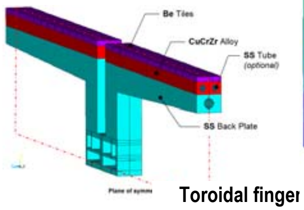



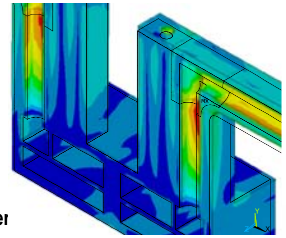
- **FE MODELLING OF THE MECHANICAL BEHAVIOUR OF SEPARABLE FIRST WALL ELEMENTS FOR ITER** (IPP, Garching, 2008)



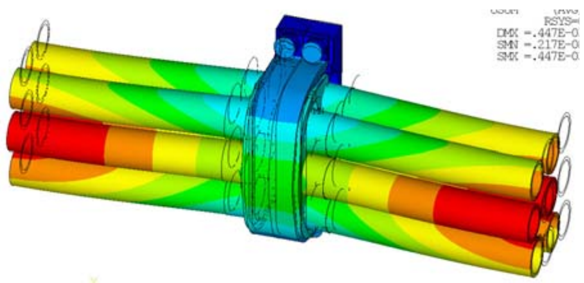
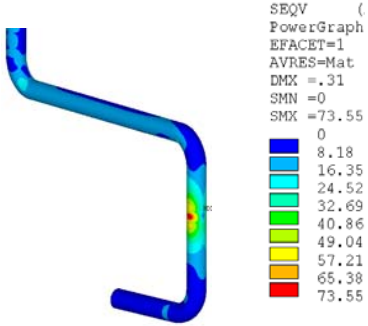


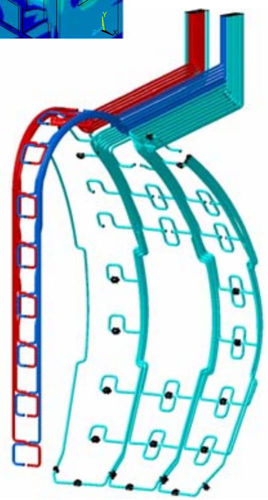




- **PRELIMINARY MECHANICAL ANALYSIS OF BLANKET MANIFOLD CONCEPT FOR ITER REACTOR** (IPP, Garching, 2008)

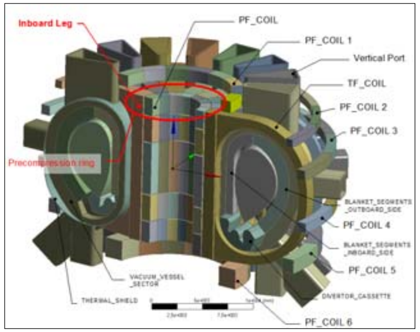





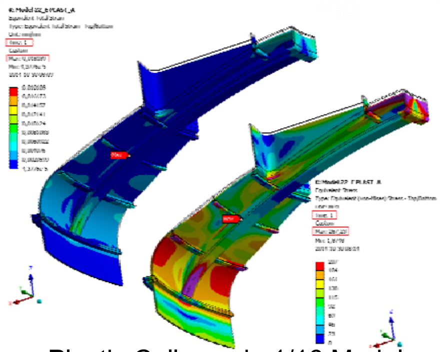
Power engineering

EUROfusion
POWER PLANT PHYSICS & TECHNOLOGY DEPARTMENT

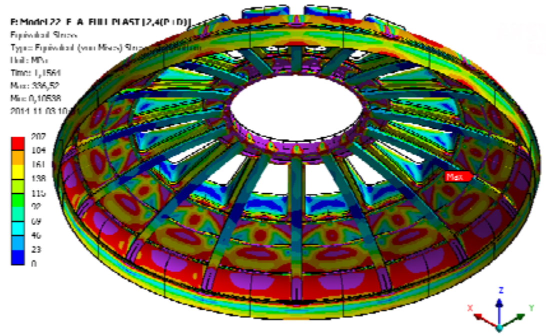
Structures of DEMO fusion reactor (2014-2018)



- **DESIGN INVESTIGATIONS OF CRYOSTAT TOP LID FOR DEMO** (2014)

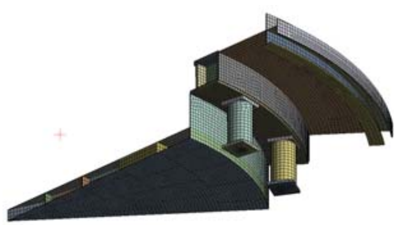


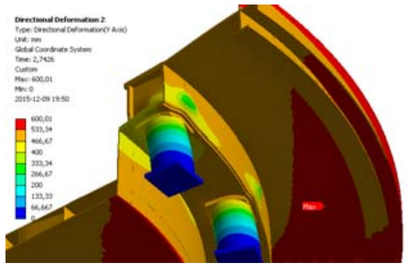
Plastic Collapse in 1/16 Model



Plastic Collapse in FULL Model

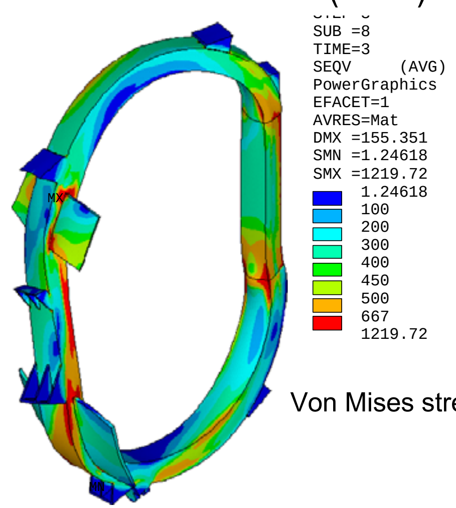
- **CRYOSTAT PEDESTAL RING DESIGN ASSESSMENT** (2015)





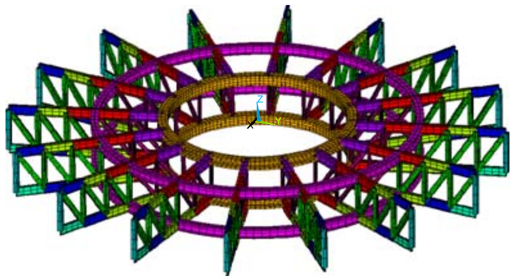
UY displacements (LF=2.7426)

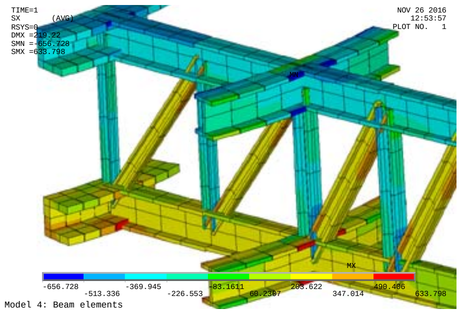
- **STRUCTURAL ANALYSES OF VARIOUS TF COIL CONFIGURATIONS** (2016)



Von Mises stress

- **DESIGN AND ANALYSIS OF BIOSHIELD ROOF** (2016)

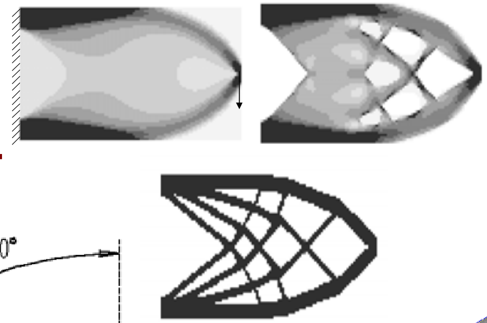


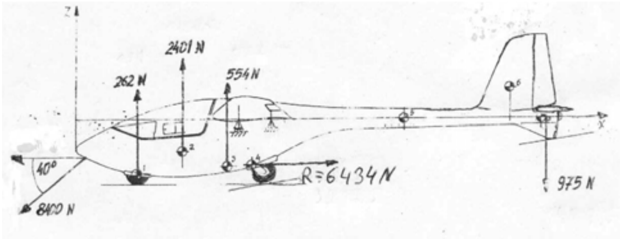


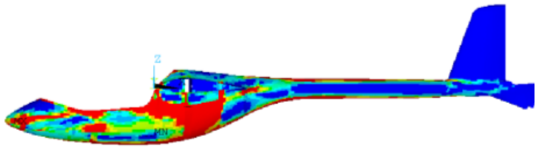
Composites, cellular solids, smart and intelligent materials

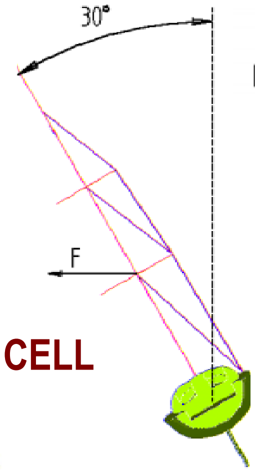
- **Structural Optimization** :

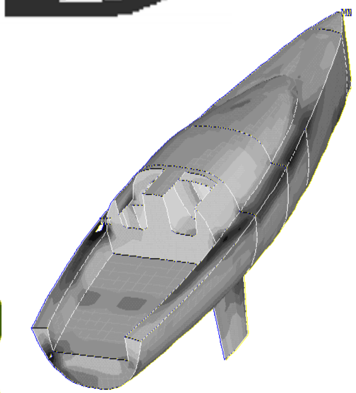
  THE PREDICTION OF OPTIMAL MATERIAL LAYOUT AND PROPERTIES FOR ELASTIC CONTINUM STRUCTURE USING WEIGHTED RESOURCE CONSTRAINT





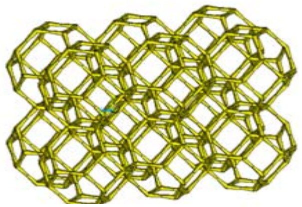


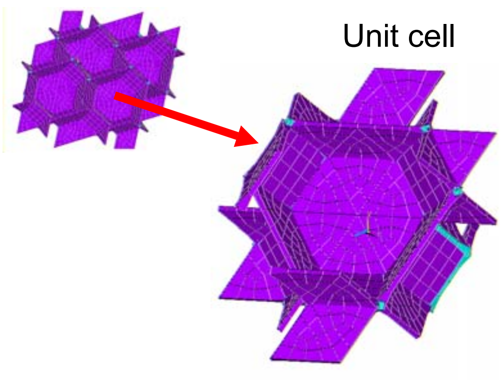


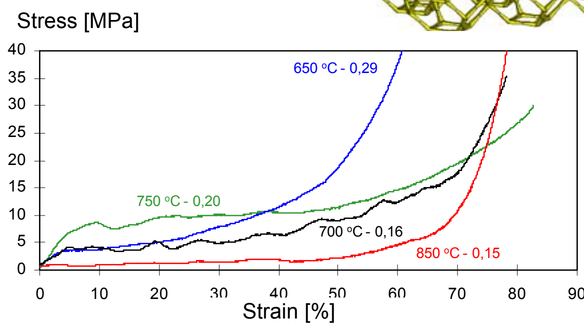


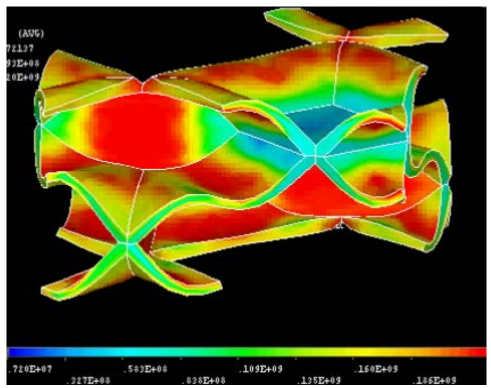
- **Mechanics of Cellular Solids**:

  MECHANICAL PROPERTIES OF LOW DENSITY OPEN & CLOSED CELL FOAMS BASED ON TETRAKAIDECAHEDRONAL MODEL OF MICROSTRUCTURE



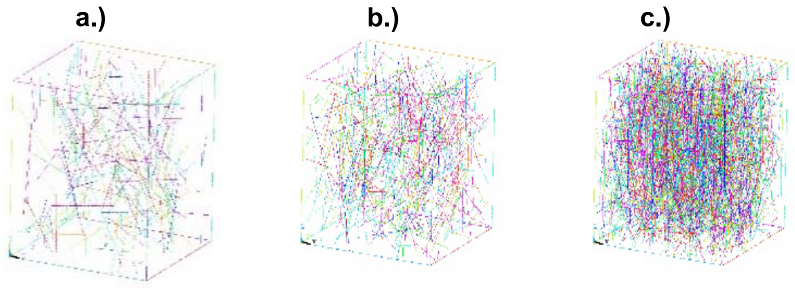




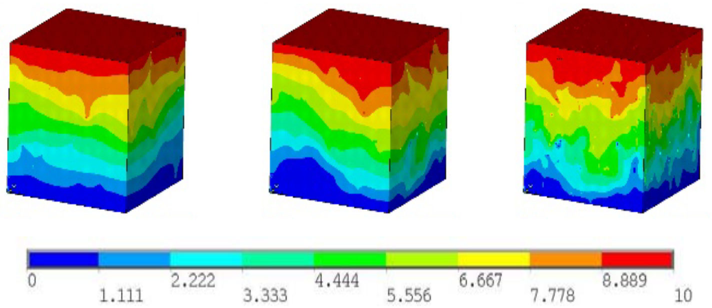


Composites, cellular solids, smart and intelligent materials

• **NANOCOMPOSITES: PARAMETRIC FE MODELLING OF MECHANICAL, ELECTRICAL AND THERMAL PROPERTIES OF NANOCOMPOSITE**

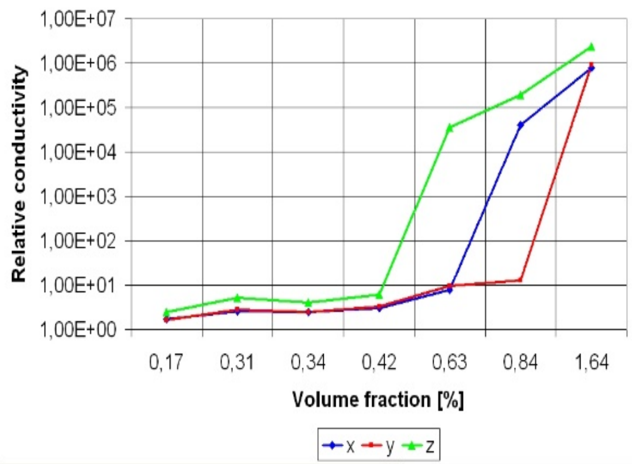


Models with different number of CNTs: a.) 200, b.) 500, c.) 2000.



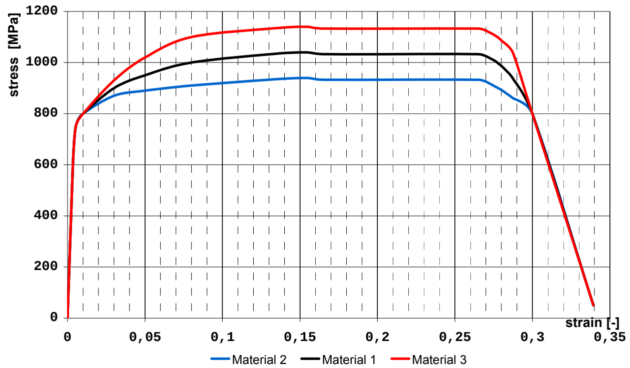
Potential [V] distribution for different number of CNTs.

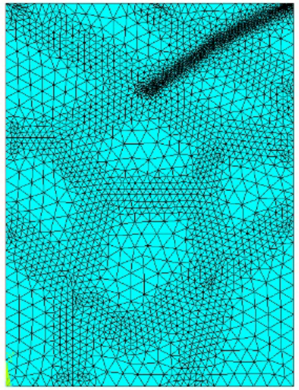
Percolation effect

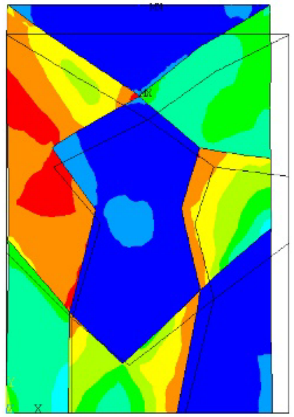


Mechanics of solids

- **FE MODELING OF MICROSCALE STRUCTURES WITH NON-UNIFORM MATERIAL DISTRIBUTION - CRYSTALLITES (NON-LINEAR MATERIAL PROPERTIES, LARGE DEFORMATION AND STRAIN)**

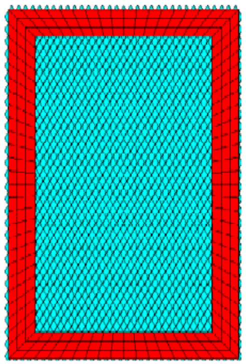


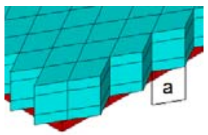


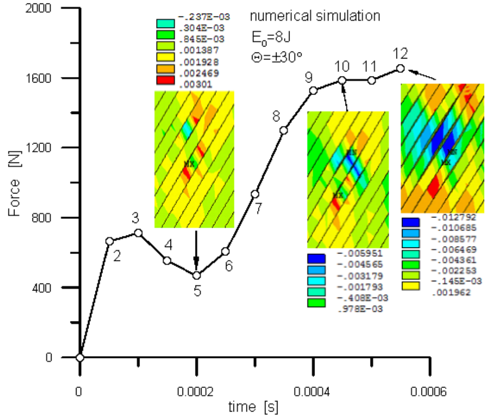


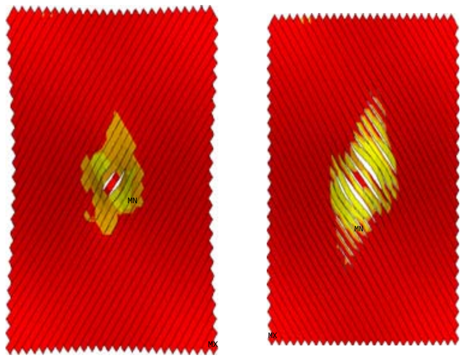
Equivalent stress distribution for 4.6% of total elongation

- **SEQUENCE OF DAMAGE EVENTS (DELAMINATION) OCCURRING IN THE COURSE OF LOW ENERGY IMPACT OF CARBON FIBRE COMPOSITES**





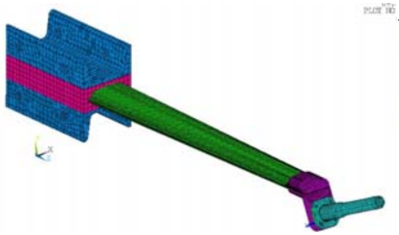
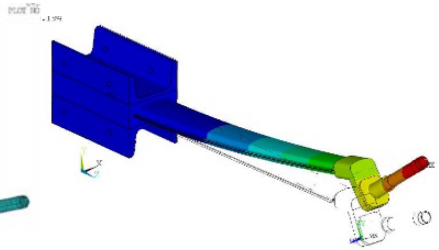
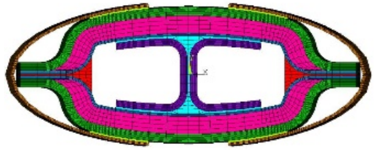




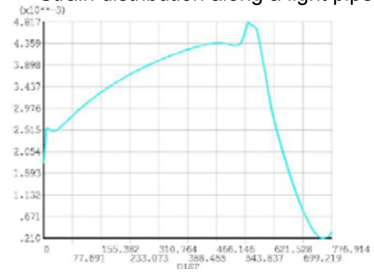
Final intra and interlaminar damage

Aviation

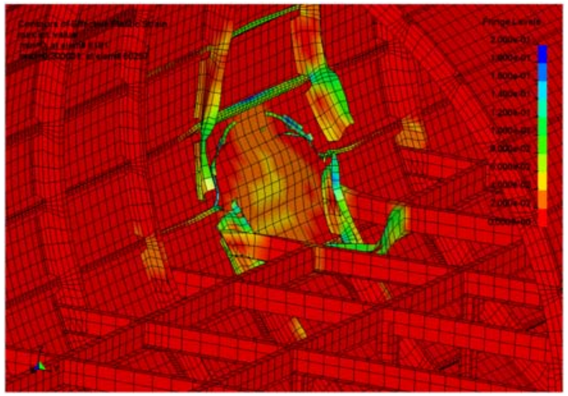
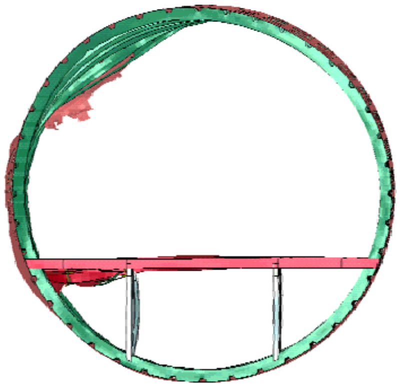
- **UNDERCARRIAGE LEG WITH LAMINATED LIGHT PIPES TO MONITOR ITS ACTUAL STATE**

Strain distribution along a light pipe



- **EXPLOSION RESISTANCE OF THE FUSELAGE** - VULCAN

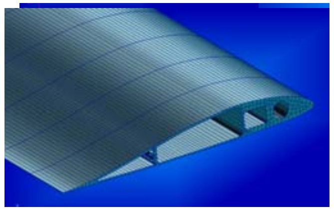



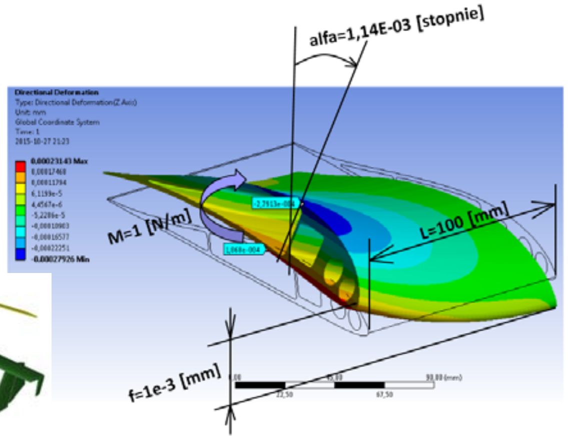
Numerical simulation

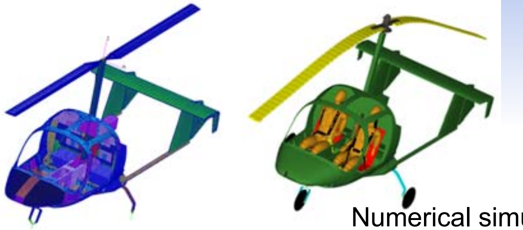

Experiments

Aviation

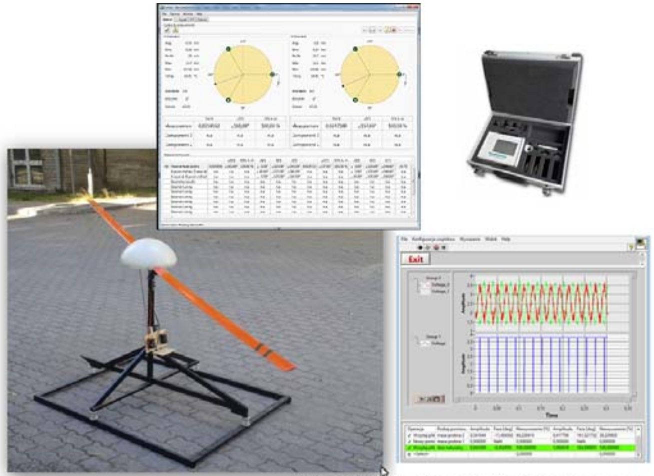
- **GIROCOPTER DYNAMICS: PRS, ROTOR BRAKING, L/G**



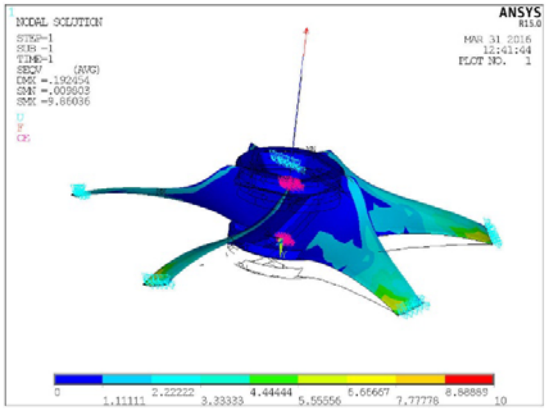


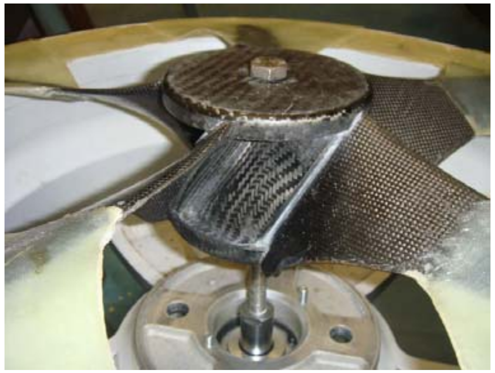


Numerical simulation



Instrumentation and software for rotor balancing





Relevant developmental project of the Institute

Project within Regionalnal Operational Funds of Mazowian Voivodeship lounched in 2019

„Implementation and traning airfield in Przasnysz"

Przasnysz (population- about 20.000) is located in the voivodeship of Mazowia

MEL