GARTEUR: 30 years of European collaboration in aeronautics research

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Outline

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

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

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)

<table>
<thead>
<tr>
<th>GoR</th>
<th>AD</th>
<th>FM</th>
<th>HC</th>
<th>SM</th>
<th>PT</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man-years</td>
<td>167</td>
<td>85</td>
<td>30</td>
<td>114</td>
<td>6</td>
<td>402</td>
</tr>
</tbody>
</table>

Status December 2003
Fields of scientific and technical activities (1/8): GoR for Aerodynamics (1/2)

- GoR(AD) focuses on aerodynamics and aero thermodynamics
- 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 Reynolds-Averaged Navier-Stokes equations

*Mach number distribution over a delta wing at $M_\infty = 0.97$, $Re = 19\times10^6$, $\alpha = 0^\circ$*

*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
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

![Image of computational modeling of bird strikes](image_url)

*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 $M_\infty=2.0$ and $\alpha = 10^\circ$
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
**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*
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
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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