Warsaw University of Technology
Faculty of Power and Aeronautical Engineering
Department of Automation and Aeronautical Systems

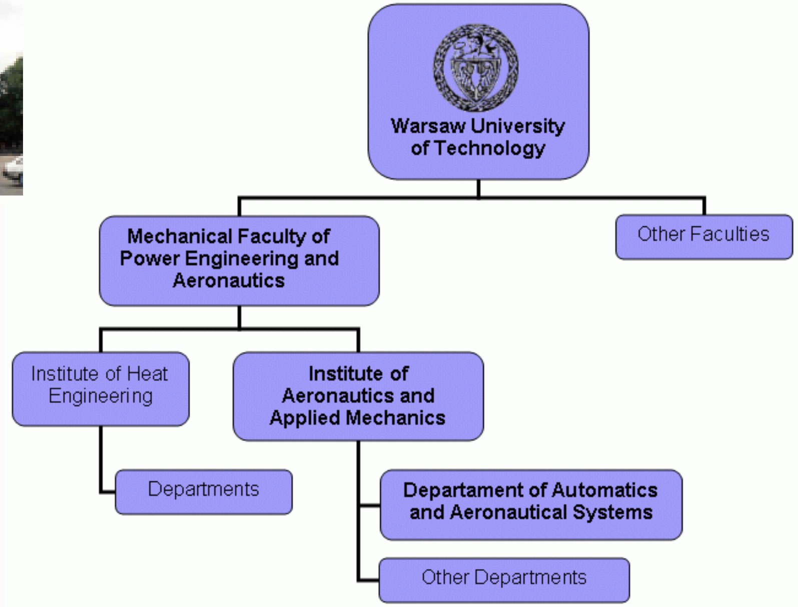
University Research Experiences in Aeronautics - Simulation, Navigation and Control Systems

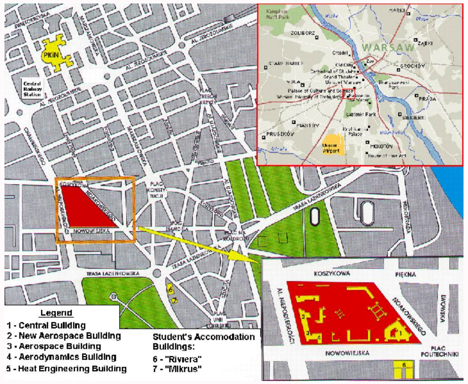
Janusz Narkiewicz

Warsaw University of Technology

Faculties

Architecture
Chemical and Process Engineering
Chemistry
Civil Engineering
Electrical Engineering
Electronics and Information Technology
Environmental Engineering
Geodesy and Cartography
Mathematics and Information Science
Physics
Power and Aeronautical Engineering
Transport
Automobiles and Heavy Machinery Engineering
Materials Science and Engineering
Mechatronics
Production Engineering





Staff - 4000+
Research - 2554
392+ professors
100+ professors (WUT)
1223+ associate (Ph.D.) & assistant prof.
489+ lecturers

The number of students 32 000+

Faculty of Power and Aeronautical Engineering

Institute of Heat Technology

Institute of Aeronautics and Applied Mechanics

Departments

- *Aerodynamics*
- ***Automation and Aeronautical Systems***
- Mechanics
- Fundamentals of Design
- *Airplanes and Helicopters*
- Theory of Machines and Robots
- Strength of Materials and Construction

Staff total ~ 120 persons

6 tenured professors

12 full professors

3 associate professors (D.Sc.)

42 adjoint (Ph.D) & assistant prof

12 senior lecturers

technical and administrative staff

IAAM one of the biggest institutes at WUT budget more then 3,5+ MEuro

Department of Automation and Aeronautical Systems

HEAD OF DEPARTMENT
Prof. Janusz Narkiewicz
jnark@meil.pw.edu.pl

- **Staff**

  Professors 2, Adjoint professors, Ph.D. - 5

  Lecturers - 1, Ph.D. Students – 3,
  Technician - 1, Secretary - 1

- **Software:** FLIGHTLAB, MatLab, simulation of airplanes, helicopters, missiles

- **Hardware:** two airplane models, two helicopter flying models, electric car, navigation sensors (GPS, INS, mgt compass, on-board computers,…)

- **Teaching**
  - ✓ Rotorcraft aeromechanics
  - ✓ Avionics
  - ✓ Aeronautical systems
  - ✓ Navigation
  - ✓ Aircraft control systems
  - ✓ Signal theory
- **Research topics**
  - ✓ rotorcraft aeromechanics
  - ✓ modeling of controlled and guided vehicles
  - ✓ aircraft control
  - ✓ integrated navigation systems
  - ✓ control of "smart structures”

EC FP Projects: ADFCS II, SEA-AHED, CAPECON, GAlileoApp, UAVNet, NACRE, NICETRIP, NEFS, TALOS

Expertise in DAAS

- ***Simulation of air, ground and water vehicles;*** performance and control analysis.
  - FLIGHTLAB software
  - computer models of various air and ground vehicles: airplane, helicopter, tilt-rotor, car, etc. various complexity of models with control modules.
- ***Control and navigation*** methods and algorithms for signal processing
- ***Autopilots and control systems of airplanes and rotorcraft***
  - fly –by- wire systems
- ***UAV*** systems
- ***Integration of navigation sensors for mobile platforms***.
  - sensors: GPS, INS, magnetic compass
  - other sensors (i.e. video camera, wheel rotations)
  - filtering methods: Kalman, Julier - Uhlmann

Research Projects EU

EU 5 FP completed

- ***ADFCS II*** *- Affordable Digital Fly-By-Wire Flight Control Systems for Small Commercial Aircraft (Second Phase)*
- ***SAE-AHEAD*** *- Simulation Environment and Advisory system for on-board Help, and Estimation of maneuvering performance during Design*
- **CAPECON** – Civil UAV Applications & Economic Effectivity of Potential Configuration solutions
- **UAV- Net** – Civilian UAV Thematic Network: Technologies, Applications, Certification

EU 6 FP going

- **NACRE -** New Aircraft Concepts REsearch
- **NICE TRIP -** Novel Innovative Competitive Effective Tilt Rotor Integrated Project
- **NEFS -** New Track integrated Electrical Single Flap Drive System

EU 7 FP going

- **TALOS -** Transportable Autonomous Patrol for Land Border Surveillance System

Research Projects PL

Polish State Committee for Scientific Research (KBN)

Ministry of Science and Higher Education

PROTEUS- Integrated mobile system for counterterrorism and rescue operations

Autonomous system for detection and neutralisation of non-metal mines

Recently completed (examples)

- ***Investigation of Tiltrotor Control in Selected Flight Conditions (PhD)***
- ***Application of Attitude and Navigation Systems in Evaluation of Helicopter Flying Qualities (PhD)***
- ***Feasibility Study on Application of Image Matching Systems in Navigation of Moving Platforms (PhD)***
- ***Impulsive Control of Small Smart Missiles Flight with Control Laws Based on Artificial Neural Networks***
- ***Integration of Control and Navigation Systems for Moving Objects***
- ***Investigation of the influence of lifting surface disturbances on aircraft performance (coordinated by Institute of Aviation, Warsaw)***

JN1

Slajd 7

JN1 Janusz N; 2006-05-20

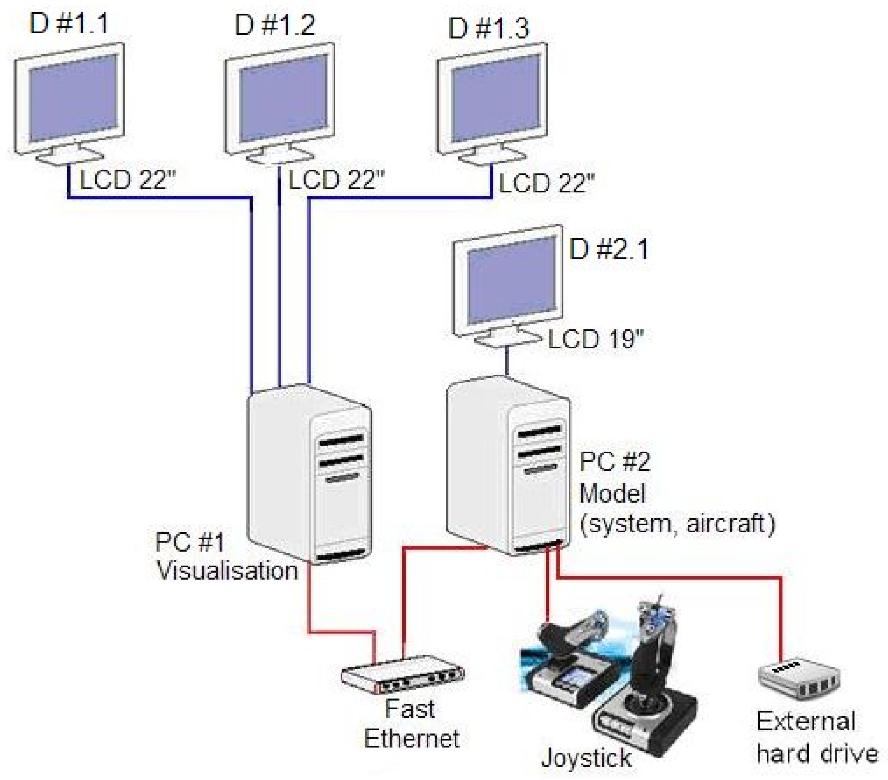
Simulation

Increased capability of visualization of calculation result in using simulators for new concept validation

Software: commercial, in-house

Simulator with option of implementing software prepared by various persons, also those with limited skills of program coding.

The fixed based simulators may apply the elements of computer games, as MS Flight Simulator to which the young people are accustomed.



Simulation

FLIGHTLAB (ART Inc., USA)

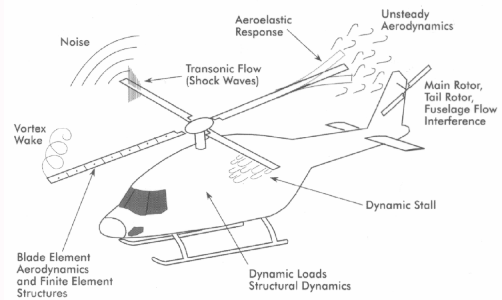
Modeling - multi-body nonlinear dynamic system, to be integrated with virtual reality environments

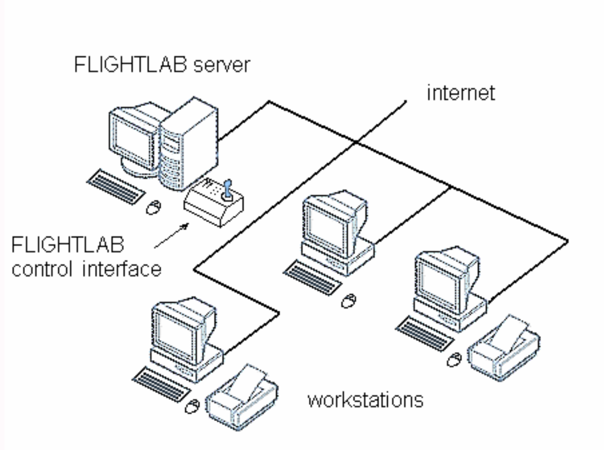
linear system analysis – extraction of linear models, model order reduction, eigenanalysis, time and frequency response

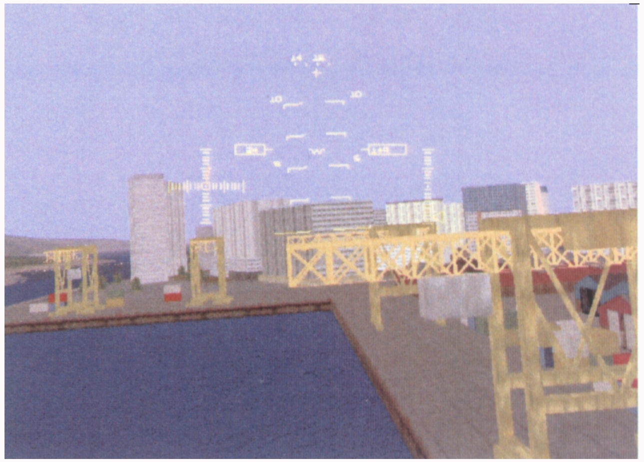
control system design - classical loop closures modern Linear Quadratic Regulator (LQR) methods

nonlinear model - trim, static equilibrium, and time and frequency response

library of components and analysis utilities and graphical user interfaces may be modified by the user





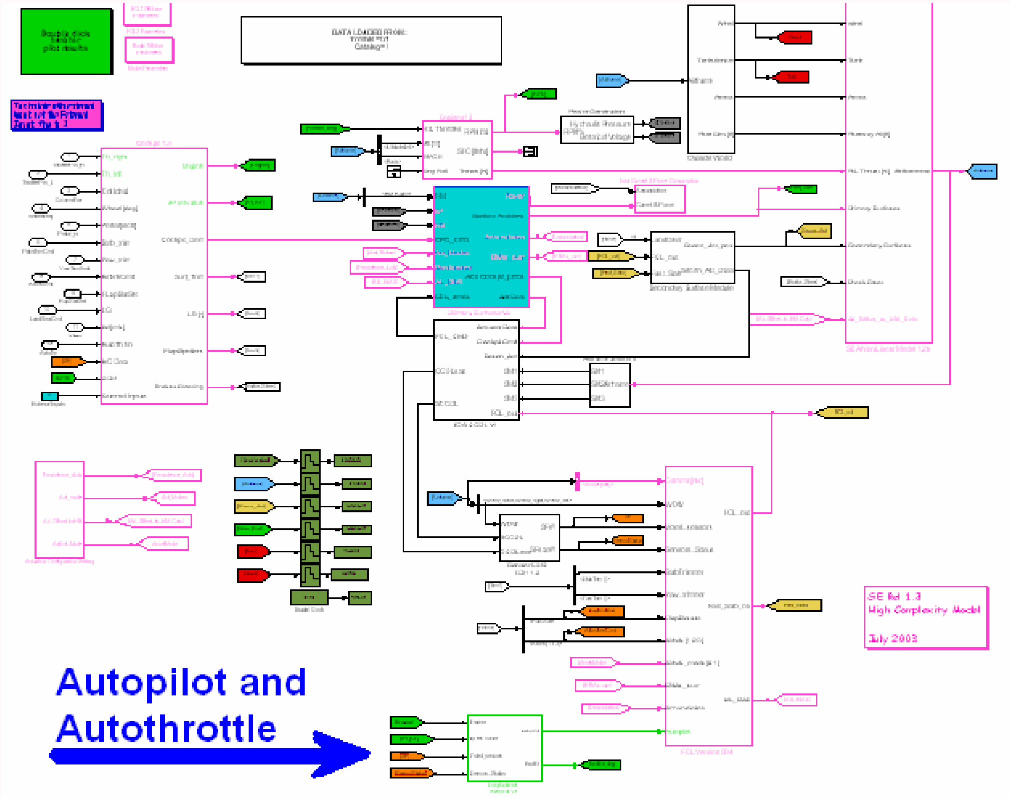


Affordable Digital Fly-By-Wire Flight Control Systems for Small Commercial Aircraft (Second Phase) (5 FP)

Objectives

ADFCS-II addressed 4 key cost drivers

- the design process by the increased use of high-fidelity simulations and analysis tools;
- Fault Tolerant Control technologies to improve Flight Control System effectiveness;
- actuation architectures to provide the required integrity and ensure the continuity of control;
- the specification of a set of Flying Qualities Requirements to focus the design process.



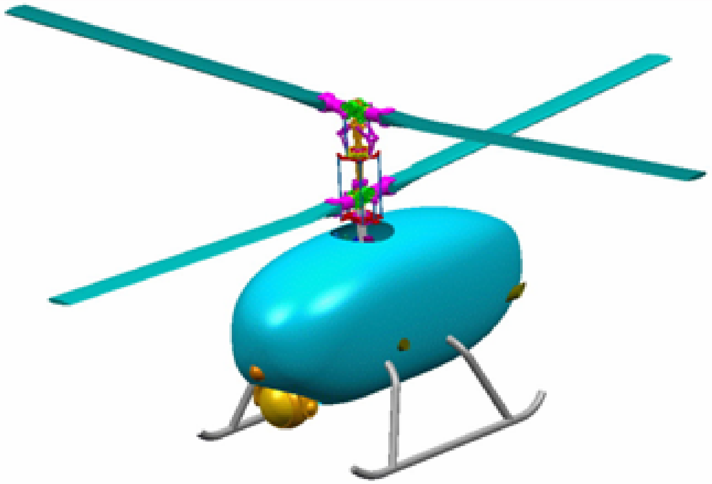
WUT results (RUT collaboration)

- Autopilot and autothrottle functions embedded into fly-by-wire system
- Tested by simulations
- Some functions validated in NLR simulator by flight test pilots

Civil UAV Applications & Economic Effectivity of Potential Configuration solutions (5FP)

WUT DAAS contribution

Two configurations selected: single rotor and coaxial.
Single rotor is 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

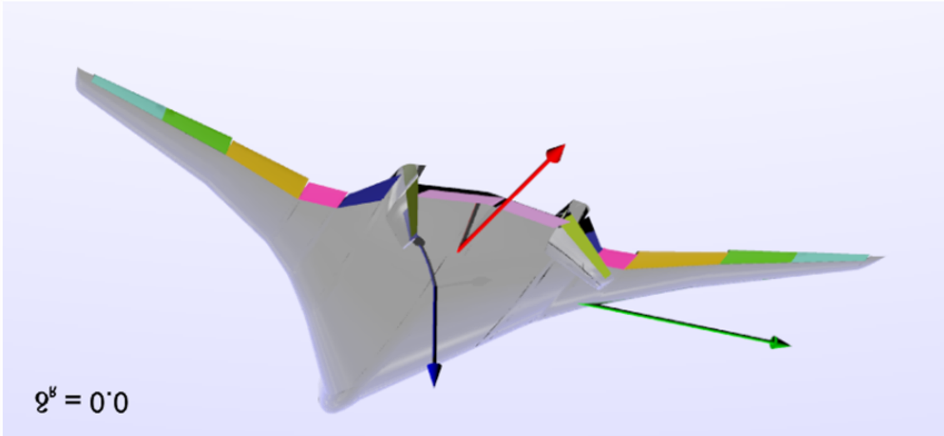
New Aircraft Concepts Research, IP (6 FP)

Number of partners: **35**
Start date: **1st April 2005**
Duration: **48 months**
Total budget: **30.3 M€**
EC funding: **16.9 M€**

WUT DAAS contribution

Simulation of Flight Control Laws for Flying Wing configuration

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



NICE TRIP

Novel Innovative Competitive Effective Tilt Rotor Integrated Project (6 FP)

Project 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 tilt-rotor elements and systems

NICETRIP consortium includes:
29 participants representing 8 EU Member States, including two new Member States (Latvia and Poland)

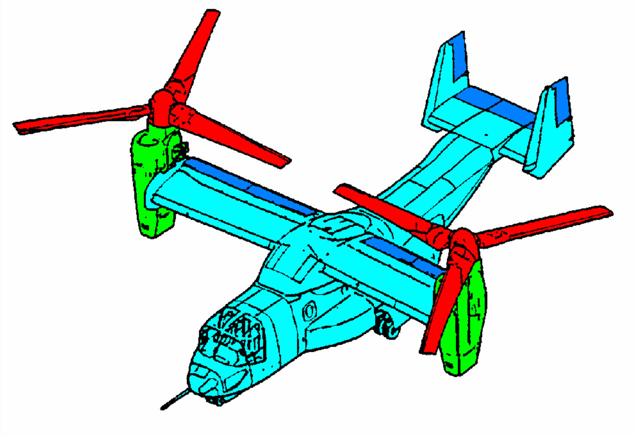
WUT DAAS contribution

- definition of an operational concept of use of the tilt rotor in the European ATM system and definition of an operational scenario for civil tilt rotor applications.
- tilt-rotor flight control system modeling

Investigation of tiltrotor control in selected flight conditions

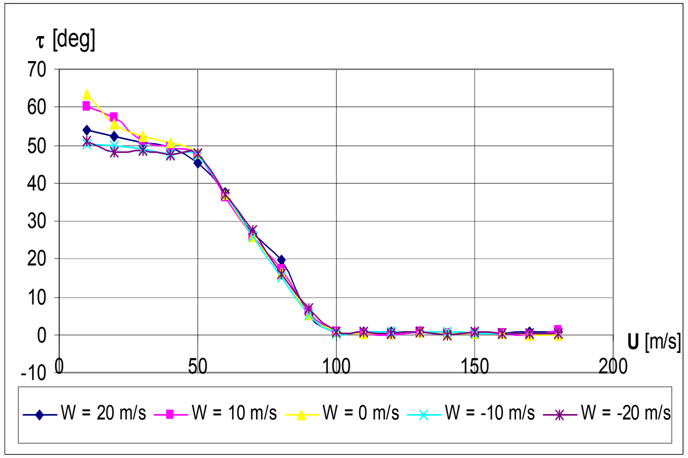
Configuration

- based on V-22 Osprey
- composed of:
  - ✓ fuselage
  - ✓ 2 wings, 2 x 2 flaps
  - ✓ 2 engine nacelles
  - ✓ 2 rotors, 2 x 3 blades
  - ✓ horizontal stabilizer, 3 elevators
  - ✓ 2 vertical fins; 2 x 1 rudder



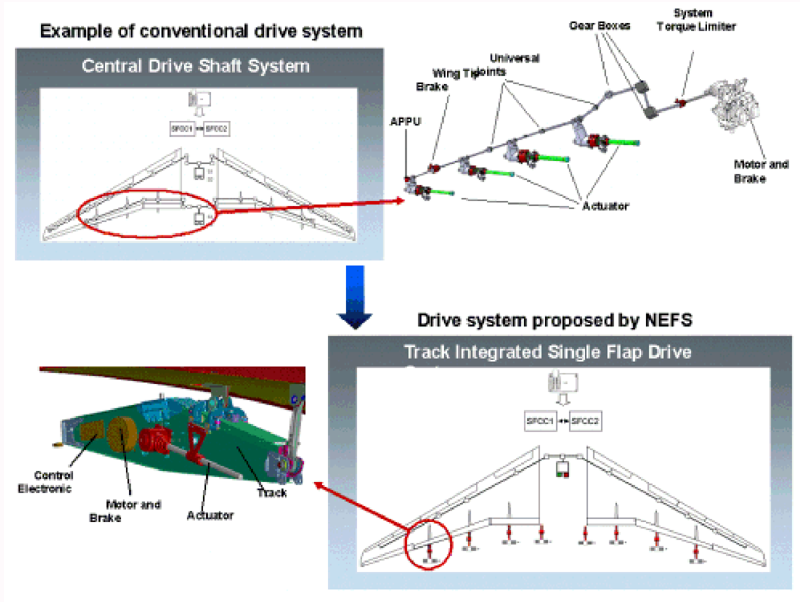
Results of the project

- Nonlinear simulation model developed coded and tested
- Trim (by minimisation algorithm)
- Linearization
- Stability (eigenvalues and modes)



Tilt angle of nacelles

New Track integrated Electrical Single Flap Drive System (6FP)



Objectives

distributed electrical flap drive system fault tolerant, redundant flap

integrated into the flap support structure in the very limited space

increased the availability and reliability, additional functionalities, simplify installation

Expected project results:

new functionalities of the high lift system via differential flap setting (DFS), accelerated vortex decay, roll trim and roll control support,

reducing operational interruptions by at least 15%,

improving the drive system efficiency by at least 25%,

2% - 3% L/D improvement in cruise,

20% weight reduction of the flap track beam

5% cost reduction in the manufacturing and assembly of the flap track beam (minimised number of parts),

improved maintainability,

reduced installation effort (for design and manufacturing).

DAAS = work package leader

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

work results :model system architecture, model of elements, models integration, implementation of diagnostic functions and failure simulation.

PROTEUS - PL

Integrated Mobile System for Counterterrorism and Rescue

develop 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. .
integrating the latest generation of IT and telecommunications systems with innovative mechanical designs in order to apply them in the mobile robotics.
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
detector modules for the detection and monitoring of terrorist threats and threats of disasters,
the system demonstrator used to verify the project achievements

DAAS = 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).

Navigation and control systems

Simulation and experimental reserach
Several navigation sensors
Mobile platforms: electrical cart, models of airplanes and helicopters, mobile robot (soon)

University multidisciplinary approach *transferring expertise in navigation systems to ground vehicles*

DAAS flying models

Citabria

- wing span 2.28 m,
- lenght 1.75 m,
- lift. surface 0.96 m^2
- mass 8.5 kg
- engine 60 cm^2

Trainer 60

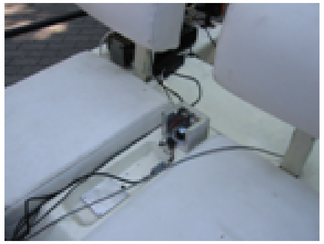
- wing span 1.95 m,
- lenght 1.455 m,
- lift. surface 0.566 m^2,
- mass 3.4 kg,
- engine 15 cm^3,

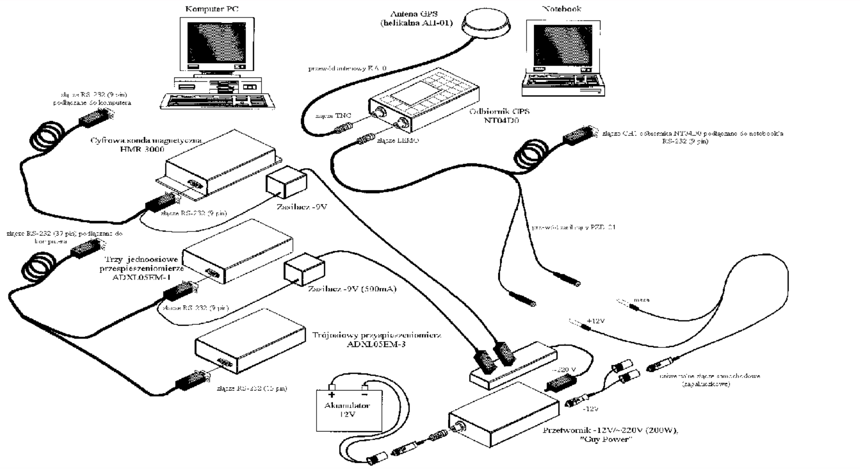
DAAS

Freya

- main rotor diam 1.633 m,
- tail rotor diam 0.27 m
- lenght 1.375 m,
- mass 5.5 kg,
- engine 15 cm^3

DAAS - electric cart

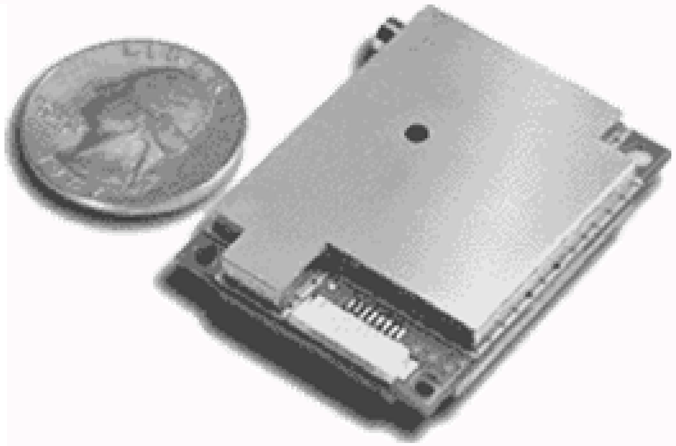




lenght 2.7 m
width 1.2 m,
wheel distance 1.6 m,
mass 350kg,
max velocity 23 km/h

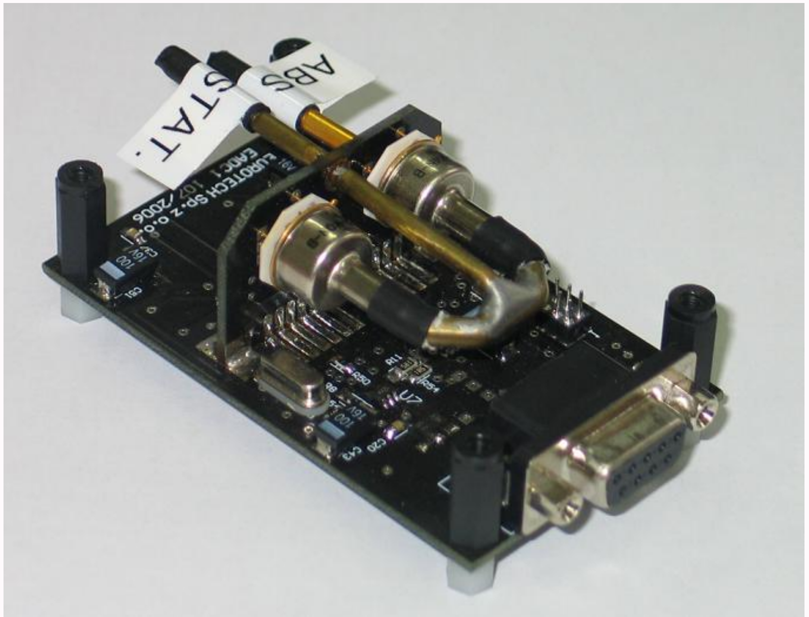
Sensors – GPS

Garmin,
BAE SmartAntena
Novatell - MILLENIUM RT-20/DGPS
Novatel FlexPak-G2L



Sensors

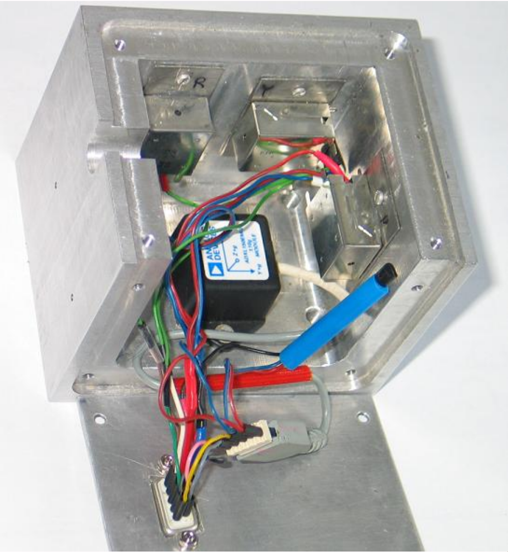
magnetic

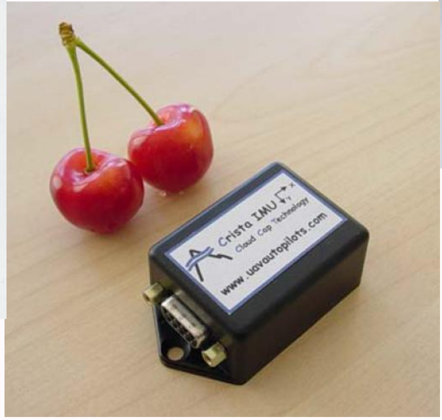


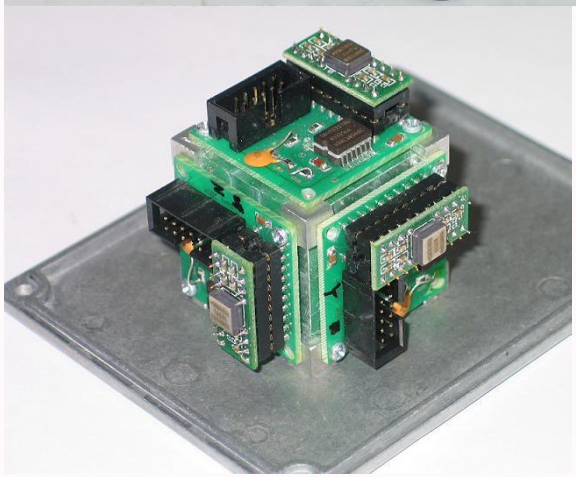
air data sensores

Sensors – IMU

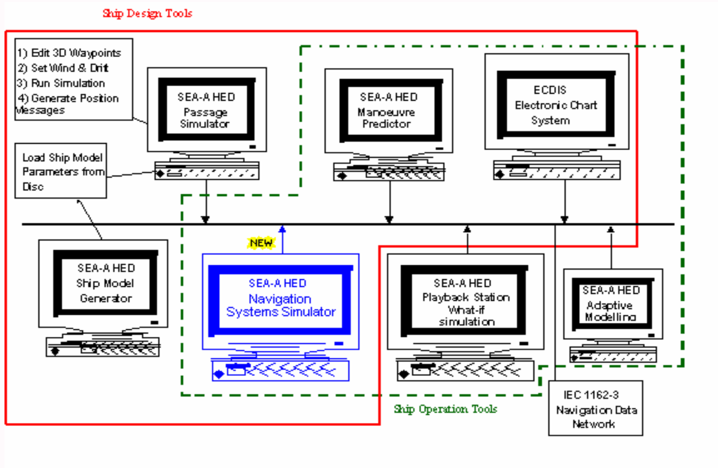
piezovibrating gyroscopes
Crista IMU, FOG KVH, LN 200

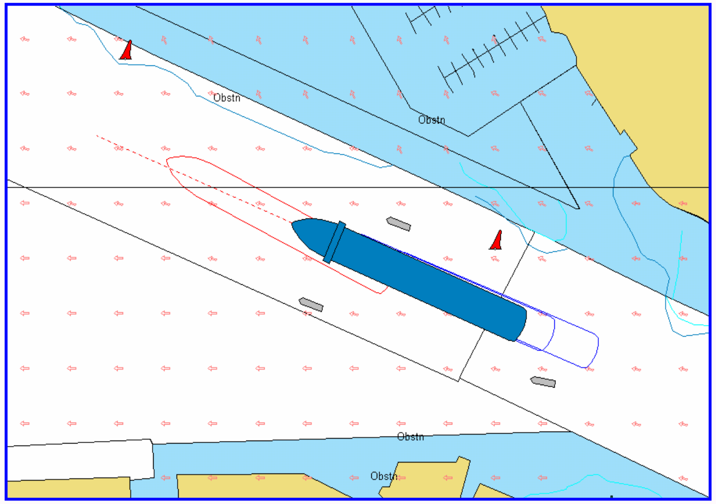






Simulation Environment and Advisory System for on-board Help, and Estimation of maneuvering performance during Design (5 FP)





WUT results

System for navigation data acquisition and processing

On-line identification of ship parameters

Prediction of ship motion in the nearest future

TALOS

Transportable Adaptable Patrol for Land Border Surveillance
(7 FP in Security priority)

designing, implementing and field-testing a prototype of adaptable and transportable border surveillance system.
use sensors allowing to detect people, vehicles and hazardous substances, crossing the unregulated land border.
carried by unmanned vehicles having a high degree of autonomy.
Scalability, Autonomous Mobility, Transportability, Tactical learning/adaptation behaviour, No need for fixed infrastructure or fences, Response to intrusion in minutes

Consortium industry, research and academia from

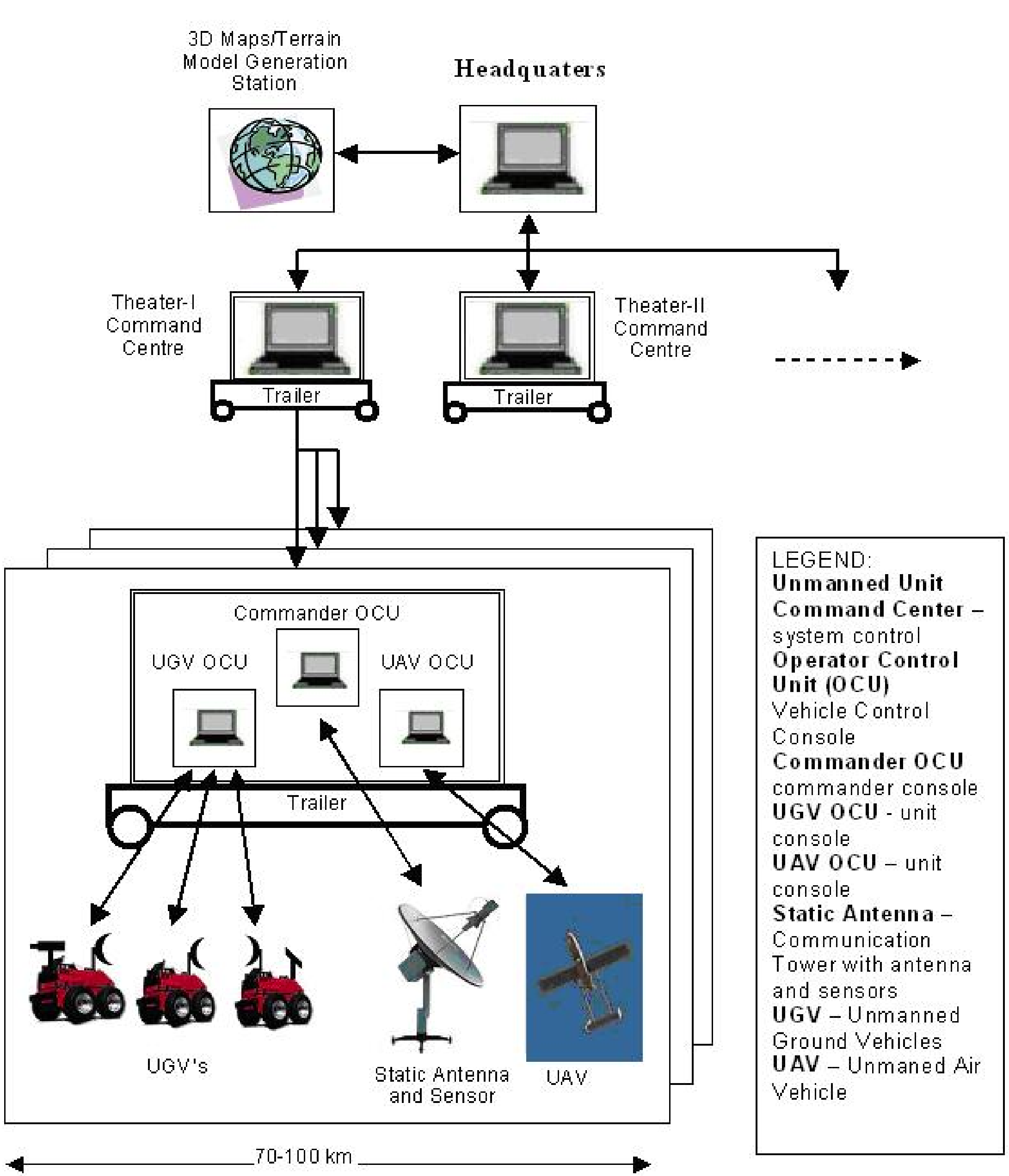
Belgium, Estonia, Finland, France, Greece, Israel, Poland, Romania, Spain and Turkey

DAAS

design and implement the UGV navigation system
creation and maintaining the public web site

TALOS Objectives

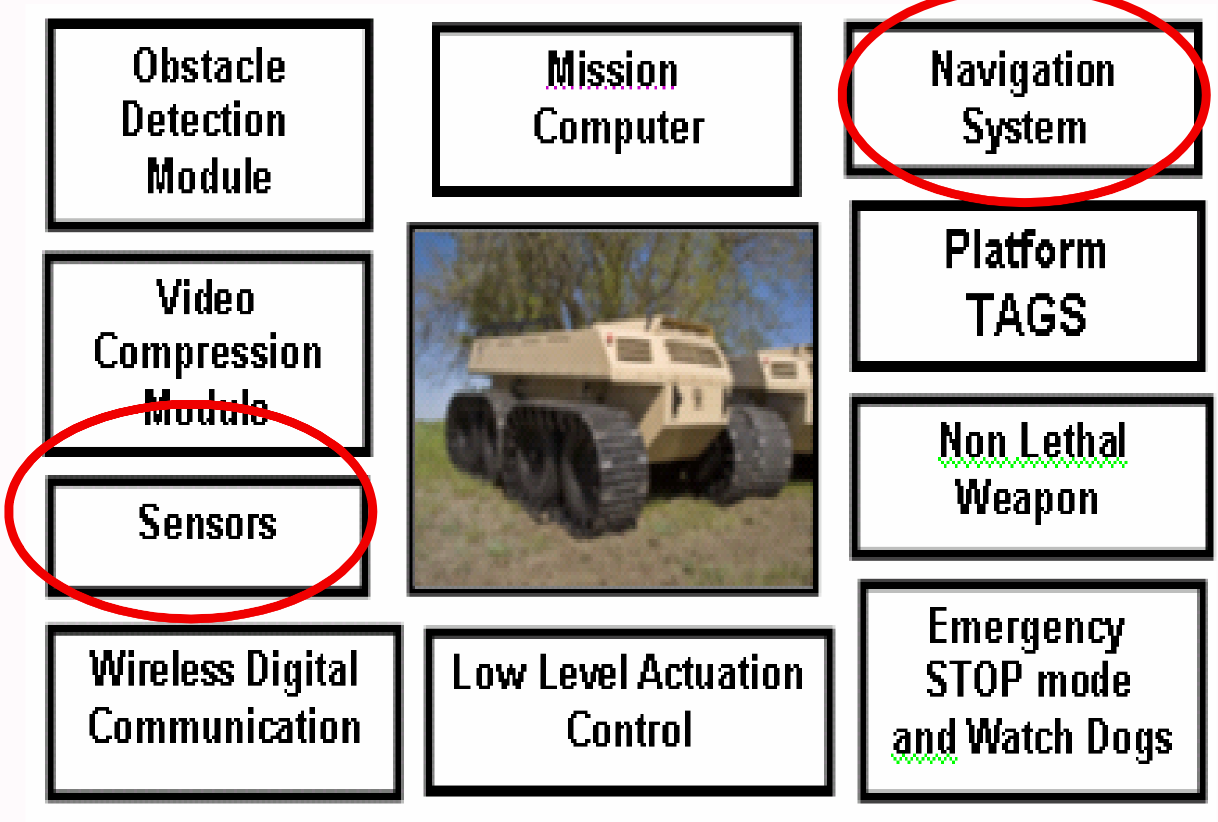
- **Objectives**: to develop and field test the innovative concept of a mobile, modular, scalable, autonomous and adaptive system for protecting European borders
- The complete system applies both aerial and ground unmanned vehicles, supervised by command and control centre,
- Emphasis put on application of UGV, communication and ability to command and control
- The system developed more versatile, efficient, flexible and cost effective



TALOS

DAAS participates in the Work Packages:

- WP 6: **UGV subsystems Design, Implementation, Integration and Test**
  - ✓ **DAAS** will design and implement the UGV navigation system
- WP 10: **Dissemination & exploitation**
  - ✓ website, workshops
- Other Work Packages
  - ✓ minor contribution



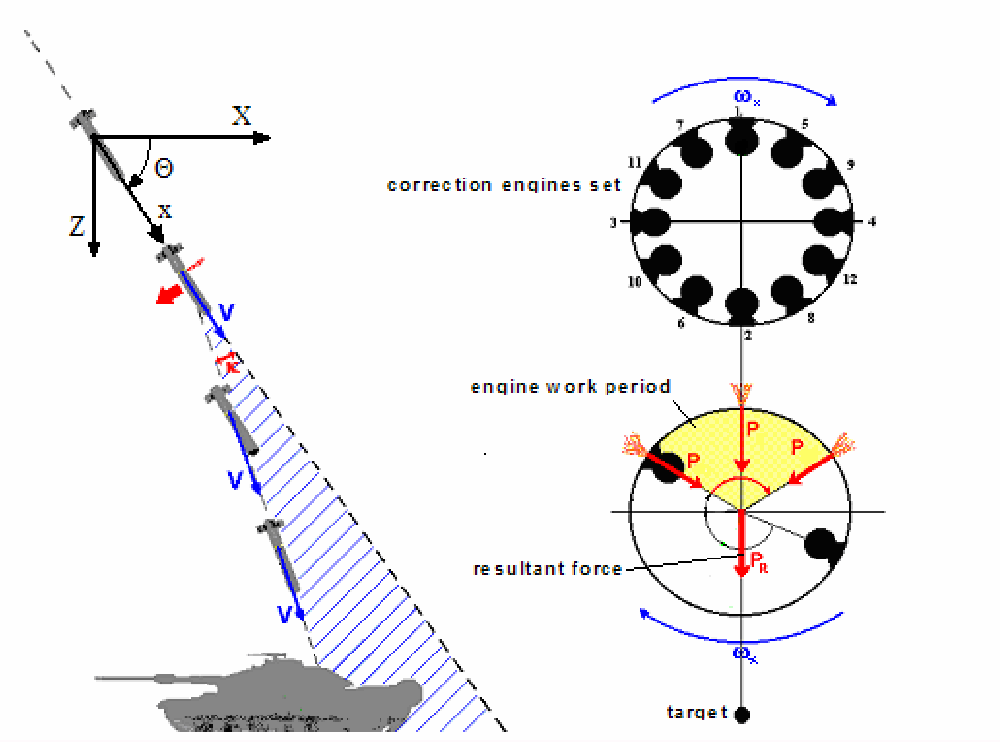
WP 6: **UGV subsystems Design, Implementation, Integration and Test**

- **DAAS** will develop and implement the UGV navigation system
- **DAAS** participates in the following tasks:
  - ✓ **UGV System Specification &Architecture Design**
    In this task the TALOS UGV system and architecture will be defined (UGV architecture, subsystems requirements definitions, interfaces between subsystems, performance etc). The output of this task is UGV system specification
  - ✓ **UGV System and Subsystems Design**
    The objective of this task in the WP to design the systems and subsystems of the UGV (Modules) and to define in details the tasks ,modes, processes and interfaces of the subsystems (including those items that will be bought and used as is) .
    The output of this task is a System Detailed Design (SDD) specification that defines in details the requirements of the S/W and H/W of the UGV subsystems.
  - ✓ **UGV Vehicles (2) Modifications Design & Implementation**
    The objective of this task in the WP is to design and implement all the mechanical and electrical modifications on the TAGS vehicles.

Smart missile impulse control with guidance system using methods based on artificial neural network.

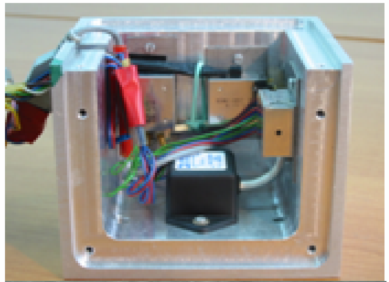
Investigation of rockets and missiles flight and control

- Flight control systems for small rockets and missiles with impulsive propulsion for control
- 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
- Attitude determination without gyro sensors



Research Projects - PL

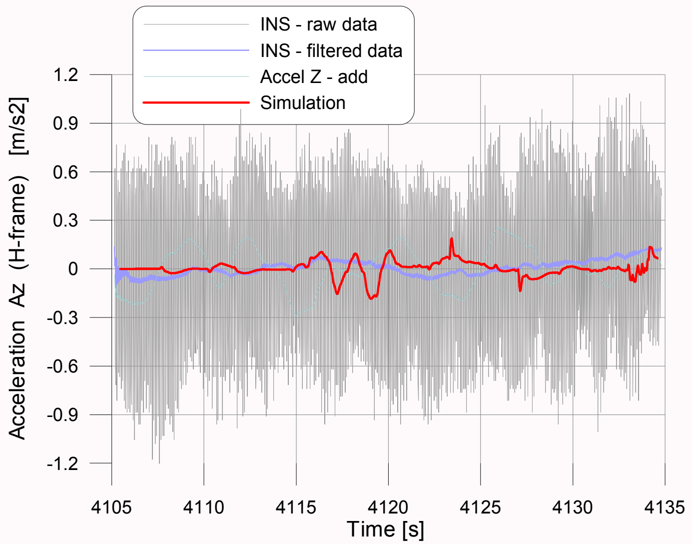
Application of Attitude and Navigation Systems in Evaluation of Helicopter Flying Qualities

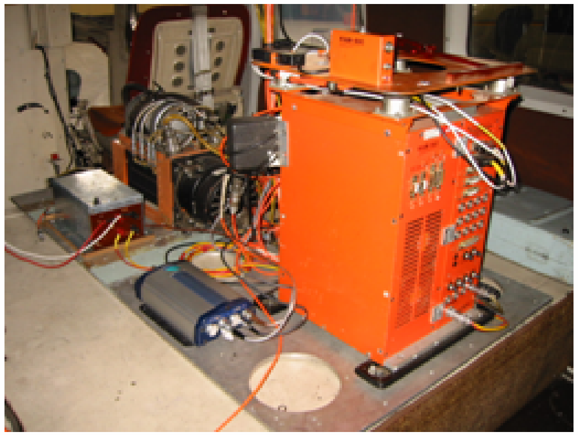


Integrated INS-GPS measurement system developed

System used in flight tests as autonomous measurement unit

Results compared with other sensors and simulations





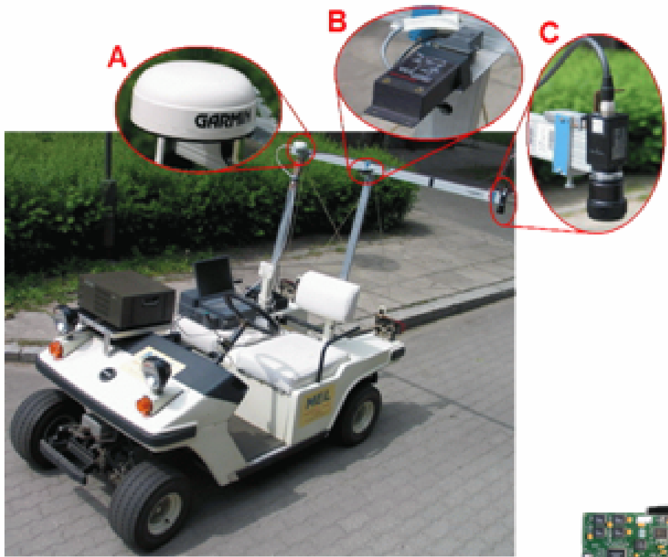
Research Projects - PL

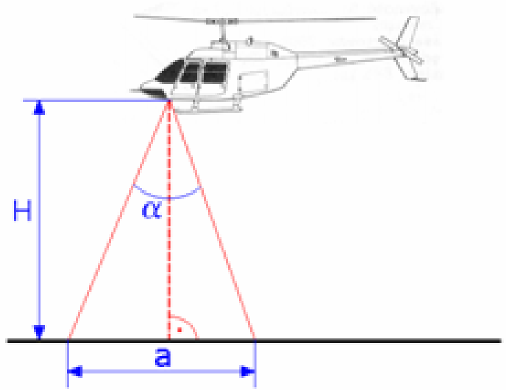
Feasibility Study on Application of Image Matching Systems in Navigation of Moving Platforms

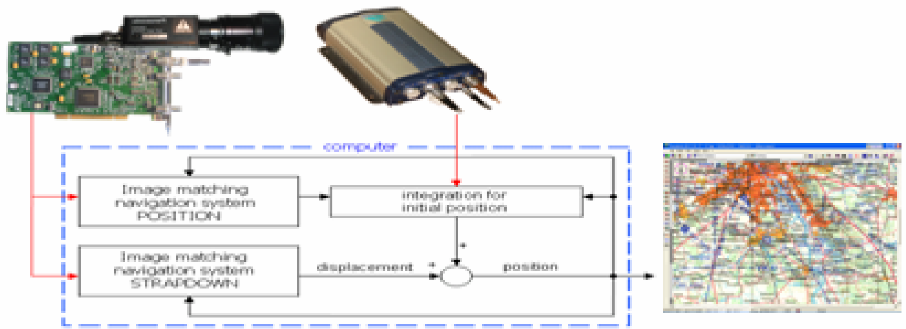
Visual strap-down navigation methods tested on-ground

Under development

Algorithms for distance and attitude measurements in flight







Research Project – PL

Methods and algorithms in integrated navigation and control systems

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

- Filtering: Kalman, Joulier-Uhlman,
- Navigation algorithms
- Control methods: classical, reconfiguration, autonomous flight

Investigated in laboratory and in field experiment

Supported by simulations (FLIGHTLAB and dedicated software)



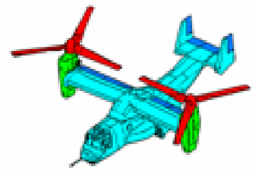

Plans / Intentions / Offer

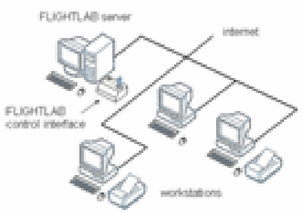
We are opened for cooperation (international / bilateral / national) to obtain **critical mass of researchers** and **more substantial results**

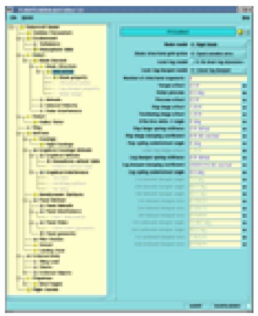
TOPICS

- Modeling and simulation using commercial and in-house developed software of various moving platforms: air, ground and water (underwater) vehicles as well as their systems

- Integrated control and navigation systems comprising modern sensors: GPS, magnetometers, accelerometers and gyroscopes; visual navigation







Contact

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  - *Nowy Lotniczy Building, 1st floor*

- Telephone: (+ 48 22) 234 74 45
- Fax: (+48 22) 622 38 77
- E-mail: **zaiol@meil.pw.edu.pl**
- Website: **http://zaiol.meil.pw.edu.pl**

DAAS role in TALOS

WP10: **Dissemination & exploitation**

- **WUT is leader of this WP**
- **DAAS** participates in the following tasks:
  - ✓ **Creation and update of the project website (http://talos-border.eu)**
  - **Workshops for end users**