GARTEUR: 30 years of European collaboration in aeronautics research

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Outline

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- **The GARTEUR organisation**
- **GARTEUR statistics**
- **Fields of scientific and technical activities**
- **Technical highlights**
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Introduction

- ***Government-to-government agreement*** **between France, Germany, Italy, the Netherlands, Spain, Sweden and United Kingdom**
- ***GARTEUR objective*** **is to improve competitiveness of aerospace industries by performing precompetitive aeronautical research**
- ***Participants:*** **research establishments, industries, academia**
- **Subjects of investigation cover *civil* and *military* R&T**
- **Identification of *innovative R&T*, and development of this R&T to application readiness in industry**
- **Permanent mutual influence between GARTEUR and European Union environment (Framework Programmes)**

The GARTEUR organisation (1/4):
Origin of GARTEUR

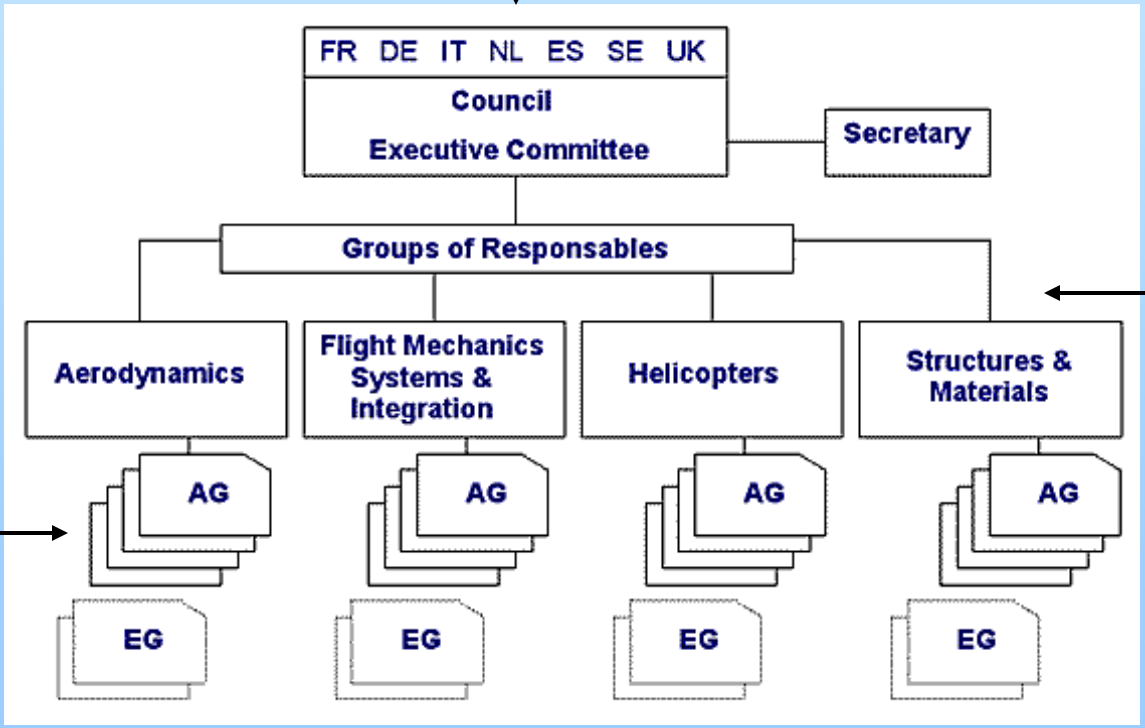
- **Establishment in 1973 by France, Germany and United Kingdom; in following years joined by the Netherlands, Sweden, Spain and Italy**
- **Collaboration based on a *Memorandum of Understanding* between seven European nations with major research and test capabilities**
- **GARTEUR focus is on long term R&T to assure sustained competitiveness of European aerospace industry**
- **GARTEUR scope covers civil and defence applications: transfer of aeronautical technology between civil and military fields**
- **Interface with European aeronautical industry through *Industrial Points of Contact* and *Industrial Management Group (IMG^4)***
- **Strong interaction with EU, EREA, ASD, WEAG**

The GARTEUR organisation (2/4):
Mission and principles

- **GARTEUR's mission is to mobilise scientific and technical skills, human resources and facilities in R&T to strengthen collaboration**
- **GARTEUR stimulates advances in aeronautical sciences**
- **GARTEUR pursues topics of application-oriented research to strengthen competitiveness of European aerospace industry**
- **GARTEUR performs research work in research groups to identify technology gaps and facility needs and to make recommendations**
- **GARTEUR adopts principle of operation to pursue overall balance of benefits between the member countries**
- **GARTEUR takes a flexible approach towards participation of non-GARTEUR countries and organisations in the research work**

The GARTEUR organisation (3/4):
Organisation (1/2)

- **GARTEUR is organised at three levels:**
  - **Council**
  - **Groups of Responsables**
  - **Action Groups (AGs)**



The GARTEUR organisation (4/4):
Organisation (2/2)

- **GARTEUR *Council*:**
  - **Composed of representatives of member countries (national delegations)**
  - **Assisted by an Executive Committee (one member of each national delegation) + Secretary**

- **GARTEUR *Groups of Responsables*:**
  - **Scientific management bodies and think-tanks**
  - **Representatives from REs, industry and academia**
  - **Four fields of activities:**
    - **Aerodynamics (AD)**
    - **Flight Mechanics, Systems and Integration (FM)**
    - **Helicopters (HC)**
    - **Structures and Materials (SM)**

- **GARTEUR *Action Groups*:**
  - **Technical expert bodies**
  - **Formulate research programme and execute the research work**
  - **Collaboration feasibility of potential research subject investigated by an *Exploratory Group (EG)* to establish an agreed proposal**
  - **Participation from at least three GARTEUR countries**

GARTEUR statistics (1/2):

- From 1970s up to end 2003: 97 AGs
- Average participation per AG: 8.5 organisation
- Largest number of AGs: GoR for Aerodynamics (39)
- Considerable variation of *kind of participant* over GoRs

Number of participants in Action Groups

Kind of participant	GoR(number of Action Groups)					
	AD (39)	FM (14)	HC (14)	SM (28)	PT (2)	Total (97)
RE	177	66	45	103	8	399
Industry	107	33	35	154	10	339
University	5	26	7	22	1	61
Other	13	4	2	11	3	33
Total	**302**	**129**	**89**	**290**	**22**	**832**

Status December 2003

GARTEUR statistics (2/2):

- **Resources spent in AGs recorded from 1989**
- **In period 1989 - 2003: 402 man-years invested in GARTEUR research**

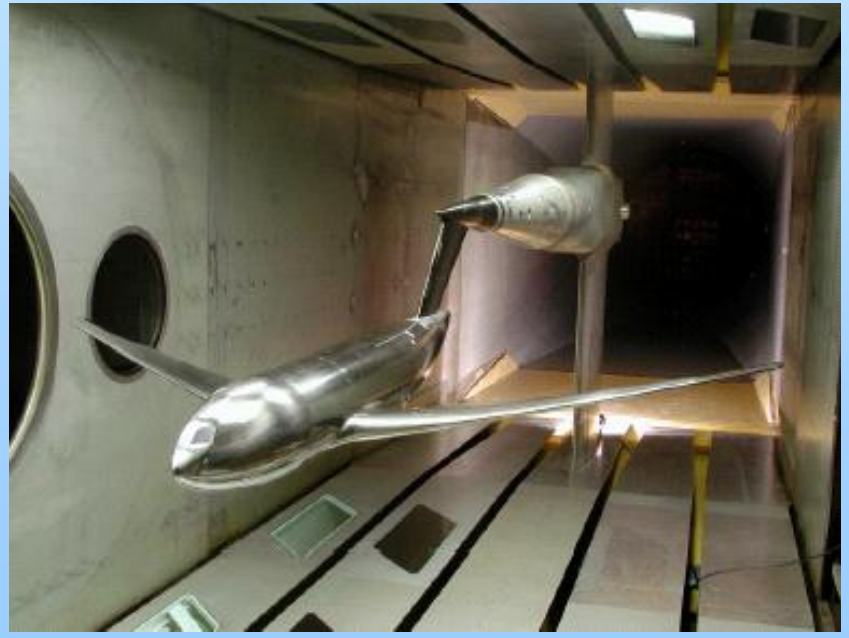
Number of man-years spent in Action Groups (from 1989)

	GoR					
	AD	**FM**	**HC**	**SM**	**PT**	**Total**
Man-years	**167**	**85**	**30**	**114**	**6**	**402**

Status December 2003

Fields of scientific and technical activities (1/8):
GoR for Aerodynamics (1/2)

- **GoR(AD) focuses on *aerodynamics* and *aerothermodynamics***
- **GoR(AD) remit covers *aerodynamics, aeroacoustics* and *aeroelasticity***
- **GoR(AD) is active in *experimental* and *theoretical* fields**

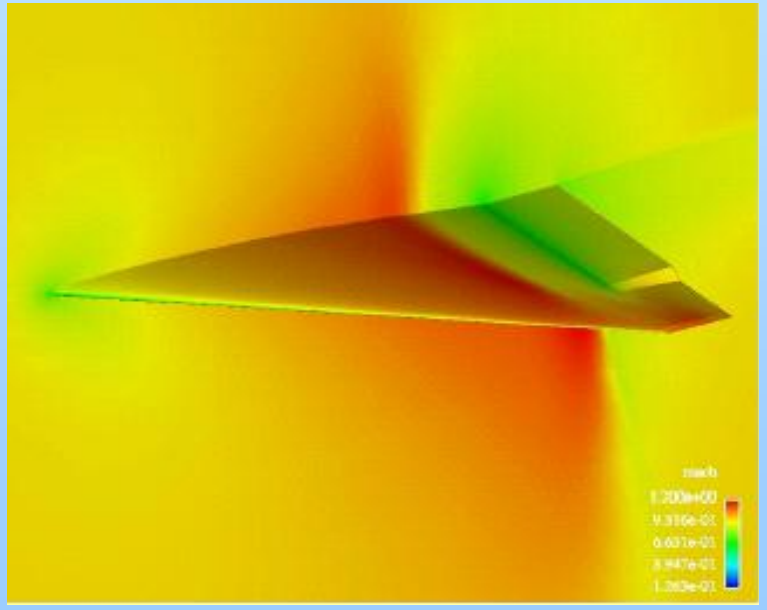


Aérospatiale AS-28 model in DNW-HST

AD(AG) on 'Transonic wing/body code validation experiment'

Fields of scientific and technical activities (2/8):
GoR for Aerodynamics (2/2)

- **Examples of current GoR(AD) projects are:**
  - ***Time-accurate methods*:**
    assessment of methods for the computation of unsteady flows
  - ***RANS code validation for transonic wing-body*:**
    assessment of capabilities of CFD codes solving the *R*eynolds-*A*veraged *N*avier-*S*tokes equations



Mach number distribution over a delta wing at M_∞= 0.97, Re = 19×10^6, α = 0°

AD(AG) on 'Time-accurate methods'

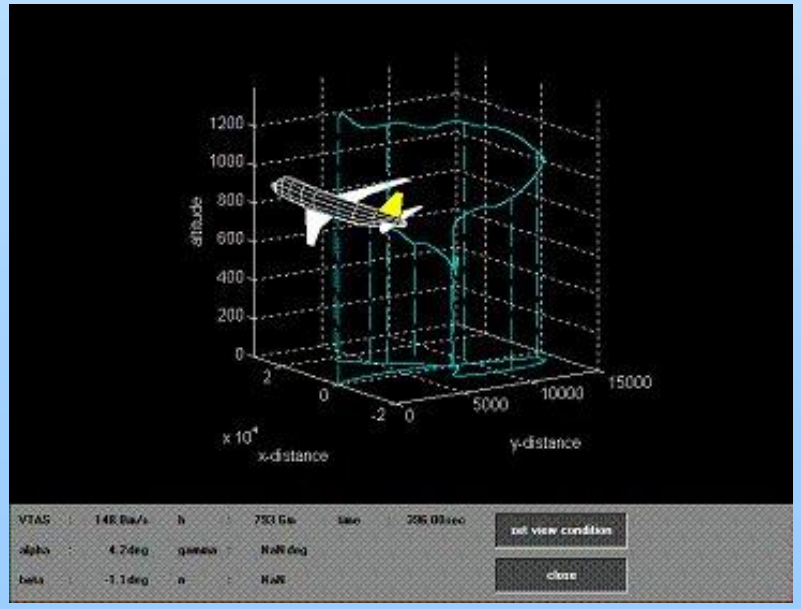
Fields of scientific and technical activities (3/8):
GoR for Flight Mechanics, Systems and Integration (1/2)

- **GoR(FM) focuses on *air vehicle systems technology* (*safety, avionics, certification, performance, stability & control*)**
- **GoR(FM) is active in *flight testing technologies* and *flight simulations***
- **GoR(FM) also investigates *air traffic control, sensor technology and systems* and *human factors***

Flight-deck illustration

Fields of scientific and technical activities (4/8):
GoR for Flight Mechanics, Systems and Integration (2/2)

- **Examples of current GoR(FM) projects are:**
  - ***Autonomy in UAVs*:**
    development and comparison of autonomous planning and decision making techniques to enable UAVs to co-operate in an uncertain environment
  - ***Pilot-in-the-Loop-Oscillations - analysis and test techniques for prevention*:**
    development and evaluation of novel methods for phase compensation and stability analysis of fixed wing aircraft handling qualities



El Al flight 1862 recovery scenario simulation

FM(EG) on 'Fault tolerant control'

Fields of scientific and technical activities (5/8):

GoR for Helicopters (1/2)

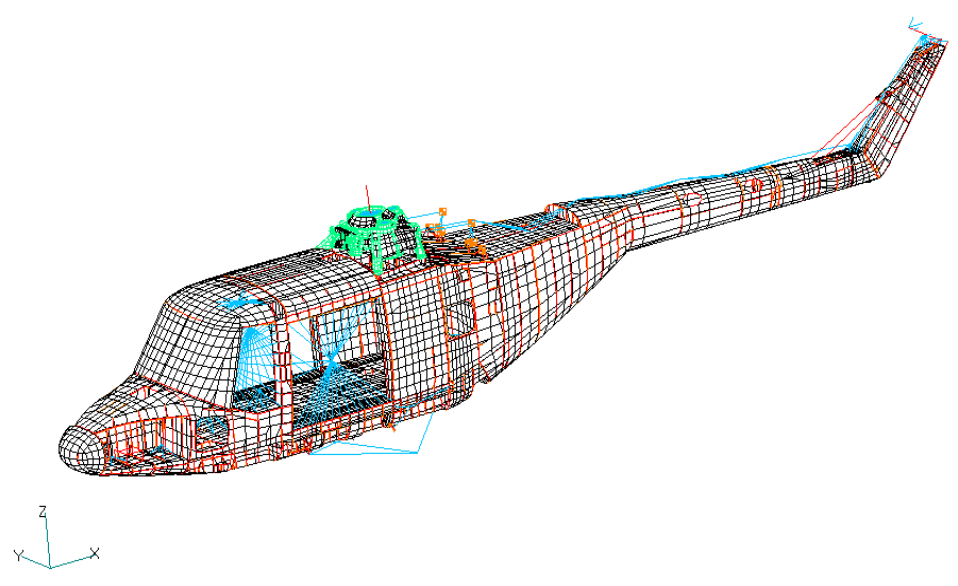
- **GoR(HC) is active to facilitate the advancement of *civil* and *military rotorcraft* technology**
- **GoR(HC) seeks to extend the *flight envelope and performance*, to increase *safety and survivability* and to increase *public acceptance***
- **GoR(HC) interests cover *aerodynamics, aeroelastics, flight mechanics, handling & control, flight tests & simulation* and *human factors***

Rotor test rig and experimental rotor in QinetiQ 5 metre wind tunnel

HC(AG) on 'Validation of rotor blade / hub load synthesis techniques'

Fields of scientific and technical activities (6/8):
GoR for Helicopters (2/2)

- **Examples of current GoR(HC) projects are:**
  - ***Validation of rotor blade / hub load synthesis techniques*: validation of hub load synthesis techniques to understand and compute dynamic hub loads**
  - ***Method for the refinement of structural dynamic finite element models*: exploration of methods and procedures for the improvement of finite element models through the use of dynamic testing**



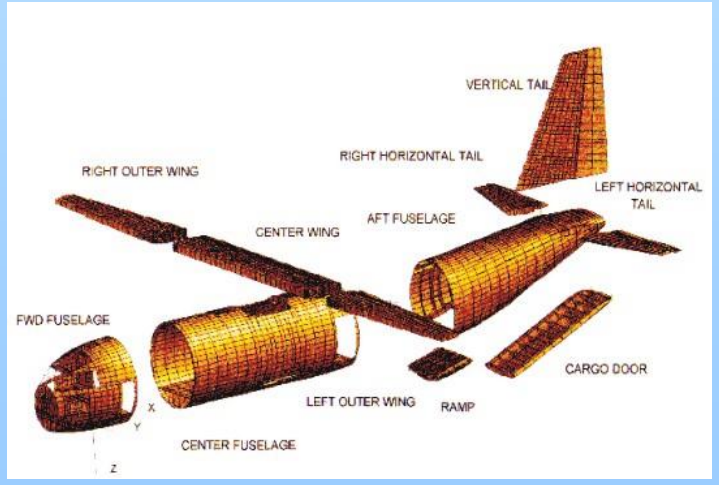
Refined finite element model of a Lynx helicopter

HC(AG) on 'Method for the refinement of structural dynamic finite element models'

Fields of scientific and technical activities (7/8):

GoR for Structures and Materials (1/2)

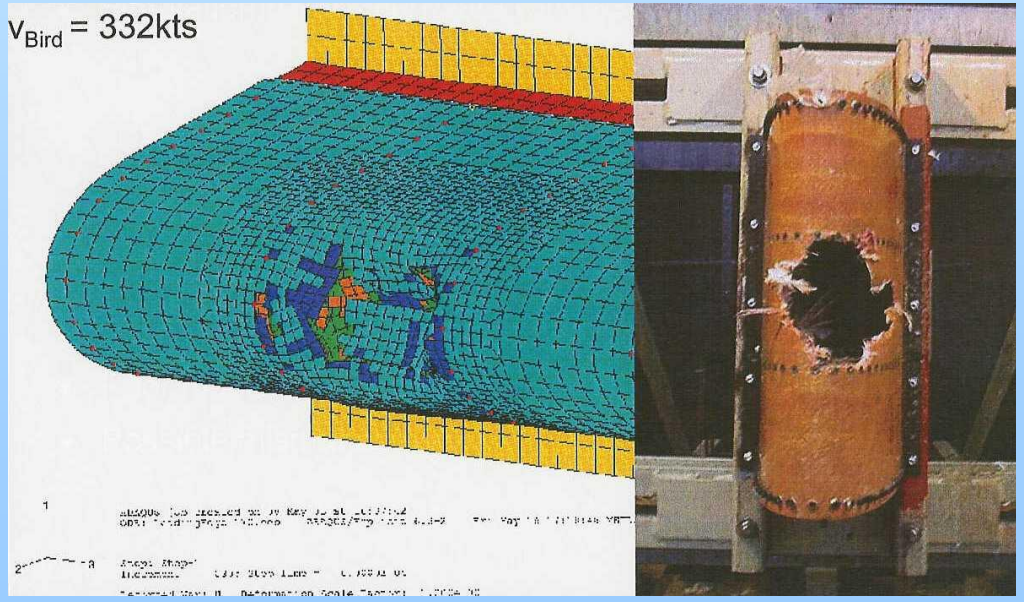
- **GoR(SM) is active in initiating and organising aeronautics-oriented research on *structures, structural dynamics* and *materials***
- ***Structures* research is devoted to *computational mechanics*, and *loads and design methodology***
- ***Structural dynamics* research involves *vibrations, responses to shock and impact load, aeroelasticity* and *acoustic response***
- ***Materials* research is related to materials systems including aspects of *polymers, metals* and *composite systems***



Fields of scientific and technical activities (8/8):

GoR for Structures and Materials (2/2)

- **Examples of current GoR(SM) projects are:**
  - ***Fractographic aspects of fatigue failure in composite laminates and structures*: extension of findings on fractographic features of laminates and structures including woven and non-crimped fabrics for component manufacture**
  - ***Impact damage and repair of composite structures:* development and validation of methods for the characterisation of impact damage in composite structures and investigation of bonded repairs**



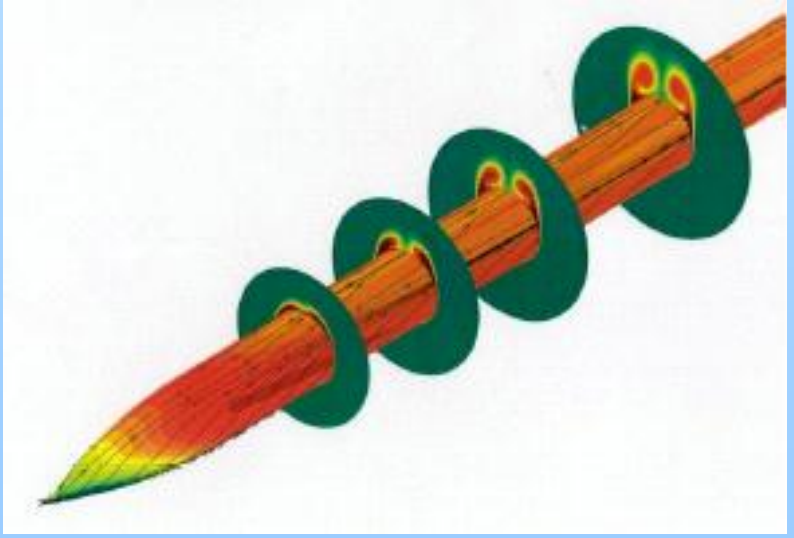
Computational modelling of bird strikes and experimental validation

SM(AG) on 'Bird strikes'

Technical highlights (1/8) - Aerodynamics AG (1/2):

Navier-Stokes calculations of the supersonic flow about slender configurations

- Investigation of CFD applications for supersonic flows around generic missile configurations (ogive-cylinder, cruciform wing-body)
- Verification that the codes were able to capture flow separation from smooth surfaces and formation of vortices
- Benefits from the AG:
  - high-quality code calibration using detailed experimental data
  - comprehensive cross-comparison of various CFD methods
  - improved understanding of flow physics around a body of revolution

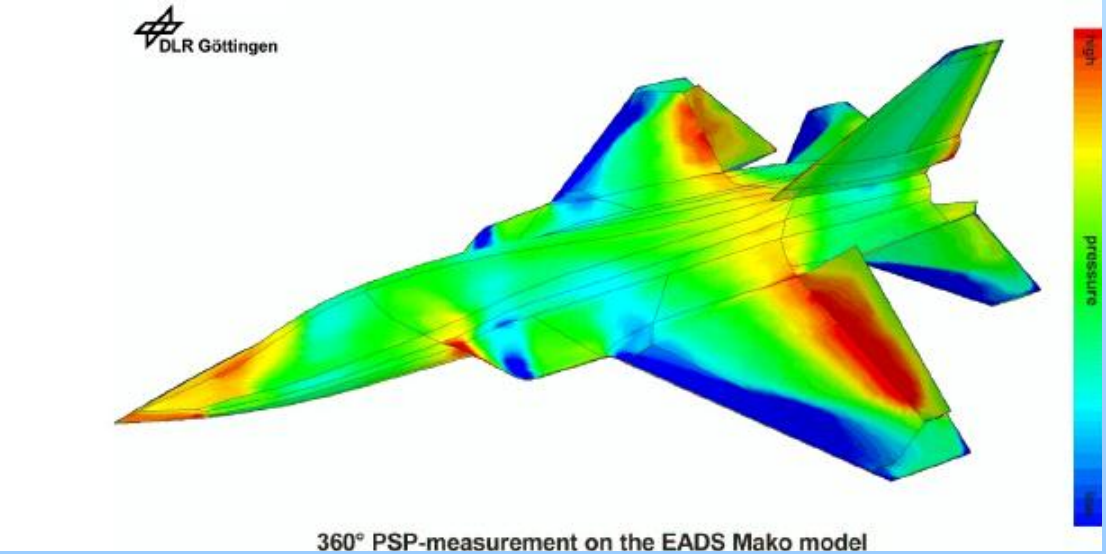


Flow field around ogive-cylinder at M_∞=2.0 and α = 10°

Technical highlights (2/8) - Aerodynamics AG (2/2):

Pressure Sensitive Paint, phase II

- **Measurement of the quantitative pressure distribution over a complete model surface by application of PSP**
- **Reduction of the number of required wind tunnel models and wind tunnel occupation time**
- **Benefits from the AG:**
  - **generation of very good examples of pressure measurements**
  - **exchange of experience with PSP application in various wind tunnels**
  - **expectation that PSP will find its place in routine wind tunnel testing**



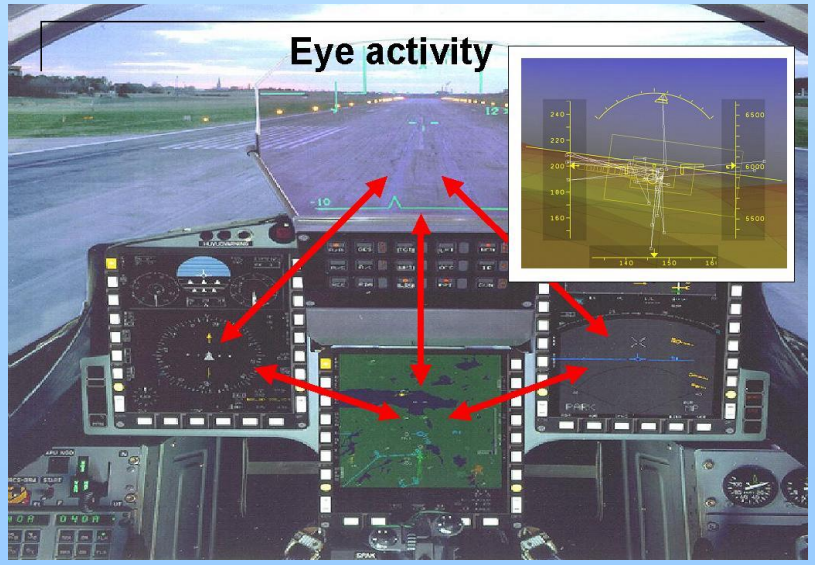
360° PSP-measurement on the EADS Mako model

Pressure Sensitive Paint surface pressure distribution

Technical highlights (3/8) - Flight Mechanics AG (1/2):

Mental workload measurement

- Inventory of mental workload measurement methods and techniques and advice on their use in various operational settings
- Development of *Measures Assessment Matrices* that assist in the selection of appropriate measures from the workload 'toolbox'
- Benefits from the AG:
  - the *GARTEUR Handbook of Mental Workload Measurement*
  - new contacts between research institutes and industries
  - industrial partners exposed to latest measurement and analysis methods

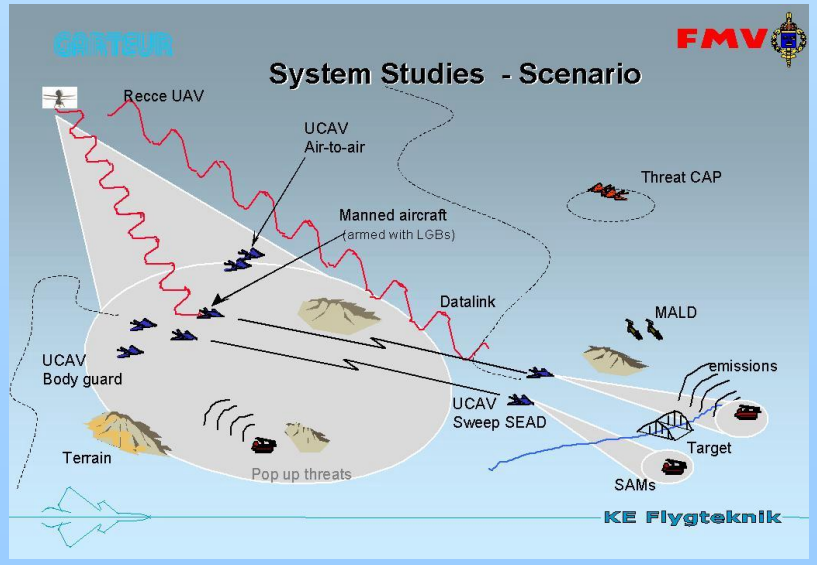


Display integration exercise

Technical highlights (4/8) - Flight Mechanics AG (2/2):

Autonomy in UAVs

- Development and comparison of autonomous planning and decision-making techniques to enable co-operation of a group of UAVs
- Change of planning of UAVs on mission/navigation level in a highly uncertain environment (unexpected events)
- Benefits from the AG:
  - great interest from research establishments and industry
  - increase of vehicle autonomy enables a reduction of operator workload
  - developed techniques will find applications in a wide range of domains



Possible operation scenario

Technical highlights (5/8) - Helicopter AG (1/2):

Helicopter yaw axis handling qualities modelling

- **Improvement of establishment of yaw axis handling qualities (Dutch roll damping, lateral dynamic response, directional control in OGE flight)**
- **Based on the availability of wind tunnel and flight test databases, and expertise and simulation capabilities of AG members**
- **Benefits from the AG:**
  - **subject is of high relevance to industry**
  - **modelling deficiencies in yaw axis handling qualities are removed**

EH Industries EH-101 Merlin helicopter

Technical highlights (6/8) - Helicopter AG (2/2):

Validation criteria for helicopter real-time simulation models

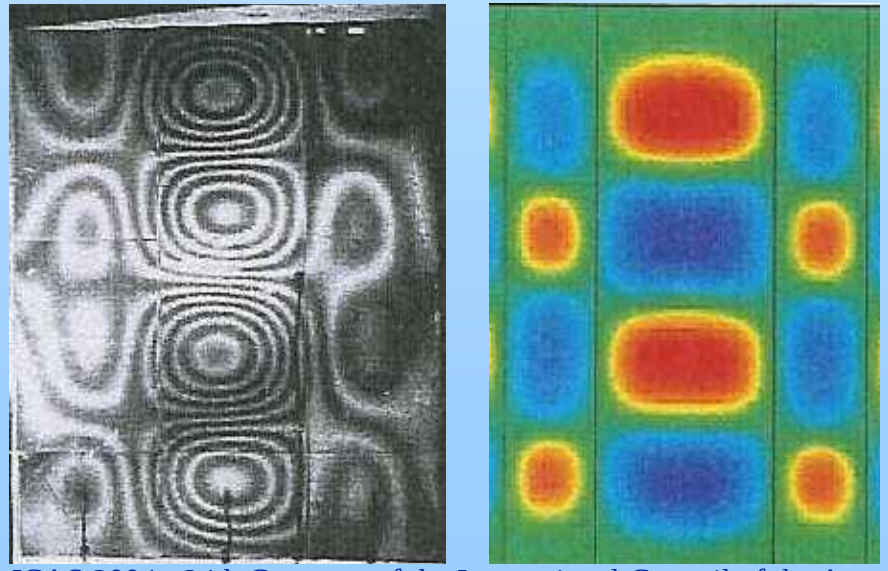
- Examination of the process and criteria for the validation of helicopter simulators, and definition of new criteria, rules and procedures
- Attention for the assessment of the requirements in JAR-STD-1H, and of the requirements and processes for simulator tuning
- Benefits from the AG:
  - important conclusions on the modelling of real-life handling qualities
  - deep understanding of process and pitfalls of simulator development
  - aircraft manufacturers have opportunity to market their simulation models

HeliFlight simulator at the University of Liverpool

Technical highlights (7/8) - Structures & Materials AG (1/2):

Post-buckling and collapse analysis

- Generation of numerical test results for aircraft structural components on the buckling load, post-buckling behaviour and final collapse
- Numerical results correspond qualitatively very well with benchmark tests and quantitatively fair from an engineering point of view
- Benefits from the AG:
  - improved knowledge of FE techniques for the analysis of (post)buckling
  - applicable to metallic and composite structures, both military and civil aircraft
  - AG developed into an active forum for universities, REs, industries

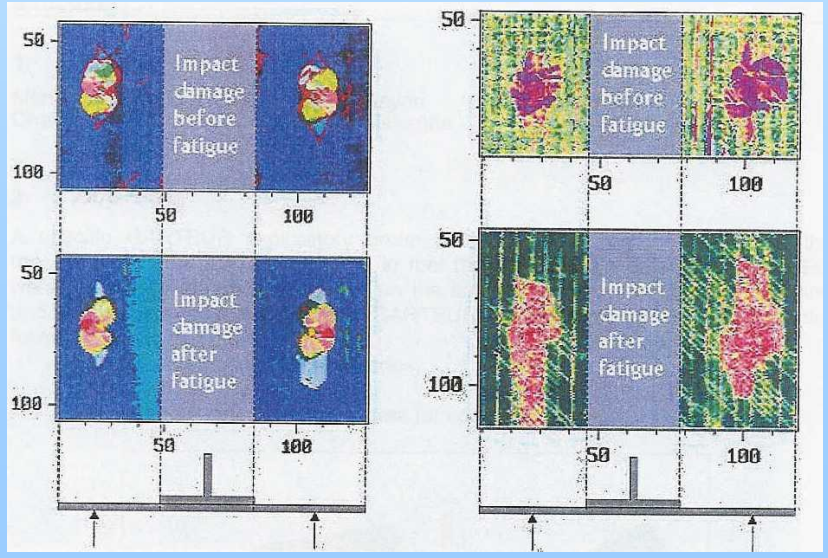


Moiré pattern of the buckling mode of a compression-loaded, curved, stiffened panel (left); results of the analysis (right)

Technical highlights (8/8) - Structures & Materials AG (2/2):

Impact damage and repair of composite structures

- Development and validation of methods for the characterisation of real impact damage in composite structures
- Investigation of the durability and efficiency of bonded repairs to composite structures under fatigue loading
- Benefits from the AG:
  - development of reliable computational methods for repaired structures
  - application of these methods will lead to a reduction of testing costs
  - opportunity for information exchange among specialists from seven countries



Impact damage growth under fatigue loading

Conclusions (1/2)

- **GARTEUR is a multinational organisation that performs high quality, collaborative, precompetitive research in the field of aeronautics**
- **Participants come from research establishments, industry and academia**
- **GARTEUR is the only framework in Europe for both civil and military Research & Technology**
- **Although operating effectively, improvements to GARTEUR's performance and efficiency are pursued:**
  - **even closer relations with civil and military industry**
  - **increase involvement of universities in basic research issues**
  - **stimulation of multidisciplinary activities for cross-fertilisation of ideas**
  - **include aviation security aspects in the research programme**
  - **increase visibility of GARTEUR and communication with aeronautics world**

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Conclusions (2/2)

…… with as striking example the submission of a proposal for nomination, resulting in:

the awarding of the

ICAS Von Kármán Award

for International Co-operation in Aeronautics 2004

to honour all persons who contributed in the spirit of *Theodore von Kármán's* vision on cross-border co-operation among scientists and engineers to the success of

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