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The Competitive and Sustainable Growth Programme

1998-2002 Project Synopses:

New Perspectives in Aeronautics

COMPETITIVE AND SUSTAINABLE GROWTH

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How to use this book

This book contains the synopses of all of the projects co-financed under the Key Action 'New Perspectives in Aeronautics', including critical technology projects, technology platforms and several projects under the CRAFT co-operative research scheme for SMEs.

The synopses are intended to provide a brief overview of project objectives, technological approaches and expected achievements. Some administrative features and partnership details are also given, allowing for a more comprehensive description of the projects. The names and addresses of the project co-ordinators are provided, should any further information be required.

The project synopses are presented in blocks in accordance with the organisation of the Key Action work programme. In addition, two indexes at the back of the book allow the identification of projects by contract number and by project acronym. Finally, an alphabetical index of all project participants gives the page number of every project in which the participant is involved.

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Preface

This book provides a comprehensive overview of all projects of specific aeronautics research and technological development (RTD) that were funded under the Key Action 'New Perspectives in Aeronautics' of the Competitive and Sustainable Growth Programme. These research projects represent a major contribution to Europe's expertise in aeronautics, being the result of Europe-wide co-operation, complementary to the RTD activities on national and industrial levels. They are significant building blocks for the European Research Area in Aeronautics.

The Competitive and Sustainable Growth Programme (the Growth Programme) is one of the four Thematic Programmes under the Fifth Framework Programme for Research and Technological Development (1998-2002). The Growth Programme supports RTD in industry-relevant areas and in different industrial sectors. It is divided into four Key Actions, one of which is Key Action 4 'New Perspectives in Aeronautics', addressing RTD activities in the aircraft and aero-engine manufacturing industries as well as in on-board systems and avionics supply.

Introduction

New Perspectives in Aeronautics

New challenges – new solutions

European aeronautics is facing a number of major challenges, many of which are linked to the globalisation of the economy. Research and Technological Development (RTD) has a key role to play in mastering these challenges, helping to guarantee future competitiveness as well as responding to the demands of society and ensuring the long-term well-being of Europe's citizens.

The ongoing globalisation of the economy can only increase the challenge to remain competitive in the aeronautics industry, as trade barriers and protectionist mechanisms continue to fall by the wayside. European aeronautics is now battling head-to-head with industries around the globe, including the traditional power of the United States, but also with up-and-coming players in Asia and South America. The growth of the air transport system, along with concerns about global warming, represent additional serious challenges, given the goals of increasing environmental compatibility and safety.

As Europe looks to the future, meeting society's needs and maintaining the competitiveness of its industries will hinge on the efficient use of advanced technologies and know-how. In tackling these problems, European researchers, engineers and policy-makers are being called upon to develop new ideas, technologies and solutions.

Overall objectives of aeronautics research

Air transport is experiencing a period of remarkable expansion and is expected to maintain and even increase its growth rate over the coming decades. Globally, over 16 000 new commercial aircraft worth more than €1 trillion will have to be produced within the next 20 years to satisfy this demand. More than ever, meeting public demands for economical vehicles will be indispensable, with an optimum level of safety and environmental friendliness with respect to noise and pollution emissions. Europe's ability to respond to these challenges depends strongly on the level of advancement of its technologies and their incorporation by industry into products. The goal of Key Action 4: 'New Perspectives in Aeronautics' is to strengthen the competitiveness of the European aeronautics industry, including small- and medium-sized enterprises (SMEs), while ensuring the sustainable growth of air transportation with regard to environmental and safety issues.

The overall aim of the Key Action is reflected in four priorities with corresponding technical objectives, which make up the main drivers of European RTD action:

- *Reduction of aircraft*[1] *procurement costs*, with the target of reducing production costs by 35% and development time by 15 to 30%;
- *Improvement of the efficiency and performance of aircraft*, with the target of reducing fuel consumption by 20%, generally improving reliability, and reducing direct operating costs;

1. The term 'aircraft' is understood to include all aircraft systems and components.

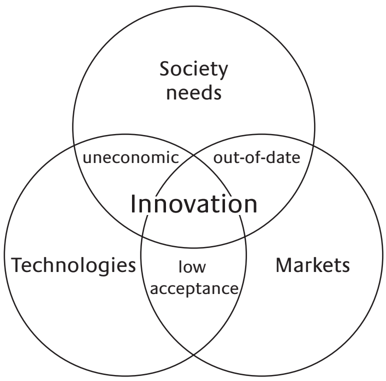
- *Reduction of impacts related to noise and climate as well as improvement in passenger environment.* Objectives are reducing emissions of NO_x by 80% and CO_2 by 20%, and decreasing external noise and cabin noise by 10 dB each;
- *Improvement of the operational capability of the aircraft within the air transport system and of its safety,* with targets of increasing airspace capacity, reducing aircraft maintenance costs by 25%, and decreasing accident rates by at least the same factor as traffic growth.

The quantified objectives are meant to be attained over a medium term of eight to ten years and should be regarded as targets for RTD action, taking the present state-of-the-art as the reference point. The achievement of each objective will be the result of a combination of contributing technologies in a multidisciplinary and multisectoral activity. Research will bring together manufacturers and suppliers including SMEs, research institutes and academia, operators and regulatory authorities.

A new strategic approach to innovation

Whereas research in the past was often characterised by the development of technology via a 'bottom-up' or 'technology push' approach, a more forward-thinking, problem-solving methodology has now become the order of the day. Today, sustainable innovation requires that at least three main factors be sufficiently addressed, ensuring a sensible and successful allocation of research resources:
- The needs of society;
- Market demand;
- Technological advantage.

Figure 1



Successful innovative research must address three main issues

A vision for 2020

In October 2000, Research Commissioner Philippe Busquin set up the 'Group of Personalities', charging it with developing a vision for aeronautics in the year 2020, with particular reference to the implementation of the European Research Area (ERA) in all key technology areas. The group comprised 14 eminent personalities from the aeronautics industry, research, air transport and public aviation services. Its report *"European Aeronautics: A Vision for 2020"* set out a wide-ranging and comprehensive common vision for European aviation, with ambitious targets for research and development, tackling issues such as safety, the environment and sustainable competitiveness and innovation.

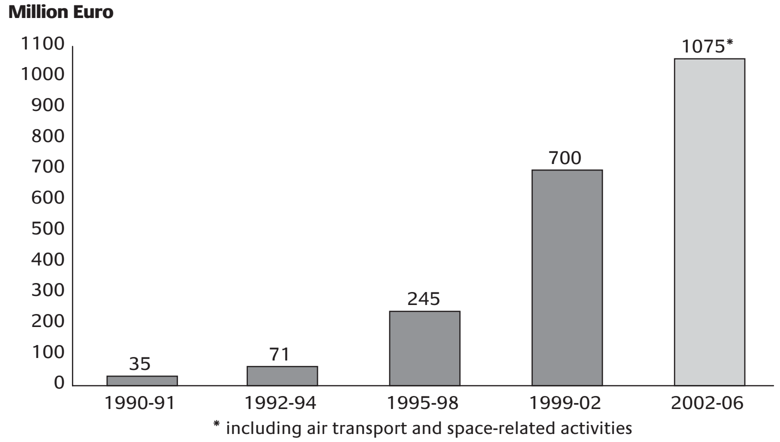
The 'Vision 2020' report recommended, among other things, the creation of an Advisory Council for Aeronautics Research in Europe (ACARE). ACARE began its work in June 2001, its primary mission being to establish and carry forward a Strategic Research Agenda (SRA) that will provide guidance in the planning of future aeronautics research in Europe.

Specific aeronautics research in the framework programmes

In aeronautics, the technology acquisition process – from focused fundamental research through technology validation and demonstration up to technological readiness – typically requires a period of from five to ten years before the first commercial application can be envisaged.

Since 1984, joint European research activities have been supported under the European Commission's Framework Programmes for RTD. Specific aeronautics research was funded for the first time under FP2 (1990-1991), under which a pilot phase provided €35 million within the BRITE-EURAM industrial technologies programme. Additional and more generic research was performed within other areas of the Framework Programmes. The provision dedicated to specific research for aeronautics was raised to € 700 million under FP5, encompassing a full range of important technologies under the Competitive and Sustainable Growth Programme's Key Action 'New Perspectives in Aeronautics'. The amount of funding has risen to over €1 billion under FP6 for combined air transport and space research.

Figure 2



An increasing EU budget for specific aeronautics research over the Commission Framework Programmes

The Growth Programme is one of four Thematic Programmes under FP5, supporting technology acquisition contributing to industrial competitiveness and sustainability, with particular focus on the transport and manufacturing industries. Under the Growth Programme, aeronautics RTD has been very much characterised by a holistic approach covering all design and production phases.

The research approach in two major strands

The Key Action work programme recognises the need for an integrated approach and is structured so as to optimise the benefits of Europe-wide RTD. It distinguishes two major strands:

Development of critical technologies, taking a medium- and long-term perspective, will extend and improve the technology base within a number of critical disciplines; these are seen as providing the most effective leverage with respect to the socio-economic objectives of the Key Action;

Technology integration and validation, taking a shorter-term perspective, is designed to reduce the risk associated with the application of innovative developments. This RTD work is most relevant to the technical complexity inherent in aeronautical products, which is the result of the combination of multiple systems and technologies. The 'Technology platforms' projects encompass integration and validation of the technologies within test rigs, flying test beds or simulators. They are normally larger than critical technology projects.

I. Critical technologies

The research objectives of 'New Perspectives in Aeronautics' reflect the Key Action's overall aims, focusing on four thematic priorities. All of them are important for ensuring industrial competitiveness while meeting the future needs of society. The objectives and specific technologies are detailed below, as they were addressed by the various projects presented in this book:

1. Reducing aircraft development cost and time to market

Research was aimed at facilitating the introduction and combination of the newest technologies, including extensive use of the tools offered by information and communication technologies (ICT), able to contribute to substantial gains in time-to-market and production costs. Advanced design approaches exploiting information technologies facilitated concurrent engineering practices in support of the design for the whole product life cycle as well as distributed inter-company design environments. Novel manufacturing and assembly processes associated with advanced materials achieved cost reduction and production flexibility while ensuring safety requirements. Development and deployment of technologies for distributed multi-site production systems helped pave the way to increased industrial partnerships and reinforced co-operation across the supply chain.

Advanced design systems and tools

RTD objectives were to help reduce time-to-market by 15 to 30% and development costs by 35% while ensuring improved response to market and societal needs. The research activities focused on:

- *development of concurrent engineering environments;*
- *development and validation of multidisciplinary optimisation methods;*
- *advanced modelling and simulation tools, including virtual reality, in support of virtual prototyping;*
- *knowledge-based systems to support design activities.*

Manufacturing

Research objectives were to reduce manufacturing costs by 30% while improving working conditions and organisational capacities of enterprises. The research activities addressed:

- *development and validation of intelligent and flexible manufacturing methodologies in support of advanced airframe assembly concepts;*
- *cost-effective manufacturing processes for airframe, engine and equipment parts best adapted to exploit the properties of advanced materials.*

Product quality control

Research emphasised the development of specific methodologies for continuous quality/cost control measures in the design and manufacturing stages. Particular attention was paid to the supply chain aspects. The RTD work addressed:

- *development of new inventory/configuration control procedures to be deployed across the supply chain;*
- *advanced in-process inspection and test techniques;*
- *development of knowledge-based diagnosis.*

2. Improving aircraft efficiency

The objectives were to improve aircraft Direct Operating Cost (DOC) through a substantial reduction in fuel consumption while ensuring and improving safety aspects. This was made possible through a combination of technology advances:

(1) to reduce drag and improve lift-to-drag ratio through improved aerodynamic designs;

(2) to reduce aircraft 'Operating Weight Empty' by increased introduction of advanced lightweight, cost-efficient structures and of power-optimised and safer, integrated flight controls, systems and equipment;

(3) to improve engine efficiency with higher performance propulsion systems and propulsion controls.

Aerodynamics

Research objectives were to support reduction of aerodynamic drag by 20% in ten years and improvement of the overall aerodynamic efficiency of the aircraft in take-off, climb, cruise, approach and landing. The RTD activities focused on:

- *development and validation of high-performance technologies, systems and support tools for drag reduction;*
- *theoretical and experimental methods for prediction and control of boundary layer behaviour;*
- *systems and technologies to enable adaptive wing concepts;*
- *computational methods and novel technologies for high-lift aerodynamics at low speed;*
- *CFD tools and integrated design methods;*
- *advanced technologies for improved propeller and rotor performance.*

Structures and materials application
Research objectives were to work towards reducing weight by 20% in ten years at no extra manufacturing cost and without reduction of structural life. Research addressed:
- *development and validation of improved theoretical tools for the simulation of structural behaviour;*
- *new structural concepts for increased use of advance materials in primary structures;*
- *tools and technologies for the application of 'smart materials';*
- *realisation of 'smart structures' integrating the sensors-structure-control-effector chain.*

Propulsion
RTD objectives were to support a 20% increase in fuel economy over 10 years and consequently reduce emissions of greenhouse gases by the same factor, as well as to increase engine thrust-to-weight ratio by 40%. The relevant RTD focused on:
- *new and improved engine cycle concepts;*
- *numerical aerothermodynamic methods for design of turbo-machinery components;*
- *application of medium- and high-temperature materials;*
- *techniques and concepts in support of the design of 'smart' engine control systems;*
- *improved measurement techniques in hazardous environments;*
- *technologies for improved mechanical transmission systems for rotorcraft and engines;*
- *innovative concepts such as compound propulsion.*

Systems and equipment
With respect to on-board systems, objectives were to reduce power consumption by 10% and weight by 20% while maintaining at least the current levels of safety, cost-effectiveness, reliability and maintainability, and while meeting better functional requirements. RTD addressed:
- *power generation and technologies in support of a more electric aircraft concept;*
- *low-power-demanding and other advanced flight control systems;*
- *improved modelling and design methods for landing gear and braking systems;*
- *techniques for improved reliability of fuel management systems;*
- *application of fibre optics to cabin utility systems, passenger services and avionics systems;*
- *development of underlying technologies and procedures for implementation of integrated modular concepts;*
- *utilisation of multimedia passenger services; application of advanced displays and sensors in cockpit functions.*

Configurational and interdisciplinary aspects
Research objectives were to provide analytical capability in support of improved and novel aircraft configurations. The research work addressed:
- *methodologies and technologies for multidisciplinary analysis of unconventional fixed-wing and rotary-wing aircraft configurations, including blended-wing-body, box-shaped wings, compound helicopters, tilt-rotors, etc;*
- *multidisciplinary airframe-propulsion integration (including fixed-wing aircraft and rotorcraft);*
- *improved analytical tools for the prediction and technologies for the prevention of static and dynamic aeroelastic phenomena.*

3. Improving environmental friendliness of aircraft

Considering the increasing societal pressure with regard to the environmental consequences of the projected growth in air traffic, aircraft size and emissions, research is needed to improve technologies for reducing engine emissions. Reduction of external noise is also becoming increasingly important for the growth of aircraft operations and aircraft size. In addition, it is necessary to improve the overall cabin environment as a combination of physical aspects such as noise, vibration and air quality, as well as human-factor-related aspects. This research should help to ensure the acceptance of future vehicles among both passengers and non-passengers.

Low pollutant emissions

Research objectives were the development of combustor concepts to achieve a significant reduction in engine emissions of NO_x and particulates, as well as enhancing knowledge of the nature and effects of emissions in support of the development of a new emissions parameter for certification, as recommended by ICAO/CAEP. The specific targets for NO_x reduction are: 1) 80% in the LTO cycle; and 2) an emission index of 8 gr. per kg fuel burnt in cruise/climb. The research activities focused on:

- *tools and technologies for low-NOx combustors; efficient combustion systems;*
- *measurement and modelling of the composition of engine exhaust gas emissions and their distribution within the jet and plume;*
- *establishment and evaluation of a global inventory of 3-D emissions distributions;*
- *developing the technical background in support of the development of new emissions parameters covering all aircraft operations.*

External noise

RTD objectives were to reduce external perceived noise by 10 dB in ten years using new design technologies as well as through advanced active control technologies. The RTD work addressed:

- *prediction methods and tools for reduction of noise at the source;*
- *technologies for active noise and vibration control;*
- *modelling of far-field noise radiation;*
- *development of the technical background in support of improved noise certification parameters and procedures;*
- *modelling of sonic boom.*

Cabin environment

Objectives were to improve environmental conditions in the cabin and cockpit and to enhance crew and passenger comfort. Medium-term targets concerning noise levels were a reduction of 5-10 dB for turbofan aircraft and 10-15 dB for turbo-propeller and rotary wing aircraft. The research activities addressed:

- *advanced methods for prediction and reduction of noise and vibration in the cabin;*
- *development and validation of subjective noise and vibration criteria for cabin environments;*
- *concepts for enhanced global cabin environment technologies for cost-efficient cabin climate control including humidification and air quality;*
- *human-centred utilisation of multimedia passenger services.*

4. Improving operational capability and safety of aircraft

New technologies, including satellite-based navigation and communications and new flight management systems, have the potential to significantly change the way airspace is managed. To exploit this potential, on-board technologies need to be developed and validated to equip the aircraft for future operational requirements. With the expected growth in air traffic and the foreseeable use of larger airliners carrying a greater number of passengers, the current accident rates must be reduced so as to ensure that aviation safety records continue to improve.

RTD work was therefore aimed in particular at an improved understanding of the causes of accidents, and of the human-machine interface. Also, the design of aircraft was to incorporate the most recent developments to improve survivability in the event of accidents.

Air traffic management (ATM)-related airborne system

The research objectives were to increase airspace and airport capacity through a more autonomous operation of aircraft consistent with the future European ATM concept. RTD addressed:

- *advanced on-board flight management functions, optimising the pilot's role and workload;*
- *integration of advanced on-board technologies in support of navigation in approach, landing and ground movements;*
- *application and integration of on-board communication and surveillance technologies.*

Operational maintenance

The objectives were to reduce maintenance costs by 25% in the medium term and by 40% within ten years while improving the reliability of maintenance operations. RTD tackled the overall maintenance cost via:

- *improved maintenance systems;*
- *the development of 'smart' maintenance systems with self-inspection and self-repair capabilities;*
- *improved non-destructive testing and analytical methodologies aiming at maintaining the integrity of ageing aircraft.*

Accident prevention

The objectives were to reduce aircraft accident rates by at least the same factor as the growth of air traffic. RTD centred around the following areas:

- *development of improved aviation safety metrics, better understanding of human-machine interaction and crew performance in the cockpit;*
- *system design and technologies to reduce pilot workload and to improve situational awareness;*
- *application and validation of airborne technologies for in-flight and on-ground aircraft collision avoidance;*
- *methodologies and technologies for alleviation and avoidance of wake vortex formation and encounter;*
- *prediction, detection and monitoring of ice accumulation;*
- *technologies for protection against lightning and single radiation effects.*

Accident survivability
The objectives were to effectively reduce the number of casualties or passengers injured in case of survivable accidents. RTD addressed the development of prediction tools as well as design techniques and structural concepts for improved airframe behaviour in case of crash and also methodologies for prediction and mitigation of fires in the aircraft.

II. Technology platforms

The Key Action identified Technology Platforms (TPs) for technology integration and validation. Each TP brought together a range of advanced technologies within a project representing a priority for the development of future aircraft. The objectives and key research areas were described for each TP in specific calls for proposals. More details can be found in the synopses of the individual TPs. The following eight TPs were selected:

- *Low-cost, low-weight primary structures;*
- *Efficient and environmentally friendly aero-engine;*
- *More autonomous aircraft in the future air traffic management system;*
- *Power-optimised aircraft;*
- *Low external noise aircraft;*
- *Friendly aircraft cabin environment;*
- *Advanced wing configuration;*
- *Integrated and modular aircraft electronic systems.*

Proposal selection and EU funding

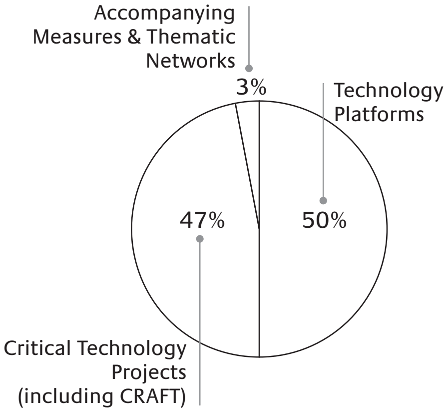
Three calls for proposals were issued for critical technologies and technology platforms in 1998, 1999 and 2000. Two groups of independent senior experts evaluated all proposals against criteria published with the calls for proposals. Their evaluation consensus was the basis for the selection of proposals for which financing was negotiated. The criteria related to how the proposed activities would contribute to realising the objectives of the Aeronautics Key Action with respect to the following areas:

- *Scientific and technological excellence;*
- *Community added value;*
- *Societal needs;*
- *Economic prospects;*
- *Partnership and management.*

A special co-operative research programme for SMEs called CRAFT addressed technology acquisition by SMEs. In addition, many aeronautics SMEs participated as normal partners without particular reference to their size.

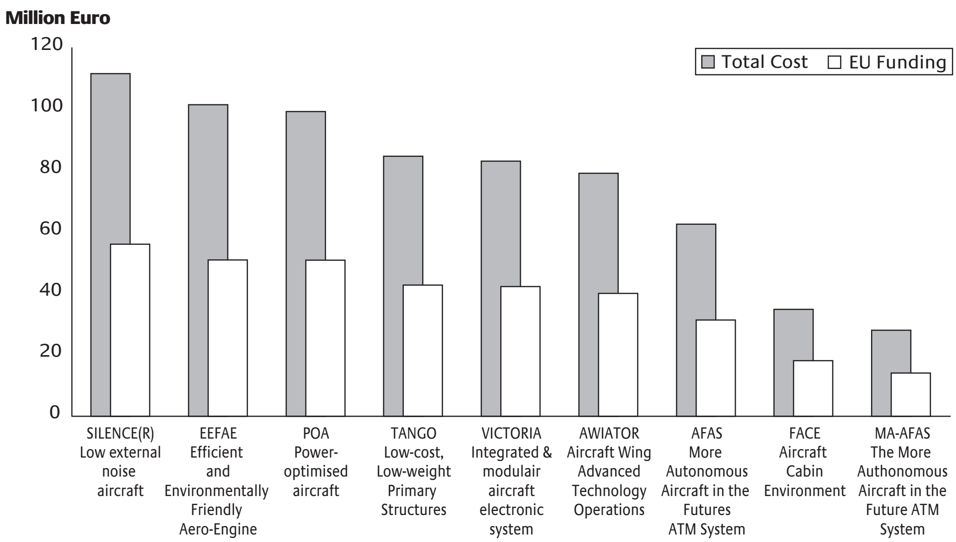
EU funding under FP5 covers 50% of eligible costs for research and industrial participants. For academic institutions, up to 100% of additional costs are covered. Accompanying measures and thematic networks are also normally financed up to 100% of actual costs.

Figure 3



Distribution of EU funding

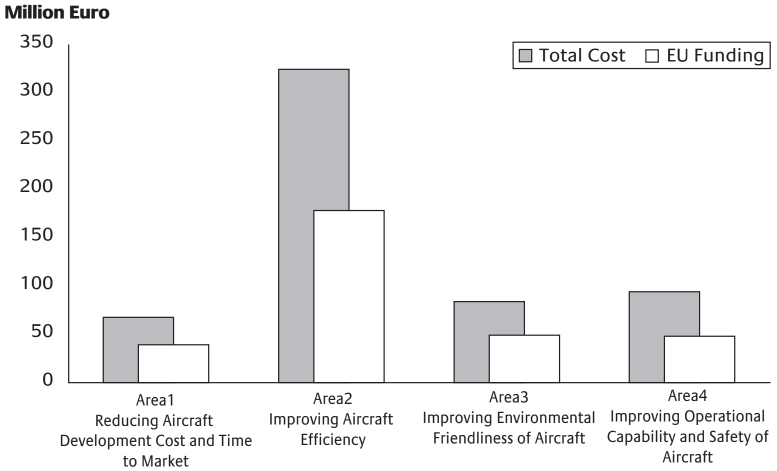
Figure 4



Technology platforms – total costs and EU funding

A significant share of the projects addressed Area 2 'Improving aircraft efficiency', as the competitiveness of Europe's industry depends especially on the efficiency of it's future products: aircraft, engines and on-board equipment and avionics.

Figure 5

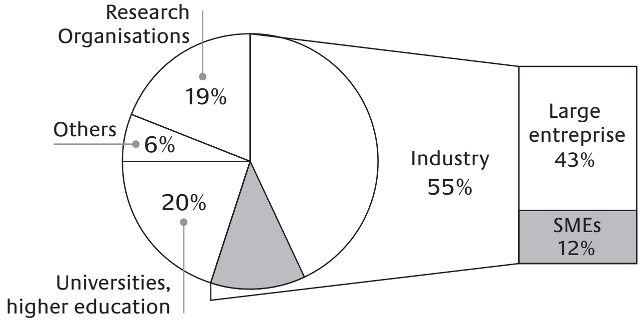


Distribution by thematic area for critical technology projects (including CRAFT)

Europe-wide participation

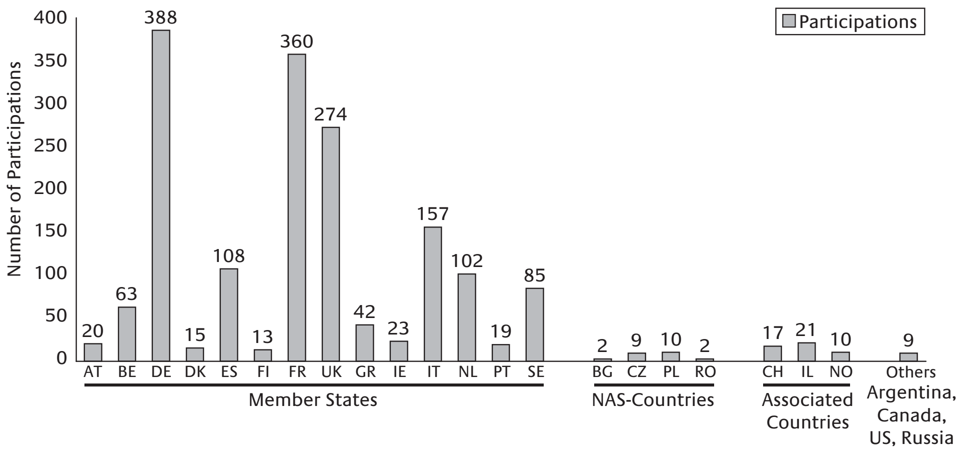
The importance of small-and medium-sized enterprises (SMEs) in stimulating new employment and innovation is well established, and the EU has a long-standing history of supporting and promoting them. In keeping with this, a number of projects have been undertaken specifically aimed at promoting the activities of SMEs in the aeronautics sector. In addition, SMEs have been important players in any number of mainstream aeronautics research initiatives. EU support, therefore, is not just for the big-name firms and research institutions but can include smaller entities, including the numerous supply companies that provide components, subsystems, materials and other support in the technology supply chain.

Figure 6



Participation by type of organisation under the Aeronautics Key Action (critical technology projects including CRAFT and technology platforms)

Figure 7



Participation by country (Member States, Associated States and other countries)

1.1. Aircraft Development Cost and Time to Market

Advanced design systems and tools

Collaborative Working within the Aeronautical Supply Chain

Project objectives

In recent years, Concurrent Engineering (CE) and Collaborative Working (CW) tools and methods have been widely developed and implemented in the aeronautic industry, especially through Europe-funded projects like ENHANCE. However, these developments have targeted the need of the large players of the sector and are not adapted to the needs of SMEs operating in the aeronautic supply chain. It is, however, of the highest importance that these SMEs should implement CE and CW best practices in order to reduce time delays when driving projects, and also to increase competition in logistics, manufacturing, and marketing, and have better communication between team members, teams and organisations. Set up by a group of SMEs, the CASH project aims to bring the aeronautical supply-chain SMEs into the world of CE. This should be made easier by the fact that, in the frame of the CASH project, SMEs will be speaking to SMEs having the same interest to implement CE in the context of Extended Enterprise.

CASH will complement existing efforts to develop CE in the aeronautic sector. It will lead researchers to evaluate and master the complexity of new Information Technology in order to adapt, package and disseminate the methods and best practices of Collaborative Working (CW) for the attention of SMEs.

CASH objectives are:

- to extend the Concurrent Engineering research effort in aeronautics to meet the specific needs of SMEs operating in the supply chain, to achieve full compatibility with the ENHANCE methodology and standards;
- to validate, in real size and real time, new CW technologies inside the aeronautical supply chain;
- to confirm that SMEs have full access to the general CE economic goals in aeronautics (30% reduction in time-to-product);
- to disseminate and transfer CW technologies between SMEs working in aeronautics.

Description of the work

The first step of the project will consist of analysis. The current status of common collaborative processes, methods and tools used in aeronautical SMEs will be analysed, and the needs of these SMEs for compliance with the results of ENHANCE project will be identified.

These needs will then enable collaborative processes and methods to be adapted to the context of aeronautical SMEs. Studies will be made of integration of market processes/methods/tools and those provided by ENHANCE project.

The following issues will be adressed:

- Corporate knowledge management, taking into account data management services for distributed products;
- Organised access to the external sources related to technical, economic and commercial data (access to remote information systems/databases);
- Integration infrastructure that enables heterogeneous tools and databases to inter-operate transparently across platforms, creating a shared project environment (dataflow management);
- The global integration of the tools used for solving the different problems in dynamic form, including the probable evolution in time (road mapping) of data.

This SME-oriented customisation will be researched through setting up test bench cases in different phases of the aircraft life cycle. Transversal phases, like remote access to data and network reliability, will be designed and/or researched first. Other specific phases will be also be tested, taking into account the requirements and specific means of aeronautic SMEs.

The project results will then be validated by ASCENT (Aeronautical SMEs Concurrent ENgineering Technopol), a network created by the CASH project.

This project will allow ENHANCE to benefit from the feedback from aeronautic SMEs (and the CASH project will also derive benefit from this project's results).

Expected results

Expected results from CASH are the validation, and implementation by SMEs, of best practices in Concurrent Engineering that have been either newly developed or disseminated from European Concurrent Engineering projects in aeronautics, then adapted to the needs and capabilities of aeronautic SMEs.
The project will launch a wide validation of the results through a group of aeronautic SMEs already created and named ASCENT.

Title: Collaborative Working within the Aeronautical Supply Chain

Acronym: **CASH**

Contract N°: G4RD-CT-2001-00494

Proposal N°: GRD1-2000-25102

Total cost: €3 361 998

EU contribution: €1 816 511

Starting date: 01/04/2001

Duration: 24 months

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Centro Sviluppo Materiali S.p.A.	I
Concurrent Engineering Consulting S.R.L.	I
Ecole Nationale d'Ingénieurs de Tarbes	F
Edisoft – Empresa de Servicos e Desenvolvimentos de Software S.A.	P
Euro Inter Toulouse	F
IDEPP S.A.	F
Institutul National de Cercetari Aerospatiale 'Elie Crafoli' (INCAS)	RO
Institutul Pentru Analiza Sistemelor S.A.	RO
Intecs Sistemi S.p.A.	I
Ligeron S.A.	F
Paragon Ltd.	EL
RHEA System S.A.	B
Université Paul Sabatier de Toulouse III	F

Project objectives

In aircraft design, efficiency is determined by the ability to predict the occurrence of turbulent flows accurately and reliably, and model their development. Hence, the main objective is to improve the capability of industrial computational fluid dynamics (CFD) to increase predictive accuracy for complex geometries and complex flows. This will ensure a necessary change in paradigm in CFD; thus the prediction of delta-value between two consecutive solutions is necessarily replaced by the provision of absolute values (e.g. for drag), which can only be solved by the use of highly resolved meshes (20 million nodes and more).

This demand for improved designs, better flight performance and enlarged flight envelopes leads to a further three objectives for enhancing flow-physics modelling. In FLOMANIA, these are related, firstly to improving the current industrially-used turbulence models, secondly to employing sophisticated differential Reynolds stress models (which are much better at representing physics in the whole-flow domain), and thirdly to detecting the limits in RANS computations by using DES for massively separated flows.

Description of the work

Working tasks in the FLOMANIA project are:

1. Management, including web server, risk monitoring and exploitation treatment.
2. Set-up of test cases, based on a list already provided, which will be used for treating generic application to investigate and assess currently used and new/improved turbulence models, both of which perform baseline and new technology-based computations. In addition to experiments, DNS results will be considered as a feedback to obtain greater understanding of the physics.
3. An implicit Reynolds-Stress model (DSM) for implementation in the industrial codes will be provided, an effort which is coupled with the results of (4).
4. Technology-transfer and standardisation issues, i.e. identical – or at least near-identical – partner-wise implementation of turbulence models will be carried out in order to gain greater understanding, knowledge and expertise.
5. Further work is linked to the short-term goal, which aims to improving robustness, accuracy and reliability of two-equation models for the immediate support of industry in its daily work.
6. DSM implementation and modelling work are medium-term goals, while DES (coupling LES and RANS) is seen as a long-term result of FLOMANIA. DES work is necessary in order to identify limits of RANS on the one hand and to gain expertise and knowledge (and feedback) on the other, while treating massively separated (vortical, transonic) flows.
7. Although no work on mesh generation itself will be carried out, substantial grid dependence issues have to be investigated for both RANS/URANS and DES. Particular attention will be paid to the development of unstructured CFD solvers within the aeronautical industry, including grid adaptation tuned at turbulent quantities.
8. Complex industrial cases will be treated, even if confidential complex geometries do not allow for a distribution among the partners, to make sure that the new FLOMANIA model basis really provides converged and reliable results for even the most up-to-date, difficult and highly sophisticated problems.

Expected results

Enhancement of flow-physics modelling issues by paying attention to industrial requirements that arise from the ever improving area of transportation means, while preserving the environment and sustaining the quality of life. To be achieved by:

1. Closing the gap between level of sophistication, model availability and current status of use of turbulence models in industry; the key to this is DSM;
2. Provision of fast, reliable and accurate turbulence models that will be used by industry; the key to this is robustness coupled with reliability;
3. Consideration of upstream research to avoid the generation of a new technology gap; the key to this is the DES approach.

Title: Flow Physics Modelling: An Integrated Approach

Acronym: **FLOMANIA**

Contract N°: G4RD-CT-2001-00613

Proposal N°: GRD1-2001-40199

Total cost: €5 209 080

EU contribution: €3 121 193

Starting date: 01/01/2002

Duration: 30 months

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Alenia Aeronautica S.p.A.	I
Bombardier Transportation GmbH	D
Centre National de la Recherche Scientifique (CNRS) – INPT Toulouse	F
Chalmers University of Technology Gothemburg	S
Dassault Aviation S.A.	F
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Electricite de France Research & Development	F
Imperial College of Science Technology and Medicine London	UK
Institut National Polytechnique de Toulouse	F
Numerical Mechanics Applications International (NUMECA)	B
Office National d’Etudes et de Recherches Aérospatiales (ONERA)	F
Swedish Defence Research Agency (FOI)	S
Technische Universität Berlin (TUB)	D
University of Manchester Institute of Science and Technology (UMIST)	UK

Modelling and Design of Advanced Wing Tip Devices

Project objectives

Wing tip device design has been identified as one of several technologies that have the potential to reduce the environmental impact of aircraft in terms of emissions and community noise through improved aircraft efficiency. Wing tip devices offer possible improvements in all flight phases, with the potential of being retrofitted onto existing aircraft products at relatively low cost.

The M-DAW programme will deliver to the European aerospace industry a novel wing tip device designed to improve aircraft efficiency, and thus environmental impact, together with a capability of predicting the effect of wing tip device design on aircraft performance. The programme will build on the existing knowledge base, such as that being generated within the HiReTT project, while its emphasis on novel design concepts (with a detailed physical understanding and prediction capability) will complement many other European investigations into other aspects of wing tip device design.

The specific objectives of this programme are: to develop a deeper understanding of the aerodynamics of conventional wing tip devices through wind tunnel testing at high and low speeds; to assess the capabilities of advanced CFD to predict the effect of these devices by benchmarking against the experimental results; to explore novel wing tip device concepts through applying qualified CFD and to demonstrate the most promising device by wind tunnel testing.

Description of the work

The technical work plan is divided into four work packages:

Work package 1 (Experimental investigation of wing tip device aerodynamics) will focus on the acquisition and analysis of an experimental data set to understand the aerodynamics of conventional wing tip devices. These devices will be tested at high and low speed on a common generic transport aircraft wing geometry, taking force, pressure and wake measurements. The ETW facility will be used at high speed to enable testing at flight Reynolds numbers and allow a detailed analysis of scale and loading effects.

Understanding the capabilities of current codes to handle the complex tip flows will be a key issue for the M-DAW project. **Work package 2** (Application of CFD to predict the aerodynamic characteristics of wing tip devices) will assess the capabilities of a range of CFD methods to be applied to the winglet design and assessment activities. These methods will be benchmarked against each other and the experimental data, and will encompass Euler-viscous-coupled through to Navier-Stokes, both structured and unstructured.

Beginning with a review of the state of the art, **Work package 3** (Novel wing tip device design using CFD) will explore novel wing tip devices. Using the knowledge gained from WP1 and the calibrated CFD approaches from WP2, four generic categories of tip device concept will be investigated: rigid single-element devices, rigid multi-element devices, flexible devices which exploit aeroelastic tailoring, and moveable devices. The aerodynamic studies will be supported by broader engineering assessments.

A series of regular design reviews will be held during the design activity as part of **Work package 4** (Wing tip design assessment, selection and demonstration). Results and recommendations for continuing research will be provided, thus steering the WP3 design activity towards a final novel wing tip device design. The work package will then end with high- and low-speed wind-tunnel tests of the final design and its associated analysis, thereby demonstrating the improvement in performance that has been achieved and giving recommendations for its exploitation.

Expected results

- an experimental database showing the effects of wing tip device type, scale and span loading on the performance of an advanced civil wing design;
- a detailed assessment of a range of flow-simulation methodologies relative to this experimental database describing the current European capability;
- a study of novel wing tip device concepts, including industrial assessments of their impact on aircraft performance and associated wing integration issues;
- a demonstration of the most promising design by wind tunnel testing, and finally preparation of recommendations for exploiting this device.

Title: Modelling and Design of Advanced Wing Tip Devices

Acronym: **M-DAW**

Contract N°: G4RD-CT2002-00837

Proposal N°: GRD1-2001-40187

Total cost: €4 971 040

EU contribution: €2 735 548

Starting date: 01/10/2002

Duration: 36 months

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Deutsches Zentrum Für Luft-und Raumfahrt e.V (DLR)	D
European Transonic Windtunnel GmbH (ETW)	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Politechnika Warszawska (Warsaw University of Technology)	PL
Technische Universität Braunschweig	D
University of Manchester Institute of Science and Technology (UMIST)	UK

A Computational Design Engine Incorporating Multi-Disciplinary Design and Optimisation for Blended Wing-Body Configuration

Project objectives

The project has two main objectives to be completed during the course of a three-year time frame. The first is the creation of a multi-disciplinary and multi-level Computational Design Engine (CDE) able to support designers working together on the creation of highly complex products while being physically distributed across Europe. The second is to use this engine in both prototype and final form to develop a Blended Wing-Body (BWB) aircraft and evaluate its potential as a competitor to conventional large civil aircraft.

Description of the work

The project has been divided into four phases, with Phase 1 being completed during the first three months and the second terminating at the mid-term point of the project. The work undertaken in Phase 1 was directed at laying down the foundations for the research programme. The basic CDE configuration was established and focused on the creation of a highly flexible system allowing engineers to enter a distributed design environment bringing their own software tools and models. It identified the need for a complex 'plug and play'design environment. In defining the BWB 'driving scenario', the decision was made to restrict the aircraft type to that of a freight carrier to avoid the problems associated with passenger evacuation.

The second phase has seen progressive development towards the objective of creating a prototype CDE system. A number of tools have been used in a basic architecture, including the use of SPINE as the communications backbone, ICAD as a multi-model generator and product data model and a number of proprietary systems for optimisation and finite element analysis. The various task teams involved in this phase of the CDE development have created low-fidelity models for structural analysis, CFD modelling, trim calculation and aeroelastic behaviour. These have been assembled into a system able to propagate design modifications dynamically down a design tree, thus creating new models for the analysis and optimisation tools as the design engineer makes changes to a selected overall design parameter.

This second objective for this phase is concerned with the development of the basic BWB design to create a reference aircraft to provide common data for the entire consortium. This reference configuration was constructed using several of the tools being developed within the consortium for the conceptual design. A process of configuration control has been agreed and adopted by the consortium. The reference design has been analysed by several of the task teams and has been shown to exhibit a number of deficiencies with respect to stability and drag characteristics. The application of a number of the tools identified for incorporation into the prototype CDE led to proposals for design modifications, either to correct these problems at once or to point to directions for finding solutions.

Expected results

Creation of the CDE leads to the development of an overall design tool and design methodology incorporating a complex set of MDO and interaction programmes. The functions associated with this set include:

- A communications tool allowing a distributed set of design modules to operate as a single entity.
- Development of a multi-model generator able to automatically create new design models corresponding to changes in major overall design parameters.
- A set of advanced behavioural models.
- Capability to place a model of a complex BWB design into an existing advanced simulation system.

The functions associated with the creation of the BWB include the creation of knowledge on:
• how to design a complex blended wing-body configuration;
• the limitations of the configuration.

Title: A Computational Design Engine Incorporating Multi-Disciplinary Design and Optimisation for Blended Wing-Body Configuration

Acronym: **MOB**

Contract N°: G4RD-CT-1999-00172

Proposal N°: GRD1-1999-11162

Total cost: €4 880 074

EU contribution: €3 133 400

Starting date: 01/03/2000

Duration: 36 months

Coordinator: CRANFIELD UNIVERSITY
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DaimlerChrysler Aerospace AG	D
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
QinetiQ Ltd.	UK
Saab AB	S
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universität Berlin (TUB)	D
Technische Universität Braunschweig	D
Technische Universität München (TUM)	D
Technische Universiteit Delft	NL
Universität Gesamthochschule Siegen	D
Universität Stuttgart	D

Synthesis Tool for Aeronautical Mechanisms Design

Project objectives

The objective of this project is to build an integrated general-purpose software for the structural (type) and dimensional syntheses of mechanisms, starting from a specification of functional requirements. The same tool may be used during the complete design work, not only during the type synthesis from scratch but also during the dimensional optimisation of the meshed mechanism. The objective function may be path generation, function generation, rigid-body guidance and/or any combination thereof. Constraints on occupied area, volume and/or displacement (i.e. territorial constraints) are applied at this stage.

New software to be developed will add functionality to the existing software already owned by partners and currently used in industry. The developed methods and tools will be applied to practical industrial cases in the field of aeronautics.

Description of the work

The software development activities will be executed in four stages. Firstly, a complete specification of the entire system to be developed will be made. The result of this first step, as system specification, will be presented at Milestone 1. The second step will be the separate development of six functional modules. The results of this second step, as standalone prototypes, will be demonstrated at Milestone 2. The third step will be the integration and concurrent development of the separate prototypes within the SYNAMEC system. This integrated system will perform the synthesis and analysis of aeronautical mechanisms. The result of this third step, as an integrated software prototype for synthesis and analysis of aeronautical mechanisms, will be demonstrated at Milestone 3. The fourth step will be an extension of this integrated system to perform optimisation tasks. The result of this fourth step, as synthesis system for aeronautical mechanisms design, will be demonstrated at Milestone 4. The development activities will be based on several existing software prototypes owned by the consortium partners, which will guarantee a stable foundation and reduces the risk of the development activities.

The main project output will be a software demonstrator for conceptual and detailed design of aeronautical mechanisms. The consortium will deliver the research and development work in eight work packages (WPs). WP1 is for the complete system specification. WP2 up to WP5 will develop the different functional modules: WP2. Mechanism synthesis; WP3. Optimisation/algorithms; WP4. Mechanism analysis; WP5. GUI development and software integration. WP6 will test the software demonstrators. Two WPs are added, one for the exploitation and dissemination of results, and the other for project management.

Expected results

Four milestones will indicate progress on the expected main results.

- System specification (report).
- Standalone software prototypes for (1) type synthesis; (2) Computation of sensitivities; (3) Configuration generation; (4) Expert advisor; (5) Generation of alternatives; (6) Performance evaluation.
- Integrated software prototype for synthesis of aeronautical mechanisms.
- Demonstrator software for aeronautical mechanisms synthesis and optimisation.

Title: Synthesis Tool for Aeronautical Mechanisms Design

Acronym: **SYNAMEC**

Contract N°: G4RD-CT-2001-00622

Proposal N°: GRD1-2001-40202

Total cost: €2 108 685

EU contribution: €1 205 067

Starting date: 01/12/2001

Duration: 30 months

Coordinator: SAMTECH SA
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Cranfield University	UK
SNECMA Moteurs	F
Société Anonyme Belge de Constructions Aéronautiques (SABCA)	B
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1.1. Aircraft Development Cost and Time to Market

Manufacturing

Automation for Drilling, Fastening, Assembly, Systems Integration, and Tooling

Project objectives

The aim of the ADFAST project is to reduce the cost of aircraft assembly through the use of innovative joining systems, affordable reconfigurable tooling, and metrology integration.

ADFAST has four technology objectives:

1. To develop orbital drilling technology towards a production system capable of drilling high quality, burrless holes for a range of aircraft assembly applications.
2. To develop a new fastening system capable of automatic rivet selection, rivet shaving, and improved end-effector speed and load control.
3. To design an affordable reconfigurable tooling system, consisting of novel jointed tooling modules that can be manipulated and set up by a single robotic device.
4. To demonstrate how an integrated metrology system (a laser tracker) can provide a high-precision positioning capability for robotic drilling and fastening machines.

Description of the work

The work programme identified to meet the technology objectives is:

- Perform baseline trials with the orbital drilling system on aircraft assembly applications.
- Design adaptations to the orbital drill to make it suitable for manual and robotic operation.
- Develop and evaluate a new riveting system to select a rivet based on material thickness, perform shaving of the rivet head, and with improved end-effector control.
- Develop new low-cost designs for affordable reconfigurable tooling (ART).
- Construct a prototype system for implementing the new reconfigurable tooling.
- Modify the laser tracker software and hardware to enable machine control.
- Develop advanced software tools to allow measurement planning and CAD comparison.

Three demonstrators will illustrate how the individual technologies can be brought together:

DEMO-ART: This demonstrator will show how component fixtures can be assembled from the new ART modules, using a robotic device to manipulate and position the modules.

DEMO-DRILL-MET: The new orbital drilling end-effector will be equipped with a novel targeting system and mounted on a robotic device. High-precision positioning of the end-effector will be achieved by the integrated metrology system co-operating with the robot's controller.

DEMO-FASTEN: This demonstrator will show the new fastening end-effector in operation.

There are three technical work packages:

WP1: Joining Systems, led by Airbus Spain
WP2: Affordable Reconfigurable Tooling, led by Saab
WP3: Integrated Metrology, led by BAe Systems

The ADFAST consortium consists of four airframe manufacturers, four tooling and equipment suppliers, and one university.

Expected results

1. An evaluation of orbital drilling for aircraft assembly
2. An orbital drilling system adapted for both manual and robotic use
3. A novel fastening system with improved end-effector control
4. A prototype system for implementing the new reconfigurable tooling
5. A laser tracker-based control system for positioning robotic equipment
6. Three demonstrators combining the technology developments

Title: Automation for Drilling, Fastening, Assembly, Systems Integration, and Tooling

Acronym: **ADFAST**

Contract N°: G4RD-CT-2000-00397

Proposal N°: GRD1-2000-25203

Total cost: €5 629 845

EU contribution: €2 743 232

Starting date: 01/01/2001

Duration: 36 months

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Alenia Aeronautica S.p.A.	I
Hyde Group Ltd.	UK
Leica Geosystems AG	CH
Linköping University	S
Novator AB	S
Saab AB	S
Torres M. Diseños Industriales SA	E

Advanced Grinding of New Aircraft Engine Materials

Project objectives

Improvements in the aircraft industry have arisen from the development of new hard-to-machine materials for aircraft engines. These new materials require new manufacturing technologies and a new process design. For an efficient and short-term introduction of these materials into the product, manufacturing technology has to evolve concurrently with the design and testing of workpieces.

During the project, the focus will be on the development of an innovative variant of the grinding process, namely speed-stroke grinding. Through the decrease of working engagement and the increase of workpiece speed, it is expected that low thermal influence of the workpiece and less wear on the grinding wheel will result when superabrasive grit materials are used. It will be necessary to develop optimised grinding wheels, to adapt dressing strategies and produce a machine tool designed to meet the requirements of the speed-stroke grinding technology. This technology will greatly enhance the process efficiency and reliability when grinding hard-to-machine aircraft engine materials.

Description of the work

The project is driven by the end-users who will define their workpiece requirements, and especially their future requirements, for machining the new materials. The requirements for both the machine tool and grinding wheel, and the associated technology, will be derived from these aspects.

During the first stage of investigation, the project will focus on developing a grinding technology to machine new materials, using superabrasive grinding wheels on existing machines. The wheels must be adapted and an innovative grinding strategy developed, including an adjusted dressing process. The results will be available for medium-term transfer to industry.

In the second stage, the focus will be on developing the innovative grinding strategy for speed-stroke grinding. To meet the requirements determined previously in the project, a new machine tool concept will be designed, including the optimisation of guideways for machining processes, using high-table velocities. The integration of strategies to monitor the grinding-wheel and dressing, based on AE, will optimise the tool conditioning process. Furthermore, high-porous superabrasive grinding wheel layers will be developed in combination with an optimised wheel body. Use will therefore be made of the Finite-Element-Method as optimisation tool.

Once the requirements for the speed stroke grinding have been met, the grinding technology will be developed. Based on fundamental tests for an enhanced understanding of the chip formation, designs will be made of the grinding process, the conditioning process and an optimised coolant supply. Comparison of the coolants oil and emulsion will provide additional knowledge. The research will be done in close co-operation with the end users. This research will not only determine the workpiece properties, but also investigate the influence of the grinding process on the material properties. In a final step, the efficiency of the speed-stroke grinding technology will be compared with conventional technology.

Expected results

For the mid-term assessment, the machine tool and system components designed for the innovative speed- stroke grinding technology will be presented. A grinding strategy using superabrasive wheels will also be available.

At the end of the project, results will include guidelines for a medium-term realisation of the technology experience and a long-term objective for increasing manufacturing efficiency through presentation of all necessary components and the developed speed-stroke grinding strategy.

Title: Advanced Grinding of New Aircraft Engine Materials

Acronym: **AGNETA**

Contract N°: G4RD-CT-2000-00184

Proposal N°: GRD1-1999-10677

Total cost: €3 807 063

EU contribution: €2 170 266

Starting date: 01/04/2000

Duration: 48 months

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Blohm Maschinenbau GmbH	D
Fiat Avio S.p.A.	I
INA Techniques Lineares	F
Rolls-Royce plc.	UK
SNECMA Moteurs	F

Bond-Assisted Single-Step Assembly of Aircraft Structural Components

Project objectives

The proposal aims to produce low-cost and low-weight structural components for both fixed-wing and rotary wing aircraft by defining a simple, high-quality manufacturing process in combination with a simplified generic tool concept. An additional benefit is that the number of fasteners can be reduced, thus lowering the structural weight and product cost.

Main innovations are:

- combination of sealing and adhesive with good processing and durability properties;
- sub-assembly with adequate handling possibilities in simplified tooling;
- single-step assembly without disassembling and de-burring;
- improved accessibility for installation of (a reduced number of) fasteners.

Description of the work

This proposal aims to introduce lean manufacturing in the assembly of aircraft components by applying either a room-temperature curing adhesive with durable anti-corrosion properties and fretting protection, or a sealant with adhesive properties.
This will enable a single-step assembly process, which consists of the following features:

1. assembly and fixation of the parts in simplified tool by bonding;
2. drilling of parts for the application of rivets or bolts, without intermediate disassembly for de-burring;
3. application of rivets or bolts.

The project will investigate the following aspects:

1. Comparison of properties of film adhesive and/or sprayable adhesive to paste adhesive.
2. Selection of the pre-treatment of the surfaces to be bonded.
3. Selection and design of the tooling principle that will be used to fix and join the relevant parts.
4. Testing of drilling with two different types of drills to avoid burrs and chips in the connection.
5. Investigation of the quality of the joints.
6. Application of the selected materials and processes in order to validate the technology.

Expected results

Reduction by 30% of recurring assembly cost of specific families of parts (e.g. control surfaces).
Reduction of non-recurring (tooling) costs by 10%.
Implementation of the design and manufacturing methodology in the organisation will lead to an additional 10% cost reduction for the non-recurring process, together with a reduction in lead-time of about 25%.
The application may easily be extended to other product families.

Title: Bond-Assisted Single-Step Assembly of Aircraft Structural Components

Acronym: **BASSA**

Contract N°: G4RD-CT-2002-00841

Proposal N°: GRD1-2001-40208

Total cost: €4 761 316

EU contribution: €2 380 658

Starting date: NA

Duration: 36 months

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Sonaca S.A.	B
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universiteit Delft	NL
Universidad Politécnica de Madrid	E

Project objectives

The development of more efficient aircraft engines has led to innovative engine designs with substantially higher rotating speeds in the low-pressure compressor and with higher temperatures in each stage. These new engine concepts require the application of more advanced materials and structures. The BLISK (bladed disk) technology is one of the latest achievements to improve the performance of aero engines, since their application overcomes the life-limiting fretting fatigue problem of the conventional disk-blade attachment. Up till now, BLISKs have been machined out of one piece forging, which implies one single material condition. The main objective of this proposal is to develop and validate a dual high-strength titanium alloy/dual microstructure linear friction-welded BLISK, with optimised material conditions for the disk and the blades.

Description of the work

To reach the overall goal of development and validation the dual high-strength titanium alloy/dual microstructure BLISK technology this programme is structured into 4 work packages which are further subdivided into a set of coherent tasks.

WP1. Manufacture and Repair of Dual Alloy Dual Microstructure Joints. Pancakes of Ti-6246 and Ti-17 used as disk material and slabs of Ti-6246, Ti-6242 and Ti-64 used as blade material will be forged and characterised by microstructural evaluation and appropriate mechanical testing. Linear friction-welded (LFW) joints will be produced for different material combinations. Joining parameters will be varied, quick- evaluated and optimised for each material combination. A thorough test programme is planned for the optimised linear friction welds of each material combination, and the mechanical properties will be compared with those of the base materials. Repair is a major subject for the airlines as end-users of the aero engines, therefore basic aspects of repair including weld-on-weld joints will be investigated and evaluated.

WP2. Quality Assurance of Linear Friction Welded Dual High-Strength Titanium Alloy Dual Microstructure Joints. New and existing NDT methods for aero engines will be assessed and, if necessary, adapted with regard to their applicability to dual titanium alloy/dual microstructure joints. Modelling of the BLISK manufacturing processes and the validation of these predictions with experimental data from WP1 will lead to a deeper understanding of the process and make it more stable. The formulation of a quality assurance guideline for LFW-joints will complete this work package.

WP3. Production and Validation of a Linear Friction Welded Demonstrator BLISK. A demonstrator BLISK with different blade materials will be manufactured and evaluated.

WP4. Project Management and Exploitation. Technical management on day-to-day basis, together with technical exploitation and dissemination of the results.

Expected results

The project comprises five milestones and 13 major deliverables, including:

- Identification of optimised linear friction-weld parameters for each material combination.
- Determination of microstructure and mechanical properties of welds.
- Evaluation and adaptation of NDT methods for aero engines with regard to dual alloy/dual microstructure joints.
- Production and validation of a demonstrator BLISK.
- Definition of a possible repair strategy and quality assurance guideline.

Title: Dual Material Titanium Alloy Friction Welded BLISK

Acronym: **DUTIFRISK**

Contract N°: G4RD-CT-2001-00631

Proposal N°: GRD1-2001-40194

Total cost: €3 988 068

EU contribution: €1 994 033

Starting date: 01/04/2002

Duration: 48 months

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Ecole Nationale Superieure de Mecanique et d'Aerotechnique (ENSMA)	F
SNECMA Moteurs	F
Universitat Politécnica de Catalunya Barcelona	E

Optimisation of Spray-Forming of Advanced High-Quality Components of Superalloys for Aeronautic Applications

Project objectives

Optimisation of the process parameters that are currently being used to spray-form aero engine components, leading to the development of better quality materials at reduced cost.

Reduction in the level of porosity that is present in current spray-forming facilities.

Improvement in the yield of the process, i.e., reduce the amount of scrap generated in each deposition.

Development of an on-line monitoring of the deposition parameters, to improve the efficiency of the process and to enhance the control of the final shape of the deposited material.

Improvement in the forgeability of high-temperature capability alloys that cannot be post-processed following conventional casting routes.

Characterisation of the materials obtained, both microstructurally and mechanically, following the optimised processing route that will be derived from the programme.

Establishment of a basis for the future implementation of a production-scale spray-forming facility in Europe, which could give significantly increase the competitiveness of the European aerospace industry.

Description of the work

The following activities will be carried out in the programme

Material procurement and first deposition trials. The spray facilities will be set up to perform the first deposition trials, which will be evaluated via microstructural observation. This study will comprise measurements of grain size, porosity, distribution of precipitates, volume fraction of different phases, etc. Mechanical testing will be conducted on samples extracted from a selection of deposited coupons.

Modelling activities. The results obtained in the first deposition trials will be used as a basis to model the deposition process. The results of the model will be validated with the materials produced during the optimisation stage of the programme. The modelling activities will lead to the implementation of the intelligent processing.

Optimisation of the deposition parameters. New deposition trials will be carried out, changing parameters such as the gas type, spray distance and melt superheat according to suggestions derived from the modelling work. The optimised materials will be assessed via microstructural and mechanical testing. One set of parameters per alloy will be selected as the optimal processing conditions. The material thus produced will undergo a complete mechanical characterisation and will be used as the starting material for subsequent post-processing operations.

Post-processing of the optimal depositions. Hot-working and HIP cycles will be applied to the optimal materials deposited with the shape of billets and rings. Compression tests will be carried out in order to have a complete understanding of the flow behaviour of the sprayed materials.

Once the optimal deposition and post-processing parameters have been defined, component and component prototypes will be manufactured. These prototypes will be inspected and tested with both non-destructive techniques and destructive techniques in the same way as for real components.

Expected results

An optimised and automated method of deposition of Ni-based superalloys will be developed. The optimal post-processing (Hot-working and HIP) conditions will also be determined. This will imply cost reductions and improved quality in spray-formed materials. At the same time, the use of a cast alloy will demonstrate success in the spray-forming of alloys that cannot be processed with conventional technologies.

Title: Optimisation of Spray-Forming of Advanced High-Quality Components of Superalloys for Aeronautic Applications

Acronym: **OPTISPRAY**

Contract N°: G4RD-CT-2002-00762

Proposal N°: GRD1-2001-40168

Total cost: €3 567 454

EU contribution: €2 394 957

Starting date: 01/06/2002

Duration: 36 months

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Böhler Schmiedetechnik GmbH & Co KG	A
Inasmet Foundation	E
MTU Aero Engines GmbH	D
Turbomeca S.A.	F
Universität Bremen	D
University of Oxford	UK

Improvement of Tools for the Machining of Aeronautic Aluminium and Titanium Alloys

Project objectives

The main objective of the project is the improvement of cutting tools for machining aeronautic aluminium and titanium alloys. This improvement will translate into longer tool life, better finishing quality of the part, reduction of coolant and speeding-up of the process. This improvement will involve a significant reduction of the machining costs of aluminium and titanium alloys, and thus bring down the manufacturing cost of the aeronautical parts. The following machining processes have been pre-selected: aluminium end-milling, titanium drilling and Al and Ti broaching. The project aims to improve the tools by redesigning them, taking into account the fact that they will be coated or surface treated. another goal is to optimise the following treatments: special ion implantation treatments, PVD multi-layer coatings and multi-process treatments. Moreover, the tools will be proved in industrial conditions and be validated in a genuine aeronautical part, acting as a demonstrator.

Description of the work

Although Al end-milling, Ti drilling, and Al and Ti broaching have been pre-selected, the needs of the machine shops will be reassessed. A final set of tools and machining processes will then be selected. At this stage, where convenient, the tools will be redesigned.

Optimisation of surface treatments and coatings will then start by a pre-selection of some treatments. The treatments will be optimised at laboratory level based on mechanical properties (hardness, friction, wear, adhesion, etc) and the machining tests. Finally, the optimised treatments will be applied to the tools.

The tools will be tested both at laboratory level and in industrial conditions. Additionally, the failure mode of the tested tools will be analysed, so the optimisation of the tools can be properly orientated. Finally, the tools will be used in the manufacture of a demonstrator, to enable the treatments to be validated in real aeronautical parts.

The economic impact of the improvements brought to the tool will be evaluated. Data from all the partners will be collected and assessed, concerning the cost and performance of the tools, treatments and processing. An estimation of the treatment industrial exploitation will be carried out, taking into account the necessary modifications of the treatment equipment.

Expected results

- Development and validation of new surface treatments and tools design.
- Assessment of the desired improvements in the selected tooling and processes.
- Specifications, geometry, performance and treatment of the tools.

Title: Improvement of Tools for the Machining of Aeronautic Aluminium and Titanium Alloys

Acronym: **TITALUM**

Contract N°: G4RD-CT-2001-00617

Proposal N°: GRD1-2001-40197

Total cost: €1 799 592

EU contribution: €1 060 284

Starting date: 01/01/2002

Duration: 24 months

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INASMET Foundation	E
Mecanizados Escribano, S.L.	E
Rheinisch-Westfälische Technische Hochschule Aachen – WZL	D
UNIMERCO A/S	DK

Welding of Airframes by Friction Stir

Project objectives

Most primary structural components in airframes are currently made by mechanically fastening subcomponents together, or by integrally NC-machining them from solid material. Mechanical fastening suffers from a weight penalty, difficulty of automation, a requirement for sealants, and problems with corrosion. NC-machining is a wasteful process in terms of time, energy and raw material.

It is known that welding can provide cost savings of up to 30% and weight savings of up to 10% for a typical airframe structure. It is claimed that FSW has many advantages in comparison to fusion welding processes. Therefore the potential for the use of FSW in airframes is extremely large. The overall objective of the WAFS project is to 'Advance the state of the art of Friction Stir Welding (FSW) to enable the widespread adoption of the technology to primary structures in airframes'.

Description of the work

A consortium has been formed of seven airframe manufacturers, one material supplier and six research organisations. Six EU countries are represented. The development is focused on four main topics (organised in work packages): developing a FSW standard, processing thin-section aerospace alloys, processing thick-section aerospace alloys, and the development of modelling capability. Main areas of innovation will be in the design of new FSW tools, the development of process parameters, the addition of novel property improvement techniques and repair procedures, and the development of an FE model for FSW.

Working standards have been produced for the project. For thin-section similar alloy combinations, most of the tool designs and welding parameters have been optimised at mid-term. Welds have been produced and the testing programme has started. Initial results and tensile properties are very good (typically 80% of base). Repair welds have also been made. The first dissimilar welds have also been successfully made (1424/6056 and 2024A/6056). Systems for online cooling for property improvement have been built and tested. The cooling has been shown to have the effect of controlling the residual stresses in 6 mm material. The stresses were changed from tensile to compressive on the weld line.

In thick section (>6 mm) single-pass welds in 2024, 7449 and IS262 have been made. Also, the process parameters and tool designs for double-sided and single-sided butt-welding of 25mm 7050 have been obtained. Again, the properties obtained are very good. A major breakthrough has been made in that a process has been developed for the control of corrosion in FSW joints. This process is laser-based and has been shown to be effective for both 2000 and 7000 series.

For the process, modeling case studies have been defined. Thermal data from the welding process has been obtained. Mechanical property data has also been obtained by testing of microtensile specimens at elevated temperatures.

Expected results

The project outputs will be:

1. FSW tool designs and process parameters for a variety of aluminium alloys and their combinations
2. New techniques for improving the properties of joints made with FSW
3. Repair procedures for FSW, both in manufacture and in service
4. Design data and rules for FSW in structural airframe applications
5. Modelling tools for FSW
6. Optimised tempers for aluminium alloys for FSW.

Title: Welding of Airframes by Friction Stir

Acronym: **WAFS**

Contract N°: G4RD-CT-2000-00191

Proposal N°: GRD1-1999-10271

Total cost: €5 064 892

EU contribution: €2 532 449

Starting date: 01/03/2000

Duration: 36 months

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Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
EADS Deutschland GmbH – Military Aircraft	D
European Aeronautic Defence and Space Company – Construcciones Aeronauticas S.A. (EADS – CASA)	E
GIE EADS – CCR France	F
GIE EADS – CCR Germany	D
GKSS Forschungszentrum Geesthacht GmbH	D
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1.1. Aircraft Development Cost and Time to Market

Product quality control

Integration of Non-Destructive Testing

Project objectives

The aim of the project is to develop a completely new structure for future NDI processes and handbooks, in order to reduce costs and increase efficiency and reliability of the diagnosis. The objectives are:

- Generation of procedures using a computer-controlled check list system;
- Development of a multimedia maintenance manual (4M);
- Integration of Internet technology for online maintenance assistance;
- Integration of qualified standard inspection procedures based on multimedia tools;
- Design of an expert system with problem-orientated inspection procedures;
- Preparation of targeted platforms;
- Automatic equipment adjustment by the software;
- Development of web-based tools for supporting remote human and machine operators;
- Development of NDT data-processing tools supporting decision processes;
- Development of protocols and procedures for monitoring life-cycles.

Description of the work

- Studies to investigate the requirements for modern inspection systems/customer surveys;
- Analysis of the existing manual, and a definition of a new multimedia-based NTM structure;
- Definition of SGML structures and preparation of a demonstrator on the basis of problem-orientated inspection and standard procedures;
- Generation of suitable inspection procedures, including qualification (POD) as the basis for the new computer-based manual system ATeMIS;
- Development of a demonstrator expert system for inspection procedures;
- Analysis of customer acceptance;
- System development for automatic test equipment adjustment;
- Preparation of an ATeMIS prototype and test under regular service conditions at the customer's facilities;
- Market study (hardware) on the transmission of electronic procedures to the aircraft;
- Internet-based development of an online maintenance assistance (OMA) system for world-wide online support of inspectors for regular maintenance tasks;
- Analysis of the telecommunications structure of the customer.

Expected results

Key elements at the end of the project will include a platform for a Multimedia-NDI-Handbook with a new user-friendly structure. To support this handbook, a web-based information system, an Online-in information system for customers and a Life-Cycle-Monitoring of inspected structure will be available as a demonstration platform.
The developed data management and processing will lead to demonstration platforms, to validate their added value.

Title: Integration of Non-Destructive Testing

Acronym: **INDeT**

Contract N°: G4RD-CT-2002-00830

Proposal N°: GRD1-2001-40177

Total cost: €5 043 953

EU contribution: €2 851 560

Starting date: 01/06/2002

Duration: 36 months

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Consiglio Nazionale delle Ricerche	I
Dassault Aviation S.A.	F
Fachhochschule Furtwangen, Hochschule für Technik und Wirtschaft	D
GIE NDT Expert	F
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Sogitec Industries	F
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University of Limerick	IRL

Integrating Process Controls with Manufacturing to Produce High Integrity Rotating Parts for Modern Gas Turbines

Project objectives

1. A reduction in the probability of burst of a disc from a manufacturing anomaly by a factor of ten.
2. The ability to specify process controls (NDI and Process Monitoring) to achieve a specified low level of risk of burst from machining anomalies.
3. A scientific basis on which to control manufacturing process development, change and sentencing of non-conforming products in terms of the required surface condition in the materials.
4. A systematic evaluation of the manufacturing processes for three features in discs to assess the types of anomaly they can produce under abusive conditions.
5. An integrated probabilistic approach, that relates process controls and manufacturing anomalies to fatigue penalty associated with the as manufactured condition, for reducing the probability of burst of high integrity rotating parts.

Description of the work

The most common hazardous effect for aircraft engines as defined in the Joint Aviation Regulations (JAR-E) is ejection from the engine of uncontained high-energy debris. Critical parts (i.e. those which have to achieve and maintain a high level of integrity to avoid hazardous effects) mostly consist of rotating high- energy discs and spacers. This programme addresses the reduction of risk of disc burst from manufacturing anomalies, which has become the largest cause of disc failure in the 1990s.

Three features in disc components will be systematically examined. The processes for each feature will be evaluated to establish which anomaly types can be produced and which Process Monitoring (PM) techniques will be effective in detecting them. A pilot study will be run from the start of the programme, which will manufacture fatigue specimens that contain anomalies, and test and evaluate them in an accelerated time-scale compared with the rest of the programme.

The main part of the programme comprises manufacturing trials using two disc materials, a titanium and a nickel alloy. Blocks of material will be systematically abused to develop the means of producing damage in a controlled manner. Once this has been established, fatigue specimens of various sizes and manufacturing anomaly type will be manufactured, and process-monitoring techniques will be used. The specimens will be made in two batches, where the first batch will examine a wide range of anomalies and the second batch will focus on a few key anomalies, which adversely affect fatigue life. These specimens will be examined using both current and near term NDI methods to establish the capability of such inspection methods. Finally they will be tested to determine the fatigue penalty. Metallographic examination of the specimens after testing will allow a correlation between the size of the anomaly and the fatigue capability. Such a relationship has not been available before. These results along with industry data may then be used to calculate the probability of creating a life-limiting anomaly. Hence a probabilistic method which combines the statistical relation between anomaly size and detection capability and the probability of a fatigue life not being achieved will follow. This will allow a probability of burst from a manufacturing anomaly to be calculated for any specified component, and should indicate what PM and NDI would be required to reduce this probability of burst to the required level. The development of quantitative methods for specifying methods and controls is totally new to the gas turbine industry.

Expected results

An integrated probabilistic approach software which would capture the previous results and evaluate the probability of burst in service in terms of the feature, the manufacturing method and the controls specified.

Title: Integrating Process Controls with Manufacturing to Produce High Integrity Rotating Parts for Modern Gas Turbines

Acronym: **MANHIRP**

Contract N°: G4RD-CT-2000-00400

Proposal N°: GRD1-2000-25567

Total cost: €5 855 883

EU contribution: €3 750 537

Starting date: 01/02/2001

Duration: 48 months

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Industria de Turbo Propulsores S.A.	E
Integrated Aerospace Sciences Corporation O.E.	EL
MTU Motoren- und Turbinen-Union München GmbH	D
Otto-von-Güricke-Universität Magdeburg	D
Politecnico of Milan	I
Rheinisch-Westfälische Technische Hochschule Aachen – LTF	D
SNECMA Moteurs	F
University of Nottingham	UK
Uppsala University	S
Volvo Aero Corporation AB	S

Manufacturing and Modelling of Fabricated Structural Components

Project objectives

The programme will develop a framework within which non-mature manufacturing and analysis techniques may be integrated to develop methodologies for the design and manufacture of fabricated structural components. This is particularly relevant to the design of aero-engine structures, where there are demands:

- to reduce manufacturing lead time
- to increase material utilisation and reduce waste
- to reduce costs
- to increase the manufacturing competitiveness of the EU countries
- to operate with integrity in a high-temperature environment
- to maximise stiffness while reducing weight
- to design with regard for aerodynamic efficiency.

The programme will particularly address the commercial risk involved when a large number of new technologies are required to complete a project. This has been the main reason why fabrication of structural components has been underdeveloped.

Description of the work

The work-plan integrates critical technologies for efficient and robust manufacturing of fabricated aerospace structural components. The primary goal is to ensure that designs can be manufactured in the most timely and cost-effective manner. The work proposed draws its requirements from the Technology Platform engine and will provide technology inputs to it. The work is divided into five Work Packages.

WP1 Design for manufacture

The aim is to develop generic tools and integration methodologies for the application of design and process simulation to enable the design of the target aero-engine components to take account of the effects of manufacturing processes on the characteristics of the component in service.

WP2 Process modelling

Tools and methods will be developed for simulating the manufacture of a component. A set of tools for the early and later phases of the design of the manufacturing process will allow optimisation of the manufacturing process and will also be of use in component design.

WP3 Welding technology and related control, sensors and NDT

The main objective is to improve automatic/robotic welding processes by on-line optical and thermal process control. Other objectives are to develop Low Stress Non Distortion, EB and laser diode welding.

WP4 Fabrication and machining of components and testing

The main objective for this Work Package will be to provide information and data to other Work Packages. This will allow the design process to be true 'Design for Manufacture', i.e. for designers to have information and tools that reflect the manufacturing processes, to give right-first-time designs at minimum cost.

WP5 Fabrication of high temperature material (IN939TM)

WP5 is focused on the welding of cast and spray-formed alloy IN939TM, a commercial alloy with potential for large load-bearing structural components and a high service temperature. Typical forming methods (i.e. casting, spray-forming) will be evaluated, and both repair and structural welding techniques will be developed.

Expected results

The programme will deliver:

- a robust methodology for optimal design of structural fabrications
- new, pertinent physical analysis methods
- a data management protocol
- increased confidence in fabrication as a method of manufacture

- increased confidence in weld strengths
- development of automated control and NDT
- greater material properties awareness
- European structural fabrication technology to compete worldwide against single piece castings.

Title: Manufacturing and Modelling of Fabricated Structural Components

Acronym: **MMFSC**

Contract N°: G4RD-CT-2000-00217

Proposal N°: GRD1-1999-10248

Total cost: €9 389 525

EU contribution: €6 219 905

Starting date: 01/03/2000

Duration: 48 months

Coordinator: INDUSTRIA DE TURBO PROPULSORES S.A.
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Ferroday Limited	UK
Fundacion Tekniker (TEKNIKER)	E
Groupement d'Etude et de Recherche pour les Applications Industrielles des Laser de Puissance	F
Heriot-Watt University	UK
Luleå University of Technology (LTU)	S
MTU Aero Engines GmbH	D
QinetiQ Ltd.	UK
Queen's University of Belfast	UK
Rheinisch-Westfälische Technische Hochschule Aachen – WZL	D
Robotiker – Technological Transfer Centre	E
Rolls-Royce plc.	UK
SNECMA Moteurs	F
Technical Research Centre of Finland	FI
Universidad de Cantabria	E
University of Nottingham	UK
University of Southampton	UK
Volvo Aero Corporation AB	S
Welding Institute	UK

Development of Novel Non-Destructive Testing Techniques and Integrated On-line Process Control for Robotic and Flexible Friction Stir-Welding Systems

Project objectives

A new environmentally friendly welding technology called Friction Stir Welding (FSW) has recently emerged as a very important process for welding of high-strength aluminium alloys (important to the aerospace and automotive industry but previously unweldable) and is now making an impact on other materials. However, two technical limitations are hampering its widespread use: the lack of Non-Destructive Testing (NDT) and in-process monitoring techniques, and also the lack of manufacturing flexibility.

The technical objectives are to develop:

1. new NDT techniques for the detection of characteristic flaws;
2. new in-process monitoring and control systems to improve joint quality by reducing manufacturing defects;
3. flexible robotic systems for the fabrication of complex shaped welds.

The economic objectives are:

1. to increase the use of FSW, resulting in a ten-fold increase in the FSW equipment market to €190 million world-wide;
2. to eliminate destructive testing and to use material more efficiently, thus generating annual savings of €63 million in the aerospace and automotive industries alone;
3. to increase the use of FSW components in cars and aircraft, thus reducing weight and leading to improved safety and reduced fuel consumption.

The social objectives are:

1. to eliminate exposure of welding operators to hazardous conditions through using FSW;
2. to increase the use of robots in industry, hence reducing labour intensive and monotonous tasks;
3. to increase safety in aerospace and automotive vehicles.

Description of the work

A novel robotic and flexible FSW system, integrated with NDT and in-process monitoring and control, suitable for welding complex 3D geometries will be developed in six work packages (WPs):

- **WP-A. System and design specification.** This will produce a full specification of the NDT system, the in-process monitoring and control system, a customised robot and a customised FSW machine.
- **WP-B. Development of NDT techniques and System.** This task will deliver NDT techniques and a NDT system based on a novel phased array design. This system will be able to detect all defects associated with friction stir welding and will be designed to be easily interfaced with the robot and the FSW machine.
- **WP-C. Development of In-process monitoring techniques and system.** This task will deliver in-process monitoring and control techniques, and also a system based on sensors which measure key weld parameters. This system will be able to optimise the friction stir-welding process by monitoring and controlling key weld parameters and will be designed to be easily interfaced with the robot and the FSW machine.
- **WP-D. Customisation of Robot to carry NDT and In-process Monitoring and Control Systems Modules.** This task will deliver a customised standard Tricept 805 robot for friction stir-welding of 3D industrial components and structural elements and will provide the Robot with appropriate interfaces for NDT and in-process monitoring and control.
- **WP-E. Customisation of a FSW machine to carry in-process monitoring and NDT modules.** This task will involve customising a standard FSW machine for friction stir-welding of 2D industrial components and structural elements and provide the machine with appropriate interfaces for NDT and in-process monitoring and control.
- **WP-F. Factory Trials with End-User Participation.** This task will deliver a complete robot for FSW with quality control and NDT, and also a complete FSW machine with quality control and NDT. The customised robot and FSW machine will be tested in the factory for the fabrication of aerospace and automotive friction stir welded components.

Research sub-contractors, who are leaders in NDT, in-process control and monitoring and friction stir- welding will execute the technical research tasks. The SMEs (consisting of NDT companies, probe/sensor manufacturers, process automation and control, and manufacturers of friction stir machines and robots) will develop NDT and monitoring and control systems, and integrate them into the friction stir robots and machines.

Expected results

The project will deliver a customised robot and a customised FSW machine, each with incorporated NDT and in-process monitoring modules for quality control. Milestones are (1) a fully developed NDT system, (2) a fully developed in-process monitoring and control system, (3) a robot customised for FSW, NDT and in-process monitoring, (4) an FSW machine customised for NDT and in-process monitoring, (5) fully integrated and factory-tested systems.
Exploitation will be through the supply chain in the project participants. CS and Neos (both SME manufacturers of FSW systems) have been appointed to sell systems to the aerospace and automotive markets respectively. The End-User Panel supporting the project contains British Aerospace and SAPA. These companies represent the first potential customers of the SMEs in the project.

Title: Development of Novel Non-Destructive Testing Techniques and Integrated On-line Process Control for Robotic and Flexible Friction Stir-Welding Systems

Acronym: **QUALISTIR**

Contract N°: G4ST-CT-2001-50117

Proposal N°: CRAF-1999-70641

Total cost: €1 997 574

EU contribution: €997 530

Starting date: 01/11/2001

Duration: 24 months

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GKSS Forschungzentrum GmbH	D
Isotest	I
Neos Robotics AB	S
Technical University of Sofia	BG
TWI Ltd.	UK
Vermon	F

1.2. Aircraft Efficiency

Aerodynamics

Project objectives

The primary objective is to identify, from an industrial engineering viewpoint, the true costs and benefits of applying Micro Electro-mechanical Systems (MEMS) technology for flow-separation control to a range of aerospace products. To achieve this, the following goals will be met:

- The performance gains of MEMS flow-separation control technology applied to high-lift systems on both conventional and novel civil aircraft will be quantified and demonstrated in large-scale industrial wind tunnel tests.
- The performance gains of MEMS flow separation control applied to nacelles and turbo-machinery will be identified.
- MEMS flow sensors, actuators and packaging concepts suitable for full-scale development for industrial application will be developed.
- Practical engineering and systems integration concepts will be developed, and key certification and operational issues identified.
- Estimates of the costs of practical implementation of a MEMS flow-separation concept on a range of aerospace products will be made.

Description of the work

The work programme consists of four discrete inter-linked work packages (WPs) structured about the scientific approach and the major technical milestones. In WP1, basic 2D and 3D experiments, supported by numerical modelling, will be carried out to optimise and further improve the active flow-control actuation concepts developed in the previous AEROMEMS project. The output from WP1 will support the industrial scale demonstrations undertaken in WP3. In addition, preliminary, low cost numerical and experimental studies will be done to advance the application of this technology to engine intakes and turbo-machinery components.

In WP2, MEMS flow actuators and sensors will be developed and fabricated for incorporation into the industrial demonstration experiments of WP3. Further development of MEMS hardware towards a flight-worthy status will be undertaken and commercial production routes and costs evaluated. Information on commercial production costs, packaging and engineering integration will be the input to WP4. In WP3 industrial-scale wind tunnel demonstrations of the application of MEMS based flow separation control systems to improve the performance of leading and trailing edge high-lift systems will be undertaken on conventional civil aircraft configurations. The results of the demonstration tests will be extrapolated to full-scale flight conditions using industrial numerical codes. Numerical studies will also be used, in conjunction with the experimental results, to explore the potential for applying this technology to a more novel civil aircraft planform, such as a slender supersonic transport.

WP4 will provide an industrial cost/benefit assessment of a range of MEMS-based low-separation control applications to aircraft high-lift and propulsion systems. Results from WPs 1, 2 and 3 will be the input for this activity. Conceptual engineering integration schemes will be developed, and important issues with respect to industrial implementation and certification will be identified.

Expected results

- Data from industrial wind tunnel tests demonstrating and quantifying the application of MEMS to flow separation control on aircraft high lift and propulsion systems.
- Assessments of cost/benefit studies determining the viability of the technology application to aircraft high lift and propulsion systems.
- Outlines of practical engineering integration concepts and identified certification issues.
- Prototype MEMS flow sensors and actuators and industrial packaging schemes.
- Results from numerical CFD prediction tools, comparisons with experiment and extrapolations to flight scale.
- Future exploitation strategy.

Title: Advanced Aerodynamic Flow Control Using MEMS

Acronym: **AEROMEMS II**

Contract N°: G4RD-CT2002-00748

Proposal N°: GRD1-2001-40167

Total cost: €4 537 993

EU contribution: €2 817 901

Starting date: 01/04/2002

Duration: 36 months

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Auxitrol SA	F
Centre National de la Recherche Scientifique – LML	F
Centre National de la Recherche Scientifique – LPMO	F
Cranfield University	UK
Dassault Aviation S.A.	F
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
EADS Deutschland GmbH – Military Aircraft	D
National Technical University of Athens (NTUA)	EL
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
SNECMA Moteurs	F
Technische Universität Berlin (TUB)	D
Université des Sciences et Technologies de Lille	F
University of Warwick	UK
Victoria University of Manchester	UK

Multi-Point Aerodynamic Shape Optimisation

Project objectives

In the ongoing competition for increased share of the world market in commercial transport aircraft, a continuous effort is being made to design and produce more cost-effective and environmentally friendly aircraft. The AEROSHAPE project aims ultimately to increase efficiency by introducing more effective numerical optimisation tools in aircraft design in order to make it possible to drive aircraft drag down to minimum levels for specified conditions. This means that fuel consumption levels will also be minimised, leading to reduced emissions of polluting exhaust gases.

The new optimisation tools in aerodynamics are also part of general practice now when designing new aircraft. They are used for extensive computational studies of airflow around the aircraft. When shapes are more thoroughly analysed and optimised, this reduces tendencies towards bad local flow situations like separation and unsteady flows, which are potential sources of fatigue problems during the lifetime of an aircraft.

The general objective concerns the assessment and enhancement of aerodynamic optimisation tools in order to solve real-life constrained multi-objective problems. A thorough assessment and exploitation report will be written at the end of the project, forming the basis for industrial activity to continue.

Description of the work

Aerodynamic shape optimisation methods (based on the Euler and Navier-Stokes equations) are assessed and enhanced. In particular, emphasis is put on their capability to solve real-life multi-point constrained problems. The project is planned to run for three years and has the following overall structure:

Work package 1. Test case definition and database, including reference geometries and design problems specification, web server.

Work package 2. Baseline evaluation, with regards to the application of existing aerodynamic optimisation tools to the test cases defined in Work package 1.

Work package 3. Enhancement of aerodynamic optimisation tools, with respect to improved adjoint formulation based on both discrete and continuous equations, evolution strategies, genetic algorithms and hybrid methods, use of fuzzy logics and neural networks, and improved gradient-based optimisation algorithms.

Work package 4. Evaluation of improved tools, with respect to demonstrating the capability of modern optimisation methods to solve the design problems defined in Work package 1, in comparison with the standard present-day methods assessed in Work package 2.

Work package 5. Management and exploitation, including actions to promote the industrial exploitation of the different methods.

Expected results

The main outcome is the implementation of the most advanced technologies into current aerodynamic optimisation systems in use in the industrial partners, in close collaboration with research institutes. At a later stage, these technologies will be integrated into large multidisciplinary systems that will be used for the product optimisation process. Modern aerodynamic optimisation methods also have potential for application in other fields, such as turbine and ship-hull development work.

Title: Multi-Point Aerodynamic Shape Optimisation

Acronym: **AEROSHAPE**

Contract N°: G4RD-CT-1999-00062

Proposal N°: GRD1-1999-10752

Total cost: €4 412 616

EU contribution: €2 206 305

Starting date: 01/01/2000

Duration: 36 months

Coordinator: ALENIA AERONAUTICA S.p.A.
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Dassault Aviation S.A.	F
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Divis Digital Solutions GmbH	D
EADS Deutschland A.G.	D
EADS France S.A.S.	F
Hellenic Company for Space Applications S.A.	EL
Institut National de Recherche en Informatique et en Automatique (INRIA)	F
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Saab AB	S
Sener Ingeniería y Sistemas S.A.	E
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Swedish Defence Research Agency (FOI)	S
Synaps Ingenieur-Gesellschaft GmbH	D

Application of Hybrid Laminar Flow Technology on Transport Aircraft

Project objectives

The ALTTA project advances hybrid laminar flow (HLF) technology for future, more fuel-efficient passenger aircraft. The work concentrates on fin and nacelle of an aircraft, because the barriers to technology implementation are lowest for these components. Furthermore, the ALTTA programme will improve the aerodynamic and system tools necessary for the design of HLF systems. The programme's three work packages reflect its three objectives:

1. conceptual design of a simplified HLF system for the fin of an airbus A320;
2. design of an HLF system for a nacelle with optimised overall performance;
3. advanced tools and methods required for designing hybrid laminar flow applications.

Description of the work

Work package 1. Prior to the commercial application of the hybrid laminar flow technology, it will be necessary to demonstrate that a simple suction system allowing drag reduction under operational conditions could be designed and manufactured. Such a system must bring about the expected savings in operating costs. In this work package, a suction leading edge for a fin will be designed, with emphasis on simplification of the suction chamber layout and making the internal systems smaller, lighter and easier to manufacture. A new production technique will be developed to improve the surface quality of the suction panel at lower cost.

Work package 2. A hybrid laminar flow nacelle, designed for maximal extent of laminar flow, carries weight penalties in structure and systems that lower the overall operational benefits. In this work package, a system for these components with a reduced extent of laminar flow but improved overall performance, using a multi-variable optimisation tool developed in work package 3, aiming at optimal trade-off between aerodynamic drag reduction and weight, or other operational penalties. Furthermore, an anti-icing and anti-contamination system for the nacelle will be designed, manufactured, and implemented in a nacelle mock-up.

Work package 3. This work package addresses the methods and tools needed for the design of hybrid laminar flow applications. The first task extends the transition prediction work started in the EUROTRANS project: current database methods are parted to 3D Navier-Stokes codes; wind tunnel and also flight test data will be evaluated to deliver critical N-factor calibrations for non-local stability methods. New adjoint methods are to be validated for sensitivity studies and their applicability to design processes.

The second task concerns the system tools development. A tool for optimising suction systems is being developed for the use in work package 2. Laser drilling techniques will be improved. A number of critical operational issues will be addressed, such as the impact of ice-crystal clouds on laminar flow.

Expected results

- conceptual design of a simpler and lighter suction leading edge for an Airbus A320, including a production mock-up as preparation for future flight tests;
- proof of concept for an HLF nacelle, with reduced laminarity and improved overall benefits;
- improved numerical design tools (transition prediction), optimisation tool for HLF systems, improved suction panel manufacturing.

Title: Application of Hybrid Laminar Flow Technology on Transport Aircraft

Acronym: ALTTA

Contract N°: G4RD-CT-2000-00143

Proposal N°: GRD1-1999-11192

Total cost: €6 942 235

EU contribution: €3 786 594

Starting date: 01/02/2000

Duration: 30 months

Coordinator: AIRBUS DEUTSCHLAND GmbH
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Dassault Aviation S.A.	F
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
FR-HiTEMP Ltd.	UK
Imperial College London	UK
Instituto Superior Técnico (IST) Lisboa	P
Nord-Micro AG & Co. oHG	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Rolls-Royce plc.	UK
Saab AB	S
Sonaca S.A.	B
Swedish Defence Research Agency (FOI)	S
Universität Bremen	D
Université Paul Sabatier de Toulouse III	F
University of Limerick	IRL

European Project for Improvement of Supersonic Transport Low-Speed Efficiency

Project objectives

Increasing long-range air travel requires that travel times be reduced. While second-generation supersonic transport could satisfy this demand, the major technologies have not yet been developed or proven. One of the Supersonic Civil Transport design drivers is the requirement to comply with airport noise rules. This requirement makes it necessary for SCT configurations to be designed with high lift-over-drag ratios at low speed during the approach, take-off and climb phases of flight.

The specific research objectives of EPISTLE are:

- to increase knowledge of influences and major sensitivities impacting high-lift device design for large delta-wing aircraft;
- to obtain design rules to be used for the aerodynamic design of future high-lift devices, particularly leading edge flaps;
- to apply and test a variety of alternate aerodynamic design methods, ranging from manual design up to constrained aerodynamic optimisation;
- to obtain high-quality experimental data on a representative SCT configuration (using the basic wing shape designed in the EUROSUP project) leading to an understanding of the flow development and providing a basis for evaluating current and future developments in viscous flow-analysis methods;
- to validate the overall aerodynamic design methodology, including the analysis tools, the design rules and the design methods;
- to increase the L/D capability of current SCT designs by 15-20%.

Description of the work

WP1. Low-speed data enhancement. Extension of the low-speed data base for the 1:80 scale EUROSUP wind tunnel will be performed, enabling confirmation that the numerical tools used within the design methodology can predict the effect of nose flap deflection on lift and drag and the development of flow separations.

Detailed analysis will be performed aiming at a better understanding of the obtained experimental and numerical data.

WP2. Assessment of numerical methods and physical models. The capabilities of the numerical methods to be used by the partners within the project will be assessed and demonstrated by varying numerical resolution and physical turbulence models and comparisons with experimental data of WP1. Numerical acceptance tests will be performed to qualify the Navier-Stokes solvers for the aerodynamic design and analysis work in WP3,WP4, and WP7.

WP3. Low-speed design methodology. The development of the low-speed design methodology is based on the following approaches, using the accepted numerical flow analysis tools:

1. Identification of the major design parameters and their sensitivities. Emphasis is placed upon the design sensitivities of nose flaps, but innovative solutions will also be considered.
2. Extraction of design rules that allow the application of simplified flow models in 3D design work.
3. Assessment of alternate design methods, subject to the new design rules to be performed within WP4.

WP4. 3D wing design. The defined design rules will allow the partners to proceed with the application of 3D design methods to design a validation configuration that can be tested in one of the major European subsonic wind tunnels. A variety of alternate design methods that will be tried will range from semi-empirical approximate flow models up to constrained optimisation and Navier-Stokes modelling.

WP5. Wind tunnel model. A large 1:22 scale model of the basic wing–body configuration generated in EUROSUP together with the high-lift devices designed in WP4 will be designed and manufactured. Three interchangeable leading-edge configurations will be provided and the trailing edge will be detachable.

WP6. Wind tunnel testing. Experimental testing in a pressurised wind tunnel will produce comprehensive high-quality data for Reynolds numbers large enough to suppress undesired side effects due to laminar-turbulent transition or laminar separation.

WP7. Data analysis and validation of numerical design approach. The analysis of the computational and experimental data in order to obtain full understanding of the flow development for a swept wing of an SCT with high-lift devices deployed for optimal aerodynamic efficiency will be performed. Moreover the experimental data will be used to validate the complete numerical design methodology.

Expected results

Reducing the aircraft drag during the take-off climb-out and landing approach phases of the flight has important benefits. Less drag at approach conditions will allow lower throttle settings and hence reduced airport noise. Similar benefits will be obtained for the flyover point at climb-out, where better L/D results in higher flight altitudes and lower noise levels on the ground. Further effects of low-speed L/D improvements are reductions of aircraft overall size and fuel burn. The specific results delivered by EPISTLE are:

- Expansion of the database of the 1:80 scale EUROSUP model;
- Analysis of complete 1:80 scale EUROSUP WT data;
- Estimation of capabilities of numerical methods and physical models to predict SCT flows near separation;
- Investigation of innovative concepts for drag reduction;
- Generation of a design parameter sensitivity database;
- Extraction of SCT low-speed high-lift design rules based on this database;
- Aerodynamic designs of SCT high lift systems to be tested;
- A large-scale wind tunnel model;
- Wind tunnel results for the 1:22 scale model;
- Validation of the SCT high-lift system design methodology;
- Estimation of the impact of improved high-lift systems on overall SCT.

Title: European Project for Improvement of Supersonic Transport Low-Speed Efficiency

Acronym: **EPISTLE**

Contract N°: G4RD-CT-1999-00063

Proposal N°: GRD1-1999-10002

Total cost: €2 737 634

EU contribution: €1 406 312

Starting date: 01/03/2000

Duration: 40 months

Coordinator: DEUTSCHES ZENTRUM FÜR LUFT-UND RAUMFAHRT E. V. (DLR)
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Airbus UK Ltd.	UK
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Helsinki University of Technology	FIN
Instituto Nacional de Técnica Aeroespacial (INTA)	E
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Project objectives

The target of EUROLIFT is to reduce the time and cost of the design process for advanced high-lift systems, improve the design accuracy with respect to real flight conditions, and thus reduce the economic risk for the aircraft manufacturer. Beneficial effects, such as improved payload capability, reduced aircraft-noise emission and improved aircraft safety, are expected from an advanced high-lift system.

The overall target is that the economic and technical competitiveness of European aircraft manufacturers should be increased due to the EUROLIFT programme. This can be reached by trying to do the following:

- Improve current understanding of dominant flow phenomena in high lift and their dependence on the Reynolds number.
- Be able to account for these effects early in the design process, with the accuracy necessary for industrial applications and in a realistic timeframe, due to improved numerical and experimental tools.
- Improve current ability to correlate wind tunnel data to flight conditions and reduce the risk of scaling effects by extensive use of the European cryogenic wind tunnel ETW.
- Demonstrate the improvement potential of a new advanced high-lift system up to realistic flight conditions in the cryogenic wind tunnel ETW.

Description of work

To achieveme these objectives a five-step strategy will be adopted:

1. Preparation of an experimental database with detailed flow-field information, providing numerical code developers with a comprehensive set of information with step-by-step increase of geometric and flow complexity.
2. Assessment of state-of-the art European high-lift codes with a clear path to industrial applications through the use of this experimental database.
3. Improvement of numerical tools in fields with clear shortcomings and derivation of common European guidelines for the further improvement and development of high lift tools.
4. Extensive use of the unique possibilities of the European cryogenic Transonic Wind tunnel (ETW) for high Reynolds number testing at low speed/high lift.
5. Application of the improved knowledge for testing of an advanced high-lift system up to flight Reynolds numbers and demonstration of the improvement potential.

Expected results

Expected achievements of EUROLIFT are:

- a complete set of detailed flow field data;
- verification of high-lift high Reynolds number testing in the ETW, and comparison with flight test results;
- additional information on flow physics at very high Reynolds numbers;
- assessment of most of the European state-of-the-art numerical tools, based on validation measurements;
- CFD improvement in areas of shortcomings and new common guidelines for future developments;
- application of testing in ETW for an advanced high-lift system and performance assessment up to flight conditions.

Title: European High-Lift Programme

Acronym: **EUROLIFT**

Contract N°: G4RD-CT1999-00072

Proposal N°: GRD1-1999-10015

Total cost: €7 162 361

EU contribution: €3 581 177

Starting date: 01/01/2000

Duration: 36 months

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Airbus España S.L.	E
Airbus France S.A.S.	F
Alenia Aeronautica S.p.A.	I
Analysis Systems Research High-Tech SA	EL
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Dassault Aviation S.A.	F
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
European Transonic Windtunnel GmbH (ETW)	D
IBK Ingenieurbüro Dr. Kretschmar	D
Instituto Nacional de Técnica Aeroespacial (INTA)	E
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Swedish Defence Research Agency (FOI)	S

A Joint Programme to Improve PIV Performance for Industry and Research

Project objectives

The main scientific and technical objectives of the project are to improve the performances of Particle Image Velocimetry (PIV) for the needs of aircraft design, and to demonstrate the applicability and interest in using this method on a large scale in industrial wind tunnels as follows: enhancement of resolution near the walls; development of capability of the method to assess turbulent flows; improvement of ability of the method to capture vortices accurately; demonstration of the ability of several leading PIV teams to perform joint experiments on large scale in industrial wind tunnels; demonstration of the applicability and interest for using stereoscopic PIV in European industrial wind tunnels; demonstration of the application of PIV to industrial transonic wind tunnels; preparation for the future by performing advanced research on improvements and extensions of PIV. By this means, Europe will have the most advanced experimental tool available for both aircraft design and validation of CFD.

Description of the work

The work programme is divided into five work packages and extends over three years. WP1 is focused on the first two scientific objectives, turbulence and near wall flows. WP2 is concerned with assessment of vortices. WP 3 is the industrial demonstration part of the programme, with three measurement campaigns in large industrial wind tunnels. It will target up-to-date aerodynamic industrial problems. WP4 (the most prospective part of the programme) has been separated into classical and holographic PIV developments. WP5 will take care of management and exploitation.

As well as several expected scientific results on the improvement of PIV capability, the most important project output will be three demonstrations of the method in European industrial research wind tunnels. The test cases selected will enable the provision of data on up-to-date industrial problems such as high-lift configurations and aircraft wakes. These results will be used directly by the industrial partners in the present programme for the validation of numerical simulation. They will also be transferred to other European projects focused on aerodynamics in order to complete the databases they use to develop European know-how on aircraft design. These demonstrations are taking place at regular intervals: 12 months, 15 months and 18 months, and are the major milestones of the programme.

Another important output is the demonstration by EREA PIV teams of their capability to perform large joint PIV experiments in any EUROPEAN industrial wind tunnel.

Expected results

- Demonstration in ONERA S2 wind tunnel of PIV around a transonic aircraft model;
- Demonstration in DASA Bremen wind tunnel on high lift configuration;
- Demonstration in DNW LST wind tunnel of stereo-DPIV on wake vortices of F29;
- International open workshop showing the progress of PIV in Europe.

Title: A Joint Programme to Improve PIV Performance for Industry and Research

Acronym: **EUROPIV 2**

Contract N°: G4RD-CT-2000-00190

Proposal N°: GRD1-1999-10835

Total cost: €2 136 755

EU contribution: €1 190 366

Starting date: 01/04/2000

Duration: 36 months

Coordinator: CNRS
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Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
CNRS – CORIA Rouen	F
Dassault Aviation S.A.	F
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Institut Franco-Allemand de Recherches de Saint-Louis	F
ITAP GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universiteit Delft	NL
Universidad Carlos III de Madrid	E
Université Jean Monnet – Saint-Etienne	F
University of Rome 'La Sapienza'	I

Project objectives

The overall objectives of HELIX are:

- to develop and explore 23 innovative solutions/concepts to overcome the basic problem of providing adequate (in terms of aerodynamic and noise characteristics) cost-effective low-speed performance without recourse to traditional flap systems;
- to down select these concepts and develop those that are most promising;
- to demonstrate and validate the best concept through experiments;
- to perform a detailed marketing study of the best concept to aid its industrial exploitation.

Description of the work

The technical work plan is divided into three main areas and supported by six technical work packages.

Concept refinement

WP1 Preliminary Concept Options: An initial exploration of the engineering feasibility and characteristics of a total of 23 high lift concept alternatives.

WP2 Concept Down Selection: Development of a process and related target application performance model to assess the total product benefits of any of the potential high lift concepts considered within WP1. Exercise the process to classify and identify a set of concepts for further investigation.

Concept maturation

WP3 Improve Concept Maturity: Refine and perform more in-depth, detailed assessments of the most promising concepts identified in WP2.

WP4 Final Concept Assessment: Reassess the merits and risks of the concepts studied in WP3, using the process developed in WP2. Using the outcome of the benefits analysis, select one or two of the candidate concepts for experimental validation within a large-scale wind tunnel test series.

Experimental validation and conclusions

WP5 Experimental Validation: Build and test a wind tunnel model of the chosen experimental validation concept, comparing its predicted performance with that established within the wind tunnel.

WP6 Recommendations and Conclusions: Using the consolidated results, the performance model will be rerun and a final potential benefits statement established. Recommendations will be made on the direction of future R&D, and a strategy for industrial exploitation will be developed.

Expected results

Initial concept assessment process of all 23 novel High Lift concepts.

Establish a multi-disciplinary High Lift assessment process and a performance model, by which novel High-lift systems can be assessed. This will be used to down select the concept catalogue.

Detailed concept assessment of down selected concepts, using high-order CFD and small-scale wind tunnel tests.

Final selection of the concept that will be used for experimental validation.

Manufacture and test of wind tunnel model, using low and high Reynolds number facilities.

Report on recommendation and conclusions plus the industrial exploitation report.

Title: Innovative Aerodynamic High-Lift Concepts

Acronym: **HELIX**

Contract N°: G4RD-CT2001-00516

Proposal N°: GRD1-2000-25205

Total cost: €4 442 944

EU contribution: €2 665 152

Starting date: 01/06/2001

Duration: 36 months

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Alenia Aeronautica S.p.A.	I
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Helsinki University of Technology	FIN
Institute of Aviation Warsawa (IoA)	PL
Instituto Nacional de Técnica Aeroespacial (INTA)	E
Instituto Superior Técnico (IST) Lisboa	P
Israel Aircraft Industries Ltd. (IAI)	IL
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
QinetiQ Ltd.	UK
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Swedish Defence Research Agency (FOI)	S
Vyzkumny a Zkusebni Letecky Ustav, A.S. (VZLU)	CZ

High-Level Modelling of High-Lift Aerodynamics

Project objectives

One of the major challenges for future generations of European transport aircraft is the development of new and unconventional high-lift devices. This will lead to improvements in both cruise efficiency and landing/ take-off performance. The goal of HiAer is to contribute to lowering the industrial cost and risk in design of new high-lift systems by improving the flow modelling state-of-the-art CFD tools. It will also demonstrate predictions of:

- 3D high-lift flows by new advanced turbulence modelling, developed in HiAer,
- wing element-setting effects, from specification of geometry and flow conditions only, through the integration of transition predictions into CFD codes for high-lift flows.

Description of the work

The transition modelling work will be directed into one major route, namely a procedure for coupling between Reynolds-averaged Navier-Stokes (RANS) and transition prediction methods, based on a computed growth rate of instabilities. For the laminar base-flow computations a boundary-layer method will be used for reaching sufficient accuracy. The pressure distribution from the RANS computation will be used as input. The growth rate will be computed using local stability analysis, both by direct stability computations and by the use of parameterised database methods. Non-local stability analysis will also be performed for comparison and assessment of needed approximation levels. The transition point, including a transition region, will be fed back to the RANS computations.

The turbulence modelling work will be focused on explicit algebraic Reynolds stress-modelling (EARSM), a rational approximation of a full differential Reynolds stress model (DRSM) at a two-equation level. Effect of strong streamline curvature will be considered by rational extensions of terms from the DRSM. The choice of a basic 'length-scale determining' equation in EARSM will be studied and optimised by using rational constraints. The near-wall treatment is closely connected to this work, but also the adaptive 'wall-function' kind of boundary conditions will be considered. The basic quasi-linear pressure-strain rate model will be optimised and a reduced functional basis in 3D mean flow will be investigated. Finally, a strongly non-linear, realisable DRSM will be tested and possibilities for including such ideas at the EARSM level will be explored.

At the project midterm, the most promising developments will be selected for further implementation, testing and validation within some of the EUROLIFT industrial hybrid codes. The effort within HiAer during the testing phase may be kept at a minimum level by using the test cases, computational grids, CFD codes, and experiences from EUROLIFT.

Expected results

The major outputs are:

- A complete method for integrating advanced transition prediction methods and advanced turbulence models for CFD predictions of 3D high-lift devices.
- Novel developments and refinements of turbulence and transition models.
- Leading European industrial CFD codes updated and validated.
- Demonstrated CFD predictions of element setting delta effects with advanced turbulence models and integrated transition predictions.

Title: High-Level Modelling of High-Lift Aerodynamics

Acronym: **HiAer**

Contract N°: G4RD-CT2001-00448

Proposal N°: GRD1-2000-25226

Total cost: €2 297 533

EU contribution: €1 385 124

Starting date: 01/03/2001

Duration: 36 months

Coordinator: SWEDISH DEFENCE RESEARCH AGENCY FOI
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Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
EADS Deutschland GmbH	D
Helsinki University of Technology	FIN
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Technische Universität Berlin (TUB)	D

High Reynolds Number Tools and Techniques for Civil Transport Aircraft Design

Project objectives

The purpose of the HiReTT programme is to deliver to the European aerospace industry a capability to predict aircraft flight performance accurately before product launch and to be able to exploit the benefits of designing using the flight Reynolds number during the aircraft product definition. This will be achieved through the development of test techniques with a high Reynolds number to ensure the accurate prediction of aircraft performance in flight conditions and by the assessment of CFD analysis methods to predict aircraft flows at this Reynolds number within the aircraft design process.

Description of the work

The technical work plan is divided into three main areas:

1. The generation of a high-quality database for clean wing flows from conventional wind tunnel sub-scale to flight scale conditions and the qualification of state-of-the-art CFD methods to predict these flows. Tests will be performed in the ETW using an existing full-span cryogenic model over a Reynolds number range, from the value obtained in conventional facilities to the value representative of aircraft flight conditions. These data will be used to understand the Reynolds number effect on wing performance and to assess the ability of CFD methods to predict these effects.
2. An investigation of tunnel wall and model support interference on the flow over the model and the enhancement of existing correction methodologies to account for these effects, particularly in the subsonic Mach number regime 0.85-0.89. Using the same cryogenic model, tests will be performed in two conventional wind tunnel facilities to ascertain the effect of wind tunnel walls on the flow over the model and the measured aerodynamic coefficients. Model support corrections for ETW will be derived, using the standard and enhanced twin sting techniques. This will require the manufacture of a solid wing and new balance components. This data will be analysed to assess the global interference effect on the measured model force data in order to enhance the existing corrections. CFD methods will be applied to investigate the near-field effects of the wall and model support in order to understand in greater detail the nature of this interference.
3. The generation of a high-quality database for the influence of scale effect on control device performance and the qualification of state of the art CFD methods to predict control device characteristics. Three different control devices will be studied – a spoiler, an aileron and a trailing edge flap. Tests will be performed in the ETW using an existing half-span cryogenic model over a Reynolds number range from that which can be obtained in conventional facilities to that which is representative of aircraft flight conditions. This data will be used to understand the effect of Reynolds number on control device performance and to assess the ability of CFD methods to predict these effects.

Expected results

- Full-span tests to ascertain the effect of Reynolds number on aircraft performance with the associated CFD assessment.
- The derivation and enhancement of the ETW wind tunnel wall and sting corrections
- Half-span tests to ascertain the effect of Reynolds number on control device performance, completed by an associated CFD assessment.

The project will produce a comprehensive set of flight scale aerodynamic data on a modern high-speed wing, including the influence of scale on wing performance and control device effectiveness. Recommendations of 'best practice' for the use of CFD in the aircraft design process will be given. The ability to determine aircraft performance ahead of first flight will be enhanced, and a facility will be put in place to exploit the benefits associated with design for flight conditions.

Title: High Reynolds Number Tools and Techniques for Civil Transport Aircraft Design

Acronym: **HiReTT**

Contract N°: G4RD-CT1999-00140

Proposal N°: GRD1-1999-11089

Total cost: €8 172 834

EU contribution: €4 197 317

Starting date: 01/01/2000

Duration: 36 months

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Partners (name, country):

Airbus Deutschland GmbH	D
Airbus France S.A.S.	F
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
European Transonic Windtunnel GmbH (ETW)	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Politechnika Warszawska (Warsaw University of Technology)	PL
QinetiQ Ltd.	UK
Rheinisch-Westfälische Technische Hochschule Aachen (RWTH)	D
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Tilt Rotor Interactional Aerodynamics

Project objectives

The scientific and technical objectives of the TILTAERO project are to develop a common European database capable of covering the main interactional phenomena that arise during different flight conditions of a Tilt Rotor aircraft, and to validate the existing prediction tools through a series of extensive wind tunnel tests on a dedicated 2.5 Mach-scaled model (half-span). The database will address the validation of CFD tools in order to assess their capabilities and will guide research work in the direction of areas where lack of knowledge is evident. This subject is being addressed because the industry needs an investigation of peculiar phenomena that have a significant impact on the Tilt Rotor performances such as rotor power and loads, and wing efficiency. In particular, the following parameters will be verified during the wind tunnel campaign: unsteady pressure distribution on blades; blade loads, rotor forces and torque; steady and unsteady wing pressure distribution; wing loads; off-body flow fields (Particle Image Velocimetry). The data will enable aerodynamic characterisation of the configuration, by evaluating the effects of different component settings.

Description of the work

TILTAERO has been arranged in six work packages:

- WP1 Aerodynamic Prediction Codes: the main objective is to analyse numerically the interactional aerodynamics over the Tilt Rotor. Critical evaluation will be made of the available tools and the validation of the codes.
- WP2 Powered full-span mock-up feasibility studies: the aim is to carry out studies that will prepare the future design of a full-span Tilt Rotor configuration capable of being tested for revealing interactional phenomena arising from non-symmetrical flight path, involving the mutual rotor/rotor interference. The results from the Wind Tunnel tests analysis will produce a complete feedback of the proposed study.
- WP3 Powered half-span mock-up: this work package is aimed at designing and manufacturing a half-span mock-up of a Tilt Rotor configuration suitable for testing in WP4. The model will follow the Mach similarity rules and will reproduce the features of a new concept design (tiltable outer wing), but it will also be suitable for conventional configuration tests (setting outer and inner wings at the same attitude).
- WP4 Wind Tunnel tests of the powered half-span mock-up: this work package will provide the required experimental database for phenomena investigation and code validation. The test series will cover a wide range of flight envelope points, from low-speed helicopter mode to high-speed airplane mode, with the parametric variation of component settings such as wing incidence and tilt angle, nacelle attitude, and rotor operating point. Flow field measurements made at selected conditions, using the PIV system, will help the investigation of phenomena.
- WP5 Wind Tunnel tests analysis: all the data acquired during the test series in WP4 will be critically analysed in order to highlight the characteristics of flow development during the different flight conditions, in particular the critical part of the conversion phase.
- WP6 Project management.

Expected results

The TILTAERO project results may be summarised as:

- to develop a common European database capable of covering the main interactional phenomena on the half-span Tilt Rotor aircraft arising during different flight conditions;
- to pre-design and to assess the feasibility of a full-span model that could be further used during the development phase of the future European Tilt Rotor;
- to direct research work towards aerodynamic where knowledge is lacking;
- to investigate peculiar phenomena that have a significant impact on the Tilt Rotor performances: rotor power and loads, wing efficiency;

- to quantify these advanced configurations more accurately by monitoring the operating characteristics of the individual components.

Title: Tilt Rotor Interactional Aerodynamics

Acronym: **TILTAERO**

Contract N°: G4RD-CT-2001-00477

Proposal N°: GRD1-2000-25610

Total cost: €7 445 139

EU contribution: €3 777 769

Starting date: 01/04/2001

Duration: 48 months

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Debis Systemhaus Solutions for Research GmbH	D
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
DNW German – Dutch Wind Tunnel	NL
Eurocopter S.A.	F
Eurocopter Deutschland GmbH	D
Israel Aircraft Industries Ltd. (IAI)	IL
National Technical University of Athens (NTUA)	EL
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Westland Helicopters Ltd.	UK

1.2. Aircraft Efficiency

Structures and materials application

Advanced Design Concepts and Maintenance by Integrated Risk Evaluation for Aerostructures

Project objectives

The principal objective is to develop a probabilistic foundation for the application of damage-tolerant design of aircraft metallic structures. This innovative approach will take into account investigations of the initial flaw concept, crack growth and residual strength in complex geometries, in order to comply with recent regulations required by the airworthiness authorities. This global risk analysis will include all statistical structural parameters, their variation, and their effects on the design and response properties of aircraft structural components. It will estimate structural safety and reliability on a probabilistic basis while providing information on the confidence that should be given to the behaviour predicted and established in an economic inspection programme. Based on these methodologies, recommendations for the use of the developed models within engineering practice will be prepared.

Description of the work

Initially, the work will consist of the development of new damage tolerance methods validated by a test programme and 'round-robin' exercises. Extensive work will be done on the Initial Flaw concept, crack growth and residual strength modelling, followed by an overall probabilistic methodology including the previous improvements and achievements. Recommendations on applying these methods will be prepared.

The programme partners will implement the following strategy, reflected in six work packages:

WP1 will provide a firm base for the subsequent work in the ADMIRE project. Of primary importance is an initial understanding of the following topics: partner interpretations of the initial flaw concept; methods of estimating residual strength; methods of estimating fatigue crack growth and improved procedures for estimating aircraft reliability.

WP2 will develop new advanced damage tolerance methods and revise and improve current approaches to comply with new regulations. These methods will then form the physical basis for the implementation in risk procedures. They will be validated for selected cases and compared to test results from WP3.

WP3 will provide experimental results for statistical evaluation and validation of predictive calculations.

WP4 will develop a probabilistic foundation for the application of damage-tolerant design of aircraft, taking into account the improvements achieved in WP2. A risk procedure will also be established as a basis for an inspections programme reflecting damage detectability.

WP5 will validate the new damage tolerance methods developed in WP2 and updated the reliability models revised in WP4.

WP6 will prepare recommendations on the new design procedures and their application within engineering practice. Application of the improved design methods will be evaluated and verified using specific examples.

Expected results

The general objective is to develop and provide recommendations on the new design procedures and on their application within engineering practice. Furthermore, the application of the improved design methods will be evaluated and verified using specific theoretical synthetic examples. Recommendations will also be prepared on inclusion of damage tolerance methods within risk procedures, and on the application of the developed risk procedures to aircraft structures designed by damage tolerance methods. The objective of a risk procedure is the computation of the failure probability multiplied by the cost of damage or repair. It provides a precise quantification of the risk level during service depending on inspection results.

Title: Advanced Design Concepts and Maintenance by Integrated Risk Evaluation for Aerostructures

Acronym: **ADMIRE**

Contract N°: G4RD-CT-2000-00396

Proposal N°: GRD1-2000-25069

Total cost: €4 959 395

EU contribution: €2 799 964

Starting date: 01/02/2001

Duration: 42 months

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Airbus UK Ltd.	UK
Construcciones Aeronáuticas S.A.	E
Eurocopter S.A.	F
GIE Aerospatiale Matra CCR	F
Instituto de Engenharia Mecanica	P
Integrated Aerospace Sciences Corporation O.E.	EL
ISTRAM – Institute of Structures and Advanced Materials	EL
Queen Mary and Westfield College	UK
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universitaet Braunschweig	D
Università Degli Studi di Napoli 'Federico II'	I
Università degli Studi di Pisa	I

Age-Formable Panels for Commercial Aircraft

Project objectives

This project has two aims:

1. to reduce aircraft procurement costs, with the goal of bringing production costs down by 35% and development time down by 15% to 30%;
2. to improve aircraft efficiency and performance by reducing fuel consumption by 20%.

This project will develop and validate intelligent, cost-effective and flexible manufacturing methodologies in support of advanced airframe assembly concepts. It will introduce age forming for the manufacture of structural components, which include lower-wing skin, fuselage panels, complex-shaped parts (in particular integrally stiffened panels), larger complex integral subassemblies joined by friction stir-welding prior to forming. The project will also exploit the properties of advanced materials through development of age-formable alloys and tempers. Six partners, including three aircraft manufacturers, from four countries, will be providing all the necessary expertise.

Description of the work

The work plan is divided into five separate work packages (WP): WP1: Process Specification, Project Infrastructure, and Pilot Studies; WP2: Integral structure; WP3: Material development; WP4: Metallurgical principles; WP5: Demonstration and validation. In WP1 the aircraft manufacturers will develop, in collaboration with Pechiney, the initial groundwork for the whole project such as specifications for standard test procedures, material and property requirements for specific target applications, and working industrial standards for the age-forming process. In WP2, typical airframe structures will be identified as target applications by the aircraft manufacturers, and studies will be carried out on the influence of welds, shape and form on the age-forming process. WP3 will develop both the new alloys-tempers and alloys-tempers with improved age-formability to meet the mechanical property requirements. WP4 is focused on understanding the basic metallurgical principles that control the age-forming process. WP5 is dedicated to demonstration and validation. Two different demonstrator parts will be designed and manufactured.

The AGEFORM partnership is composed of six partners from four different countries (Belgium, France, Italy and the UK). Each partner has a different and complementary role. The French coordinator, Pechiney, will develop new age-formable damage-tolerant alloys for structural components in aircraft. The UK partner, UMIST, will develop improved metallurgical understanding of the age-forming process.

The aircraft manufacturers will develop and optimise the age-forming process for each specific target application: AUK (UK) with wing skin structures for large commercial aircraft, Dassault (F) with wing-skin structures of small business aircraft, Sabca (B) with space-vehicle structural elements and fuselage structures of aircraft, Alenia (I) with integral structural elements for fuselage and wing-skin (stiffened by laser beam welded stringers and a friction stir-welded joint, sheet by sheet).

Expected results

The overall project results of the AGEFORM project that could be exploited are:

- the development of new age-formable alloys/tempers for damage-tolerant applications, like lower wing-skin and fuselage panels;
- extension of the age-forming process to complex-shaped parts, especially to integrally stiffened panels obtained by the machining of thick plates;
- further extension of the age-forming process to larger, more complex, integral sub-assemblies joined by friction stir-welding.

Title: Age-Formable Panels for Commercial Aircraft

Acronym: **AGEFORM**

Contract N°: G4RD-CT-2002-00743

Proposal N°: GRD1-2001-40209

Total cost: €3 127 684

EU contribution: €1 759 692

Starting date: 01/05/2002

Duration: 36 months

Coordinator: PECHINEY CENTRE DE RECHERCHES DE VOREPPE
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Partners (name, country):

Airbus UK Ltd.	UK
Alenia Aeronautica S.p.A.	I
Dassault Aviation S.A.	F
Sociéte Anonyme Belge de Constructions Aéronautiques (SABCA)	B
University of Manchester Institute of Science and Technology (UMIST)	UK

Bolted Joints in Composite Aircraft Structures

Project objectives

The goal of BOJCAS is to develop advanced design methods for bolted joints in composite aircraft structures. This is a critical technology for the introduction of composites into the primary structure of large commercial aircraft. Current design methods date from the 1970s/1980s, are largely empirical, and tend to be over-reliant on testing. The methods being developed here will incorporate recent developments in computational mechanics and will be more adaptable to new materials and configurations. They have the potential to reduce testing significantly, and hence the time and cost of development, and also the weight of aircraft, leading to a consequential increase in efficiency. These methods will also help to ensure continued safety.

Description of the work

The project is divided into two strands directed towards two major goals: global design methods for preliminary design, and detailed design methods for the final design of critical joints. Each strand contains major testing and analysis components. At the global level, a series of benchmark structures are being defined and tested that are representative of primary, multi-fastener joint configurations. The structures address key issues such as composite-to-metal joints (for potential composite wings), and the optimisation of bolted repairs for reduced life-cycle costs. Global design techniques are being developed, based on two-dimensional Finite Element methods, and are being benchmarked for validation. At the detailed level, an extensive programme of specimen tests will support the development of detailed design methods based on three-dimensional Finite Element techniques. These account for non-uniform through-thickness stress distributions, which are particularly important for primary joints with thick laminates. Progressive damage models and new fatigue-based failure criteria are also being developed, and automated model-building tools are being created.

Bridging the two strands are methods to automatically couple global and detailed methods. Results from the detailed analyses and tests will also be used to provide correction factors for the global design methods. Tests are being extensively instrumented, and detailed fractographic failure analysis is being performed. The tests and analyses will form the basis for design guidelines on key issues.

Expected results

The main results will be:

- global design methods, for preliminary design of complex, multi-fastener joints;
- detailed design methods for final design of critical joints;
- methods to couple global and detailed design methods;
- design guidelines for composite bolted joints.

Major milestones are: the design of the benchmarks by month 6; the completion of the specimen tests in month 18; completion of benchmark tests and input of detailed results to the global models by month 21; and the start of project assessment by month 30.

Title: Bolted Joints in Composite Aircraft Structures

Acronym: **BOJCAS**

Contract N°: G4RD-CT-1999-00036

Proposal N°: GRD1-1999-10216

Total cost: €2 130 858

EU contribution: €1 251 911

Starting date: 01/02/2000

Duration: 36 months

Coordinator: UNIVERSITY OF LIMERICK
MECHANICAL AND AERONAUTICAL ENGINEERING
PLASSEY TECHNOLOGICAL PARK
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Partners (name, country):

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BAE SYSTEMS (Operations) Ltd.	UK
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
FFA – The Aeronautical Research Institute of Sweden	S
Institute of Structures and Advanced Materials Patras (ISTRAM)	EL
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
QinetiQ Ltd.	UK
Saab AB	S
Stehling – Merazzi Research S.A.	CH
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Development of Lightweight Stiff Static Sheet Structures in Gamma Titanium Aluminide

Project objectives

The main objective is to increase thrust-to-weight ratios and improve fuel efficiencies of gas turbine aero engines to achieve competitive life-cycle costs coupled to minimum emissions. This will benefit society by improving the environment and reducing the cost of flights to enhance European integration. Increased employment levels and prosperity will come from improved competitiveness and maximised manufacturing commonality. Application of gamma titanium aluminides (γ-TiAl) offers the most attractive solution. With a temperature capability of up to 800°C they are non-burning, have up to half the density of currently used steel and nickel alloys, and have specific strengths and stiffness that are competitive with these alloys. The practical objective of this programme is to develop a γ-TiAl component, selected for its property and manufacturing requirements, that will be generic to the range of applications defined by the consortium of engine makers. This will be achieved by gaining a full understanding of the complex microstructural-property relationships during thermo-mechanical processing trials and mechanical testing, supported by microstructural analysis.

Description of the work

TP and the engine-maker partners need static fabricated γ-TiAl structures in the combustor and exhaust systems. The partners have the relevant expertise gained from in-house or national funded programmes which will be integrated to a common 'state-of-the-art' technology within Europe. Strong 'non-aerospace' technical and business links of the members will then permit rapid exploitation and expansion of possible applications.

A structural exhaust cone will be produced in γ-TiAl, using techniques established for other materials: sheet production, forming to shape, joining to adjacent components and consolidation of shape. Through use of the new component, the experience gained from a current 700ºC capability γ-TiAl alloy may be build on to develop an alloy with higher strength and higher temperature 800ºC capability. This will permit early progress to the creep/super-plastic forming and joining stages, while sheet production of the new generation alloy is established. Essential to the forming process are the flow characteristics of the alloy, which will be determined in the laboratory prior to production. Minimal residual tensile stresses are required for joining TiAl, and brazing or diffusion bonding are the most promising techniques.

It is essential to pool existing European knowledge and expertise, since no single organisation has the experience, facilities or the wide business focus necessary to develop γ-TiAl structures. Subsequent engine use will depend on excellent supplier-chain interaction and a critical mass of end-users will be needed to ensure a sustainable market with minimised risks. The partners proposed provide an excellent balance and are well placed to make significant advances under the auspices of this programme.

Expected results

A finished component in high-strength, high-temperature γ-TiAl alloy will demonstrate success in applying characterisation of the material through sheet fabrication and joining. Evaluation of the associated microstructural and mechanical properties will lead to alloy-specific designs of LSIP and partner components.

Exploitation will be through patent protection and material application to aero engines. Cross fertilisation of the technology to non-aerospace sectors will be ensured via the partners' strong automotive links, whilst versatile production capability will guarantee material stock for the supply chain. All information generated will be widely disseminated through the publication of papers, and website and conference presentations consistent with the commercial interests of the partners.

Title: Development of Lightweight Stiff Static Sheet Structures in Gamma Titanium Aluminide

Acronym: **DOLSIG**

Contract N°: G4RD-CT-1999-00061

Proposal N°: GRD1-1999-10259

Total cost: €2 922 526

EU contribution: €1 563 763

Starting date: 01/01/2000

Duration: 48 months

Coordinator: ROLLS-ROYCE plc.
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Partners (name, country):

Industria de Turbo Propulsores S.A.	E
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Plansee AG – High Performance Materials	A
QinetiQ Ltd.	UK
Rolls-Royce Deutschland GmbH	D
Universität Gesamthochschule Siegen	D
Volvo Aero Corporation AB	S

Failure, Performance and Processing Prediction for Enhanced Design with Non-Crimp Fabric Composites

Project objectives

The overall goals are to achieve improved aircraft efficiency and reduce both aircraft development costs and the time to market. These will be met through making a more efficient and confident use of low-cost composites based on resin-infused non-crimp fabrics (NCF) that offer an affordable solution to safety-critical structures. NCFs will be characterised, and predictive models developed, with an emphasis on understanding the relationship between processability and performance. Issues of cost and certification will be addressed, leading to a more confident use of NCF composites in primary aerospace structures.

At present, high certification costs and poor out-of-plane properties are inhibiting the use of high-performance (prepreg) composites in civil aerospace. NCFs offer a solution to these concerns with their lower cost and lack of significant drop in performance. However, there is evidence of a trade-off between processability and performance, which is controlled by the selection of manufacturing variables. The main aim of FALCOM is to identify and understand the effect of manufacturing variables on downstream processability and performance of NCF composites, and also on their product and in-service costs. The savings to the aerospace industry are potentially up to 35% in cost and weight, and 5% in emissions, when compared with aluminium.

Description of the work

The work will be divided in three main blocks: experimental characterisation of processability and performance, analytical and numerical modelling, and the analysis and integration of project results.

Processability will be addressed in terms of NCF characteristics (permeability, compressibility and drapeability) and manufacturing variables (of fabric and composite). In terms of performance, basic mechanical and engineering properties will be measured to define the material design allowables. Both coupon and structural tests will be carried out. The focus will be on obtaining relationships between processing and performance through fractography, leading to physically-based failure criteria. The experimental results will be used to validate the predictive models that will be developed in parallel.

Modelling will be carried out at two levels: meso-scale (local models), to study the impact of processing variables and geometric configurations on processing and performance properties, and macro-scale (global models), to analyse the behaviour of aerospace components. Local models will provide homogenised properties within unit-cell as input to global models. Both the experimental results and the modelling routes will be integrated in a design toolset consisting of a database containing the experimental output of the project, a set of algorithms based on the unit-cell approach and semi-empirical laws, cost analysis tools and a suggested certification methodology for NCF primary structures. The latter will indicate an appropriate set of test and benchmark simulations required for the qualification of a particular NCF-composite configuration. The cost-certification route will permit a more rapid evaluation and incorporation of low-cost composite primary components based on NCF and liquid resin-infusion in the aerospace production chain.

Expected results

The main deliverable will be an integrated design toolset that will collate all the project result, leading to a more efficient certification and cost analysis methodology. Other objectives include: a database of experimental data that will characterise processability and mechanical performance; predictive algorithms which will increase designer confidence; and numerical models that will deliver better simulation capabilities for NCF composites.

Title: Failure, Performance and Processing Prediction for Enhanced Design with Non-Crimp Fabric Composites

Acronym: **FALCOM**

Contract N°: G4RD-CT-2001-00604

Proposal N°: GRD1-2001-40184

Total cost: €7 083 278

EU contribution: €4 101 507

Starting date: 01/12/2001

Duration: 36 months

Coordinator: QINETIQ Ltd.
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Partners (name, country):

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Airbus UK Ltd.	UK
Alenia Aeronautica S.p.A.	I
Associacion de la Investigacion y Cooperacion Industrial de Andalucia	E
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Devold AMT AS	NO
EADS Deutschland GmbH – Military Aircraft	D
Engineering Systems International GmbH	D
ESI Software	F
Fischer Advanced Composite Components AG	A
Imperial College of Science Technology and Medicine London	UK
Luleaa University of Technology	S
Sicomp AB	S
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universität Dresden	D
Tenax Fibers GmbH & Co. KG	D
Universiteit Twente	NL
University of Naples 'Federico II' –Depart.of Materials and Production Engineering	I

Foldable, Adaptive, Steerable, Textile Wing Structure for Heavy Load Delivery

Project objectives

FASTWing will enable European industry to develop new textile wing structures for parachute-like use but with increased aerodynamic efficiency (L/D>5) and low weight. A low-cost high-performance guidance unit is envisaged for this purpose, able to control the parachute flight path, based on GPS navigation. New actuator concepts for control mechanisms will be investigated and developed, and also sensor and navigation techniques.

FASTWing research and technical development work will create new and enhanced design tools for textile wing structures. This will significantly increase understanding of aerodynamics for flexible lightweight wing structures, and will give the European aerospace industry the lead in applying textile structures for lifting surfaces. The major upcoming applications for this technology are aircraft recovery systems for improved survivability in general aviation, and also aerial delivery systems for use in humanitarian aid programmes.

Description of the work

As a first step, application scenarios will be analysed and design requirements drawn up for a system using the technology to be developed. After assessment of these requirements, a concepts trade-off will be outlined, resulting into a preliminary design specification which will act as a baseline for further research.

Software tools for aerodynamics, performance evaluation and flight mechanics, including deployment and dynamic flare analysis, will then be developed and/or adapted for use in the respective parachute technology. These tools will be validated both theoretically and in wind-tunnel and flight tests.

The adapted software tools will be used for technology assessment and development, in accordance with the preliminary design specification. This will be conducted in separate tasks for the wing assembly, platform systems and actuators and the flight control unit. Another task for system design integration will verify compatibility of this new technology in the different fields. In each field, demonstrators will be set up to validate the software tools developed earlier. The result will be scaled up to full-scale technology demonstrators for use in the wind-tunnel and flight tests.

The results will be validated in wind-tunnel and flight tests. Compliance of the demonstrators with the preliminary design specification will be assessed with respect to the scenarios defined. Wind-tunnel and flight test results will be compared with a computer simulation of each scenario.

Expected results

- Development and validation of a new textile wing structure for parachute-like use, equipped with low-cost high-performance guidance unit and new actuator concepts.
- Development and validation of numerical tools for aerodynamic, deployment and dynamic flare analysis of textile structures. Combination of tools in a tool chain for performance evaluation.

Title: Foldable, Adaptive, Steerable, Textile Wing Structure for Heavy Load Delivery

Acronym: **FASTWing**

Contract N°: G4RD-CT-2002-00739

Proposal N°: GRD1-2001-40155

Total cost: €3 749 843

EU contribution: €1 874 921

Starting date: 01/05/2002

Duration: 36 months

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Astrium GmbH, Space Infrastructure	D
CFD Norway A.S.	NO
Cimsa Ingenieria de Sistemas, S.A.	E
Compania Española de Sistemas Aeronauticos, S.A.	E
Deutsches Zentrum für Luft- und Raumfahrttechnik (DLR)	D
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Full-Barrel Composite Fuselage

Project objectives

FUBACOMP is a project to develop and validate manufacturing techniques and structural design concepts for a small integrated composite barrel fuselage structure. The project objectives are to:

1. Reduce component costs through applying Fibre Placement technology, advanced airframe design concepts and advanced manufacturing techniques in an advanced integrated structure.
2. Develop a European capability in Fibre Placement and associated engineering knowledge, and validate the technology through a small-diameter fully-integrated composite fuselage section, which aims to be the first of its kind to be manufactured in Europe.
3. Configure and evaluate unique structural concepts, developing the design rules for fully integrated composite structures taking full advantage of enhanced Fibre Placement technology e.g. full barrel fuselage.
4. Reduce the dependence of EU nations on the US for materials, tools and machinery.

Description of the work

FUBACOMP will proceed with six interdependent work packages, each managed by one of the project partners.

WP1. Project Management. Delivery to time and budget in accordance with project regulations, controlling both the risk within the project and the quality of the outputs delivered.

WP2. Engineering Definition and Initial Assessments. Identification of WP3 configuration and WP4 validation structure concept. Risk analysis and detailed programme definition, fuselage design concept studies and basic test requirements, including coupon testing and inspection system definition.

WP3. Machine Functionality Assessments. Will deliver Fibre Placement design guidelines for validation design through practical evaluation and testing. Develop and validate tooling methods through mandrel manufacture and proving, process modelling, element manufacture, element testing and development of Quality Assurance methods.

WP4. Validation (Proof of Concept) Article Design and Manufacture. Manufacture and assembly of an integrated barrel fuselage component which incorporates complexities such as cockpit area and openings. Delivery of a concept design, evaluation of structural options, mandrel design and manufacture (including additional tooling requirements), detail component manufacture and structural assembly (minimised due to the integrated nature of the design).

WP5. Validation (Proof of Concept Test). Addresses rig design, manufacture and instrumentation prior to structural testing.

WP6. Analysis, Exploitation and Dissemination. Will provide performance assessments of preceding work packages and undertake final reporting, dissemination and exploitation planning. Reporting and exploitation and dissemination will disclose the knowledge acquired within the programme to the public domain through various media, including trade publications, a website, seminars and a video.

Expected results

- Availability of initial feature-based and nominal test data relating to Fibre Placement.
- Validation of capability for Fibre Placement processing, enabling subsequent technology transfer/ integration into EU industry in both aerospace and non-aerospace sector applications.

- Detailed tolerance and repeatability assessment.
- Deposition data supporting a Fibre Placement process capability.
- Laser-imaging techniques for capturing suitable operational data in Fibre Placement and the associated software.

Title: Full-Barrel Composite Fuselage

Acronym: **FUBACOMP**

Contract N°: G4RD-CT-2001-00496

Proposal N°: GRD1-2000-25232

Total cost: €10 277 978

EU contribution: €5 399 559

Starting date: 01/09/2001

Duration: 42 months

Coordinator: BAE SYSTEMS (OPERATIONS) Ltd.
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Partners (name, country):

Advanced Composites Group Ltd.	UK
Alenia Aeronautica S.p.A.	I
Brunel University	UK
Centre d'Essais Aéronautique de Toulouse (CEAT)	F
Dassault Aviation S.A.	F
Eurocopter Deutschland GmbH	D
Eurocopter S.A.	F

Improve and Assess Repair Capability of Aircraft Structures

Project objectives

The primary aim of IARCAS is to improve the efficiency of repair work on aircraft structures in order to obtain a significant reduction of the direct operational and maintenance costs. The basic targets are to reduce the down-time of aircraft by 25%, and also to increase the average number of flight cycles between inspections by more than 20%. To achieve the required levels of maintenance while maintaining the same level of safety, improvements in current repair principles and an extension of allowable damage limits for primary metallic structures are required.

The following specific technical objectives have been identified:

1. to take advantage of forthcoming changes in airworthiness regulations,
2. to develop and implement repair procedures for new technologies and materials,
3. to increase the fatigue life of the repaired structures using new repair techniques, materials, processes,
4. to develop a better approach for the sizing criteria that govern the structural strength of repairs and permissible damage.

Description of the work

The general aim is to reduce the burden of in-service damage on the airlines and to minimize the intervention of the manufacturers in the repair process. The proposed investigations will cover three fields of interest:

1. To develop, improve or adapt calculation approaches and optimisation methods for fatigue, damage tolerance (including crack propagation, Initial Flaw Concept, and residual strength), static and dynamic (bird impact) aspects. These analytical and/or numerical (FEM/BEM) calculation methods will enable the study of both riveted and bonded repairs, dents and/or reworks.
2. To assess the potential benefit on the fatigue life of repairs of specific life-improvement processes (e.g. cold expansion, interference fit fasteners, squeeze dimpling). These processes will be modelled and the benefits will be confirmed by tests on coupons.
3. To design repair principles involving new technologies (e.g. laser-beam welding of stringers) and advanced metallic materials (e.g. Glare), and to investigate new repair procedures (e.g. novel applications of bonded patches, mechanically fastened Glare patches, and a portable device for the Friction Stir Welding repair of cracks).

Improved calculation tools and repair principles will be validated using appropriate test facilities. These will allow the assessment of repair solutions in realistic conditions (curved panels, pressure, combined shear/compression, etc) without performing expensive full-scale tests. New repair techniques/processes/procedures will be compiled. Technical benefits for manufacturers and maintenance/operational benefits for airlines will be assessed by comparison between existing and new/improved repair principles.

To achieve the technical objectives, the project is divided into five work packages, which are split further into subtasks. Work Package Leaders have been assigned to supervise each work package, and they will manage and co-ordinate the technical work of each participant.

Expected results

The key IARCAS milestones are: (a) development of advanced repair techniques and improved repair design principles for new technologies; (b) development of advanced tools to analyse repairs and permissible damage; (c) experimental validation of improved tools and techniques; (d) industrial evaluation of investigated technologies.

The results of the programme will be exploited over different timescales, both short and medium term. The improvement of current repair techniques and assessment of permissible damage will be exploited in the short-term. Other technologies (e.g. bonded patches, friction stir-welding, welded structures) are more likely to see exploitation in the medium term.

Title: Improve and Assess Repair Capability of Aircraft Structures

Acronym: **IARCAS**

Contract N°: G4RD-CT-2000-00401

Proposal N°: GRD1-2000-25182

Total cost: €7 792 695

EU contribution: €4 061 366

Starting date: 01/07/2001

Duration: 48 months

Coordinator: AIRBUS FRANCE S.A.S.
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Partners (name, country):

Airbus Deutschland GmbH	D
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Airbus UK Ltd.	UK
Alenia Aeronautica S.p.A.	I
Centre d'Essais Aéronautique de Toulouse (CEAT)	F
EADS CCR	F
Integrated Aerospace Sciences Corporation O.E.	EL
ISTRAM – Institute of Structures and Advanced Materials	EL
QinetiQ Ltd.	UK
SA Belge de Constructions Aéronautiques (SABCA)	B
Sonaca S.A.	B
Technische Universiteit Delft	NL
Trinity College Dublin	IRL

Investigation of Damage-Tolerance Behaviour of Aluminium Alloys

Project objectives

Modern transport aircraft are designed for high efficiency and long service lives, resulting in heavily loaded structures. This application requires damage-tolerant materials with low rates of crack propagation. Recently, improved alloys have been developed, which also enables new joining technologies like laser-beam welding. Use of these materials reveals a gap in knowledge about the relationship between microstructure and crack growth that exists for the well-known alloy 2024. This missing knowledge will be gained by comprehensive characterisation of materials to identify the complex fatigue- and fracture-relevant microstructure/crack-growth relationship. Thorough testing will be done on fatigue-crack propagation and complementary examinations made of crack-surface morphology, plastic zone and crack-closure effects. Based on the knowledge thus gained, prediction models will be established and verified. Recommendations for the optimisation of microstructures will be derived. This specific information will allow optimised application of the recently developed damage-tolerant materials and laser beam welding technology, with consequent improvements to aircraft efficiency.

Description of the work

The IDA project focuses on the recently developed materials 2024 High Purity, 6056 and 7449 and also on Laser-Beam-Welded joints, in order to fill the knowledge gap concerning crack-growth mechanisms. Missing information about the selected alloys will be identified. Probable mechanisms for fatigue-crack propagation will be described and priorities will be set for further investigation. The reference material will be alloy 2024, which has been used in the aircraft industry for decades. The IDA-consortium will provide an extensive database from its own experience, and also detailed knowledge on crack-growth mechanisms. To categorise the selected alloys and the laser beam welded specimens, specific mechanical examinations (tensile, cyclic stress-strain-curve and fracture toughness testing) and microstructural investigations (quantitative analysis of grain structure, constituents and dispersoids as well as texture analysis) will be conducted. Thorough testing will be performed of Fatigue-Crack Propagation under well-defined conditions (R-Ratio, overloads, frequency), based on agreed procedures (specified geometries, relevant spectra, etc.). Complementary examination will focus on crack-surface morphology, plastic zone and crack-closure effects according to different test parameters. This comprehensive investigation will lead to the identification of the relevant microstructural features responsible for the specific crack-growth mechanisms of the different materials.

Furthermore, approaches will be derived for the prediction of crack-propagation behaviour based on the microstructure-crack growth relationships that have been identified. Reasonable models will be developed, providing the basis for establishment of advanced numerical simulation tools for crack propagation under variable amplitudes (spectra), low-cycle fatigue and static loading. The special situation for welding (alloy 6056) will be considered as far as possible. Subsequently, the prediction models will be verified and recommendations for optimised alloy microstructures in respect to crack propagation will be made, enabling the development of improved damage-tolerant aircraft structures.

Expected results

- Establishment of an extensive microstructural database on advanced aluminium alloys and on their relationships with crack-growth performance.
- Identification of major differences in governing the crack-growth micro-mechanism compared with the conventional 2024 alloy.
- Development of validated predictive FEM models and their general applicability to the different alloys and laser welds.

- Specific recommendations for further optimisation of European damage-tolerant aluminium alloys.
- Use of the data and knowledge collected for the design of improved damage-tolerant structures.

Title: Investigation of Damage-Tolerance Behaviour of Aluminium Alloys

Acronym: **IDA**

Contract N°: G4RD-CT-2001-00629

Proposal N°: GRD1-2001-40120

Total cost: €3 699 851

EU contribution: €2 049 999

Starting date: 01/01/2002

Duration: 36 months

Coordinator: AIRBUS DEUTSCHLAND GmbH
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Deutsches Zentrum für Luft-und Raumfahn e.V. (DLR)	D
EADS Deutschland GmbH	D
EADS France CCR	F
GKSS Forschungszentrum Geesthacht GmbH	D
Institute of Structures and Advanced Materials Patras (ISTRAM)	EL
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Pechiney CRV	F
University of Limerick	IRL

Improved NDE Concepts for Innovative Aircraft Structures and Efficient Operational Maintenance

Project objectives

Any improvements in environmental friendliness, cost efficiency, new materials or structures in aircraft must be implemented in future aircraft. For a successful introduction of new structural technologies to the aeronautic industry, guarantees must be given of excellent quality control and the recommended practices for operational maintenance need to be outstanding. New optical and thermo-optical test methods can ensure the necessary quality rise for inspections, but the broad range of different materials, geometries, and structures requires a great deal of knowledge to adapt inspection methods to the full range of aeronautic inspection demands. In addition, improved concepts for contact methods (like eddy current testing (ET) and ultrasonic testing (UT)) may drastically increase their potential. This project pays particular attention to LaserUltrasonics, a method which links traditional contact and new non-contact test methods, and also addresses methods such as pulse thermography, shearography, digital-X-ray and new approaches for UT and ET.

Description of the work

The first – Laser Ultrasonic Testing (LUT) – work package will be divided into three tasks:
1. establishing a platform as a basis for technology know-how in Europe;
2. optimisation of the technique subsystems (higher efficiency of laser generation to cope with thick composite structures, higher sensitivity of detector, increased speed); these developments will be validated using the platform from (1);
3. industrial applications will be developed and tested.

The second work package addresses improvements of non-contact NDT techniques (Thermography, Shearography, Digital Radiography) and contact techniques like ultrasonic resonance spectroscopy (URS) and ET:
- new heat loading methods for thermography,
- adaptation of shearography to rough industrial environments and daylight conditions,
- film less digital radiography system,
- sophisticated innovative sensor and array probe concepts for ET,
- new signal processing methods combined with URS.
- merging data from several NDT methods will be addressed in a dedicated task, since quality control never relies on one method only.

The consortium consists of the major European airframe manufacturers supported by research establishments and industrial integrators. This provides the balance between end users, academics and system integrators, with a major emphasis being placed on integration and therefore final exploitation.

Expected results

Key elements available at the end of the project will be:
- a laser ultrasonic platform with improved subsystems; industrialised later by one partne, it will become available on the European market for future aeronautical programmes.
- other methods developed will also result in demonstration platforms to validate their added potential.

The platforms will be ready for industrialisation too. Guidelines will be developed and written down for the use of the new capabilities from the improved methods.

Title: Improved NDE Concepts for Innovative Aircraft Structures and Efficient Operational Maintenance

Acronym: **INCA**

Contract N°: G4RD-CT-2001-0050

Proposal N°: GRD1-2000-25309

Total cost: €7 748 202

EU contribution: €3 742 420

Starting date: 01/09/2001

Duration: 48 months

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Alenia Aeronautica S.p.A.	I
BAE SYSTEMS (Operations) Ltd.	UK
Centre National de la Recherche Scientifique (CNRS.LCFIO.NLP)	F
CESI – Centro Elettrotecnico Sperimentale Italiano 'Giacinto Motta' SpA	I
CSM Materialteknik AB	S
Dassault Aviation S.A.	F
EADS Deutschland GmbH	D
General Electric Research & Development	US
GIE EADS CCR	F
Groupe d'Interêt Economique NDT Expert	F
Institut d'Optique Théorique et Appliquée	F
MY Optical Systems GmbH	D
National Research Council of Canada	CA
NUKEM Nutronik GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
TECNATOM S.A.	E
Universitaet Stuttgart	D
University of Central Lancashire	UK
Uppsala University	S

Light-Weight Low-Cost Surface Protection for Advanced Aircraft Structures

Project objectives

LiSA supports the EU policy which states that "the European aerospace industry should be a credible counterweight to the very real threat of a US monopoly in the aerospace business". Its goal is to develop a novel testing methodology and coating system for aircraft surface protection that:

1. simplifies the manufacture of advanced aircraft structures to reduce aircraft production costs,
2. uses light-weight coatings to reduce fuel consumption and direct operating costs for aircraft,
3. uses an environment-friendly technology to reduce toxic waste, lower production and maintenance costs, and improve health and working conditions, and
4. provides a major step towards a new Europe-wide validation process (European standard).

It will enable an assembly optimisation of advanced aircraft structures, and will stimulate further developments in European automotive, food and architectural sectors. LiSA will contribute to the envisaged annual 5% growth of the European aircraft industry and its supply chain.

Description of the work

LiSA will build on the European projects ROPCAS, DOCT, and MaSSPS. Their goal was a comprehensive chromate-free materials system, in which, however, success was only achieved in a few minor cases. LiSA tackles several current problems that were not covered by ROPCAS, DOCT and MaSSPS. First, the current tests for aircraft surface protection were introduced entirely on the basis of chromate-based corrosion experience. Thus, they are not *a priori* suitable for non-chromate protection systems, although they have been used for systems such as those in ROPCAS, DOCT, and MaSSPS. Second, the current multi-layer protection system has omitted a major potential for optimisation of weight reduction (single layer) and of steps in manufacturing assembly lines (in general, but especially for large advanced aircraft structures).

LiSA will determine the atomistic anti-corrosion mechanisms of chromate-free protection systems It will also develop a test methodology based on in-service and laboratory experience that will consider the different mechanisms of chromate and chromate-free protection systems and provide trustworthy test results within a period of six weeks (suitability test), and also ultimate results for validation within a period of six months. LiSA will also research and develop light-weight, chromate-free paint systems and also develop single-layer surface protection systems that will be both lightweight (35% reduction) and able to completely applied after assembly.

The work is divided into nine work packages. WP1: assessment of in-service corrosion; WP2: report on real-life in-service test; WP3: in-depth investigation of basic anti-corrosion mechanisms, six-week suitability and six-month validation test; WP4: necessary adhesive strength and passive corrosion retardation; WP5: corresponding novel pretreatment; WP6: development and understanding of low-weight paints; WP7: novel surface protection, to be applied after structural completion; WP8: demonstration of new tests and protection system; and WP9: exploitation and project management.

Expected results

Mid-milestones: (1) Assessment of real-life in-service corrosion behaviour; (2) verification of quantum-mechanical-model model; (3) measurement of critical parameters of anodic interfaces; (4) verification whether new pretreatments satisfy critical parameters; (4) demonstration of weight reduction of paint systems; (5) agreement on technologies for further development.

Deliverables: (1) six-weeks suitability and six-months validation test; (2) low-weight pretreatment and paint systems; (3) single-layer protection systems; (4) demonstration of technical feasibility.

Title: Light-Weight Low-Cost Surface Protection for Advanced Aircraft Structures

Acronym: **LiSA**

Contract N°: G4RD-CT-2002-00691

Proposal N°: GRD1-2001-40121

Total cost: €5 636 863

EU contribution: €3 000 000

Starting date: 01/05/2002

Duration: 48 months

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Consejo Superior de Investigaciones Cientificas	E
Fraunhofer Institut für Fertigungstechnik und Angewandte Materialforschung	D
Pechiney CRV	F
Sonaca S.A.	B
University of Manchester Institute of Science and Technology (UMIST)	UK

Improved Postbuckling Simulation for Design of Fibre Composite Stiffened Fuselage Structures

Project objectives

In order to reduce the weight of aircraft substantially without prejudice to costs and safety, it is indispensable to make increased use of advanced fibre composites for primary structures and for the exploitation of all structural reserves. Current demand in this respect from industry is for fibre composite fuselage structures to be designed for postbuckling under ultimate load. To do this cost-effectively, improved simulation tools and new design procedures for stiffened panels are needed. However, the calculations are still extremely time-consuming. The project will develop fast and reliable procedures ready for industrial application, which will cut down the time for design and analysis by an order of magnitude, and thus make a vital contribution to current engineering practice. This will achieve substantial weight reduction, increase lifetime, reduce response-to-market time and create jobs in industry. Fuel consumption and air pollution will also be decreased, while raw materials and energy resources of fossil energy will be conserved.

Description of the work

The technical work is divided into six work packages.

WP1. Benchmarking for postbuckling and collapse analysis. Knowledge of the partners will be collected and compared, and the actual deficiencies in existing software identified.

WP2. Design of stiffened fibre composite verification structures. Material properties will be characterised; test structures will be designed for research needs in order to overcome these deficiencies.

WP3. Manufacture, characterisation and testing of verification structures. The data base for evaluation of improved simulation procedures will be extended by testing the verification structures.

WP4. Development of improved simulation procedures and preliminary design guidelines. Development of improved simulation procedures and their evaluation will be based on exploitation of the extended database. Preliminary design guidelines will be derived via parametric studies using the improved procedures.

WP5. Design, manufacture and testing of fibre composite industrial panels. These will be made according to industrial application needs.

WP6. Development of final design guidelines for stiffened fibre composite curved panels. The improved simulation procedures and preliminary design guidelines will be reviewed and again improved against the test results on the industrial panels. Based on this, final design guidelines will be derived.

The industrial partners will be contributing their experience of design and manufacture of real shells. The research partners will bring in complementary knowledge mainly on testing and development of simulation tools. When the results have been checked by industry, the final design guidelines will be defined in consultation. In this project, practical and theoretical disciplines are closely combined, and experience from four Member States is exchanged and exploited together. The European cohesion benefits through inclusion of three partners from associated states (Israel and Latvia).

Expected results

The results comprise substantially increased experimental databases on material properties and – in particular – on postbuckling behaviour of light-weight fibre composite structures, as well as fast and reliable software and design guidelines. Reports, conference presentations, publications, lectures and workshops will be used to disseminate results. Industrial exploitation will be assured through close interaction between industry and research, setting up a new user group with SMEs, and continual contact with certification authorities.

Title: Improved Postbuckling Simulation for Design of Fibre Composite Stiffened Fuselage Structures

Acronym: **POSICOSS**

Contract N°: G4RD-CT-1999-00103

Proposal N°: GRD1-1999-10082

Total cost: €4 867 348

EU contribution: €3 509 021

Starting date: 01/01/2000

Duration: 48 months

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Politecnico di Milano	I
Rheinisch-Westfälische Technische Hochschule Aachen	D
Riga Technical University	LV
Technion – Israel Institute of Technology	IL

1.2. Aircraft Efficiency

Propulsion

Advanced 3D Compressor Blade Design

Project objectives

To strengthen the competitiveness of the European aeroengine industry, with due concern for environment and safety, gas turbine engines must provide better performance at reduced weight. The objective for the compressor is achievement of a higher pressure ratio realised with fewer blade rows, which implies higher aerodynamic loadings. In parallel, the costs of development and time-to-market must be reduced through improved engineering methods. Progress in viscous and unsteady computational methods will allow 3D blade features to be modelled in detail, including tip clearance, end-wall and blade row interactions.

The scope of this proposal covers the systematic exploitation of these aspects of compressor aerodynamics to improve performance, and also validation of the process by which this is achieved. Innovative representative compressor stages are to be tested in cascade, low-speed rigs, and ultimately in a high-speed three-stage facility. These methods will be applicable to future compressors for Technology Platforms.

Description of the work

Four industrial partners will provide most of the financial and human resource required to meet the design and analytical challenge. Four universities with international reputations will contribute advanced optimisation technologies and experimental facilities. The project will exploit advanced 3D viscous steady and unsteady methods for multistage axial compressor design. Building on the partners' collective experience, these tools will be used to maximise performance improvement through the control of internal flow structures, particularly in tip and end wall regions and blade row interactions. The design-by-computation approach will be supported by an experimental programme, resulting in systematic verification of design rules and analytical accuracy for each element of the design process. The project has been structured as six work packages, each with a core theme and an output whose contribution to the whole programme will be both recognisable and significant.

1. **Pre-study and generic 3D design approach** Task 1.1 Through-flow modelling; Task 1.2 Identification of improved blade design approach by numerical modelling.
2. **Annulus boundary layer control using hub contouring** Task 2.1 Selection and optimisation of wall geometry; Task 2.2 Cascade tests.
3. **End wall flow control using blade tip tailoring** Task 3.1 Throughflow and 3D blade design by numerical modelling; Task 3.2 Single-stage and cascade tests.
4. **Advanced multi-stage design investigation** Task 4.1 Test datum compressor; Task 4.2 Benchmarking and integration of generic concepts; Task 4.3 Throughflow and 3D blade design; Task 4.4 High-speed testing of advanced HSRC.
5. **Synthesis of results** Task 5.1 Evaluation of WPs 1 to 4 and validation of numerical design tools; Task 5.2 Definition of multi-stage design procedures and design rules for highly loaded compressor blades.
6. **Project management** Task 6.1 Project coordination; Task 6.2 Leadership of WPs.

Expected results

- 2% increase in efficiency through using advanced 3D compressor blading;
- validation of advanced numerical aero-thermodynamic methods;
- reduction in design cycle time and costs of 25%.

Title: Advanced 3D Compressor Blade Design

Acronym: **ADCOMB**

Contract N°: G4RD-CT-2000-00073

Proposal N°: GRD1-1999-10384

Total cost: €4 380 119

EU contribution: €2 682 010

Starting date: 01/02/2000

Duration: 48 months

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Cranfield University	UK
MTU Aero Engines GmbH	D
Rolls-Royce Deutschland GmbH	D
Technische Universität Braunschweig	D
Universität der Bundeswehr München	D
Universität Gesamthochschule Kassel	D
Volvo Aero Corporation AB	S

Investigation in Advanced High Temperature Turbine Seals

Project objectives

The development of high temperature advanced turbine abradables and seals will have a major impact on the feasibility of future aero engines with improved efficiency and reduced fuel consumption, exhaust gas emissions and life cycle costs.

Abradables and seals for turbine applications with a higher temperature capability, extended life time and reliability than the state of the art technology will reduce cooling air consumption, extend the inspection cycles interval and reduce the repair costs of the aero engine.

The production of advanced technical products and the ability to compete in the global market will be improved for the European aero engine and the basic materials supply industry.

Air transport will become less expensive, environmentally friendly, more reliable as well as safe.

Description of the work

Abradables and seals for turbine applications with a temperature capability up to 1200°C and extended life time and reliability up to 36.000 hours are designed, manufactured on a laboratory scale and tested according to the requirements of technology platform vehicles. Different high temperature materials and structures combinations like filled honeycombs, foams, hollow sphere structures with available potential candidate materials, like PM 2000, MCrAlY's, nickel aluminides and ceramics are evaluated. Trial components and prototypes of the most capable material/structure combinations are tested in a real aero engine environment Available test vehicles are the technology platform engines or other relevant engines of the gas turbine manufacturers involved in the program.

The successful project completion will be achieved by an international highly interdisciplinary consortium of aero engine manufacturers, basic material suppliers, research institutions and small and medium enterprises.

The most experienced project partner will co-ordinate the following work packages necessary for the success of the project:

- Design of optimised and improved abradables and seals for advanced turbine applications;
- Manufacturing of specimens, trial components and prototypes representing incremental and radical innovative material / structure combinations for turbine seals;
- Investigation of relevant material/structure properties, e.g. resistance to wear, oxidation and fatigue
- Testing of trial components and prototypes in components test rigs and gas turbine rigs,
- Project management and exploitation of project results

Expected results

- Design concepts developed
- Test components with incremental improvements available
- Test components with radical improvements available
- Lifetime prediction concept developed for turbine seals

The expected results are: concepts for design, material properties, rig test and engine test results, lifing concept for advanced turbine seals are developed and validated in order to apply the most innovative material.

Title: Investigation in Advanced High Temperature Turbine Seals

Acronym: **ADSEALS**

Contract N°: G4RD-CT-2000-00185

Proposal N°: GRD1-1999-10608

Total cost: €2 468 647

EU contribution: €1 324 299

Starting date: 01/05/2000

Duration: 48 months

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Ecole Centrale de Lyon	F
Fiat Avio S.p.A.	I
Neomet Ltd.	UK
Rolls-Royce Deutschland GmbH	D
Rolls-Royce plc.	UK

Advanced Exhaust Gas Recuperator Technology for Aero Engine Applications

Project objectives

The main objective of this proposal is to achieve a fuel economy of 20% within ten years, together with a corresponding reduction of greenhouse gases by the same factor. The development of this new engine cycle design will enhance the competitiveness of European aero engine companies. A substantial increase in market share is expected, thereby creating new high-skilled jobs. The RTD objectives considered in this project are:

- to support the development of an efficient and environmentally friendly intercooled recuperative engine by providing a realistic exhaust gas-recuperator (hex) design;
- to develop and improve the technology for obtaining the most favourable hex design in terms of efficiency, operational life, and savings in weight and costs;
- to enable a realistic assessment of the Intercooled Recuperative Aero engine (IRA) emission characteristics, through determination of the hex efficiency and pressure losses on the exhaust gas–air sides, including pipes and ducts;
- to determine the optimum process for manufacturing the hex matrix;
- to obtain the hex matrix design for the EEFAE-LSIP and determine its optimum arrangement in the exhaust duct;
- to supply the technology to manufacture the hex for the EEFAE-LSIP.

Description of the work

Work package 1 deals with all design aspects and is subdivided into four tasks. The performance task will define the design conditions and dimensions of the heat exchanger. Results from other work packages will be continuously supplied in order to improve the quality of the performance assessment of the IRA-engine. The design task includes the provision of construction drawings for the heat exchanger, including all piping and support structure for the IRA engine. In the remaining two tasks, thermal and structural analysis will be carried out. Along with the engine producers MTU and ALSTOM, the manufactures BINDER and SERCK will be co-operating in this work package, with MTU as coordinator.

Work package 2 is concerned with the flow investigations needed to determine the pressure drop and flow distribution on the hot gas side, on the air side and in the connection piping and hex manifold. The investigation will be carried out both numerically and experimentally. The results will help improve the hex arrangement in the IRA engine and also in EEFAE-LSIP and the alternative gas turbines. The work package will be directed by the Aristotle University of Thessalonica and will include co-operation from the industrial partners MTU and ALSTOM.

Work package 3 will develop the manufacturing methods for the individual components of the heat exchanger. The complete manufacturing process will be derived and cost-evaluated. The technology to manufacture the hex casing of the EEFAE-LSIP will also be applied. This work package will be undertaken by the firms SERCK and BINDER, with SERCK providing co-ordination. At the end of the project, a trade-off study will be carried out to consider the interdependence between hex efficiency, pressure losses, savings in weight and costs, in order to derive the optimum design of the hex in the engine.

The consortium consists of four industrial partners, two of them engaged in engine design and manufacture, the other two are oriented toward manufacturing methods of heat exchangers. These industrial partners will be complemented by two institutes from the University of Thessalonica, responsible for flow investigations.

Expected results

- matrix design to initiate the flow and manufacturing investigations;
- CFD porosity model to determine the optimum arrangement of the hex;
- final hex design to be used in the IRA-engine.

The results will be exploited additionally to provide the hex design for the EEFAE-LSIP and to investigate the introduction of an exhaust gas recuperator for alternative gas turbine applications.

Title: Advanced Exhaust Gas Recuperator Technology for Aero Engine Applications

Acronym: **AEROHEX**

Contract N°: G4RD-CT-1999-00069

Proposal N°: GRD1-1999-10602

Total cost: €4 393 289

EU contribution: €2 641 641

Starting date: 01/02/2000

Duration: 48 months

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Aristotle University of Thessaloniki	EL
Dunlop Aerospace Ltd.	UK
Karl Binder GmbH	D
MTU Aero Engines GmbH	D

Aerothermal Investigation of Turbine Endwalls and Blades

Project objectives

Today's aerothermodynamic design tools and cooling technologies in gas turbine and aero engine industry comprise a state-of-the-art capability for predicting 2D and 3D flows in turbine components. However, they still suffer from appropriate accuracy and gaps in knowledge as far as complex heat transfer problems in 3D parts of turbines (e.g. endwalls), or complex, separated flows and cooling concepts for these areas, are concerned. To enhance – or at least maintain – its competitive position as a global player, and to meet the ever more stringent emission limits, the European aero engine industry must make the following achievements in the turbine domain as a matter of urgency: increased capability of turbines for higher heat load on turbine endwalls; increased stage-loading; acquisition of new understanding of high-speed low-pressure turbines; reductions in engineering time-scales and cost. The RTD project aims to put forward an integrated package of technology and design tools for the advanced, aerothermally highly loaded design of turbine endwalls and blades.

Description of the work

The technical project structure of AITEB is orientated towards problem solving. To tackle the main problems of aerothermal highly loaded turbines the work comprises seven work packages (WP). These WPs are the logical answers to the abovementioned competitive and challenging demands in the turbine domain. The first five WPs comprise a comprehensive, experimental, analytical and numerical approach for close engine-oriented technology problems, such as:

- **Heat transfer/Cooling in separated flow areas:** Experimental and numerical investigation of heat transfer and film cooling in separated flow for highly loaded blades, including advanced trailing-edge cooling (WP1 and WP2).
- **Heat transfer/Improved cooling of turbine endwalls:** Experimental and numerical work on heat transfer and cooling of turbine endwalls (WP3, WP4 and WP5). These WPs cover new technologies for passive shroud cooling and unshrouded blade tip groove cooling. All experimental data will be analysed for aerothermal correlations and design rules that will be implemented by the industrial partners in advanced design tools.
- **Optimised CFD-process:** All CFD-work in the project will be co-ordinated in WP6. Furthermore, as an innovation, WP6 aims to validate and optimise the whole CFD-process (risk assessment of drawing-grid modelling after processing) in order to derive best practice for engineers to follow when using CFD as a risk-reduction and time-effective tool.

All management and co-ordination work (comprised in WP7) is focused on a straightforward technical and financial management. Here, the commercialisation manager will ensure the rapid assimilation of the results into the industrial partners' future competitive products, and look for opportunities to enhance the technology needed in targeted platforms (e.g. EEFAE), together with a rapid dissemination of papers, workshop results and reports made by all participants.

Expected results

The competitiveness of the European gas turbine industry will be enhanced, due to: increased turbine peak cycle temperature; improved S.F.C.; increased component life; reduced coolant flows. Aerothermodynamic correlations, improved cooling technologies and a validated and improved CFD-process will also be delivered.

Title: Aerothermal Investigation of Turbine Endwalls and Blades

Acronym: **AITEB**

Contract N°: G4RD-CT-1999-00055

Proposal N°: GRD1-1999-10241

Total cost: €5 538 941

EU contribution: €3 695 514

Starting date: 01/02/2000

Duration: 48 months

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Fiat Avio S.p.A.	I
Industria de Turbo Propulsores S.A.	E
Institut von Karman de Dynamique des Fluides	B
MTU Aero Engines GmbH	D
Polska Akademia Nauk	PL
SNECMA Moteurs	F
Technische Universität Berlin (TUB)	D
Turbomeca S.A.	F
Universität der Bundeswehr München	D
Universität Karlsruhe (ITS)	D
University of Cambridge	UK
University of Florence	I
Volvo Aero Corporation AB	S

Project objectives

The technical objectives are to develop innovative transmission components and advanced methods for aero-engine oil systems design. The development of entirely new technologies includes ceramic bearings, dual alloy shafts and variable speed lubrication oil pumps, together with the required design rules. The expected results of this project will also improve the understanding of the potential failure mechanisms required to safely exploit such new technology as quickly as possible.

Additionally, methods to predict the complex behaviour of existing systems such as oil churning and two-phase flow in bearing chambers, vent systems and air/oil separators will be provided which will reduce the design lead time and development costs by right-first-time design.

It is anticipated that aero-engine and aircraft efficiency, reliability and safety can be increased, whilst reducing the impact on the environment by reduced emissions and oil consumption. A strategic contribution to European technological progress is expected as well as societal improvements through sustained employment, better qualified jobs and economic growth.

Description of the work

The project comprises six technical work packages, with the following content:

1) Validation of ceramic element bearings that offer higher load and speed capability than today's bearings using steel rolling elements. The work will include various tests of gearboxes and main shafts under extreme conditions as well as a wear sensing study.
2) Improvement of methods for detailed prediction of heat transfer and oil flow in bearing chambers, including rig tests on two-phase flows and CFD model development and predictions.
3) Design method to avoid oil firing near bearing chamber seals in adverse conditions, comprising auto-ignition temperature measurements, characterisation of two-phase flow and CFD predictions.
4) Vent system and air/oil separator study for minimised oil mist generation including rig tests to assess condensation and atomisation phenomena, systematic rig tests on oil mist generation with application of laser optical measurement technique, air/oil separator design and validation tests.
5) Development of an electrically-driven variable speed lubrication pump for more precise oil supply in accordance with the exact requirements of the engine, including the development of prototypes, oil system and control law optimisation and reliability study to assess certification needs.
6) Investigation of dual alloy engine main shafts and torsional buckling comprising rig tests of various specimens and Finite Element modelling.

Finally, in Work Package 7, all management work is focused on effective project management, trouble-shooting and continuous exploitation of the results.

This comprehensive investigation of new transmissions technology includes experimental and numerical work at established centres of excellence in five European countries. The consortium involves nine industrial partners, i.e. leading European aircraft engine manufacturers, many component manufacture companies including one SME, and four universities in Europe. The universities bring world-class expertise in laser optics, sensors, modelling of air/oil flows, Finite Element analysis and rig test capability.

Expected results

Specific exploitable results of this project are as follows:

- Validated ceramic element (hybrid) bearings
- Improved methods for detailed and fast prediction of heat transfer and oil flow in bearing chambers

- Auto-ignition temperatures at high pressure and design methods to avoid oil firing in adverse conditions
- Vent system and air/oil separator with minimised oil mist generation for cleaner engines
- Reliable variable-speed lubrication pump within an optimised oil system
- Engine main shafts with reduced weight and improved dynamics and life.

Title: Advanced Transmission and Oil System Concepts

Acronym: **ATOS**

Contract N°: G4RD-CT-2000-00391

Proposal N°: GRD1-2000-25077

Total cost: €5 455 128

EU contribution: €3 496 484

Starting date: 01/02/2001

Duration: 36 months

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FAG Aircraft/Super Precision Bearings GmbH	D
Fiat Avio S.p.A.	I
Hispano-Suiza S.A.	F
MTU Motoren- und Turbinen-Union München GmbH	D
Rolls-Royce plc.	UK
Technische Hochschule Karlsruhe	D
Techspace Aero S.A.	B
Université de Liège	B
University of Nottingham	UK
University of Southampton	UK

Advanced Welding Technologies for Repair and Salvage of High-Value Engine Components on Nickel and Titanium-Based Alloys

Project objectives

Aero engines today and (more important) future aero engines will consist of engine parts of high-value materials, for example, BLISKs (blade-integrated disks) with 3D blading in the High Pressure Compressor (HPC) and single-crystal High-Pressure Turbine (HPT) blades. The goal of this project is to develop and validate advanced repair and salvage processes on BLISKs and HPT blades. The process for repair on BLISKs and single crystal HPT blades will be suited for industrial use and semi-automatically developed, including both the complete manufacturing sequence and inspection technology development and process control. Mock-ups and real parts, such as HPT blades and one BLISK stage (of the 5th Framework Programme's ANTLE project) will be repaired. Acceptance by airlines of using BLISKs will be increased due to the availability of economical repair processes. This allows aero engine manufacturers to make and an increased use of BLISKs in future civil engines and will lead to improved engine performance (less weight, lower specific fuel consumption, less pollution).

Description of the work

The RTD project, structured into ten work packages, aims to develop economical high-precision repair and salvage technologies using LC (Laser Cladding) and CDW (Capacity discharge welding) on BLISKs and HPT blades. LC and CDW may be used on BLISKs where Linear Friction Welding (LFW) is not feasible, and on HPT blades where conventional welding technologies are not possible. Both proposed welding technologies have their technical advantages, such as near-net shape blade build-up and low distortion for LC, and low heat input and fine microstructure for CDW. Modelling, metallurgical analysis and mechanical testing also contribute to the general feasibility (constant risk assessment). Processing operations (heat treatment, etching etc.) and non-destructive testing are also part of the work programme. Consequently, the ten work packages are mostly orientated on technology issues and defined as follows.

In WP1, test pieces will be manufactured and additives provided. The materials considered for BLISKs are Titanium (e.g. TI6246) and Nickel-based (e.g. Inco718) as well as single-crystal materials (e.g. CMSX2) for HPT blades. On the basis of process and microstructure modelling (WP2), the process layout for the repair techniques will be developed on simple test pieces. During the project the geometrical complexity of the parts will be increased (WP5). Geometrical and metallurgical analysis (WP5), mechanical testing (WP6) and NDT examination (WP7) are carried out simultaneously with the process development. For quality assurance, process monitoring and control systems will be developed or adapted (WP4). In WP8 the results will be transferred to real parts (BLISKs, HPT blades) and mock-ups, and these parts will be completely repaired. The project ends with an assessment of the technical and economic results in comparison to conventional repair techniques (WP9). All management and coordination work is comprised in WP10 and focused on straightforward technical and financial management.

Expected results

The competitiveness of the European aero engine industry will be enhanced, due to the economic repair technologies for LC and CDW-based blades, and the improved properties and service performance of BLISK and HP Turbine blades. With regard to BLISK, the project closes the technology gap of missing repair technology, and thus will enable the wider use of BLISKs in civil aero engines.

Milestones: month 24 – repaired test pieces; month 48 – repaired parts, mock ups, final report.

Deliverables: integrated repair process, repaired test pieces, mock-ups, parts.

Dissemination: open literature, university courses, conferences.

Title: Advanced Welding Technologies for Repair and Salvage of High-Value Engine Components on Nickel and Titanium-Based Alloys

Acronym: **AWFORS**

Contract N°: G4RD-CT-2000-00404

Proposal N°: GRD1-2000-25067

Total cost: €6 188 466

EU contribution: €3 196 556

Starting date: 01/02/2001

Duration: 48 months

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Ecole Polytechnique Fédérale de Lausanne	CH
ELASIS – Sistema Ricerca Nel Mezzogiorno SCpA	I
Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA)	I
Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V.	D
GEVA Adlershof GmbH	D
Groupement d'Etude et de Recherche pour les Applications Industrielles des Lasers de Puisance	F
Lombardini F.I.M. Srl	I
Materials Research Centre	I
Megatronic Schweissmaschinenbau GmbH	D
MTU Motoren- und Turbinen-Union München GmbH	D
Rheinisch-Westfälische Technische Hochschule Aachen (RWTH)	D
Schwarz GmbH & Co. KG	D
Sulzer Innotec – Sulzer Markets and Technology AG	CH
Turbomeca S.A.	F
Università Degli Studi di Lecce	I

Cost-Effective Rotordynamics Engineering Solutions

Project objectives

- reduction of time for validatation of engine dynamics models from 12 months to 3 months;
- more accurate predictions of engine response (+/-10% compared with +100/-50% achieved today);
- verification of the new procedures by producing a validated model of a part-engine structure;
- Laboratory test-rig determination and classification of possible windmill rotordynamic regimes;
- more accurate engine response and predictions of internal loads (within +/-10%) for high-amplitude fan blade-off and windmill cases;
- improved use of the validated model for the diagnosis of location of engine imbalance.

Description of the work

The work consists of:

1. Development of new procedures to assess the response sensitivity of the whole-engine model to the model parameters. This will enable model validation efforts to be concentrated on the areas that have greatest effect on the engine's response.
2. Development of new models for non-linear stiffness and damping at joints. This will reduce current reliance on global damping assumptions in engine dynamics.
3. Extension of model updating codes for systems with non-linear elements.
4. Development of validation test design methods, which with (1)–(3) will allow early validation, using a reduced number of components and sub-assemblies.
5. Construction and validation of a model of a real engine parts structure, including its non-linear large amplitude response.
6. Development of efficient elastic-plastic models for dynamics analysis of structural components, to allow accurate simulation of the deformation of under blade loss.
7. Test-rig investigation and validation of non-linear rotordynamics in blade off and windmill, e.g. for damaged bearing supports and rotor/casing rubbing.
8. Development of the engine model as a diagnostic tool, with optimum processing of measured responses to diagnose location of engine imbalance.

Expected results

- new model sensitivity assessment procedure,
- stiffness and damping models for joints,
- test planning algorithms for correlation/updating,
- modal testing of non-linear systems,
- updating for non-linear structures/multiple boundary conditions,
- validation of engine structure model based on the above,
- elastic-plastic collapse model for dynamic analysis of blade-off,
- understanding and analysis for windmill,
- demonstration of unbalance location diagnosis.

Title: Cost-Effective Rotordynamics Engineering Solutions

Acronym: **CERES**

Contract N°: G4RD-CT-1999-00074

Proposal N°: GRD1-1999-10388

Total cost: €3 162 363

EU contribution: €1 999 880

Starting date: 01/03/2000

Duration: 42 months

Coordinator: ROLLS-ROYCE plc.
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MTU Aero Engines GmbH	D
Rolls-Royce Deutschland GmbH	D
SNECMA Moteurs	F
Universität Gesamthochschule Kassel	D
Université de Franche-Comté	F
Université de Liège	B

Project objectives

The design of the combustor requires the prediction of the temperature and flow field inside the combustor. The combustion process itself is governed by the reaction kinetics, the fuel-preparation process, the turbulent fluid flow and the radiative to combustor the walls. The main step of the programme is the development of physical models for CFD computation to describe the abovementioned physical phenomena. These models will be connected to a generic industrial code with common interfaces for the subroutines to enable all industrial partners to attach them to their own in-house CFD-code. To show the functionality of the developed models, validation experiments will be carried out. Current optical measurement techniques will enable a detailed comparison of numerical predictions and experimental data. A key step, to be done before the start of the validation experiments, is the definition of a model fuel. This step is very important for the validation of the models, because aviation fuel kerosene shows a wide variation in its composition.

Description of the work

The physical phenomena will be tackled in four work packages (WP).

WP1. Chemical Mechanisms (CM). The first target is to define a model fuel representing kerosene with respect to heat release, flame speed, ignition delay and main species, including soot. Based on the definition of the model fuel, a detailed mechanism may then be deduced. In addition, it will be possible to generate reduced chemical mechanisms suitable for inclusion in CFD codes.

WP2. Turbulence Chemistry Interaction (TCI). The aim here is to validate the PDF transport methods that were successfully developed within the 4th Framework, and to adapt them to the generic CFD format defined within the project. Some promising new methods have been developed within the 4th Framework. Some computationally cheaper but less accurate methods, such as the unsteady flamelet and the EDCWC models (Eddy-Dissipation-Concept With Combustion) will be developed further to investigate their potential.

WP3. Modelling of 2-phase flows (M2PF). The atomisation of fuel inside jet engines combustors is based on the concept of airblast atomisation, which employs the kinetic energy of a flowing airstream to shatter the fuel sheet, first into ligaments and then into drops. This atomisation strongly depends on the liquid fuel flow inside the fuel nozzle. To optimise the atomisation process, an already existing model for single-component liquids based on Cartesian co-ordinates will be extended in order allow the prediction of the coupled two-phase flow in complex geometries.

WP4. Soot and radiation modelling (SRM). The first objective is to measure the production and oxidation of soot at pressures up to 16 bar in order to provide data which help to extrapolate developed models to higher pressures (up to 40 bar). In parallel, detailed reaction mechanisms which model the fuel pyrolysis and soot formation will be developed. As these models are based on fundamental chemical steps, it will be possible to extend these to higher pressure conditions with more confidence than models based on empirical approaches. Finally the problems of modelling the oxidation rate are believed to be due the effects of turbulence on the soot and oxidising species. This will be addressed by using the transported PDF approach, which represents the turbulence effects on species concentration.

Expected results

Milestones: CM: definition of model fuel; detailed and reduced chemistry mechanism; TCI: chemistry module coupled to CFD solver; M2PF – look-up tables for thermophysical properties, fuel film model; SRM – heat loss terms for flamelet library; soot reaction mechanism.

Results: CM – reaction mechanism suitable for inclusion in CFD codes; validation data for model kerosene; TCI – PDF transport module; M2PH: film flow properties (velocity thickness) as a function of air flow; validation data for curved surfaces; SRM: soot formation and oxidation model; validation data for elevated pressures.

Title: Computational Fluid Dynamics for Combustion

Acronym: **CFD4C**

Contract N°: G4RD-CT-1999-00075

Proposal N°: GRD1-1999-10325

Total cost: €3 447 052

EU contribution: €2 622 840

Starting date: 01/02/2000

Duration: 42 months

Coordinator: MTU AERO ENGINES GmbH
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Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Fiat Avio S.p.A.	I
Imperial College of Science Technology and Medicine London	UK
Lund University	S
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Rheinisch-Westfälische Technische Hochschule, Aachen (RWTH)	D
Rolls-Royce Deutschland GmbH	D
Rolls-Royce plc.	UK
Ruprecht-Karls-Universität, Heidelberg	D
SNECMA Moteurs	F
Turbomeca S.A.	F
Universidad de Zaragoza	E
Universität Karlsruhe (Technische Hochschule)	D

Heat and Oxidation Resistant Titanium Alloys Applications

Project objectives

Due to further hardening of environmental standards, aircraft and helicopter manufacturers will have to reduce the noise, CO_2 and NOx levels of aircraft. Studies on noise damping nozzles reveal that the weight and complexity of these components will induce the loss of one paying passenger over six for a twin engine helicopter and significant cost increases.

Consequently, restoration of aircraft payload and thrust to weight ratio, induced by the use of light-weight titanium alloys, and cost reductions of the silent nozzles, by smart processes, are HORTIA main objectives.

To meet these goals, HORTIA will scan all the aspects of the final applications, from the characterisation of the available materials and protective processes to the performance validation including, not only technical criteria, but also costs, producibility and maintainability.

Description of the work

WP1: Project requirements will bring functional and industrial requirements (performances, operating conditions, weight, materials formability, weldability, tooling material/design, costs, etc).

WP2: Materials & processes analysis and selection will focus on the characterisation and selection of the materials and associated oxidation protection processes.

WP3: Design & Manufacturing Processes, Simulation Tools will bring thermo mechanical analysis of the exhaust nozzles and Super Plastic Forming and Laser Beam Welding modellings for relevant titanium alloys.

WP4: Mock-Ups Components Design & Manufacturing: MUC1 will be a noise damping exhaust nozzle for a helicopter engine. MUC2 will be a feasibility MUC for explosion forming and cladding processes validation. Both of these MUC will be analysed in terms of process capability and economic performances.

WP5: Tests and measurements will bring engine test results on MUC1 which will be compared to the technical specification to anticipate life limit and performances. Thermal cycling test results on MUC2 will determine life limit under operating conditions.

Expected results

- Technical and industrial specification.
- Titanium alloys and protections performances / selection.
- Computer models for forming and welding processes. Computer models for thermal mechanical analysis of exhaust nozzles.
- Final designs of silent light-weight nozzles, integrating industrial constraints.
- Fully assembled mock-ups. Optimised industrial processes for forming, protecting and assembling heat resistant titanium alloys skins.

Title: Heat and Oxidation Resistant Titanium Alloy Applications

Acronym: **HORTIA**

Contract N°: G4RD-CT-2001-00630

Proposal N°: GRD1-2001-40129

Total cost: €4 718 392

EU contribution: €2 359 194

Starting date: 01/03/2002

Duration: 48 months

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Exameca SA	F
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Instituto Superior Técnico (IST) Lisboa	P
Netherlands Organisation for Applied Scientific research (TNO)	NL
PRODEM	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
TUHH-Technologie GmbH	D

Fluid Flow and Heat Transfer within the Rotating Internal Cooling Air Systems of Gas Turbines 2

Project objectives

The objectives of this RTD project are to reduce gas-turbine engine-specific fuel consumption by 1%, and to reduce the time to market for new products, in order to sustain the competitive position of European industry. This will be achieved by improving available data and predictive design methods for optimising the internal air systems within gas-turbine power plants. The specific objectives are therefore:

1. To establish an experimental database of measurements for engine-representative internal air-system fluid flow and heat transfer.
2. To use this data to establish a validated set of tools and numerical modelling methods for internal air system design and performance prediction.
3. To develop and demonstrate optimised designs for turbine rim seals, stator wells and pre-swirl systems, and for controlling rotating cavity heat transfer.

Description of the work

The previous ICAS-GT programme addressed five areas of the internal air system:

1. turbine annulus hot-gas ingestion control,
2. airflow and heat transfer in rotating cavities, such as those formed between adjacent compressor discs,
3. compressor stator well-heating,
4. turbine-cooling air pre-swirl systems,
5. airflow and heat transfer in a high-pressure compressor-drive cone cavity.

The technology developed in tasks 3 and 5 was fully exploitable by the time ICAS-GT concluded at the end of 2000. The objectives set for tasks 1, 2 and 4 were also met, but further work was required to build on this outcome and to exploit the technology to the full. In addition, two new technical work packages have been identified by the partners as necessary for reducing SFC by 1%. ICAS-GT2 therefore comprises five work packages, specifically:

1. turbine-rim sealing, including rim seal optimisation,
2. rotating cavity flow and heat transfer, including heat transfer control,
3. turbine stator well-heating and design optimisation,
4. turbine cooling air pre-swirl systems, including system optimisation and particle separation,
5. windage heating of static and rotating components.

Experimental data is being obtained from advanced facilities that exist at the partner universities, using state-of-the-art optical and high-frequency response measurement techniques. An engine parts rig is included to bridge the gap between research facilities and the real engine, thus promoting rapid exploitation. This data will be used by the industrial partners to improve their design methods and to validate flow and heat transfer models, CFD and LES codes. Optimised rim seal, stator well and pre-swirl system designs will be produced using these tools, and tested ready for exploitation within four to six years of the project's start date. Representatives of the industrial partners will coordinate the project and manage each of the work packages.

Expected results

Progress will be monitored against the specific milestones defined for each work package. The project will deliver a database of experimental information under engine-representative non-dimensional conditions, together with validated CFD numerical modelling methods for all five rotating-flow systems. It will deliver validated design methods in the form of correlations which will be applicable in engine-representative conditions and exploitable by gas-turbine designers, and also optimised air-system design features.

Title: Fluid Flow and Heat Transfer within the Rotating Internal Cooling Air Systems of Gas Turbines 2

Acronym: **ICAS-GT2**

Contract N°: G4RD-CT-2001-00451

Proposal N°: GRD1-2000-25414

Total cost: €4 796 313

EU contribution: €2 732 220

Starting date: 01/04/2001

Duration: 48 months

Coordinator: ROLLS-ROYCE plc.
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MTU Motoren- und Turbinen-Union München GmbH	D
Rheinisch-Westfälische Technische Hochschule Aachen	D
Rolls-Royce Deutschland GmbH	D
Siemens Nuclear Power GmbH	D
SNECMA Moteurs	F
Turbomeca S.A.	F
Universität Karlsruhe (Technische Hochschule)	D
University of Surrey	UK
University of Sussex	UK
Volvo Aero Corporation AB	S

Magnetic Bearings for Smart Aero Engines

Project objectives

The main focus of the research project is the development of a technology for smart aero engines based on the use of Active Magnetic Bearings (AMBs). These 'mechatronic' bearings offer the following considerable potential benefits:

- to reduce the aero engine's weight;
- to lower the friction losses and to avoid wear in the bearings;
- to eliminate the need for lubricating oil systems and to reduce complicated labyrinth seals;
- to reduce emissions and noise, and to reduce fire hazards;
- to increase operating speeds and also performance;
- to improve monitoring, diagnosis, prognosis and correction capabilities;
- to move towards an all-electric engine.

Description of the work

The central feature of the MAGFLY project is the Whole-Engine Design Process which will be managed by the aero engine manufacturers, working together with university partners and a software supplier. In another work package, an AMB manufacturer will work mainly with three university partners to optimise the mechatronic system of the Active Magnetic Bearing as required for aero-engine applications. A whole-system model will be developed by four university partners, a software company and the aero engine manufacturers. In order to make the aero engine really 'Smart', the same group of university and industry partners will be working together in the place where the necessary Smart Machine Technology is to be developed. Two demonstration test rigs will be built and operated by the aero engine manufacturers, guided by the judicious use of virtual test techniques to optimise the actual rigs and tests.

On completion of the MAGFLY project, the following products will be delivered by the partners:

- an optimised Active Magnetic Bearing (AMB) design for smart aero-engines;
- a whole-system modelling tool, constituting a future development software tool for the design of smart aero engines with AMBs;
- a whole-engine mechatronic design capability, leading to an efficient damage-tolerant and smart aero engine design with AMBs;
- a Smart Machine Technology, consisting of hardware and software components to manage the monitoring, diagnosis, prognosis and correction procedures for the engine on model-based and signal-based routines;
- design tools and the new design, validated by different test rigs;
- a new generation of Active Magnetic Bearings (AMBs) for use in smart aero engines;
- a Whole System Modelling Tool will be available, which is the basic future development software tool for the design of smart aero engines with AMBs;
- a Smart Machine Technology, particularly for aero engines, consisting of hardware and software components;
- whole Engine Mechatronic Design for the smart aero engine with AMBs.

Expected results

- a new generation of Active Magnetic Bearings (AMBs) for use in smart aero-engines;
- a Whole System Modelling Tool, which will be the basic future development software tool for the design of smart aero engines with AMBs;
- a Smart Machine Technology, particularly for aero engines, consisting of hardware and software components;
- a whole Engine Mechatronic Design for the smart aero engine with AMBs.

Title: Magnetic Bearings for Smart Aero Engines

Acronym: **MAGFLY**

Contract N°: G4RD-CT-2001-00625

Proposal N°: GRD1-2001-40191

Total cost: €4 113 532

EU contribution: €2 418 230

Starting date: 01/01/2002

Duration: 42 months

Coordinator: MTU AERO ENGINES GmbH
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Imperial College of Science Technology and Medicine London	UK
MECOS Traxler AG	CH
MTU Aero Engines GmbH	D
SAMTECH S.A.	B
Technion Research and Development Foundation Ltd.	IL
The Barden Corporation (UK) Ltd.	UK
Turbomeca S.A.	F

Oxidation Resistant Al and PtAl Diffusion Coatings with Improved Oxidation and Thermomechanical Fatigue Life

Project objectives

Improve the competitiveness of aero engines by increasing turbine efficiency and life at lower cost. This is done by developing oxidation-resistant turbine-blade coatings as follows:

- Development of new coatings of Al and PtAl diffusion type with higher and balanced mechanical performance and oxidation resistance at reduced production cost.
- Modification of composition, microstructure and reduction of defects for mechanical performance, including the active elements for oxidation resistance.
- Development of an environmentally clean and low-cost out-of-pack process for an accurate control of coating quality and simultaneous inclusion of active elements.
- Increase in basic understanding to give guidelines for coating development.
- Process development to deposit new coatings on real blades.
- Procurement of coated blades for testing in validator engine and on wing and post-test evaluation of coating behaviour.

Description of the work

Following the sequence of work, six work packages have been defined. The technical targets will be refined in WP1.

In WP2, all the work will be done on developing the coating process on a laboratory scale. This includes work targeted at controlling the Al activity and Pt concentration in the resulting coatings as well as microstructure and defects. It includes the selection of precursers, and the investigation of process parameters for incorporating active elements. It will establish the basic understanding and modelling of the coating process. Promising coating qualities will be selected and provided to WP3 for evaluation fo their properties.

The investigation of coating performance in WP3 will be done on a laboratory scale. Coating variants will be tested, ranked and down-selected in phases 1 (standard testing) and 2 (full-size investigations). In-depth investigations of mechanical performance (of thermomechanical and oxidation behaviour in particular) will provide a basic understanding of the influence of coating structure and of the effects of the active elements in given coatings. The WP3 work will provide specifications for new coating qualitities with improved and balanced properties.

There will be further development in WP4 of the coating processes for this finally selected set of coating qualities. This will study the coating of real turbine blades under economic and well-controlled conditions, and make use of the basic understanding, modelling and experience gained in WP2. Coated blades will be provided for engine testing.

In WP5, all preparations will be made for the testing of coated blades in a validator engine (ANTLE) and on-wing of an aircraft. Evaluation of ANTLE-tested blades forms part of this programme.

WP6 will serve to compare the technical achievements of the coating process against costs, and assess their impact on life-cycle costs. This will be the basis for taking decisions on the exploitation of results.

Expected results

Milestones:

- Coating process available for new Al and PtAl qualities, including active elements.
- Properties investigated to identify requisite new coating characteristics.
- Procurement of coatings for validator engine testing.

Results:

- Environmentally friendly and low-cost processes for Al and PtAl coatings.
- A method for simultaneous inclusion of active elements at the aluminising stage.
- New Al and PtAl coatings with balanced mechanical and oxidation properties.

Title: Oxidation Resistant Al and PtAl Diffusion Coatings with Improved Oxidation and Thermomechanical Fatigue Life

Acronym: **ORDICO**

Contract N°: G4RD-CT-2000-00319

Proposal N°: GRD1-2000-25119

Total cost: €4 166 888

EU contribution: €2 205 204

Starting date: 01/01/2001

Duration: 48 months

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Commission of the European Communities (JRC)	B
Fiat Avio S.p.A.	I
Lufthansa Technik AG	D
MTU Aero Engines GmbH	D
SIFCO Irish Holdings Ltd.	IE
Techspace Aero S.A.	B

Project objectives

To deliver enhanced aerofoil design tools to achieve optimum balance between engine efficiency and reliability. This will be achieved by characterising the effects of complex loading conditions and foreign- object damage on the fatigue performance of aerofoils. Design methods are to be provided for aerofoils manufactured in titanium and nickel alloys. The specific objectives of the programme are to:

- Provide an improved method to assess the vulnerability of aerofoils to specified levels of high-cycle fatigue.
- Determine empirically the negative effects of foreign-object damage on the fatigue capability of the aerofoil.
- Provide a method of predicting the combined-cycle fatigue behaviour of an undamaged aerofoil, based on the results of high-cycle and combined high- and low-cycle fatigue tests carried out using conventional specimens.
- Provide a model that can predict any fatigue penalty associated with specified levels of damage caused by the impact of foreign bodies.
- Provide a probabilistic tool for assessing the rate of failure of an aerofoil for a specified rate and severity of foreign body ingestion.

Description of the work

To achieve the objectives listed above, the following activities are under way:

The Development of a High Frequency Combined Cycle Fatigue (CCF) Test Facility: A novel test facility has been developed that allows blade-like specimens to be subjected to an axial load while a bending load is superimposed by exciting a natural frequency of the specimen. Six test machines will be used. This will allow approximately 340 blade simulation tests to be carried out over the duration of the project.

Material Procurement: The two materials selected by the partners are typical grades of forged Ti6Al4V and IN 718, which represent the two families of alloys most used by the aeronautical industry.

Design and Manufacture of Blade-like Test Specimens: The programme will investigate the fatigue behaviour of the blade-like specimens at the fillet radius, the leading edge (mid-chord and fillet) and the mid- chord/ mid-height locations.

Conventional Test Specimen Test Programme: A programme of fatigue testing, using conventional plane and notched specimens, is to be carried out to characterise the behaviour of the two alloys chosen. The work will include tensile tests, strain and load controlled Low-Cycle Fatigue (LCF) tests, load controlled High- Cycle Fatigue (HCF) tests and crack propagation tests. Testing will include an assessment of the effects of surface treatment, including shot peening.

Foreign Object Damage (FOD): A technique has been developed to introduce FOD representative of what is typically seen in-service. The technique will be used to simulate FOD on the leading edge of blade-like specimens prior to their being subject to CCF testing.

Combined-Cycle Fatigue Test Programme: A test matrix is to be carried out that involves approximately 340 CCF tests on five designs of blade-like specimens. Approximately 120 of the leading-edge specimens will contain simulated FOD damage.

Data Analysis and Fatigue Modelling: An extensive programme of analytical work will be developed to gain understanding and interpretation of the test results. The work will include the development of fatigue models for Ti6Al4V under CCF loading, determination of the fatigue penalty associated with FOD, and the development of probabilistic assessment methods and software.

Expected results

The programme will deliver:

- A novel CCF test on a blade-like specimen.

- An extensive fatigue test database for Ti6Al4V and IN718 alloys generated on conventional and blade-like test specimens, including leading-edge blade-like specimens on which FOD has been simulated.
- An assessment of the fatigue performance of blade-like specimens in a titanium alloy after FOD.
- The development of deterministic and probabilistic CCF-fatigue life-assessment methods. Software will be developed to allow the probabilistic methods to be applied.

Title: Robust Aerofoils for Modern Gas Turbines

Acronym: **RAMGT**

Contract N°: G4RD-CT-2000-00183

Proposal N°: GRD1-1999-10490

Total cost: €3 853 096

EU contribution: €2 062 284

Starting date: 01/04/2000

Duration: 48 months

Coordinator: ROLLS-ROYCE plc.
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Fundacion INASMET – Asociacion de Investigation Metalurgica del Pais Vasco	E
Industria de Turbo Propulsores S.A.	E
Integrated Aerospace Sciences Corporation O.E.	EL
MTU Motoren- und Turbinen-Union München GmbH	D
QinetiQ Ltd.	UK
Rolls-Royce plc.	UK
Rolls-Royce Deutschland GmbH	D
SNECMA Moteurs	F
Turbomeca S.A.	F
University of Oxford	UK
Volvo Aero Corporation AB	S

Abradable Seal Coatings and Claddings for Compressor Applications

Project objectives

The main objectives are to:

1. Produce and validate a computer model for abradability that can accurately predict the behaviour of current in-service abradables in specific engine applications, then further develop and validate the model as an effective design tool for rotor path and air seals.
2. Investigate the feasibility of abradable tape manufacture as a new seal system.
3. Develop a family of novel seal coating materials and define the performance envelope of this system.
4. Develop a new material for the HP compressor that is stable, has less susceptibility to corrosion, has superior erosion resistance and is 'titanium friendly'.
5. Apply the above technologies to gain a 0.25% increase in Specific Fuel Consumption (SFC).

Description of the work

The project will follow two closely interlinked approaches to solve the problem of improving abradable seals.

The first will be to establish a computer simulation model for abradability and wear. Initial development will be based upon existing systems which will enable it to be fully validated against extensive OEM data. Once validated, the model will be further developed for the new material systems produced in this project. Using feedback from project test results it will then be further developed as a predictive tool based around the new powders/coatings systems developed in this project.

The second approach materials development, will be to design a new, multi-component abradable system using a combination of a metal alloy matrix material (Al, Ni, Cr, Co, Y), a solid lubricant (Cap, EN, Ag) and a dislocator (Glasses, Clays, Ceramics) . Furthermore, a range of techniques will be used to manufacture the new abradable powders for coatings and also as a totally new type of abradable tapes.

The materials and model development stages will be closely linked and highly interactive, and the aim is to provide ongoing model validation and support for materials development.

Finally, the optimised coating systems will be built into prototype components and subjected to full service simulation rig testing.

The strategy to develop the simulation package in parallel with materials development and testing to provide ongoing validation of the model is seen as an important and new approach to making a significant advance in this difficult field.

Expected results

Five major results are expected from this project:

- a fully validated model for abradability;
- development of a new family of abradable powder materials;
- a set of fully optimised and tested coating structures;
- a number of fully tested prototype casings;
- a fully predictive simulation package for abradability.

Title: Abradable Seal Coatings and Claddings for Compressor Applications

Acronym: **SEAL-COAT**

Contract N°: G4RD-CT-2002-00707

Proposal N°: GRD1-2001-40124

Total cost: €3 300 049

EU contribution: €1 988 576

Starting date: 01/05/2002

Duration: 48 months

Coordinator: ENGINEERING SOLUTIONS INTERNATIONAL Ltd.
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EUROMAT GmbH	D
Institute of Plasma Physics of the Academy of Sciences of the Czech Republic	CZ
MTU Aero Engines GmbH	D
Neomet Ltd.	UK
Rilla, Alvarez y Lopez S.A.	E
Rolls-Royce plc.	UK
University of Technology of Belfort-Montbeliard	F

Soot in Aeronautics – Towards Enhanced Aero Engine Combustor Modelling

Project objectives

Soot is an unwanted pollutant emitted by aeroengine combustors. It affects heterogeneous atmospheric chemistry, especially at high altitudes. Therefore, improving soot model prediction capabilities in connection with CFD codes has implications on the design, performance and soot emissions of future aero engines, thus addressing the research objective 4.3.1 in KA 4. The objectives of this proposal are:

1. the development of an validated enhanced mechanistic soot model for kerosene-like fuels,
2. implementation of the model in CFD-codes, coupled to radiative heat transfer models, demonstrating their predictive capability under aero engine combuster conditions,
3. proving the existence, and quantifying the possible extent of, the influence of liquid phase on soot formation. This project will develop the basic requirements for enhanced modelling of soot within CFD codes.

Description of the work

The approach chosen consists of the detailed investigation of the influence of a variety of kerosene fuel compounds on soot formation. Extended knowledge of the relation of fuel compounds or blends to growth species like polycyclic aromatic hydrocarbons (PAHs) and subsequent chemical/physical growth mechanisms (PAH polymerisation, coagulation, surface growth etc.) leading to soot nuclei will improve the prediction of soot formation through development of an enhanced mechanistic soot model. Validation data will be provided for elevated pressures from flame and shock tube experiments. This will give rise to the reduction of the detailed soot model according to the objectives of scientific CFD codes.

The model will be implemented into four scientific CFD codes. Three of them use different PDF approaches describing turbulence-chemistry interaction, and the fourth uses the flamelet approach with postprocessing. The CFD codes will couple the information on soot to advanced radiative heat transfer models, thus predicting not only soot evolution and emission, but also temperature loads of combustors. Combustor rig tests at elevated pressures at semi-technical scale (typical aero engine combustor nozzel operated with gaseous and pre-evaporated fuels) and at technical scale (closest approach to a real aero engine with LPP/RQL design concept) will be performed to generate comprehensive databases on validation. The improved prediction capabilities of those extended CFD codes will be demonstrated by comparison with experimental results and with each other. Liquid phase influence on soot formation will be investigated in an experiment under engine combustor conditions, alternatively fuelled with liquid and gaseous kerosene with best possible *ab initio* similarity of gaseous to liquid fuel mixing. Soot formation from monodisperse droplet combustion will deliver data for a modelling approach, using ESM.

Expected results

This project will provide a new model approach and enhanced knowledge on soot formation from kerosene- like fuels and its dependence on the liquid phase. The main output will be a validated Enhanced mechanistic Soot Model (ESM). The ESM reduction, its CFD code implementation and its coupling to radiative heat transfer models will be processed. The enhanced predictive capability will be demonstrated through comparison with experiments replicating aero engine combustor conditions.

Title: Soot in Aeronautics – Towards Enhanced Aero Engine Combustor Modelling

Acronym: **SiA-TEAM**

Contract N°: G4RD-CT-2001-00670

Proposal N°: GRD1-2001-41804

Total cost: €3 461 577

EU contribution: €2 000 000

Starting date: 01/05/2002

Duration: 48 months

Coordinator: DEUTSCHES ZENTRUM FÜR LUFT-UND RAUMFAHRT e.V. (DLR)
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Cranfield University	UK
Fiat Avio S.p.A.	I
MTU Aero Engines GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Rolls-Royce plc.	UK
SNECMA Moteurs	F
Universita di Napoli 'Frederico II'	I
Universität Karlsruhe (TH)	D

New Increased Temperature-Capability Thermal Barrier Coatings

Project objectives

The project aims to develop a thermal barrier-coating system for hot-section components of gas turbines (GT) with a 50°C minimum increase in operating temperature over the current state-of-the art coating (7% -8% $Y2O_3$ partially stabilised ZrO_2, YSZ), thereby maintaining the good material properties of YSZ. This will allow higher turbine entry temperatures, and therefore more efficient GT engines with reduced fuel consumption and fewer harmful emissions.

European companies currently have a 33% share of the fast-growing world civil aviation market. EU exports in the aeronautic sector amount to about €33 billion per year and sustain more than 400 000 jobs. This project will assist European companies to compete in GT world markets, secure and create highly skilled jobs, and protect the environment and natural resources.

A highly inter-disciplinary consortium from five European countries (i.e. the major European manufacturers of aero- and industrial- GT engines, research organisations, an end-user of the technology, and a major supplier of advanced coatings) makes full use of European resources.

Description of the work

A dual approach that balances the R&D risks (and thereby promises the highest rate of success) will be chosen for this project. The first approach will investigate the possibility of compositional and morphological changes to the existing TBC system. The second, highly innovative approach, will develop new coating compositions based on materials other than ZrO_2. Standard production techniques (EB-PVD and APS) will be employed for coating deposition. Initially, a total of twenty different systems (including references) will be screened for their most critical properties (i.e. phase stability and sintering resistance). After a thorough assessment of screening test results against project objectives, six systems (including references) will be selected for processing in industrial equipment and further evaluation. The performance of the thermal barrier coatings will be experimentally quantified and described by theoretical means and benchmarked against reference systems. All evaluations will include virgin and aged samples. The best coating systems will be tested and ranked in service (rig and engine tests).

The project is organised in eight technical work packages with one management task package as follows:

0. Project Management
1. Background and technical specification; procurement of substrates and bond coats.
2. Development of spray powders and ingots.
3. Development of coatings and manufacture of test specimens for initial screening.
4. Screening of 'key' properties and process parameters and down-selection.
5. Technology transfer and industrial processing of selected coatings.
6. Full characterisation of the relevant physical, thermal and mechanical properties for the selected coatings; modelling and lifting of the alloy/coating system for design optimisation. Benchmarking against reference systems.
7. Coating and process optimisation of engine components
8. 'Rainbow Testing' of development and state of the art coatings under real conditions.

Expected results

- The development of new TBC with a minimum 50°C temperature advantage over state-of-the-art YSZ.
- Approval of industrial-scale manufacturing processes for the new TBC.
- Full characterisation of the coating.
- Evaluation under service conditions.

An implementation plan to allow industrial exploitation of the technology within five years: Increase in the TET of GT engines by +50 °C, resulting in a 2%-4% increase in efficiency which corresponds to an overall cost savings on fuel of around €120 million per annum and a reduction of about 750 thousand tonnes of CO_2 and 3 000 tonnes of NO_x (for all partners).

Title: New Increased Temperature-Capability Thermal Barrier Coatings

Acronym: **TBC PLUS**

Contract N°: G4RD-CT-2001-00504

Proposal N°: GRD1-2000-26800

Total cost: €4 372 578

EU contribution: €2 186 289

Starting date: 01/04/2001

Duration: 48 months

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Commission of the European Communities (JRC)	B
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Fiat Avio S.p.A.	I
Forschungszentrum Juelich GmbH	D
Lufthansa Technik AG	D
MTU Motoren- und Turbinen-Union München GmbH	D
Office National d’Etudes et de Recherches Aérospatiales (ONERA)	F
SNECMA Moteurs	F

Unsteady Transitional Flows in Axial Turbomachines

Project objectives

Improvement of stage performance of gas turbines to allow for a reduction in the number of blades in order to contribute to the objectives of FP5, i.e. increasing the thrust-to-weight ratio by 40%, decreasing manufacturing/development costs, and reducing SFC/CO_2 by 20%. Physical understanding and numerical modelling of unsteady transitional flow in axial turbomachines will be considerably improved and applied to the design process of new turbines. The main objectives are: generic assessment and development of transition models; experimental investigation of transition induced by wakes, potential disturbances and surface roughness; application of new design tools/methods to the design of highly loaded axial gas turbine blades. The results will be fed into a unique database, thus improving physical understanding and future validation of transition models.

Description of the work

WP1. Generic Assessment and Development. The various mechanisms that induce unsteady transition will be investigated with analytical models of different complexity following the two major strands of (a) RANS-based transition models and (b) simulation methodologies. Strand (a) covers unsteady intermittency-based two-equation models as well as unsteady modelling of blade wake-boundary layer transitions using adaptively-resolved prescribed unsteady intermittency modelling, the eN-method, non-linear eddy-viscosity two-equation models; development of turbulence models will include surface roughness effects. Part (b) deals with unsteady modelling of detached wake and transition and also numerical experiments on transition based on the LES concept.

WP2. Experimental investigations/Provision of test cases for validation. Investigation of the influence of relevant parameters on transition (vorticity- and pressure waves, free-stream turbulence, separation and surface roughness) for a flat plate, unsteady cascade experiments for low Mach-number flow and high Mach- number flow around newly designed, highly loaded turbine cascades.

WP3. Unsteady 2D and 3D blade row and stage calculations. The wake-induced transition is investigated using newly developed and validated transition models from WP1 in industrial design procedures by numerical investigation of the unsteady wake development and wake-boundary layer interaction in new designs of high-lift turbines and compressors. In addition, the influence of surface roughness and pressure waves on transition is numerically predicted for WP2 test cases.

WP4. Synthesis of the results and data integration. Evaluation, conclusion, data definition and standardisation will be performed and a database created.

WP5. Administration and Exploitation.

Expected results

- Understanding of unsteady transition in turbomachines and validated modelling methods in industrial design tools;
- reports on the physics of transition;
- the theoretical background of the models and their prediction capabilities;
- their application to high-lift, high-speed airfoils;
- models made available as subroutines with generic interface to facilitate dissemination;
- application of transition models in design methods of all major European gas-turbine manufactures for highly loaded blade designs.

Title: Unsteady Transitional Flows in Axial Turbomachines

Acronym: **UTAT**

Contract N°: G4RD-CT-2001-00628

Proposal N°: GRD1-2001-40192

Total cost: €3 927 462

EU contribution: €2 444 068

Starting date: 01/01/2002

Duration: 36 months

Coordinator: MTU AERO ENGINES GmbH
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Partners (name, country):

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Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Fiat Avio S.p.A.	I
Industria de Turbo Propulsores S.A.	E
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
MTU Aero Engines GmbH	D
Office National d'Etudes et de Recherches Aérospatiales	F
Rolls-Royce Deutschland Ltd. & Co KG	D
SNECMA Moteurs	F
The Imperial College of Science, Technology and Medicine	UK
Turbomeca S.A.	F
Universiteit Gent	B
University of Cambridge (UCAM-DENG)	UK
Volvo Aero Corporation AB	S
Von Karman Institute for Fluid Dynamics	B

1.2. Aircraft Efficiency

Systems and equipment

Project objectives

The goal of project ACT-TILT is to define and to validate the architecture and control laws of a Flight Control System (FCS) for tilt rotor. The project aims to make a significant contribution to the development of a flying tilt rotor demonstrator by both reducing the risk related to the development of an advanced European tilt rotor and improving the standards for safety, dispatch reliability, and affordability of current US tilt rotors. The objectives are:

- to define the safety, reliability, and cost targets for the flight control system;
- to define the architecture and to select the technologies able to meet these targets;
- to define the Handing Qualities (HQ) criteria that a commercial tilt rotor should meet;
- to develop control laws according to these criteria;
- to demonstrate through pilot-in-the-loop simulations that the proposed tilt rotor configuration, together with the control laws developed in the project, all meet the criteria defined for handling qualities over the whole flight domain.

Description of the work

The work plan defined to achieve the scientific and technological objectives set for the project includes six technical work packages (WP) and one management work package (WP7).

WP1 (General engineering) will provide the tools and inputs for other activities: Flight mechanics models and handling qualities (HQ) criteria for the development and assessment of control laws (WP3 to WP6), actuator load estimates for the flight control system (FCS) pre-design in WP2.

WP2 (System safety analysis and pre-design) includes the pre-design of the aircraft flight control system up to the preliminary sizing of its main components. It is supported by WP1 for the safety analysis with regard to impact of failures on HQ and for the definition of actuator loads. The sizing of the flight control computers (FCCs) will be based on the control laws defined in WP3 to WP5.

WP3 (Overall aircraft control laws), WP4 (Power/thrust management) and WP5 (Side-stick/cockpit layout) all relate to the development of specific aspects of the complete control laws: the general control laws (including carefree handling) in WP3, the specific aspects relative to power/thrust management in WP4, and inceptor/side-stick problems in WP5. For all these activities, a control strategy will first be defined, then the laws will be developed using off-line simulation first, then pilot-in-the-loop simulations for tuning. The simulation effort will be shared by using different existing facilities, which will need only minor modifications to accommodate the retained aircraft configuration. All the results from WP3 to WP5 will be integrated in WP6 for an assessment of the handling qualities of the proposed aircraft using the criteria defined in WP1. The results will be synthesised into recommendations for a future demonstrator tilt rotor FCS.

Expected results

The following is a summary of the results to be achieved progressively throughout the project:

- preliminary version of flight mechanics model available;
- FCS architecture selected, control strategies defined, basic control laws defined;
- validated version of flight mechanics models available; definition of inceptor functions and installation guidelines;
- complete set of control laws defined, handling quality (HQ) criteria defined;
- preliminary design review of FCS components; evaluation tests in pilot-in-the-loop simulator completed; recommendations on demonstrator produced.

Title: Active Control Technologies for Tilt-Rotor

Acronym: **ACT-TILT**

Contract N°: G4RD-CT-2001-00608

Proposal N°: GRD1-2001-40145

Total cost: €6 799 917

EU contribution: €3 598 133

Starting date: 01/11/2001

Duration: 36 months

Coordinator: EUROCOPTER S.A.
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Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Eurocopter Deutschland GmbH	D
Glasgow Caledonian University	UK
Liebherr-Aerospace Lindenberg GmbH	D
Office National d’Etudes et de Recherches Aérospatiales (ONERA)	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
TELEAVIO	I
University of Liverpool	UK
Westland Helicopters Ltd.	UK

Affordable Digital Fly-by-Wire Flight Control Systems for Small Commercial Aircraft

Project objectives

The overall goal is to reduce the cost of digital fly-by-wire technology to a level that is affordable for small commercial aircraft applications. A previous phase has identified and addressed some of the major cost drivers. This programme will build on these results and address the remaining cost drivers.

The first objective is to address the actuation architecture and technology, and the use of dissimilarity to avoid the need for a third hydraulic supply.

The second objective is to investigate fault tolerant control technologies. This new study will consider a range of possibilities to improve the robustness of the control system and the safety of the aircraft.

The third objective is to define a set of flying quality requirements applicable to small commercial aircraft.

Description of the work

The first item is to create a synthetic environment that is functionally and architecturally representative to assess the effectiveness and viability of different designs. This virtual prototype design validation tool will be created in the MATLAB/Simulink™ environment.

The second item is to consider a wide range of approaches to redundancy management and the use of multiple systems when applied to sensors and to actuator equalisation. These technologies range from improving the Fault Detection and Identification capability, through virtual sensors, to reducing the flight control system sensitivity to faults. Of particular interest is the ability to improve the detection and identification of indistinct, or dormant, fault conditions.

The third item is the general application of modern control technology to design the flight control system. Conventional structures are well understood and are designed to be modular and give good functional visibility. These requirements may impose undesirable performance, together with cost penalties, on the flight control system.

The fourth item will create an actuation test rig to be used in a closed-loop assessment of the actuation-related studies. This is necessary to assess different actuation technologies at a level of detail that is difficult to define mathematically without building and measuring the characteristics.

The fifth item will derive and validate a set of flying quality requirements applicable to small commercial aircraft. These will be developed from a mix of theoretical studies and practical assessments, using a mix of flight simulators and pilots.

Expected results

Each of the above five items represents a major project achievement. The three critical milestones for the programme are the availability of the synthetic environment, the actuator test rig, and the flying quality requirements.

The test rig is an internal assessment tool. The remaining items represent outputs from the project. The synthetic environment, redundancy management, flying quality requirements, and design tools will be reusable for future aircraft programmes to reduce design costs and increase safety. The architecture studies will result in more effective use of components to reduce cost and weight.

Title: Affordable Digital Fly-by-Wire Flight Control Systems for Small Commercial Aircraft

Acronym: **ADFCS-II**

Contract N°: G4RD-CT-2000-00286

Proposal N°: GRD1-2000-25261

Total cost: €6 926 046

EU contribution: €3 765 410

Starting date: 01/02/2001

Duration: 36 months

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Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Fairchild Dornier GmbH	D
Israel Aircraft Industries Ltd. (IAI)	IL
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technion – Israel Institute of Technology	IL
Technische Universiteit Delft	NL
Università Degli Studi di Napoli ‘Federico II’	I
University of Patras	EL

New Concept of High-Pressure Hydraulic Filter for Aeronautics Preserving Environment

Project objectives

The objectives of the project are to study new filtration systems that will be compatible with environmental constraints, together with future hydraulic systems of either fully hydraulic or hybrid architecture (electro-hydraulic actuator). The project also aims to improve fundamental knowledge and capacity for simulations in this field

Description of the work

The proposed approach consists of first understanding the physical mechanisms of filtration by simulating parameters such as pressure drop, mechanical constraints, global geometry, nature and combination of media, size and nature of pollutants, clogging level and distribution, and manufacturing possibilities. Theoretical models will be proposed for comparison with experiments to obtain a high degree of confidence. The output of this study will be a simulation software tool to design new filter systems for various fluids and applications (pure hydraulic and EHA approaches). In parallel with this, new concepts of materials architecture and manufacturing filtration functions will be studied in order to fulfil future requirements for filtering as follows:

- filtration requirements (10 micron particles under 500 psi pressure) ;
- chemical compatibility with an aggressive hydraulic fluid (ester phosphate);
- increased autonomy (by a factor of two);
- waste reduction through the use of incinerable material.

New synthetic media (composite and plastic material structures) are to be studied, then adapted and tested to fulfil performance requirements.

Manufacturing processes will be investigated for availability, cost impacts and environmental constraints.

Mock-ups will be designed according to simulation tools and then manufactured and characterised through applying hydraulic and clogging tests.

Certification aspects will be considered and a strong emphases placed on the diffusion and dissemination of the test results in order to find their applications in other industrial fields.

Expected results

The nine work packages are controlled by six main stages, to be achieved progressively throughout the project:

- availability of requirements;
- model validation on media using standard technologies;
- delivery of database and design tools on new materials;
- delivery of mock-ups;
- validation of simulation software on the filtration system;
- analysis of economic and environmental aspects.

Title: New Concept of High-Pressure Hydraulic Filter for Aeronautics Preserving Environment

Acronym: **AEROFIL**

Contract N°: G4RD-CT-2001-00609

Proposal N°: GRD1-2001-40149

Total cost: €2 631 491

EU contribution: €1 596 998

Starting date: 01/11/2001

Duration: 36 months

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Development of Temperature-Controlled Air Freight Containers

Project objectives

Today goods in large volumes – about 4.400 million tons (1998) – are carried by airfreight. According to a study made by the American trade journal Merge Global, the volumes will increase to about 7.700 million tons at the end of the year 2004. Of these volumes are today about 15 – 17% temperature sensitive goods. It is expected that this % will increase more than the market in total. There are needs for measuring the temperature inside the container to meet the increasing demand for carrying perishables. Another need is to improve the State-of-the-Art as about 25% of the carried goods in containers get some form of damage or problem on the transport from "door-to-door" study by KLM in Nov. 1998. There is a CEN standard in progress stating how to log food carrying.

Perishables – like fresh food, pharmaceuticals, cut flowers, electronics etc- are dependant of a stable temperature. 50-55% of the perishable commodities should be maintained within a temperature range of 2° – 10° C. to minimise the growth of bacteria there should be an even and low temperature. But as most of the perishables today are carried in baggage containers or in insulated packaging/containers with limited possibilities to maintain the desired temperature there are unacceptable amounts of damages.

The **need** is to use temperature controlled containers. The deficit with existing types of containers is the high cost and their limited performance as they are powered by dry ice. The SME proposers have studied this issue during several years and are developing a new type of air freight container with temperature control and log system.

The industrial objectives are to develop a climate controlled airfreight cargo carrier – RCTC container-

- with a system able to control and log the climate from -20° to +20° C in at least 60 hours.
- which optimises space for carrying, weight insulation and is insensitive to careless handling.

The economic/social objectives are to:

- reduce the claims due to defective temperature from 25% to 5%.
- reduce the weight of a container with 20%.
- increase the space for goods in the container with 10%.
- reduce the manufacturing cost and life time cost of an RCTC container with 20%.
- make sure that transports of pharmaceuticals, foods and sensitive goods can be done at even temperature.
- reduce reloading of the goods at airports and thereby reducing unhealthy working conditions.
- reduce the energy consumption per transported ton/km with approximately 20%.

Description of the work

The realisation of the container with the required performances necessitate the following developments which will be undertaken in the frame of this project:

- development of new types of composites material and design of walls- frame of the container for optimising insulation capacity
- development of a climate control system – low energy consumption – that can work without external energy supply
- development of log system that can log the temperature of the goods – above all foods and pharmaceuticals

The new container will improve intermobility and create an unbroken cold chain between sender and receiver.

The solutions will be a significant step forward beyond the State-of -the-Art- also relevant in other SME sectors.

Expected results

The result will be a climate controlled airfreight container to fit in most kinds of aeroplanes. The SME core group will exploit the RTD results and sell the new air freight container to airlines in Europe starting in the end of 2003. In 2003 – 4 it will be marketed world-wide.

Title: Development of Temperature-Controlled Air Freight Containers

Acronym: **AIR FREIGHT CONTAINER**

Contract N°: G4ST-CT-2001-50092

Proposal N°: CRAF-1999-70414

Total cost: €678 000

EU contribution: €339 000

Starting date: 01/04/2001

Duration: 24 months

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Diab APS	DK
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Utvecklingsbyraan Sverige AB	S

Development of Stabilisation, Route Guidance, Propulsion and Ground Segment Control Systems for the Autonomous Operation of Unmanned Surveillance/Scanning Airships

Project objectives

The overall objective of this applied research programme is to develop the first practical, commercial, safe, quiet and acceptable application of Unmanned Aerial Vehicle (UAV) system technology for use in civilian applications.

Small unmanned electric lighter-than-air (LTA) UAVs offer this potential. However they are difficult to operate commercially, due to poor stability in even light wind conditions, and their limited range, limited endurance, high operator fatigue and inadequate propulsion systems.

To meet this challenge the AIRSCAN research programme has the following specific objectives:

- to improve take-off and landing performance in gusty and turbulent conditions by 150% (from 8 knots to 20 knots);
- to extend the endurance by 600% (45 minutes to 5 hours);
- to extend the range of operation from 1 km to 10 km and service 500% (300 m to 1500 m above mean sea level);
- improve operator management and control for the safe and simultaneous operation of multiple airships.

Description of the work

The main areas of work involved cover the airship flight system, power and propulsion system, onboard communications, air/ground communications, ground control system and mission management system.

- **Airship flight control system.** New algorithms and airship control mechanisms will be developed to ensure that the airship can be stabilised and in gusty and turbulent conditions. The system employed will allow the airships to operate autonomously on pre-planned routes, or to be dynamically re-routed from the ground.
- **Power and propulsion system.** Greater power is required to operate in turbulent conditions, so the programme will include major improvements to the power systems by integrating edge battery and solar technologies. The power management issues will be a major research area.
- **Onboard communications.** New technologies in wireless communication will be integrated to reduce the weight of the communication system.
- **Air/ground communications.** An air/ground communications system will be developed that allows for the simultaneous operation of more than one airship health telemetry data system.
- **Ground control system.** An existing advanced ground control system will be modified in order to accommodate the unique characteristics of the airship design and operation.
- **Mission management system.** A pre-mission simulator will be developed for the AIRSCAN system to aid both multiple airship operations, initial trials and to act as the basis for training and support in the exploitation phase.

Success will depend on the careful integration of innovative concepts within the overall AIRSCAN system. The improved capability will lead to the acceptance of unmanned airships within the current regulatory framework, providing increased economic opportunities. Applications include air sampling, crop surveying, security surveillance, wild life tracking etc., not only within all European countries but also world-wide.

Expected results

The major milestone is the full specification, integration and test of a completely new unmanned airship system. Milestones include project management framework, communications sub-system delivery, airborne sub system delivery, ground sub-system delivery and completed documentation.

Exploitation will be done by a new company owned by the SME partners offering franchises for the operation of AIRSCAN systems throughout Europe. A website will be used to build a customer/user network.

Title: Development of Stabilisation, Route Guidance, Propulsion and Ground Segment Control Systems for the Autonomous Operation of Unmanned Surveillance/Scanning Airships

Acronym: **AIRSCAN**

Contract N°: G4ST-CT-2002-50327

Proposal N°: CRAF-1999-71439

Total cost: €1 474 360

EU contribution: €737 180

Starting date: NA

Duration: 22 months

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Advanced Network Architecture for In-Flight Cabin Systems

Project objectives

The project aims to develop a new standard for IFC (In-Flight Cabin) systems, capable of providing services to up to 1,000 passengers and to crew members. Passenger services include Video On Demand, internet access, e-mails, games, etc. Crew services include passenger control, IFC system control and maintenance. An additional objective is to combine the several existing analogue and digital distribution systems (audio/video, control and command, phone) into a single high-throughput fault-tolerant digital distribution network that will be linked to existing legacy systems: OIS (On-board Information Systems), avionics, and satellite communication systems. In addition to fault tolerance, having a system available and working is a particular requirement of those airlines that have been disappointed by current systems.

The ANAIS project also places special emphasis on offering significantly reduced weight, volume and power consumption in comparison to existing systems.

Description of the work

The development of the ANAIS test-bed is structured in six phases: Preliminary studies, Test-bed specification, Test-bed realisation, integration and validation, Evaluation and Dissemination.

Preliminary studies are dedicated to:

- gathering requirements for an airborne In-Flight Cabin (IFC) multimedia system, with particular attention paid to efficiency and certification;
- selecting applicable standards with the view to using COTS products that comply with these standards;
- studying the concepts of modularity and establishing a proper reliability analysis.

Test-bed specification can then be tackled. This will take into account the results of the previous work phase and the initial objectives of the project, and focus its efforts on selected pertinent aspects or key features of the system. The specification encompasses system architecture and implemented services.

Realisation of the test-bed is divided into the four main different parts of the system: seat, network, server, and Cabin Crew Console. All work devoted to building these parts will be subject to make-or-buy decisions; the goal is to use COTS components when they satisfy the test-bed requirements.

After the development of parts of the IFC system, **Integration and Validation** work will pay particular attention to testing the performance of the system through network load simulation tools. Operational tests will be carried out on the system, with appropriate in-situation user scenarios.

An **Evaluation** phase of the technology test-bed will be organised with the companies involved in defining the requirements, as well as other users. Costing evaluations will also be made to provide estimates of the cost of implementing the ANAIS system.

After 32 months of development through the previous work packages, **Dissemination** of the results will be organised. The ANAIS test-bed will be put on show at several aviation and IFE events, such as the Paris or Farnborough Air Shows. The test-bed may also be used to integrate third-party supplier products (software or hardware), and may be reused in other European projects.

Expected results

Results are expected at different levels:

System: Definition of a standard network architecture for future digital In-Flight cabin system with its associated set of management protocols.

Network: Innovative high bandwidth fault tolerant architecture and network monitoring scheme applied to IFC system.

Servers and services: Mock-up of an interactive Flight Information service, and integrated set of entertainment services.
Terminal: Light terminal with laptop connectivity.
Cabin Crew Console: New generation prototype using Web standard.

Title: Advanced Network Architecture for In-Flight Cabin Systems

Acronym: **ANAIS**

Contract N°: G4RD-CT-1999-00094

Proposal N°: GRD1-1999-10472

Total cost: €6 580 040

EU contribution: €3 439 986

Starting date: 15/03/2000

Duration: 48 months

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Inflight Peripherals Ltd.	UK
Interfacing Ltd.	UK
Intracom	EL
KID-Systeme GmbH	D
Lazulent Ltd.	UK
Rumbold	UK
THALES Airborne Systems	F
Universität Ulm	D

Aircraft Service Logistics

Project objectives

The growing demand for air transport world-wide requires new technologies for on-board passenger service and logistic systems. Existing usage has revealed a need for expanded storage space. In addition, the average flight time for long-range flights has also been increased, ranging now up to 16 hours. This requires not only additional meals but also storage of additional service items in the cabin area. Future development of aircraft in the 500+ pax-size class will aggravate this situation.

An updated service system would have the following objectives: passenger capacity increased by up to 6% by using new service boxes; improved airport capacity exploitation through reduced catering loading/unloading time; reduction of catering and cabin crew workloads by eliminating the need for pushing/pulling heavy trolleys; increase in variety of meals individually selected by passengers; weight-reduction through elimination of trolleys; reduced preparation process time in catering facilities.

Description of the work

The project goal is to develop technologies for a highly reliable on-board passenger service and logistics system by relocating the storage of food trolleys to the cargo compartment without direct access to the cabin crew. This goal will be accomplished by an Aircraft Service Logistics (ASL) system. Meals and other service items will be stored in sealed service boxes inside standard-sized cargo containers, each housing a kinematics system which will enable the transport of individually-addressed boxes to a service station in the cabin. The meal boxes themselves could be cooled by connecting the container to the aircraft systems. An internal data-storage device in each container would contain information on each individual box, which would be inputted by the caterer when loading the meal boxes into the container. This information will be used in the aircraft to retrieve the boxes, using the ASL to deliver selected boxes via a vertical conveyance system to a service station in the cabin. Using a newly-developed lightweight service cart, the cabin crew would then distribute the service items to the passengers.

Other service concepts like self-service will also be considered. Newly-developed service boxes will minimise the volume of waste and unavoidable waste will be stored in empty boxes. This system will also make a significant impact on the catering and loading logistics. The project may require new standards for container-to-aircraft interface (mechanical, data transmission, etc.), which should allow the combination of products originating from different equipment suppliers world-wide. To allow economic predictions to be made, standard layouts for different aircraft types will be developed. To predict an optimised service process, a simulation programme for visualization of the service process in the cabin will be developed.

Expected results

The following project results are expected:
- proof of concept feasiblity for a remote-operated storage and logistics system to be installed in a wide-body long- range aircraft;
- proof that a seat gain in the range of 6% is achievable within standard airline layouts;
- weight estimates for an airworthy system;
- hands-on handling experience with various airline cabin crews.

At the end of the project, the concept of a technical research platform will be proven. The ASL system will be installed in a 6-axis movable double-deck simulator (provided by Airbus) consisting of a removable lightweight LD6 container shell with reduced internal kinematics, a simulator-installed lift device, and a service station on the main deck. A second container with a full-scale operational internal kinematics will be available for the container kinematics analysis.

Title: Aircraft Service Logistics

Acronym: **ASL**

Contract N°: G4RD-CT-1999-00098

Proposal N°: GRD1-1999-10281

Total cost: €5 401 600

EU contribution: €2 711 033

Starting date: 01/01/2000

Duration: 36 months

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Driessen Aircraft Interior Systems (Europe)	NL
Fuselage Engineering Services 2000 Ltd.	IL
Gate Gourmet International AG	CH
Israel Aircraft Industries Ltd. (IAI)	IL
Technische Universität Berlin (TUB)	D

Project objectives

The project has two main objectives. The first is to design, implement and validate a software environment for the automatic production of FMECA (Failure Mode Effects Criticality Analysis), starting from qualitative models of aircraft systems. The second is to implement libraries of equipment used in the aircraft/rotorcraft domain, in order to maximise the re-cycling of knowledge and to reduce the effort for modelling.

Description of the work

At first, a sound and effective specification for the FMECA support tool will be produced. During this design phase, efforts will be made to produce requirements that match the needs expressed by the industries that are already able to use these technologies. Considerable effort will also be devoted to select some test cases inside each industry, to provide a guideline for the following phases of testing and validation.
After this, the tool software will be developed. In this project, the choice has been made to work by incremental steps: the first step will be the production of a prototype where the crucial concepts will be addressed, while two other releases will be provided during the course of the project to implement all the functions. The industrial partners will use the software environment to model some test cases selected at the beginning of the project and to produce the FMECA, in order to verify the compliance of the tool against the initial requirements and against user needs. The test cases will be significant for their size and complexity, and will be chosen from different domains (e.g. mechanical, electrical etc.).

Another aim of this project is to develop a repository of commonly used entities in the domain of aircraft and rotorcraft design in order to ensure an effective recycling of technical knowledge. The objective is to speed up efforts in modelling aircraft systems, avoiding the need to describe each entity from scratch every time that a new model is implemented.
Exploitation and information dissemination activities will target both the aerospace domain and software vendors. Initiatives inside the aerospace domain are expected from those companies that share a partnership in multinational programmes with the industrialists.

Expected results

The two main results of this project are:
- a software environment that will allow reliability engineers inside aeronautic industries to create models of aircraft systems and to produce the FMECA analysis automatically. The environment will have graphic interface that will allow the user a user-friendly interaction with the system.
- a set of equipment libraries that will allow the user to build system models quickly by using pre-defined model fragments.

Title: Automating FMECA for Aircraft Systems

Acronym: **AUTAS**

Contract N°: G4RD-CT-2002-00754

Proposal N°: GRD1-2001-40133

Total cost: €4 745 512

EU contribution: €2 543 875

Starting date: 01/06/2002

Duration: 36 months

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Occ'm Software GmbH	D
Sofreten	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universität München (TUM)	D
Università Degli Studi di Torino	I

Advanced Digital Network for New Cockpit Overhead Panel

Project objectives

A revision is necessary of the cockpit overhead panel and its environment in commercial aircraft. The project will study a new concept of overhead panel that is compatible with modern avionics and will exploit emerging display technologies for the benefit of increased flight safety, reduced maintenance costs, greater situation awareness and improved working conditions for the crew. The project deals with new architecture using digital network communication, avionics interface, man-machine interface and display indicators. Trade-offs of new technological solutions will then be conducted. Mock-ups will be designed, manufactured and tested on a simulator. The results of this study will be made available for future large and regional transport aircraft. Expected achievements of the project will include the validation of a new concept of overhead panel for future aircraft production.

Description of the work

The project work is divided among six work packages (WP).

WP1. Top Level Requirements for Large and Regional Aircraft

- Identify needs and requirements on large and regional aircraft.
- Define a common system approach on large and regional aircraft.
- List all potential improvements and make technology recommendations.

WP2. HMI Intuitive and Perceptual Studies

Based on top-level requirements from aircraft manufacturers, this WP aims to:

- Perform a theoretical study of HMI concepts, enabling technologies and human-factor guidelines for system control.
- Evaluate new technology O/P on ergonomic aspects.
- Evaluate new system-control cockpit concepts for acceptance by flight crew, and for performance and workload aspects.
- Recommend new HMI approach on O/P for validation.

WP3. Conceptual Concept Studies

Based on the top-level requirement from aircraft manufacturers, HMI theoretical analysis and HMI new technologies evaluation progress, the task of this WP is to specify a clear set of requirements for technologies development (WP4) and laboratory-system integration (WP5).

WP4. Technologies Development and Verification

Based on specifications issued in WP3, this WP objective is to design, manufacture and verify new architecture demonstrator (hardware and software), including O/P, network and BSIU, for integration and validation performed in WP5.

WP5. Laboratories System Integration and Technical Validations

This WP aims to demonstrate (on a complete system integration test configuration, and also in a cockpit simulator) the validity of the concepts for a new O/P generation and the relevant architecture to command and monitor systems in aircraft.

WP6. Consortium Coordination

This WP will effectively manage the project, ensuring the timely delivery of the solutions developed in the technical WPs, and ensure compliance with the cost and quality requirements of the contract between the CEC and the COCOPAN consortium.

Expected results

Estimates for the expected technical achievements are as follows:

		Regional aircraft		Large aircraft	
		Current value	Gain (%)	Current value	Gain (%)
O/P	Depth	14 cm	50	30 cm	75
O/P	Weight	15 kg	20	50 kg	20
O/P	Reliability	CV*	30	CV	30
Harnesses	Weight	CV	40	CV	50
Harnesses	Number of connections	900	60	1 400	70
Harnesses	Production cost	CV	30	CV	30
Harnesses	Volume	CV	50	CV	60

* CV = Confidential Value, available on request from the EC officer.

Title: Advanced Digital Network for New Cockpit Overhead Panel

Acronym: **COCOPAN**

Contract N°: G4RD-CT-2000-00405

Proposal N°: GRD1-2000-25683

Total cost: €3 963 107

EU contribution: €2 004 043

Starting date: 01/01/2001

Duration: 30 months

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Fairchild Dornier GmbH	D
Fokker Elmo B.V.	NL
Groupement des Industries Françaises Aéronautiques et Spatiales (GIFAS)	F
Page Iberica SA	E
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Development of an Advanced Rotor for Tilt-rotor

Project objectives

The goal of project DART is to develop a full-scale rotor hub for a future tilt-rotor aircraft. The project aims to make a significant contribution to the development of a flying tilt-rotor demonstrator by achieving the following objectives:

- Define, design, manufacture and test an advanced rotor hub for future implementation on a tilt-rotor aircraft;
- Investigate the technological issues associated with tilt-rotor rotor hub design, proposing innovative solutions in terms of rotor hub architecture and manufacturing processes;
- Bring significant improvements, especially in terms of performance, external noise, vibration and dynamic loads, safety / reliability and costs;
- Adapt and validate theoretical tools to be used during the design process, particularly concerning aeromechanics aspects: loads and dynamic behaviour.

This work will pave the way for the next phase of development of the European tilt-rotor with the integration of this rotor with other key components of a tilt-rotor aircraft on a Ground Test Article.

Description of the work

The proposed research work is organised along five main lines:

- Refine the detailed rotor requirements, based on iterative process during pre-design activities.
- Design the different rotor hub components.
- Manufacture the designed elements.
- Integrate and test the rotor hub in laboratory conditions.
- Provide general engineering support.

The work plan includes four technical work packages (WP) and one management work package (WP5).

The general engineering activities (WP1) will support the pre-design and design activities for loads and dynamic behaviour assessment. The first year of the project will be devoted to pre-design activities (WP2) to refine the main design parameters, in particular the blade aerodynamic design, the rotor architecture, the manufacturing processes and the interfaces. This basis will open the way to the detailed design process (second year), during which all the rotor hub components will be defined (WP3 for the hub design). These components will then be manufactured and tested at the component level during the third year (WP4 for the hub manufacturing and tests). Alternative manufacturing processes will be evaluated in parallel for certain selected rotor components. The results of these tests will be analysed to derive recommendations for the development of a future European tilt-rotor demonstrator.

Expected results

The main outcome of the project will be the production of a tested full-scale rotor hub for tilt-rotor aircraft, complemented with:

- documented detailed designs and drawings of the various rotor parts;
- validated manufacturing processes for the hub elements;
- overall rotor assessment in terms of costs, loads and stability behaviour in forward flight through theoretical studies.

This project will provide a sizeable leap towards the development of a flying tilt-rotor demonstrator.

Title: Development of an Advanced Rotor for Tilt-rotor

Acronym: **DART**

Contract N°: G4RD-CT2001-00634

Proposal N°: GRD1-2001-40146

Total cost: €9 744 714

EU contribution: €4 872 456

Starting date: 01/03/2002

Duration: 36 months

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Eurocopter Deutschland GmbH	D
Office National d’Etudes et de Recherches Aérospatiales (ONERA)	F
Paulstra	F
SENER Ingenieria y Sistemas S.A.	E
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Subcontratacion Proyectos Aeronauticos, S.A.	E
Westland Helicopters Ltd.	UK

Efficient and Economic Cabling System

Project objectives

There has been little change in the field of aeronautical electrical wiring over the last 25 years. Current 'wire-by-wire' technologies are reaching their limits with the demand for more functions, sensors and services, more 'electrical' aircraft, together with a significant increase in the use of composite structures and calls for reductions in manufacturing cycles and costs. It has therefore been envisaged to adapt the 'packet wiring' technologies that have been developed for the electronics industry, and are now starting in the automotive industry, to aeronautical applications. This requires the fixing of definitions for aeronautical components, screened cable endings, and finding new industrial design and manufacturing tools. All this leads to the need to develop a new, efficient and economical wiring design including the following requirements: modular flat harness concept, distribution of signals allowing the elimination of most screening, and definition of simple harnesses with few branches that are easy to make and install.

Description of the work

The proposed approach, during which the defined objectives will be followed-up on a continuous basis, comprises the following independent stages:

1. Design of a new modular flat harness concept, including: a review of the state-of-the-art and a survey of technologies other than aeronautics, the definition of a new concept on the basis of the accessible technologies and acceptable installation principles, an investigation of the impact of this concept on electrical distribution architectures, and the specification of exact component requirements (AECMA format).
2. Study of the distribution of the electrical signals, with preparation of an exhaustive list of all the different types with their electrical and thermal characteristics; distribution in different categories of EMC behaviour and the definition of proximity rules according to different topologies; distribution in different categories of thermal behaviour and the definition of proximity rules according to different topologies; definition of signal distribution models on the basis of the above rules.
3. Definition of rules, directives and IT tools associated with their implementation, including studies of their various impacts on all our computerised design tools; definition of the rules and directives induced by the new constraints accompanying this new concept; definition of an experimental mock-up necessary to validate both concept and estimated savings; definition of the requirements to be considered in terms of maintainability and repair.
4. Design of components: flat cables, associated connectors, wiring supports, various additional accessories required, etc., and also a study of the capability of rectangular bundles to be screened.
5. Concept validation process, including the production of an experimental mock-up together with implementation tools; production of prototype harnesses; integration with the rules defined; verification of functionality.

Expected results

This evolution for electrical harnesses of new programmes should enable the following savings:

1. 10% minimum in weight (elimination of screening and jackets, use of smaller gauges);
2. 30% minimum in implementation times (grouping or elimination of elementary manufacturing operations and industrialisation of new processes);
3. 20% minimum in overall costs (definition of the components, limitation of models and standardisation). This evolution will also lead to improvements in the advanced design tools (innovative models) and improvements in safety (through managing the position of links according the type of signals).

Title: Efficient and Economic Cabling System

Acronym: **EECS**

Contract N°: G4RD-CT-2001-00406

Proposal N°: GRD1-2000-25179

Total cost: €3 624 607

EU contribution: €1 812 303

Starting date: 01/03/2001

Duration: 32 months

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Airbus España S.L.	E
Airbus UK Ltd.	UK
Compagnie Deutsch GmbH	D
Connecteurs Electriques Deutsch	F
Draka Fileca -Foptica SA	F
EADS CIMPA	F
Eurocopter France S.A.	F
GIE EADS – CCR France	F
Kabelbedrijven Draka Nederland BV	NL
Nexans Harnesses	B
Università di Genova	I

Project objectives

The technical evolution of aviation will imply the use of numerous electro-hydraulic actuator (EHA) servo-controls to increase aeroplane performance and at the same time to reduce weight. But this new system of servo-controls could be limited by the pollution created in its short hydraulic circuits. The aim of the project is, therefore, to develop a system able to control and eliminate the pollution in such circuits.

As a result, the objectives of the project are to develop a de-pollution module, a pollution-detection system and a specific bleeding/filling coupling to control, capture and eliminate the specific pollution created in EHA. This will allow:

- a decrease in the frequency of maintenance visits; it is anticipated that the EHA with the de-pollution module will have fewer and better optimised scheduled maintenance cycles during its life.
- a decrease in the rate of incidents, made possible due to the pollution-detection system, which will inform the technician of an abnormal pollution of the hydraulic circuit and will allow preventive actions to be taken. Furthermore, the new coupling system will be specifically designed to drain and avoid the inlet of water or air in the hydraulic circuit.

Description of the work

As stated above, the main objectives are to develop three modules that will comprise a system for control and elimination of pollution in EHA. A work plan has been defined by all partners, composed of ten work packages which include design phases, tests programmes and a management task. These technical tasks will cover several fields:

- **Hydraulic fluid pollution:** by studying the evolution and the characteristics of the pollution of a conventional EHA to determine the operating cycle life, the efficiency required for competitive use and the cycles of maintenance;
- **Hydraulic fluid de-pollution:** by developing a system able to capture the type of pollution present in EHAs, taking into account the data obtained from the previous task;
- **Hydraulic fluid pollution detection:** by developing a new system to warn the pilots and the maintenance officers of problems. This indicator will allow the optimisation of maintenance cycles, and thus reduce maintenance costs while at the same time increasing the reliability of the system;
- **Coupling:** this coupling will be used for the bleeding and filling of the EHA during refuelling stops and maintenance operations. In order to reduce hydraulic consumption and pollution by external factors as far as possible, development of the coupling will concentrate on hydraulic tightness.
- **General system design:** the three parts of the system will have to be integrated in various types of EHA and in various aircraft; this implies special requirements for connections, volumes, mass, materials...
- **Testing:** specific tests will be divided in two phases, firstly to validate the functional characteristics and the choices of technologies , and secondly to validate the global system.

As EHA de-pollution requires numerous developments and technologies knowledge, three SMEs (NOVINTEC France, ASG Germany, AMCA Netherlands) will subcontract a large part of their activities to four RTD centres: TRW, SABCA, Messier Bugatti and VZLU.

Expected results

The project, which will develop three modules capable of controlling EHA pollution, will include the manufacture of mock-ups and prototypes, and will also validate the technologies selected and the design. Hence the expected results are the validation of the specifications (including the positive achievement of the mock-up tests and ground tests), and the proper integration of the prototypes in the selected EHA. In parallel the partners will have to identify the evolution of the pollution in EHA and its impact on the EHA's operation, in order to specify the performances required for the modules.

Title: Electro-Hydraulic Actuators

Acronym: **EHA**

Contract N°: NA

Proposal N°: CRAF-1999-71314

Total cost: €1 986 97

EU contribution: €981 085

Starting date: NA

Duration: 24 months

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Messier Bugatti	F
Société Anonyme Belge de Constructions Aéronautiques (SABCA)	B
TRW Systemes Aeronautiques Civil	F
Vyzkumny a Zkusebni Letecky Ustav, A.S. (VZLU)	CZ

GNSS – Inertial Future Landing Techniques

Project objectives

An ‘all weather landing system’ based only on satellite positioning (GPS/GALILEO) would need to have a complex architecture in order to ensure the required level of safety while not raising cost when compared to current ILS or MLS systems. However, early developments have shown that a combination of the ARNS positioning and cinematic capabilities with other onboard navigation sensors (inertia, air data, altimeter) simplifies the overall system so that it does become competitive in comparison to ILS or MLS. Moreover, it offers new operational capabilities, such as various approach trajectory. GIFT will study and evaluate such an hybrid augmented system, leading to reach the precision approach and landing RNP requirements. It includes aircraft navigation architecture study, hybridisation algorithms design, performance evaluation.

GIFT’s final objective is to demonstrate that GNSS navigation, when augmented by IRS and other onboard sensors, can respond to the two following operational needs: Cat2/Cat3 precision approach and landing, and autoland in Cat 1 condition. Results of this study are expected to prepare future European certification of satellite-based navigation systems.

Description of the work

The GIFT project is split into five work-packages. WP1 is devoted to the management and the co-ordination of the project while WP5 will support the exploitation and dissemination plan.

WP2 is dedicated to system studies: performances for certification will be reviewed, in order to allocate requirements applicable to navigation (positioning) parameters for Cat I autoland, and for Cat II / Cat III precision approach and landing. Starting from existing architectures on AIRBUS aircrafts, an analysis will be made of how to modify them within the frame of a positioning and guidance system that will no longer be based on a single sensor (typically ILS) but combining different sensors (hybridisation concept). This architecture study will be orientated towards safety, and will conclude by allocating requirements (accuracy, integrity, continuity, availability) to the navigation subsystem components. A detailed safety analysis will refine these objectives on the different system components, thus providing preliminary requirements for certification issues and airport infrastructures.

WP3 is dedicated to algorithms study: Hybridisation algorithms combining benefits of the different navigation sources available on aircraft (especially IRS and GNSS) will be studied. This WP includes the definition and software realisations of realistic behaviour models of the different sensors. A sensitivity analysis will extend the algorithms study with the aim to evaluate the applicability of the proposed concept to regional and smaller aircraft.

WP4 is dedicated to the development of a functional aircraft simulator, to perform simulated approaches and autoland, for evaluation of algorithms efficiency in various approach conditions. The flight simulation will be performed, with a double objective: first, to demonstrate that algorithms can achieve the Performances Required for Navigation, in realistic dynamic conditions, and second, to evaluate the complexity of the proposed algorithms and the potentiality to use them in real time conditions.

Expected results

The expected results of the GIFT project are to demonstrate that the GNSS hybridised navigation systems can provide integrity and continuity improvement. The proposed algorithms will be assessed with regard to the operational needs on the basis of an AIRBUS simulator.

The main issues are: -M9: proposed Hybridisation techniques and preliminary architecture studies; -M 15: Algorithms and simulation package design; -M 21: final system studies, models definition and the aircraft simulator; -M 30: algorithms performance evaluation on simulator and GIFT dissemination conclusions.

Title: GNSS – Inertial Future Landing Techniques

Acronym: **GIFT**

Contract N°: G4RD-CT-2002-00806

Proposal N°: GRD1-2001-40172

Total cost: €5 570 959

EU contribution: €2 867 726

Starting date: 01/09/2002

Duration: 30 months

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Park Air Systems SA	NL
Skysoft Portugal, Software e Tecnologias de Informaçao, S.A.	PO
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Swedish Civil Aviation Administration	S
Technische Universität Braunschweig Institut für Flugführung	D

Improving the Cockpit Application Development Process

Project objectives

The objective of IMCAD is to study and validate the use of novel ICT technologies that could considerably reduce development costs and time-to-market for cockpit application development programmes. IMCAD aims to achieve a 30% improvement in the above-mentioned areas for new cockpit applications. For cockpit upgrades and modifications (that account for the vast majority of this type of development programme) IMCAD is aiming for a 50% improvement. In addition, enhanced and better-integrated definition tools will contribute to a process that will be much more flexible and more swiftly adaptable to changing customer requirements. Such tools promise a standardised and certifiable design process that would ultimately be expected to enhance aviation safety, enabling a more rapid introduction of new technologies in the cockpit.

Description of the work

IMCAD is starting with a study of current and proposed cockpit application development processes, methodology and guidelines. This includes a survey of applicable information technologies and tools. The choice of a suitable formalism will complete the first part of IMCAD. Next, IMCAD will improve, integrate and extend software tools for the graphical and functional part of the development. To achieve this, IMCAD will deal with three main subjects:

1. to define and implement prototype improvements in functional specification tools. The objective is to provide a unified framework for consistent handling of event-driven behaviour and sampling/clock-driven behaviour. Coupling with the graphical tools for pilot interaction will be carefully considered.
2. to define and implement a prototype of improvements in graphical specification means. A major objective is to achieve a reusable and extensible graphical framework. The interconnection between the graphical tools and the functional tools will also be considered from the graphical side.
3. to define, prototype and validate innovative 'early validation' tools for the application designer. This would provide design-time verification of graphical performance of the application on the target hardware. It would also allow design-time feedback on the human factor aspects of the application design.

The improved, integrated and extended tools, and also the guidelines (strategies) will then be tested in a case study. A design team will perform a realistic case, so to allow estimation of the true benefits of the IMCAD methodology and tools. Finally, the guidelines will be updated with the results of the case study. The IMCAD partners operate in the global community of aircraft and avionics development. Dissemination of results, communication with the user community, and active involvement in standardisation and regulation activities will therefore attract considerable attention.

Expected results

- Guidelines for an effective, efficient, and flexible development process for interactive cockpit applications.
- A harmonised set of improved software tools for functional and graphical specification.
- Graphical performance and human factors assessment tools for design-time "early validation".

Title: Improving the Cockpit Application Development Process

Acronym: **IMCAD**

Contract N°: G4RD-CT-2001-00632

Proposal N°: GRD1-2001-40210

Total cost: €3 732 386

EU contribution: €1 866 192

Starting date: 01/01/2002

Duration: 36 months

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Low-Cost Optical Avionics Data Networks

Project objectives

The overall objective of LOADNet is to exploit optical network technologies that have been developed for large-volume commercial markets, such as telecommunications and local area networks, and to apply them in avionic applications. The driver is to improve the affordability of on-board aircraft photonic systems whilst retaining their inherent advantages over electrical interconnect and ensuring their ability to operate in the aircraft environment. Emphasis is also placed on cost-effective through-life support of avionic optical networks, from the development of physical layer design tools through diagnostic and prognostic techniques to repair and maintenance procedures. Finally, the LOADNet project aims to standardise both the physical layer components and devices and the through-life support procedures, in order to drive down further the life-cycle costs of on-board optical networks.

Description of the work

LOADNet is an RTD project that responds to, and is clearly aligned with, the aims and objectives of the 5th Framework Programme *Growth 1999* call, Key Action 'New perspectives in Aeronautics'. LOADNet specifically addresses all the items identified against the application of fibre optics under 1.1.3.- 4.2.4 Systems and equipment:

- The application of fibre optics to cabin utility systems, in the context of polymer fibre component development;
- Passenger services, through the development of multi-mode/single-mode high speed silica fibre packaging for In-Flight Entertainment (IFE) systems and polymer fibre for interconnection to passenger seats;
- Avionic systems – through the modelling of optimised physical layer topologies;
- Development of underlying technologies and procedures for implementation of integrated modular concepts; network modelling within LOADNet has IMA as its core application, however, other applications (e.g. IFE) will also be addressed;
- Application of advanced displays and sensors in cockpit functions, through the development of high speed fibre optic communication networks.

With through-life cost effectiveness being the research driver, LOADNet will place particular emphasis on:

- Selecting COTS optoelectronic network components that will meet functional requirements, and re-packaging them to operate in an aircraft environment;
- Generating a network modelling and design-tool capability;
- Developing critical through-life support techniques and equipment (for both manufacturing and in-service operation);
- Reducing technological risk through network prototyping, evaluation and model validation activities;
- Standardisation of optical network technologies across the aerospace industry.

Expected results

The LOADNet project will deliver standardised physical layer components, and also a physical layer design capability with validated optical component models in conjunction with through-life support procedures. This will be further supported through international standardisation activities.

The standardised outputs from the project will be critical to the future of the aerospace industry, in that they will provide cost-competitive and therefore exploitable solutions that may be used to implement a high-integrity communications infrastructure within the context of future integrated modular avionics architectures.

Title: Low-Cost Optical Avionics Data Networks

Acronym: **LOADNet**

Contract N°: G4RD-CT-2000-00142

Proposal N°: GRD1-1999-10298

Total cost: €6 052 962

EU contribution: €3 212 740

Starting date: 01/04/2000

Duration: 36 months

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Alcatel Fabrisys S.A.	B
DaimlerChrysler AG	D
Framatome Connectors International	F
Institut für Mikrotechnik Mainz GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Sistemas y Redes Telematicas- SIRE S.L.	E
Smiths Industries Aerospace and Defence Systems Ltd.	UK
Universidad Carlos III de Madrid	E
University of Strathclyde	UK

Project objectives

MALVINA project objectives are:

- to standardise the design of light aircraft/helicopter core avionics architecture to allow easy integration of equipment coming from several manufacturers
- to enhance light aircraft/helicopter operational safety by reducing pilot workload (enabled by the use of displays which in turn will allow the use of enhanced man machine interfaces)
- to reduce the cost of aircraft/helicopter ownership and maintenance
- to improve flexibility of evolution and retrofit for the manufacturer and the owner
- to validate this architecture concept
- to reduce weight and power consumption of on-board equipment.

Description of the work

The MALVINA project will be organised in four areas:

Standard open architecture definition: This includes a system requirements consolidation, a review of the existing standards and commercial components, and the selection of the architecture suitable for light aircraft and helicopters with particular attention being paid to safety requirements, ergonomy, certificability and costs of ownership and maintenance. The architecture will be based on a wide-spread automotive data bus, such as CAN or TTP.

Demonstrator implementation: A demonstrator will be implemented to validate the core avionics architecture. The backbone will be developed and existing equipment will be adapted or simulated to plug into it.

Equipment stimulators will be used as support tools for the demonstrator. The integration will be performed with a specifically adapted commercial tool.

Validation: The goal of this phase is to run performance measurement tests on the demonstrator.

Industrial exploitation: Once the standard architecture has been defined, a large dissemination activity is planned: website, publications, participation in exhibitions in 2002/2003, links with other open architecture groups, such as OSEK in the automotive field, AECMA, ARINC, equipment manufacturer associations, general aviation associations, and pilot associations – they will all be met and kept informed.

The success of MALVINA relies on its capability to standardise and disseminate its architecture. In order to spread the standard, no property right may be claimed from the programme's main output, i.e. the standard architecture. Specific items, hardware or software, developed in the project framework may remain the property of the developer, but their functional specification and interface definition will be made public.

A market analysis update, cost evaluation and exploitation plan will ensure the compatibility of the proposed architecture with light aircraft/helicopter economic constraints and assist industrial exploitation.

Expected results

The MALVINA project spans a 24-month period. The first expected results at T0+9 months will be definition of the open architecture and detailed definition of the demonstrator. The second milestone is the mid-term review which will assess the satisfactory progress of the project. The third milestone will be the successful integration of the demonstrator at T0+22 months. Finally, the fourth milestone will be the performance measurement and final report at T0+24 months.

Title: Modular Avionics for Light Vehicles in Aeronautics

Acronym: **MALVINA**

Contract N°: G4RD-CT-2002-00770

Proposal N°: GRD1-2001-40182

Total cost: €2 217 723

EU contribution: €1 108 861

Starting date: 01/06/2002

Duration: 24 months

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IBK- Ingenieurbüro Dr. Kretzschmar	D
Robin Aviation	F

Highly Dissipative Integrated Modular Electronic Packages

Project objectives

Avionics and electronic equipment manufacturers are today faced with technological challenges linked to miniaturisation and the need to cut costs. At the level of electronic equipment, however, improvements in aircraft efficiency can only be obtained through miniaturisation, which will lead to improvements in system performance, weight and volume reductions, energy efficiency and greater reliability. For avionics and equipment manufacturers, miniaturisation is a requirement for survival and competitiveness: it helps save resources and opens up new markets.

The objective of this proposal is to develop highly dissipative 3D modules having the following characteristics :

- minimum size, volume and weight: expected gains are 50% in surface, 50% in volume and 30% in mass when compared with existing function on PCB (Printed Circuit Board);
- highly dissipative capabilities (up to 30W) through the use of integrated Micro Heat Pipes;
- possibility to integrate slices from different technologies (surface mount components on epoxy, chips on alumina substrate, chip on board, RF substrates);
- modularity and interchangeability of the slices in a standardised format;
- the slice are tested as components before integration, no need for KGD (know-good dies);
- increase in reliability (a benefit of 10°C is expected, compared with same 3D set-up without MHP in Airbus conditions 30W).

Description of the work

The enabling technologies for developing highly dissipative 3D package are Micro Heat Pipes and microassembly techniques. Studies on Flat Heat Pipes have been initiated in Europe though a previous BE project named KHIEPCOOL; the same team, together with two new associated partners experienced in micro packaging and 3D structures, plan to extend the HP technology development to 3D miniaturised structures.

The technical programme is divided in six work packages:

WP1. General Technical Analysis. For system specifications, definition of demonstrators, and comparison of existing options.

WP2. Technological Studies. For MHP analysis, module housing analysis and interconnection analysis.

WP3. Demonstrator Design. For thermomechanical demonstrator and functional avionics demonstrator

WP4. Demonstrators Development. For thermomechanical demonstrators manufacturing and functional demonstrator implantation

WP5. Performance Evaluation. For evaluating thermomechanical performances under stress and thermal static performance

WP6. Synthesis. Limits, cost analysis and management

The consortium is made up of transnational organisations including research establishments, international companies and an SME. The complementarity of the different teams is based on the specific non-overlapping areas of activity of individual partners. Five countries are involved with a total of seven partners.

Expected results

The project output will be composed of technological reports, demonstrators for thermomechanical evaluations (mock-up) and a feasability analysis on a GPS integrated receiver. Apart from the standard milestones after each task, a mid term review is planned 18 months from the start to check progress against planned objectives and devise a revised work programme for the next phase of the project.

Title: Highly Dissipative Integrated Modular Electronic Packages

Acronym: **MCUBE**

Contract N°: G4RD-CT- 1999 -00054

Proposal N°: GRD1-1999-10360

Total cost: €4 318 832

EU contribution: €2 290 318

Starting date: 01/04/2000

Duration: 36 months

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Electrovac Fabrikation Elektrotechnischer Spezialartikel GmbH	A
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Universität Stuttgart	D

Magnetostrictive Equipment and Systems for More Electric Aircraft

Project objectives

MESA partners will advance the state of the art in magnetostrictive actuation, secure Europe's technological competence and demonstrate its potential in the development of actuator systems to satisfy the demand for more electric aircraft and improved cabin comfort. The developments of magnetostrictive motors and their supporting controller and amplifier electronics will be guided by the need to reduce power take-up and weight while simplifying maintenance and maintaining (or improving) current levels of aircraft safety and reliability. Direct-drive actuators will contribute to the reduction of noise and vibration. Developments in the United States, Japan and Europe demonstrate the increasing potential of magnetostrictive technologies. Current application development in the aeronautic sector will keep Europe in the running for future markets of all-electric aircraft.

Description of the work

The development and implementation of magnetostrictive motors and actuators for three aeronautical applications will take place over three years. Applications include noise and vibration control for improving cabin comfort, the control of helicopter rotor blades, and aircraft equipment such as control surfaces that using electrically driven actuators in place of hydraulic ones. The work begins with the specification of actuator and electronic requirements. Material studies and simulation work will support the design and development of actuator mechanics together with controller and amplifier electronics. After the manufacturing stage, the hardware and software results will be integrated into complete systems, and then tested both for their intrinsic performance and with respect to the application requirements. The consortium will apply its complementary expertise in fulfilling the technical specifications of the applications, which will be defined and evaluated by the three aeronautic industry partners.

Good communication and a clear management structure will enable the effective transfer of intermediate results to all partners, largely by modern means of communication and data management. Meetings will be held twice yearly to share development results, clarify administrative and organisational issues and to strengthen contacts through intercultural exchanges and presentations of partner laboratories. The partners will hold regular workshops to present technical achievements to the scientific community, with a view to establishing new contacts. Much emphasis will be focused on planning exploitation to benefit the commercially-oriented partners and maximise the European added value, resulting in a Technology Implementation Plan. The MESA consortium supports participation in clusters to increase the exchange of information between projects with related objectives and activities.

Expected results

Three applications of magnetostrictive actuation in aeronautics will lead to proof-of-concept form. Characterised by innovation, the actuator systems will advance Europe's standing and strengthen the SME's and other suppliers. The aerospace partners are well-placed to exploit the results, many of which are expected to be patentable. Reports will document the advances in development and performance. Workshops and publications will communicate the new technology to the scientific community.

Title: Magnetostrictive Equipment and Systems for More Electric Aircraft

Acronym: **MESA**

Contract N°: G4RD-CT-1999-00035

Proposal N°: GRD1-1999-10550

Total cost: €2 512 817

EU contribution: €1 796 204

Starting date: 01/02/2000

Duration: 36 months

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Università Degli Studi di Napoli ‘Federico II’	I
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ZF Luftfahrttechnik GmbH	D

Multimedia Optical-Plastic Technologies for In-Flight Entertainment

Project objectives

The objective of the MOTIFES project is to research and develop the key enabling technologies of high-bandwidth plastic optical fibre (POF) and the new emerging consumer information technology standard, IEEE 1394 for the benefit of Europe's aeronautics programme. This combination will allow the installation in civil aircraft of cheap, robust and high-performance plastic fibre networks that will form the basis of future cabin utility systems for a variety of passenger on-demand services.

Description of the work

1. To design and develop appropriate POF jacketing that enables SI-POF, GI-POF and fluorinated GI-POF to comply with both aviation cabling and IEEE 1394 standards.
2. To research and develop and life-test 1394 POF compatible 650 nm VCSELs operating between -20oC and 70oC at wavelengths between 640 and 660 nm that can meet a mean launched power of -8 to -2 dB into a standard SI-POF.
3. To fabricate 650 nm VCSEL duplex high-speed transceivers, and demonstrate their compliance to IEEE P1394.b at S800 and S1600 over a 100 m PMMA GI-POF cable and a 100 m fluorinated GI-POF cable. Compliance will also be demonstrated with avionic specifications (RTCA/DO-0160C, Radio Technical Commission for Aeronautics, environmental conditions and test procedures for airborne equipment).
4. To fabricate IEEE P1394.b compatible 850 nm VCSEL duplex transceivers and demonstrate their compliance to IEEE P1394.b at S800 and S1600 over a 100 m fluorinated GI-POF cable and RTCA/DO-0160C.
5. To fabricate 1394-to-PCI (peripheral component interconnect) adapter boards utilising the VCSEL transceivers and POF receptacles, thereby demonstrating and evaluating a point-to-point link that will operate at S800 over 100 m of GI-POF.
6. To assess how future IEEE 1394 and POF data networks may best be implemented in civil aircraft.

Expected results

The MOTIFES project will demonstrate:

1. a European manufacturing source of high-speed PMMA and fluorinated POF cable compatible with avionic standards. This cable will form the basis of future digital in-cabin utility systems.
2. a European competence in the fabrication of visible VCSELs.
3. a European competence in IEEE 1394 POF-compatible products. These milestones will all contribute to the competitive growth of the European aerospace industry.

Title: Multimedia Optical-Plastic Technologies for In-Flight Entertainment

Acronym: **MOTIFES**

Contract N°: G4RD-CT-2001-00583

Proposal N°: GRD1-2000-25589

Total cost: €3 041 935

EU contribution: €1 697 520

Starting date: 01/12/2001

Duration: 30 months

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National Microelectronics Research Centre	IRL
Nexans France	F
THALES Avionics S.A.	F
THALES Research & Technology	F
University of Surrey, Department of Physics	UK

Network Architectures and Technologies for Airborne Communication of Internet High-Bandwidth Applications

Project objectives

NATACHA focuses on an airborne system to provide a new generation of mobile real-time Internet communication to users on board aircraft in-flight. This communication system will interface to bi-directional high-bandwidth satellite data links.

At the moment, on-board communication means for air travellers are still very limited. This also applies to the crew data communication. Demonstrations of experimental airline systems today use terrestrial telephony networks during flight over continents, or narrow-and satellite links (e.g. Inmarsat) over water. These communication means do not support the high data rate needed for mobile information technology applications. This major gap will be filled by systems based on the results of the NATACHA project, which will provide a combination of true aircraft mobility and true broadband. The novel airborne platform, combined with the broadband satellite data link, will support a new mobile Internet facility for passenger and crew communication.

Description of the work

The NATACHA project work is broken down into five major technical work packages and one administrative activity. The work packages, each managed by a consortium partner, are further broken down into tasks. The administrative activity covers the management and quality assurance tasks and lasts for the full length of the programme. The work packages contain:

1. Standards and requirements for cockpit, cabin crew and passenger information services are established, and general constraints identified. An overall system architecture is defined with an outline of Intranet and communication interfaces. Study Item: air-ground communication at high latitudes.
2. A design concept of the airborne intranet subsystem is developed, including example information services. Major items are the distribution of services and the network servers. Study item: on-board use of Internet protocol.
3. The testbed applications of cabin, maintenance crew and passenger broadband services are specified and developed.
4. The testbed system development and integration contains the following tasks: Definition of tests and demonstrations; airborne Intranet specification and development; development of specific test tools; realisation of the experimental communication satellite link; integration and verification of testbed hardware and application software; development of test tools; validation of the testbed functions; tests definition for all functional and performance demonstrations.
5. Testing for performance measurement and assessment of the example application services. The major assessment activity is a workshop with airlines, service providers and other users.

The dissemination of the NATACHA results and the technology implementation plan are tasks included in this work package.

Expected results

The overall objective of the NATACHA project is to design, build and test a representative mobile airborne communication system with bi-directional high-bandwidth capability in order to generate know-how on feasibility, performance, constraints and acceptance of such systems.

This applies specifically to the following subjects:

1. Network servers and architecture of an aircraft Intranet;
2. Air-to-ground/ground-to-air broad-band communication via satellite data links;
3. On-board service applications for aircraft crew and passengers.

Title: Network Architecture and Technologies for Airborne Communication of Internet High-Bandwith Applications

Acronym: **NATACHA**

Contract N°: G4RD-CT-2002-00771

Proposal N°: GRD1-2001-40196

Total cost: €4 891 960

EU contribution: €2 498 649

Starting date: 01/05/2002

Duration: 27 months

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Astrium GmbH, Space Infrastructure	D
Astrium	F
Cebenetwork Gesellschaft für Computersimulation und Breitbandkommunikation GmbH	D
Centre National d'Etudes Spatiales (CNES)	F
Giunti Multimedia SRL	I
Société Internationale de Télécommunications Aéronautiques (SITA)	CH
THALES Avionics S.A.	F
Universita' di Roma 'La Sapienza'	I
Xplore Technologies International OY	FIN

Three Large-Display Cockpit Approach

Project objectives

Safety is a highly important feature in avionics systems, hence the idea of pursuing normal airplane operation with information presented on a failed display is an extremely innovative concept. The NEWSCREEN objective is to use that idea to demonstrate the feasibility of a three-displays cockpit.

With the improvement of flat panel displays – and particularly LCDs – it is possible to develop displays that are double in size or more. Thus a cockpit would need only three such large displays (8x10 square inches or 8x12 square inches) to present the same information as the six displays needed today.

The main purpose of NEWSCREEN is to demonstrate the feasibility, certifiability, dispatchability and cost advantages of the new displays. Moreover, a display area as large as this will open the path to greater flexibility for presenting information, and will provide opportunities for windowing and reconfiguration of new images from systems such as GCAS, taxiing, surveillance, Jeppsen maps, Open World, SVS, and 3-D.

The suppression of forced air is also an innovative aspect of the NEWSCREEN proposal, and there are other innovations, like integrated drivers or chip-on-glass, for higher reliability of avionics.

Description of the work

The essential efforts proposed will relate to:

1. **System architecture.** Different electronics partitioning will be investigated (dumb or smart displays) to select the one that is most cost-effective. This will be done in co-operation with the European integrated modular avionics community (European programme PAMELA and VICTORIA).
2. **Certifiability.** A certifiability plan will be established at the beginning of the programme, to identify the objectives and means of compliance. An advisory board with certification specialists (JAA and/or country authorities) will be set to check the certifiability plan and its application.
3. **End-user acceptability.** Pilots from airlines or certification authorities will participate in simulator evaluations in order to adapt the images and system to their needs. Air framers and airlines will be involved through an advisory board, most probably from an existing Integrated Modular Avionics (IMA) European consortium (PAMELA, VICTORIA).
4. **Man-machine interface (MMI).** To present standard information on a failed display (failed lines or pixels, for example) it is necessary to adapt the symbols and fonts (size of reticules/alphanumerics, new positioning). The intention is to simulate different options for each possible display degradation. The objective is to identify solutions that are acceptable both from a certification and end-user point of view. In order to validate technical feasibility, cost impact and image quality, a large display mock-up (8x10 square inches) will be designed and installed in a fixed-base simulator. Standard symbols will be adapted to the large display, taking into account the results of the MMI work. The consortium intends to build a cockpit and display design that does not require forced air (cooling system based on natural convection), but will have a display reliability over 100 000 operating hours (design goal).

The NEWSCREEN programme is organised around eight major workpackages in two phases. The first phase, lasting one year, relates to system architectures, certifiability and end-user acceptability. The second phase will cover to the development of a large display, using the results from the first phase. There will also be an evaluation of availability, reliability, maintainability, and cost impacts.

Expected results

Milestones:

- System design and certifiability plan: 6 months;

- Mid-term assessment report and review at the middle of the programme: 18 months;
- Final meeting and reports at the end of the programme: 36 months.

Expected quantified results of NEWSCREEN:

- 20% to 40% reduction of direct cost (Smart or Dumb architecture, i.e. the display resembles that of a PC or monitor);
- 20% reduction in maintenance costs;
- suppression of forced air at the cockpit level (Dumb architecture) and demonstration of feasibility of a large display.

Title: Three Large-Display Cockpit Approach

Acronym: **NEWSCREEN**

Contract N°: G4RD-CT-2001-00503

Proposal N°: GRD1-2000-25298

Total cost: €6 047 291

EU contribution: €3 023 642

Starting date: 01/04/2001

Duration: 36 months

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Interuniversity Microelectronics Centre	B
N.D.F. Special Light Products B.V.	NL
National Aerospace Laboratory (NLR)	NL
Thomson Liquid Crystal Display S.A.	F
Thomson-CSF	F
VDO Luftfahrtgeräte Werk GmbH	D

Prospective Analysis of Modular Electronic Integration in Airborne Systems

Project objectives

New crew and passenger services place increasing demand on the electronics resources of aircraft. They make extensive use of multimedia/networking techniques and require increased connectivity between aircraft and ground information networks. On the other hand, the rapid advances in information and communications technology bring new potential to improve performance and reduce costs, even though they also present new challenges for the longevity and incremental certification of airborne electronics. The approach through the concept of Integrated Modular Avionics, developed in the recent years, reduces the number and type of hardware items, and facilitates the introduction of new functions through standardised processing platforms that support several independent software applications. But the technologies used in this field have generally been developed specifically for flight-critical avionics.

The objectives of PAMELA are to build a framework for the future implementation of Integrated Modular Aircraft Electronics in the full range of cockpit avionics and crew/passengers service and communications utilities, keeping a view on long-term technological trends. PAMELA will assess those technologies, define concepts for use on board aircraft, and prepare standards and methods that will be able to cope with several technology upgrades. In this way, enabling improvements in product capability and flexibility at reduced cost.

Description of the work

The PAMELA project focuses primarily on technologies and tools that will have to be shared across different domains of aircraft electronics and with different industrial bodies. This will require standardisation, for example of the following:

- for building technologies: high-throughput databus to be derived from LAN/WAN technologies, low-cost databus to be derived from automotive or industrial engineering; airborne mass data storage devices; low-cost, low-weight electronic packaging; scalable application programming interface (API); secured inter-network gateways;
- for methods and implementation: system resource management; system communication management; system integration/verification/validation; incremental certification.

The work packages are organised by type of activity: consolidation of requirements; technology assessment; selection and concept elaboration; specification and prototyping of methods and means; preparation of standards; technology experiments. The PAMELA team is made up of 14 partners from six European countries. The project brings together the different actors for future implementation as well as the skills needed to investigate the most recent technologies. The main European aircraft electronics equipment suppliers are participating in the evaluation of technologies and tools and the preparation of new standards. They will be assisted by three SMEs and two universities. The main Airbus partners will define the requirements and concepts for applications. The analysis will be extended to regional aircraft and helicopters (Westland Helicopters).

Expected results

From a technical perspective:

The definition of the most appropriate future aircraft technologies:

- high-throughput databus
- low-cost databus
- mass data storage
- software.

The definition of the electronics concepts for each selected technology

- how to use it,
- impact of constraints (reliability, safety, maintainability).

From an industrial perspective:

- Elaboration of roadmap for introducing new technologies

- Preparation of new open standards
- Definition of processes, tools and means to enable application of new technology

Most outputs will be used by the essential VICTORIA project.

Title: Prospective Analysis of Modular Electronic Integration in Airborne Systems

Acronym: **PAMELA**

Contract N°: G4RD-CT-1999-00086

Proposal N°: GRD1-1999-10647

Total cost: €4 756 047

EU contribution: €2 443 473

Starting date: 01/01/2000

Duration: 24 months

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Airbus France S.A.S.	F
Airbus UK Ltd.	UK
BAE SYSTEMS Avionics Ltd.	UK
Diehl Avionik Systeme GmbH Überlingen	D
Gesellschaft für Angewandte Informatik und Mikroelektronik GmbH	D
Institut für Technische Informatik, Technische Universität Wien	A
Liebherr Aerospace Lindebergh GmbH	D
Sinters	F
Smiths Aerospace Ltd.	UK
Terma Elektronik A/S	DK
University of York	UK
Westland Helicopters Ltd.	UK

Project objectives

The overall project objective is the enhancement of aircraft fluid system reliability, performance and safety through a third-generation digital fluid management system that uses smart distributed components. A third-generation fluid system will be defined, and demonstrations made of the concept, improved performance, reliability and safety. The predicted reductions in operating costs will be validated. SmartFuel will be validated through demonstrations of the new fuel system design, including a number of smart components, in fuel test rigs.

The overall objectives for SmartFuel are: Definition of the fuel computer; digitising components and sensors; comparative analysis of bus-systems; definition of a fail-safe communication concept; definition of a unique central processing unit (CPU) for all components; demonstration of cost and weight savings; trial installation/testing in test rigs; transferability to other airborne fluid systems (hydraulics, grey water).

Description of the work

The SmartFuel project is split into six work packages, with the tasks as detailed below.

WP1. System Definition. The basic requirements for the research and development of smart distributed fuel system components and fuel computers will be prepared.

WP2. Protocol. A protocol for the intercommunication of the SmartFuel system components will be prepared. Depending on the databus system selection, this protocol also has to be adapted to the needs of airborne systems.

WP3. Smart Components. The task of this work package is to define the requirements for smart components, and validate their performance, by using off-the-shelf units married with a common core CPU, which has also to be defined and validated under this task to make each component bus compatible.

WP4. Computer. Preparation of the hardware and software requirements for the fuel computers, which will provide the control logic for SmartFuel to perform the management modes and contents-gauging functions as specified in WP1.

WP5. Integration and Validation. Installation of the SmartFuel system components in test rigs. Comprehensive testing and validation of the individual equipment functions. Testing and validation of the intercommunication and fuel management modes. Preparation of test reports and recommendations for further improvements and certification.

WP6. Management. Meetings of the Project Coordinating Committee; preparation of a plan for exploitation.

Expected results

Improvement of the reliability and availability of airborne liquid management systems. Improvement of their performance and safety through the introduction of industrial fault-tolerant and redundant bus architectures into aircraft systems. Achievement of weight reductions in aircraft through lighter wiring harness. Improvement of the overall electromagnetic compatibility by avoiding the bottlenecks usually formed by complex centralised computers. Cost-reduction by using common electronic circuits on all the smart distributed components.

Title: Third-Generation Digital Fluid Management System

Acronym: **SmartFuel**

Contract N°: G4RD-CT-2002-00769

Proposal N°: GRD1-2001-40175

Total cost: €4 219 640

EU contribution: €2 488 110

Starting date: 01/04/2002

Duration: 36 months

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Dornier GmbH	D
Eurocopter Deutschland GmbH	D
Secondo Mona S.p.A.	I
TRW Systemes Aeronautiques SA	F
Universidad Computense de Madrid	E
Universidad de Alcala	E
Vysoké Uceni Technické V BRNE, Fakulta Electrotechniky a Informatiky (BRNO University of Technology, Faculty of Electrical Engineering and Computer Science)	CZ

Tilt-Rotor Integrated Drive System Development

Project objectives

The main object of the present project is to investigate and make detailed tests on the advantages of a transmission of a new design concept of the European tilt rotor (ERICA). It aims especially to carry out the following tasks:

- Improve existing analytical tools to predict dynamic phenomena in a non-conventional integrated drive system that includes the main transmission and all mechanisms to allow the rotation of nacelles and of the outer part of the aircraft wing.
- Examine the tools to maintain necessary design efficiency while keeping both cost and weight as low as possible, by using new-generation materials, emerging technologies in tooth design/architecture, and advanced manufacturing processes.
- Define the requirements of a HUMS (Health and Usage Monitoring System) for the drive system, which should be compatible in weight, reliability and cost requirements with the most advanced combination of sensor and new algorithms for life prediction.
- Cross-correlation of data from a test series on a full-scale item to verify all lubrication issues.

Description of the work

The scientific and technical work plan of the project, together with its expected main outputs, starting from requirements that comply with the ERICA advanced new generation tilt rotor specification, are summarised as follows:

- definition and preparation of the general requirements and basic design criteria;
- design the trade-off of the complete drive system, including nacelles and wing tilting mechanisms, with the aim to define the detailed specification and requirements for the final configuration of the integrated drive system;
- technological assessment and definition of general requirements for an advanced HUMS, to increase safety and reduce direct operating costs;
- detailed design of the components, including the preparation of all necessary drawings and accompanying documentation;
- manufacture and assembly of the drive system in order to complete the technological assessment of the innovative technologies adopted, and to test compliance with the design requirements in terms of lubrication capabilities and dynamic behaviour of selected/representative components;
- planning and execution of a complete series of tests, including critical analysis of the acquired data;
- final recommendations for a future flight demonstrator.

Expected results

The project will provide invaluable experience in the technologies for the design and manufacture of gearbox casing using advanced aluminium or magnesium alloys with advanced casting processes, or composite materials, to reduce cost and weight. The gear arrangement will be investigated in depth, because the weight reduction potential is inherent in the transmission architecture. The use of face gears instead of conventional bevel gears will also be investigated. HUMS concepts will be integrated in the gearbox layout, as this is the system that will allow the application of new design criteria to dimension gears and bearings. Shaft materials will be investigated for both the main rotor (where titanium could be used instead of steel) and for the interconnecting shafts (where composite materials could be used instead of aluminium). Composite materials will be also investigated on the housing side, since a significant weight reduction there could be achieved. The use of sophisticated lubrication fluids to improve gearbox performance will be investigated. Finally, the new manufacturing technologies will be tested to validate them with respect to the lubrication capabilities of the gearbox. These results are regarded as critical.

Title: Tilt-Rotor Integrated Drive System Development

Acronym: **TRISYD**

Contract N°: G4RD-CT-2002-00779

Proposal N°: GRD1-2001-40125

Total cost: €9 595 711

EU contribution: €4 797 852

Starting date: 01/05/2002

Duration: 42 months

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IMA Materialforschung und Anwendungstechnik GmbH	D
MECAER – Meccanica Aeronautica S.p.A.	I
SENER Ingenieria y Sistemas S.A.	E
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Subcontratacion Proyectos Aeronauticos, S.A	E
Westland Helicopters Ltd.	UK
ZF Luftfahrttechnik GmbH	D

1.2. Aircraft Efficiency

Configurational and interdisciplinary aspects

Active Aeroelastic Aircraft Structures

Project objectives

Novel design concepts will be developed and demonstrated to improve aircraft efficiency and performance by exploiting aerodynamic energy to deform the airframe in a favourable way. Negative impacts of aeroelasticity on aircraft performance will be identified and quantified (in terms of aerodynamics, weight and complexity of the structure, actuation systems power demand, operating and procurement costs, and aeroelastic 'design drivers' for the aircraft configuration). The feasibility and efficiency of new smart materials for active deformations of aerodynamic surfaces will be evaluated, based on structural characteristics of different classes of airplane, ranging from small and large unmanned aircraft to wide-bodied transport aircraft. Selected concepts on aeroelastic wind tunnel models will be verified, based on existing hardware as far as possible. One aeroelastic wind tunnel model will be transformed into a modular, multi-function aeroelastic wind tunnel model for future research.

Description of the work

The impacts of aeroelasticity on conventional aircraft performance (aerodynamics, structure, power demand, stability, handling, flight control system, costs) will be assessed, based on published data, partners' experience, and interviews with external experts. Design-drivers and sensitivities from aeroelasticity for aircraft configuration (geometry, stabiliser and control surface arrangement) and structural design (aeroelastic effectiveness, loads, flutter) will be identified. 'Active Aeroelastic' design concepts will be developed to improve aircraft efficiency, flight stability and agility, and reduce structural weight, complexity, and actuation systems power demand. Analytical design of three categories of active aeroelastic concepts:

1. novel control surface concepts to deform main aerodynamic surfaces via resultant external load re-distributions;
2. active control of high aeroelastic effectiveness at all speeds via variable attachment stiffness of all-movable aerodynamic surfaces (smaller and lighter stabiliser surfaces with less parasite drag);
3. application of 'smart materials' and active structural elements with variable stiffness to adjust the wing shape and improve the aerodynamic effectiveness.

There will be an analytical evaluation of expected performance improvements (aerodynamic efficiency, structural weight and complexity, design loads, costs) for different classes and types of aircraft. This will include experimental validation of selected concepts on aeroelastic wind tunnel models, primarily based on existing models and the modification of one model into a unique modular and multi-functional aeroelastic research wind tunnel model. It is intended to assess the current and projected future potential of smart materials for adaptive shape control of aerodynamic surfaces. The project findings will be disseminated to the European Aerospace industry, research establishments and universities to stimulate application of 'Active Aeroelastic Aircraft Structures' concepts. A database will be created, along with publications and presentations made at appropriate forums, on the Internet and in educational courses.

Expected results

- Better knowledge of the magnitude of impacts from aeroelasticity on aircraft efficiency and performance.
- Summary and database for new aircraft design concepts with adaptive shape control, based on aeroelastic deformations.
- Quantification of expected improvements and benefits.
- Improvements for analytical aircraft design methods and tools.
- Stimulation of new applications of 'smart' materials outside Aeronautics.

Creation of a European Aeroelastic research wind tunnel model.

Title: Active Aeroelastic Aircraft Structures

Acronym: **3AS**

Contract N°: G4RD-CT-2002-00679

Proposal N°: GRD1-2001-40122

Total cost: €6 334 772

EU contribution: €3 806 661

Starting date: 01/04/2002

Duration: 36 months

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Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Gamesa Desarrollos Aeronauticos	E
Instituto Nacional de Técnica Aeroespacial (INTA)	E
Instituto Superior Técnico (IST) Lisboa	P
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
Politecnico di Milano	I
Saab AB	S
Technion Research and Development Foundation Ltd.	IL
Victoria University of Manchester	UK
Vyzkumny a Zkusebni Letecky Ustav, A.S. (VZLU)	CZ

Aeroelastic Design of Turbine Blades II

Project objectives

The overall aims of the ADTurBII project are to acquire good quality experimental data from a series of experiments that investigate different aspects of vibration response in turbine blading. These results will then be used to increase understanding of the phenomena, and in particular to validate prediction methods used in the design of rotating turbomachinery components. Subjects under investigation are:

- Low Engine Order (LEO) aerodynamic forcing – influence on forced response;
- mistune effects on dynamic characteristics, especially vibration amplitude scatter;
- damping (mechanical and aerodynamic) –minimisation of vibration amplitudes.

By increasing the accuracy of design tools in this way, it is expected that significant reductions in High Cycle Fatigue (HCF) problems will be achieved, resulting in improved safety and reliability, together with reduced costs of developing turbomachinery. The cost of ownership will thereby be reduced for the customer. In addition, the project should allow the removal of unnecessary constraints on aerodynamic design which affect engine performance.

Description of the work

The subjects under investigation are:

- **Low Engine Order (LEO) excitation**
  This accounts for half the vibration problems experienced in turbomachinery blading, and is caused by non-uniformities in flow around the annulus due to differences in nominally identical vanes, burners etc.
- **Influence of mistune/damping on vibration amplitude**
  Blade-to-blade variations in frequency, mode-shape, damping and aerodynamics are the cause of a large amplitude scatter (up to 10:1). It is crucial to be able to predict not just typical but maximum amplitudes, as it would normally be the maximum amplitude blade that could fail in high-cycle fatigue (HCF).

Both of these subjects have a common underlying theme, i.e. examining the effects of non-uniformities.

It is intended to explore these subjects by carrying out a series of experiments on the same heavily instrumented, continuous-flow rig as for ADTurB, but with a new, more flexible rotor, investigating vane flow variation and blade response.

In addition, mechanical and aerodynamic mistuning and damping experiments will be performed on separate simplified (mostly rotating) rigs, to be developed as part of the project.

Expected results

Removal of some of the uncertainty in vibration amplitude predictions, specifically by:

- quantifying the relationship between response and geometrical or environmental variation to allow predictions to be made of LEO resonant amplitudes and formulate design rules to limit them;
- validating / improving the tools available for predicting maximum blade amplitude, either in a particular assembly or in a whole population;
- Creation of a secure database of experimental data and related predictions, to allow future correlations to be made.

Title: Aeroelastic Design of Turbine Blades II

Acronym: **ADTurBII**

Contract N°: G4RD-CT-2000-00189

Proposal N°: GRD1-1999-10258

Total cost: €5 511 476

EU contribution: €3 003 221

Starting date: 01/05/2000

Duration: 48 months

Coordinator: ROLLS-ROYCE plc.
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Partners (name, country):

Alstom (Switzerland) Ltd.	CH
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Ecole Centrale de Lyon	F
Ecole Polytechnique Fédérale de Lausanne	CH
Fiat Avio S.p.A.	I
Imperial College of Science Technology and Medicine London	UK
Industria de Turbo Propulsores S.A.	E
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
MTU Aero Engines GmbH	D
Office National d’Etudes et de Recherches Aérospatiales (ONERA)	F
Rolls-Royce Deutschland Ltd. & Co KG	D
SNECMA Moteurs	F
Turbomeca S.A.	F
Università Degli Studi di Napoli ‘Federico II’	I
University of Oxford	UK

Civil UAV Application and Economic Effectiveness of Potential Configuration Solutions

Project objectives

The main objectives are to:

- identify civil UAV applications;
- indicate critical technologies;
- improve on the present state of the art;
- define cost-effective safe civil UAV configurations which could be candidate solutions for the identified applications and also meet the performance design goals;
- develop a costing model for civil UAVs which would include all parameters for the Total Operating Cost of the various civil UAVs, and would enable comparison of various configurations as well as economic feasibility analysis;
- give the industry a lead for design and production of civil UAVs and shorten the time-to-market.

CAPECON's objective is to bring forth reliable comparisons of different configurations. It will synthesise the identification, configuration design and cost-appraisal methods for critical technology aimed at the design of civil UAVs. The expected result will be the definition of possible civil UAV configurations that could be ready for further development. The interaction between operational requirements and configurations will influence the required critical technologies necessary to ensure safe and cost-effective performance.

Description of the work

The work is organised in nine work packages.

WP1. Management. The management plan is determined by budget allocation and technical effort. The technical effort will be driven by:

- monitoring of resources that will be critical to the technical success of the project;
- determination and communication of the technical process to be used on the project;
- monitoring the technical activities throughout the project life-cycle: (Schedules, Milestones, Coordination, Deliverables);
- determination of the technical parameters and thresholds for decision-making.

WP2. Applications Survey and Evaluation. Investigation and analysis of the possible civil applications of different foreseeable configurations of system based on UAVs.

WP3. Requirements Definition. Definition of the requirements of the different foreseeable civil UAV configurations according to application needs.

WP4. HALE UAV Technologies and Configurations. This is a two-phase work package: Technologies Investigation and Configurations Preliminary Design. The synthesis of three different conceptual configurations will be realised and serve as an input for WP 8.

WP5. MALE UAV Technologies and Configurations. Identification of technologies and potential configurations in the segment of MALE UAVs. The most promising configurations will be analysed more in detail. The synthesis of these configurations will be realised and will serve as an input for WP 8.

WP6. Rotary-Wing UAV Technologies and Configurations. Identification of technologies and potential configurations in the segment of Rotary UAVs. The study will consider both conventional and unconventional Rotary UAV configurations. The most promising configurations will be analysed in more detail. The synthesis of these configurations will be realised and will serve as an input for WP 8.

WP7. Cost Evaluation

WP7.1 – Cost Models Development and calibration – preparation of Cost Models

WP7.2– Configurations cost estimation – of HALE MALE and Rotary configurations (WP4, WP5 and WP6).

WP8. Configurations Evaluation. Summary of configurations assessments made during the design process in terms of suitability for user needs, to make recommendations for future uses of civil UAVs, and to propose directions for next phase activities (CTP and TP).

WP9. Dissemination and Exploitation. Dissemination of information and exploitation of the results of the CAPECON study.

Expected results

The first attempt to assemble the efforts of industry, universities and research centres in a single approach to define the specific civil UAVs which would be dedicated to the solution of quite a number of problems for which manned aircraft cannot be used efficiently.

Definition of cost-effective advanced High/Medium-Altitude Long-Endurance (HALE / MALE) and Vertical Take-Off and Landing (VTOL/rotary) configurations based on the perceived market drivers, while meeting the safety requirements.
An opportunity for Europe to define the European civil UAV market, to pave the way and be the trendsetters.

Title: Civil UAV Application and Economic Effectiveness of Potential Configuration Solutions

Acronym: **CAPECON**

Contract N°: G4RD-CT-1999-00172

Proposal N°: GRD1-2001-40162

Total cost: €5 136 539

EU contribution: €2 899 992

Starting date: 01/05/2002

Duration: 30 months

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Carlo Gavazzi Space S.p.A.	I
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
EADS SYSTEMS Services & Telecom	F
Eurocopter S.A.	F
Eurocopter Deutschland Gmbh	D
Institute Nacional de Tecnica Aeroespacial – (INTA)	E
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Politechnika Warszawska (Warsaw University of Technology)	PL
Politecnico di Torino	I
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Swedish Space Corporation	S
Tadiran Electronic Systems Ltd.	IL
Tadiran Spectralink Ltd.	IL
Technion – Israel Institute of Technology	IL
Universita Degli Studi di Bologna	I
Universita Degli Studi di Lecce	I
Università Degli Studi di Napoli 'Federico II'	I

Liquid Hydrogen-Fuelled Aircraft – System Analysis

Project objectives

Liquid Hydrogen is the only known fuel suitable for production from renewable energy sources that offers extremely low emissions (zero CO_2, very low NO_x). Using hydrogen can eliminate the dependency of aviation upon dwindling crude oil resources, and eliminate (or at least drastically reduce) the contribution of aviation to the anthropogenic greenhouse effect. The use of Liquid Hydrogen could therefore allow aviation to grow at sustainably high rates (typically 4% – 5% per year). The project will help to achieve a time advantage for the European industry and its partners to master the technology. The project will provide a comprehensive analysis of the complex interrelated aspects as a basis for overall judgement. It will investigate feasibility, safety, and environmental compatibility of the fuel and produce technical solutions and tools. It will indicate strategies for Europe to lead a smooth worldwide transition to the new fuel.

Description of the work

The project includes the assessment of all aspects relevant to the formation of an overall judgement and the definition of technical concepts for implementation:

- Practical solutions (configurations) will be identified for all categories of commercial aircraft, from business jets to A380-type very large long-range aircraft, and their performance and fuel efficiency will be compared to those of conventional kerosene aircraft. Unconventional concepts will be studied as an alternative and their advantages quantified.
- The architecture of a representative fuel system will be defined and the system will be sized. Outline requirements for components will be established, design principles/availability of such components will be reviewed. A hydrogen-specific Fire Protection System will be defined.
- A computer model will be developed for the functional simulation of fuel systems. A parametric method for estimating weight will be prepared.
- Ways to create synergies of the Liquid Hydrogen system with other aircraft systems will screened. Engine concepts (both minimum change and unconventional) will be defined, with emphasis on minimising NO_x.
- Airport infrastructure for fuel production and distribution will be considered. Ground and flight operations will be analysed.
- Aircraft specific safety aspects (e.g. bird strike, turbine disk failure) will be considered, and taken into account when assessing aircraft concepts.
- Environmental compatibility (atmospheric effects – condensation trails, Life Cycle Analysis) will be assessed.
- Transition scenarios, global and regional (with Sweden as leading region), will be developed and quantified. The advantages and disadvantages of using hydrogen slush in place of Liquid Hydrogen will be quantified.

There are 35 highly-qualified partners from 11 European countries, representing industry, research establishments and academia. The project will profit from experience gained in space technology and from work done for ground transportation during the past decade.

Expected results

The project will provide a comprehensive analysis and discussion of the complex and interrelated aspects of a changeover to Liquid Hydrogen. It will produce concepts for technical solutions (aircraft configurations, system architectures), tools, and quantitative results. It will clarify compatibility with society (safety, infrastructure) and environment. It will identify technical challenges requiring further dedicated R&D. It will indicate strategies for Europe to exploit the new technologies.

Title: Liquid Hydrogen-Fuelled Aircraft – System Analysis

Acronym: **CRYOPLANE**
Contract N°: G4RD-CT-2000-00192
Proposal N°: GRD1-1999-10014
Total cost: €4 473 595
EU contribution: €2 817 848
Starting date: 01/04/2000
Duration: 24 months

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Partners (name, country):

Advanced Products N.V.	B
Airbus España S.L.	E
Airbus France S.A.S.	F
Airbus UK Ltd.	UK
Alenia Aeronautica S.p.A.	I
Aristotle University of Thessaloniki	EL
Bundesanstalt für Materialforschung und Materialprüfung	D
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Commission of the European Communities, Ispra Site (J.R.C)	B
Cranfield University	UK
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Diehl Avionik Systeme GmbH	D
Fachhochschule Aachen	D
Fairchild Dornier GmbH	D
Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V.	D
Grimm Aerosol Technik GmbH & Co. KG	D
Hydrogen Technology and Test Center	D
L'Air Liquide S.A.	F
Linde AG	D
MI Developments Austria Space Technology	A
MTU Motoren- und Turbinen-Union München GmbH	D
Secondo Mona S.p.A.	I
Shell Hydrogen B.V.	NL
SNECMA Moteurs	F
Swedish Defence Research Agency (FOI)	S
Technical University Berlin	D
Technical University Delft	NL
Technical University Hamburg	D
Technical University München	D
THALES Avionics S.A.	F
Universidad Politécnica de Madrid	E
University of Oslo	NO

Rotorcraft Handling, Interactions and Loads Prediction

Project objectives

The RHILP project is focused on critical Tilt-Rotor (T/R) flight technologies. The prime objective is to study specific aspects of T/R aeromechanics and flight characteristics that are considered to be of the highest importance before designing and testing a flying demonstrator:

- Handling Qualities: Current helicopter and airplane design standards are either inadequate for, or not well adapted to, the Tilt-Rotor concept.
- Aerodynamics: The combination of wing with the side-by-side rotors generates strong aerodynamic interactions when flying at low speeds in helicopter mode.
- Structural Transient Loads: During manoeuvring, the large rotors can generate high transient loads that create obstacles for the design of airframe and dynamic components.

In addition to reducing risk for the development of a Tilt-Rotor demonstrator, it is expected that RHILP will also contribute positively to future European airworthiness regulations, as well as to active helicopter technology in general.

Description of the work

The RHILP work programme comprises four main technical workpackages (WPs).

WP1. Handling Qualities Criteria consists in reviewing the existing helicopter and airplane handling qualities standards, and then defining criteria which could be applied to the design of a Tilt-Rotor civil transport. The validation of these criteria is being supported by piloted simulations in the HELIFLIGHT facility of the University of Liverpool.

WP2. Hover and Low-Speed Aerodynamics will analyse and model the aerodynamic interaction phenomena which can affect Tilt-Rotor controllability and/or performance at low speed. The aerodynamic database will be obtained through testing a powered Tilt-Rotor model in the Eurocopter wind tunnel.

WP3. Structural Load Alleviation consists in identifying the flight conditions that may produce large transient loads and then to propose active control solutions for Tilt-Rotor Structural Load Alleviation (SLA).

WP4. Piloted Simulation plans to use piloted simulation to validate the models developed in WP2 and WP3 and to validate further the criteria for handling qualities developed in WP1. The trials will be conducted in the SPHERE facility of Eurocopter, a fixed-base simulator located in an 8 m-diameter dome.

Expected results

- A Handling Qualities Design Guide for the development of a future European Tilt-Rotor demonstrator and in particular of its flight control system. It will also constitute a useful reference in preparation of future European rotorcraft airworthiness regulations.
- Physical models for the prediction and simulation of Tilt-Rotor aerodynamic interactions
- Active control solutions for Tilt-Rotor load alleviation during manoeuvres

Title: Rotorcraft Handling, Interactions and Loads Prediction

Acronym: **RHILP**

Contract N°: G4RD-CT-2000-00208

Proposal N°: GRD1-1999-10348

Total cost: €2 280 056

EU contribution: €1 242 906

Starting date: 01/03/2000

Duration: 36 months

Coordinator: EUROCOPTER S.A.
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Partners (name, country):

Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Eurocopter Deutschland GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
University of Liverpool	UK

Technology Development for Aeroelastic Simulations on Unstructured Grids

Project objectives

An efficient, user-friendly, common simulation technology is being developed for fluid-structure interaction (aeroelasticity) applications, utilising available experience on an existing unstructured CFD (Navier-Stokes) method and also the experience gained from the UNSI project on validation of fluid-structure methods in general. The major innovation here is that the TAURUS software supports the standardisation of software currently in use by European industry, thus supporting closely-connected new aircraft design. Hence, the main objective is to establish a common European software technology for aeroelastic applications which is robust, sufficiently fast and providing a high level of accuracy; by this meqns, design costs and time-to-market will be reduced. Moreover, TAURUS will be a basis for interdisciplinary design processes where also optimisation is playing a major role.

Description of the work

The main working tasks are:

1. Management, including setting up a web server.
2. GUI and visualisation, user on-line help, results monitoring and post-processing features for CFD/CSM.
3. Survey and selection of CFD-CSM coupling software. Integration of this coupling software including all aspects of interfaces needed for an easy plug-in of partners' CSM software. A second interface will allow partners to also exchange the TAURUS CFD part in order to validate it against in-house software..
4. An integration platform will be provided, together with a more generic CSM tool to allow partners to test the complete system at an early stage, in particular those partners who have no access to their own CSM code (hence, no need for purchasing such a software is necessary).
5. Improvements of the CFD software will be carried out in order to meet the high goals of the TAURUS technology. Improvements to be made are related to acceleration techniques, implementation of robust turbulence model(s), grid refinement/de-refinement, mesh adaptation and Chimera grid enhancements.
6. Validation and assessment of the complete TAURUS software technology, based on the integration platform and the generic CSM model. Validation concerns also the particular testing of the CFD software which is the backbone of the system. This will be carried out by several partners, validating against in-house software methods.
7. The TAURUS software tool is intended to become a common European technology for aeroelasticity simulation with precise exploitation plans for commercialising this software.

Expected results

Expected results and major milestones are:

1. Definition of intellectual property rights (to be defined by all partners providing background information)
2. Establishment of a risk catalogue
3. Decision on selected coupling software
4. First enhancements of the CFD method
5. Release of the first TAURUS system
6. Improved TAURUS system
7. Final technology to be provided and refined TAURUS software technology, together with reports on achievements, validation results and exploitation means at the end of the project.

Title: Technology Development for Aeroelastic Simulations on Unstructured Grids

Acronym: **TAURUS**

Contract N°: G4RD-CT-2001-00403

Proposal N°: GRD1-2000-25278

Total cost: €5 442 269

EU contribution: €2 846 369

Starting date: 01/05/2001

Duration: 36 months

Coordinator: EADS DEUTSCHLAND GmbH – MILITARY AIRCRAFT
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Partners (name, country):

Airbus Deutschland GmbH	D
Airbus España S.L.	E
Alenia Aeronautica S.p.A.	I
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Fairchild Dornier GmbH	D
FFA – The Aeronautical Research Institute of Sweden	S
Israel Aircraft Industries Ltd. (IAI)	IL
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Poznan University of Technology	PL
Saab AB	S
Stehling – Merazzi Research S.A.	CH
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universität Berlin (TUB)	D
University of Wales, Swansea	UK

Project objectives

The VELA project aims to increase the general knowledge of the areas of aerodynamic, stability and control (S&C) and also structural conception of flying wing aircraft configurations. Rules will be obtained for the design and assessment of unconventional aircraft configurations, which will include the tools and methods that are additionally necessary for the preliminary design.

With the application and validation of the tools on the initial configurations, the project community will obtain profound knowledge of the potential and risk of flying wing configurations, especially in view of the transport of passengers.

The VELA project will initiate the work on flying wing configurations in Europe and draft a scheme for further investigation requiring more detailed studies or additional configurations.

These objectives and achievements will lead to the establishment of an organised and rigorous approach for European industry and the European research community that will meet future challenges regarding emissions (initially through 30% less fuel consumption) and affordable air transport.

Description of the work

Fast and advanced prediction tools and profound knowledge are available for conventional aircraft. The tools show a high degree of accuracy, primarily as a result of an enormous amount of data available from experience. But for unconventional configurations, such as the flying wing configuration, available basic knowledge is marginal and extrapolations towards new types of aircraft are expected to produce results that may prove to go beyond the horizon of current knowledge.

VELA will develop the missing links, knowledge, data, methods, processes and tools.

Two test configurations have been selected as benchmarks for validation. Once the tools and calculations specific to the selected configurations are available, the different investigation streams will merge into the integration work package, which will be used to establish the level of confidence in the results.

Thus it will be shown that this is an efficient approach to the field of unconventional flying wing aircraft configuration, and that specific problems can be identified and handled. Moreover, after completing this programme, additional configurations may be added and compared on the same basis.

The assessment and exploitation of the programme will be done in the last work package, where the potential for future configuration in the complete environment will be shown. This part is essential for long-term exploitation and will serve as an important guide to the programmes and activities, which will follow up this programme.

The main tasks are:

- aerodynamic,
- structure and weight
- stability and control (S&C), including a low-speed wind tunnel test
- innovative payload accommodation and passenger acceptability, including certification issues

A tool and work management method will be established to ensure consistency and tool quality, and to facilitate spin-offs between the work packages.

The work will be done through co-operation between industry and the research community.

Expected results

Work package 2 will deliver the high-speed database with tradeoffs in AR, thickness, leading and trailing edge variation.

Work package 3 will deliver design database, requirements and tools for the definition of the stability and control system philosophy. This outcome will also be supported by a wind tunnel test.

Work package 4 will deliver innovative structural concepts and weight prediction capability.
Work package 5 will build knowledge around the design and certification of passenger egress capability and innovative solutions for payload accommodation.
Work package 6 will integrate the results, back the potential and propose further work.

Title: Very Efficient Large Aircraft

Acronym: **VELA**

Contract N°: G4RD-CT-2002-00842

Proposal N°: GRD1-2001-40140

Total cost: €8 101 683

EU contribution: €4 329 057

Starting date: 15/10/2002

Duration: 36 months

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Airbus España S.L.	E
Airbus France S.A.S.	F
Airbus UK Ltd.	UK
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
IBK Ingenieurbüro Dr. Kretschmar	D
Instituto Nacional de Técnica Aeroespacial (INTA)	E
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Projecto, Empreendimentos, Desenvolvimento e Equipamentos Cientificos e de Engenharia	P
SENER Ingenieria y Sistemas S.A.	E
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universität Braunschweig Institut für Flugführung	D
Technische Universität München (TUM)	D
University of Bristol	UK
University of Greenwich	UK
Vyzkumny a Zkusebni Letecky Ustav, A.S. (VZLU)	CZ

1.3. Environmental Friendliness of Aircraft

Pollutant emissions

Global Aircraft Emissions Data Project for Climate Impact Evaluation

Project objectives

AERO2K's overall objective is to develop and improve methodologies and analytical tools that will facilitate new and improved evaluations of aircraft emissions on the global atmosphere. This will be done by setting up a new European database of global aircraft emissions of priority pollutants. Within this overall objective the intention is to:

- develop a database of global aircraft movements for the year 2001–2002, using new approaches;
- improve routing assumptions and representation of flight profiles for present-day traffic;
- compare and develop methodologies for determining fuel usage;
- provide new inventory parameters, e.g. flow distances per grid cell per hour (for contrail impact analysis), and CO/HC and particle number emission indices;
- investigate the uncertainties within the various assumptions;
- establish a new 25-year forecast of aviation emissions encompassing new series and the parameters identified above;
- make the data and documentation publicly available on the World-Wide-Web.

Description of the work

AERO2K builds upon previous European work, including: AERONOX, POLINAT, AEROTRACE, AEROCHEM1/2, ANCAT/EC1/EC2 and AERONET. Recent discussions within the Thematic Network AERONET concluded that current inventories of global aircraft emissions are out-of-date and inadequate. This has been confirmed by recent assessment efforts within the Intergovernmental Panel on Climate Change on aviation and the global atmosphere.

AERO2K will establish a new inventory of aircraft emissions of pollutants that are important for climate change. Civil and military movements will be determined for the year 2001–2002. This will provide an up-to-date base year with data, new series and parameters that are being demanded by policy-makers and climate modellers, but are currently unavailable. Provision of these new data and parameters will allow more reliable assessments to be made of aviation's impacts on climate. In addition, a new forecast inventory for 2025 will be prepared.

Previous inventories have provided only seasonal 3D distributions of fuel usage and NOx emissions. AERO2K aims to provide the following that are **new** and innovative; their advantages are indicated below:

- real routing from ATC data and simulations where ATC data are unavailable:
- high vertical resolution of gridded fuel, NOx, H_2O, particles (especially soot), CO and HCs-CH/CL,
- monthly distributions of the above,
- more realistic routing,
- diurnal emission cycles,
- forecast emissions for 2025,
- flight movements (distance and time) per grid cell,
- geographical data extraction facilities for allocations.

In addition, uncertainties in the inventory assumptions will be assessed and quantified where possible.

Output from AERO2K will be useful for defining post-Kyoto aircraft emission scenarios. Policy can only be developed if the basic data are available. AERO2K will provide such fundamental data for aviation impact assessments.

Expected results

Up-to-date aircraft emissions and forecast databases that will be used worldwide by policy-makers and scientists when assessing the impact of aircraft emissions on climate change.

Title: Global Aircraft Emissions Data Project for Climate Impact Evaluation

Acronym: **AERO2K**

Contract N°: G4RD-CT-2000-00382

Proposal N°: GRD1-2000-25042

Total cost: €1 676 611

EU contribution: €889 788

Starting date: 01/01/2001

Duration: 36 months

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Partners (name, country):

Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
EADS France S.A.S.	F
EUROCONTROL – European Organisation for the Safety of Air Navigation	INT
Manchester Metropolitan University	UK
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Future Engine Cycle Prediction and Emissions Study

Project objectives

At the start of the LOWNOX projects, predictions were made of combustor operating conditions that would exist in advanced engines ten years into the future. These data defined the conditions that combustors in the LOWNOX programmes would be required to meet. Since the potentialities of the various ultra low-NO_x technologies were largely unknown, there had been no possibility at that time to make predictions on emissions for these cycles. Today there is a need to predict both engine/combustor conditions and emissions for many years into the future.

Ten years ago, the objectives were to reduce oxides of nitrogen (NO_x). Today the role of CO_2 in global warming has been recognised and the need to reduce CO_2 emissions has been embodied in the Kyoto Protocol. However, the most obvious changes in engine cycles that can improve efficiency and CO_2 emissions also appear to increase NO_x. There is a possibility of trade-offs between the various emissions, and also trade-offs within the engine cycle, the combustion system and around the flight cycle.

The CYPRESS programme aims to meet this uncertain scene by predicting the characteristics of future engine cycles, designing appropriate combustion systems and predicting the emissions that these systems should produce.

Description of the work

The predictive process of the CYPRESS programme involves a sequence of predictive steps, each one feeding into the next. The final step is the prediction of emissions. To avoid the possibility of errors propagating and multiplying along the predictive chain, the first task is to validate the process using a bare minimum of data for an existing engine to start with. At the conclusion of the process, the predicted engine cycle, combustor design and emissions can be compared for accuracy with the values for manufacturers performance data and emissions stored in the ICAO data bank.

After successful validation, this engine, together with others in the range of engines to be studied will be used as reference points against which future predictions may be compared. Following this stage, the design and performance of future engines for entry into service in 2007 and in 2017 will be identified in outline and then modelled in detail. This will provide LTO and flight cycle data (including CO_2 emissions). The best compromise combustor designs will be matched to these cycles while making reasonable assumptions on possible advances in design. Finally, predictions of gaseous emissions species will be made. Efforts will be made at each stage to evaluate the sensitivity of the process to the input data. In general, these activities have in the past been undertaken independently of each other and will only rarely have been applied to the full flight cycle. The engines and cycles to be studied cover the range of interest of European aero engine manufacturers.

Expected results

The results of this programme will be the identification and definition of possible future aero engine cycles representative of the range of products of European industry. For these engines the main performance parameters of these cycles for seven and seventeen years in the future will be predicted (both in outline and in detail) well enough to predict gaseous emissions. This will lead to the production of detailed functional and thermodynamic cycles for these engines. For each specimen cycle and engine, a study will be made of a combustion system best suited for performance under the cycle conditions and for emissions performance. The predictions will be used by industry as a guide to the direction of future engine development and by governments and the EU as data from which informed judgements may be made in the debate on emissions legislation.

Title: Future Engine Cycle Prediction and Emissions Study

Acronym: **CYPRESS**

Contract N°: G4RD-CT-2000-00383

Proposal N°: GRD1-2000-25218

Total cost: €532 483

EU contribution: €313 485

Starting date: 01/02/2001

Duration: 24 months

Coordinator: QINETIQ Ltd.
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MTU Motoren- und Turbinen-Union München GmbH	D
Rolls-Royce Deutschland GmbH	D
Rolls-Royce plc.	UK
SNECMA Moteurs	F
Turbomeca S.A.	F
Universität Karlsruhe (Technische Hochschule)	D

Instability Control of Low-Emission Aero Engine Combustors

Project objectives

Among the Low-Emission techniques developed for aero engines within Low NOx II & III EC funded programmes, Lean Premixed (partially Prevaporised) combustion turned out to be the most promising. However, there are problems associated with the excellent figures on emission reduction, problems such as combustion instabilities.These can lead to intense pressure oscillations and enhanced heat transfer, which cause structural damage to engine components.

This programme addresses the physics of interactions between turbulence, chemistry and the feedback mechanisms that allow the self-sustained oscillations to occur. Design rules will be established for aero engine combustors, and suitable damping methods will be developed for existing low-emission combustors that suffer from instabilities. Global and detailed predictive tools will be evolved and applied to real combustors. A separate work package for project management and exploitation will be generated, to facilitate transfer of the models to the industry partners, and to provide the necessary input for the research establishments and universities. The benefits this programme will bring may be measured by the time reduction fpr engine development (through avoiding test-facility failure) and also in the number of tests.

Description of the work

On the technical field, the main areas of interest are addressed in four separate work packages. An extra work package is dedicated to the management of the project and the exploitation of the results.

WP1. Unsteady behaviour of LP and LPP injection systems. Both naturally occurring and forced aerodynamic instabilities will be characterised on LPP and also LP combustion systems under isothermal conditions. We are looking for the factors that trigger combustion instability. The application of conventional and advanced measurement techniques (as developed in the fourth work package) will enable temporal monitoring of the injector efflux, including details of mixing quality and details of the size, shape and frequency of flow field downstream of the injectors.

WP2. Transfer functions measurements. The flame transfer functions and injector patternation transfer functions will be characterised for wide range of fuel injectors. These functions will then be used in the following work package as input for prediction of combustion instability using a network approach, validation data for advanced simulation tools and elaboration of design rules for avoiding combustion instabilities.

WP3. Combustion instability predictions. Two levels of numerical prediction tools will be investigated and coupled : a low order approach using 1D models for representing combustion dynamics and acoustic pressure propagation outfitted with the transfer functions obtained in the above work package and detailed CFD approaches using LES as well as unsteady RANS simulations. Regarding the industrials design methods, innovation consists in feeding CFD generated data into low order models to predict combustion instabilities up to their amplitude .

WP4. Advanced diagnostics on combustors. Development and adaptation of advanced experimental methods for the investigation of the periodicity of the mixing process, aerodynamics, flame thermo-acoustics and the heat release.

WP5. The results of the investigations will be compiled in exhaustive databases to represent code validation data for thermoacoustic networks and also in stationary CFD, and to generate a better physical understanding.

Expected results

This new approach of combustion instabilities for Low-Emission Aero Engine Combustors (LEAEC) is focused on:

- comprehension of detailed mechanisms leading to combustion instability;
- comprehension of the aero engine architecture contribution to generation, amplification or damping of combustion instabilities;
- to deliver a validated low order model to be used as a global tool to predict the resonant modes in combustors;
- elaboration/validation of global transfer functions and detailed predictive tools for design;
- definition of design rules for advanced LEAEC that will not suffer from combustion instabilities.

Title: Instability Control of Low-Emission Aero Engine Combustors

Acronym: **ICLEAC**

Contract N°: G4RD-CT-2000-00215

Proposal N°: GRD1-1999-10514

Total cost: €3 644 430

EU contribution: €2 684 240

Starting date: 01/03/2000

Duration: 48 months

Coordinator: TURBOMECA S.A.
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Centre National de la Recherche Scientifique (CNRS)	F
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Fiat Avio S.p.A.	I
MTU Motoren- und Turbinen-Union München GmbH	D
QinetiQ Ltd.	UK
Rolls-Royce Deutschland GmbH	D
Rolls-Royce plc.	UK
SNECMA Moteurs	F
Technische Universität München (TUM)	D
Turbomeca S.A.	F
Università Degli Studi di Genova	I
Universität Karlsruhe (Technische Hochschule)	D
University of Cambridge	UK

Project objectives

According to the Kyoto Protocol and the report of the International Panel on Climage Change, significant improvements in engine technology are needed. The first target is to reduce NO_x emissions by 80% from the ICAO96 standard. Over the last few years, some significant technological advances have been made towards the reduction of NOx emissions, and some encouraging results have been demonstrated with lean pre-mixed technology (60% has been achieved). However, it has been demonstrated that significant problems remain and require additional studies. The second target is reducing CO_2. This CO_2 reduction is specifically linked to lower fuel consumption which can be achieved through higher bypass ratio, but this increases NO_x emissions. These two ambitious objectives require the simultaneous development of injection systems, cooling and combustor integration.

Description of the work

A range of low-emission lean fuel-injection concepts for both large and small engines will be designed, tested and refined via comprehensive test-rig programmes. The designs will be developed from concepts evaluated in previous programmes. Results have demonstrated the NO_x-reduction potential of lean pre-mixed systems, but practical applications require further work to overcome observed problems such as flashback or strong combustion instabilities. The RQL concept, initially developed as pilot stage for large engine applications, will be applied in this programme to small engines. In order to achieve low-power stability while reducing high-power emissions, staged combustor designs are considered essential for ultra-low NO_x large engines.

The final evaluation will therefore be in multi-sector staged combustor test units at near-engine conditions. However, to keep costs down, preliminary testing will include single-sector testing at slightly lower pressures. To understand the basic phenomena, combustion diagnostics will be performed with advanced techniques developed in previous programmes and applied to industrial devices at realistic engine conditions. In order to release sufficient air for lean fuel-injection devices, specific studies will be carried out to reduce the air devoted to the wall cooling from 50% to 20%. This programme will be the main vehicle to achieve new low-emission combustor technology, but there is a strong link to the other combustion-related programme through the low-pollutant emissions cluster. The results from the ICLEAC programme and numerical tools from the CFD4C programme will all contribute to the successful development of low-emissions systems in this programme.

Expected results

This programme will deliver practical, rig-demonstrated designs of combustor with NO_x emissions reduction of 80% from ICAO96. The end point of the programme is a demonstration of the combustor, while demonstration in an engine could be achieved in future projects. The consortium partnership will ensure the Europe-wide exploitation potential in future engine applications, thereby enhancing European competitiveness in the aviation sector relative to the United States and emerging countries.

Title: Low-Pollutant Combustor Technology Programme

Acronym: **LOPOCOTEP**

Contract N°: G4RD-CT-2001-00447

Proposal N°: GRD1-2000-25062

Total cost: €7 054 750

EU contribution: €3 986 518

Starting date: 01/04/2001

Duration: 48 months

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Fiat Avio S.p.A.	I
Loughborough University	UK
Lund University	S
MTU Motoren- und Turbinen-Union München GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ plc	UK
Rolls-Royce plc.	UK
Rolls-Royce Deutschland GmbH	D
Technische Universität München (TUM)	D
Turbomeca S.A.	F
University of Cambridge	UK
University of Florence	I

Minority Exhaust Measurements of Aircraft Engine Emissions by Infrared Laser Spectroscopy

Project objectives

The technical and scientific objectives of the project are the development and demonstration of innovative optical instrumentation and methodology to make non-instrusive measurements of aircraft engine exhaust-gas emissions for the most important exhaust gases, i.e. NOx, CO_2, H_2O, etc. according to the International Civil Aviation Organisation's Annex 16 and beyond. The project aims to develop efficient new instruments based on specially designed tunable coherent sources that emit in the infrared (3-5µm) spectrum, where detectivity is highest. They will allow concentration and temperature measurements with high detectivities (in the ppb-ppm range according to species). They will be compact, reproducible and ruggedised to allow easy on-site experiments. This will provide the European aeronautics industry with a competitive advantage through the achievement of cost-effective and time-saving measurements.

Description of the work

Work will begin with the identification and selection of spectral lines of the species which are best suited for quantitative laser analysis in the infrared and display the highest industrial relevance. Ultimate species detectivites will be calculated taking into account detection processes, laser performances (power, bandwidth, repetition rate, etc). Based on this, the different apparatus designs will be optimised which, by order of risk, are: lead salt-based tunable diodes (which will be used as a calibration source), dual-cavity mid-infrared nanosecond optical parametric oscillator (MIDROPO)- which will be the workhorse of high detectivity set-ups, picosecond difference frequency generator lidar (MIRL) which has a potential open-air spatial resolution of a few centimetres. Based on this development, a compact ruggedized prototype of the MIDROPO will be built with its software as an output made available to the consortium members and for future applications such as tomographic apparatus. Mid-infrared fibres will be investigated to ease the signal handling in harsh environments. High-spatial resolution using degenerate four-wave mixing on resonant molecular transitions in the infrared will also be investigated, using the MIDROPO. The MIDROPO and the MIRL will be calibrated and validated on specially designed hot gas cells under laboratory conditions.

Several consecutive measurements, analysis and verification campaigns at combustor and engine ground tests including intrusive reference measurements will repeatedly enhance and verify the instrumentation, methodology and quality. Project outputs will be the technology demonstration (as well as a prototype) of innovative optical non-intrusive aircraft engine exhaust-gas analysis systems designed for test rig application but capable of open air remote operations (airport monitoring, etc). It will cover the most important gases including NO_x but also allow flexible shifts to cover a wide variety of gases.

Expected results

- Innovative optical instruments able to detect non intrusively traces of pollutant in aircraft engine exhausts in the ppb to ppm range, based on specially designed largely tunable mid-infrared laser sources.
- Fabrication of a prototype.
- Validation of apparatus and prototype on combustor test-rigs and at aircraft engine exhaust.

Title: Minority Exhaust Measurements of Aircraft Engine Emissions by Infrared Laser Spectroscopy

Acronym: **MENELAS**

Contract N°: G4RD-CT-2001-00645

Proposal N°: GRD1-2001-40116

Total cost: €2 371 147

EU contribution: €1 299 991

Starting date: 01/05/2002

Duration: 36 months

Coordinator: OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AÉROSPATIALES (ONERA)
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Norsk Elektro Optikk AS	NO
Risoe National Laboratory	DK
SNECMA Moteurs	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universität Clausthal	D

Modelling of Low Emissions Combustors Using Large Eddy Simulation

Project objectives

The optimisation of current low NO_x emissions combustors requires a detailed prediction of the combustion flow field, temperatures and pollutant emissions. The highly swirling and turbulent combustor flows cannot be simulated accurately using Reynolds averages Navier-Stokes (RANS) CFD codes with standard turbulence models. Large Eddy Simulations (LES) provide more accurate predictions, since more details of the turbulence are being solved. The objective of the MOLECULES project is to develop the methodology of combustion LES methods further, to validate the codes, and subsequently provide the LES codes in a generic format to the industrial partners for application in the combustor design process. The codes will be validated against data obtained from experiments using configurations with critical features like strong swirl and mixing jets and from a generic combustor. This kind of data is not available from the literature or previous projects, and is an essential part of the MOLECULES project.

Description of the work

The objective of providing validated combustion LES CFD codes to the industry will be achieved through four technical work packages:

WP1 will develop the methodology of efficient LES codes with variable density and using body-fitted computational grids. The numerical schemes best suited for this will be identified, turbulence and combustion sub-grid models will be implemented. The codes will be validated and generic LES CFD modules will be generated for transfer to the industrial partners. The codes will be exploited to the industrial partners for application to model industrial aero-engine combustors.

WP2 will provide combustion subgrid models for the LES codes, which model the interaction of turbulence and chemistry on spatial and temporal scales which are not resolved on the computational grid of the LES simulation. These models are extensions of models developed for use in RANS codes.

WP3 will generate the validation data from generic configurations sharing critical features with realistic combustors like strong swirl, mixing jets in a cross flow and will provide unique data which are particularly required for the validation of the LES codes.

WP4 will provide high quality validation test data from a generic sector combustor at atmospheric and elevated pressures up to 10 Bar. The database of the validation data will be used as benchmark data for the validation of the combustion CFD codes in general, but in particular for the codes developed in project MOLECULES.

The project and all work packages will be managed by the industrial partners. A management work package will ensure that project management is efficient and that the results will be transferrd to the industrial partners.

Expected results

Major milestones of the project MOLECULES are:

- generation and validation of LES codes for combusting flows;
- generation of combustion sub-grid models;
- generation of experimental validation data in WP3 and WP4;
- delivery of LES code and also generic LES modules for industrial exploitation.

Title: Modelling of Low Emissions Combustors Using Large Eddy Simulation

Acronym: **MOLECULES**

Contract N°: G4RD-CT-2000-00402

Proposal N°: GRD1-2000-25221

Total cost: €2 762 501

EU contribution: €1 696 370

Starting date: 01/05/2001

Duration: 42 months

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Centre National de la Recherche Scientifique (CNRS.CORIA.INSA)	F
Centre National de la Recherche Scientifique (CNRS.LCD)	F
Consejo Superior de Investigaciones Científicas	E
Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Foundation of Research and Technology – Hellas	EL
Imperial College of Science Technology and Medicine London	UK
Loughborough University	UK
MTU Motoren- und Turbinen-Union München GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Rolls-Royce plc.	UK
SNECMA Moteurs	F
Turbomeca S.A.	F
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Modelling of Unsteady Combustion in Low-Emission Systems

Project objectives

The objectives of the proposal are fourfold:

1. to understand in detail the direct effect of a pressure wave on flow aerodynamics, especially in flow features which have marginally stable states;
2. to measure the behaviour of a combustor operating near lean extinction, under both steady and unsteady condtions, to establish how oscillations may affect the degree of extinction;
3. to study droplet and spray behaviour under unsteady conditions, so that the response of a spray to pressure waves may be determined;
4. to synthesise the individual process models into a single description of the unsteady combustion process and hence to provide a method for estimating pressure levels and frequencies in real gas turbine combustors.

These studies will include measurements in combusting systems subject to oscillating pressure fields.

Description of the work

All low-emission combustor designs are inherently prone to suffer from unstable combustion. In practice it is often this issue which places limits to attainable NOx levels in practical gas-turbine designs. Hence the understanding and prevention of acoustic oscillation in gas turbine combustors is fundamentally linked to the ability to deliver low NOx, and hence a cleaner environment.

The project consists of a series of coupled experiments at leading research centres in Europe, where local experts will be used to devise the experiments in detail and to develop existing measurement techniques to study the time-variable properties of the flow under investigation. Studies to date have concentrated on either eliminating problems with specific hardware or in describing a pre-supposed mechanism for coupling the flow pressure variations to the fluctuating heat release rate. This project is different in that no presumption will be made of the modes of oscillation, and so any methods developed should be equally applicable to understand oscillation issues at all frequencies of interest.

At present most models of combustion instability are based on linearised theory and also rely on the provision of a 'flame transfer function'. While these are undoubtedly useful, and can be run rapidly, they do suffer from two major flaws – all the physics is wrapped up in the flame-transfer function, and thus it is difficult to extrapolate to new geometries and conditions. As for the linearised theory, while it also predicts unstable frequencies well, it does not give information about the pressure levels which may be reached. Both these deficiencies are addressed in the proposed project, and a new model of the process will be delivered which can then be applied to all gas turbine combustors using the partners' own CFD codes.

Expected results

- Stationary lean combustion completed. Kinetic scheme devised, Droplet evaporation measurements made for one case. LPP rig set-up completed. Non-linear model devised, aerodynamic response measured.
- Aerodynamic studies completed, combusting system response measured. Spray response completed, LPP basic configuration done. CFD simulations of steady combustion complete, module delivered.
- Reports, model and data delivered to partners. M42-Model applied to real cases.

Title: Modelling of Unsteady Combustion in Low-Emission Systems

Acronym: **MUSCLES**

Contract N°: G4RD-CT-2001-00644

Proposal N°: GRD1-2001-40198

Total cost: €4 818 276

EU contribution: €3 248 955

Starting date: 01/06/2002

Duration: 42 months

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Partners (name, country):

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Centre National de la Recherche Scientifique (CNRS/DR5/EM2C)	F
Centre National de la Recherche Scientifique (CNRS/LEMTA)	F
Dipartimento di Ingegneria Chimica Università Degli Studi di Napoli, Federico II	I
Fiat Avio S.p.A.	I
Institut National des Sciences Appliquées de Rouen	F
Instituto Superior Técnico (IST) Lisboa	P
Loughborough University	UK
MTU Aero Engines GmbH	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
SNECMA Moteurs	F
Turbomeca S.A.	F
Universita' di Genova – Dipartimento di Macchine, Sistemi Energetici e Trasporti	I
Universitaet Karlsruhe – Engler Bunte Institut	D
Universitaet Karlsruhe – ITS	D
Université de Rouen	F
University of Cambridge	UK

Development of the Technical Basis for a New Emissions Parameter Covering the Whole Aircraft Operation

Project objectives

The objectives of NEPAIR are to:

1. Develop a methodology to predict emissions, including particulates, from aircraft at all phases of flight. This will include the currently-regulated emissions and particulates, and take into account the productivity of the aircraft.
2. Validate this methodology against actual measurement data from carefully controlled altitude-simulation test running conditions.
3. Comparison of this methodology for prediction of LTO (Landing/Take-Off) cycle emissions with established ICAO LTO certification methodology.

The results of this proposal will be exploited (i) in the short term within ICAO by the European Union during the course of the project, and (ii) in any development of new emissions standards through future Calls, and in the development of new European and international policy initiatives in the medium to long term.

Description of the work

Description of the work

The work will consist of:

- Drawing together the background, history and development of the current emissions certification regime. This will result in a definitive document describing the current regime, its basis and assumptions, application and uses.
- Determination of altitude emissions performance, to the accuracy required by certification authorities. Prediction methodologies will be developed which enable ground-level results to be used to predict altitude emissions rather than stipulate that testing should be carried out in altitude test facilities, which is expensive and difficult.
- An investigation into the feasibility and accuracy of including some form of measurement of aerosols and particulates which are not within the regulatory framework at present, from ground-level testing, and prediction of their levels emitted at altitude running conditions.
- Future combustor concepts will be examined to establish whether the methodologies and prediction methods developed for existing engine designs will still be valid.
- Development of definitions of productivity, and definitions of cruise point(s) for application to a certification regime.
- Development of a new methodology, and a new emissions parameter, which takes emissions at flight altitudes into account, and the effect of the airframe's contribution to the emissions performance of the engine.

A Workshop will be organised to ensure that the knowledge and opinions of major stakeholders will be fully integrated into the project.

Careful monitoring of, and interaction with, ICAO on this subject will be undertaken to ensure that the direction of this research programme will strongly influence the ICAO, and respond to proposals resulting from its work.

Expected results

The workplan, milestones and outputs cover: assessment of current emissions regulations; development of methods for prediction of in-flight emissions from ground level measurements; definition of representative certification points and aircraft productivity; a stakeholders workshop; synthesis into new methodology.

Main outputs are a methodology (in-flight emissions parameter) and contribution to policy definition (Transport, Environment and Competitiveness).

Title: Development of the Technical Basis for a New Emissions Parameter Covering the Whole Aircraft Operation

Acronym: **NEPAIR**

Contract N°: G4RD-CT-2000-00182

Proposal N°: GRD1-1999-10439

Total cost: €892 264

EU contribution: €446 133

Starting date: 01/04/2000

Duration: 24 months

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Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
GIE Airbus Industrie	F
Rolls-Royce plc.	UK
SNECMA Moteurs	F

Measurement and Predictions of the Emission of Aerosols and Gaseous Precursors from Gas Turbine Engines

Project objectives

The objective of the work undertaken in the PartEmis programme is to develop an understanding of carbonaceous and volatile particles emitted from aero engines. The work aims to characterise and quantify particles formed in the engine combustion chamber, together with any changes in the particles as they progress through the engine turbine stages. It will also study the effects of fuel sulphur content and of non-methane hydrocarbons and chemi-ions in exhaust emissions on the formation of new particles.

During the first year of this programme, the Dutch airline KLM started evaluation of the Additive APA101 in a few of their long-haul Boeing 747 aircraft. This additive has been shown to affect particulate emissions. To avoid compromising the PartEmis objectives, the project has been extended, with funding from Boeing and Shell, to evaluate the effect of Additive AP101 alongside that of the sulphur.

Description of the work

The project is broken down into four principal work packages. **Work Package 1** is concerned with the overall management and co-ordination effort.

In a project concerned with the measurement of very small concentrations of chemical species and extremely small particles, much rests on the accuracy and reliability of the measurement systems. **Work Package 2** is designed with these issues very much in mind. Significant effort will, therefore be expended in calibration and in exploration of potential sources of error in the early phases of the measurement programme.

Modelling is the principal concern in **Work Package 3**. While there is much to do in the development of the mathematical models representing the physical and chemical processes of interest, this phase will be paced to some extent by the availability of the data gathered in WP 2.

The final work package, **Work package 4**, is dedicated to the procurement and commissioning of the special-purpose testing unit that is required to simulate the turbine unit downstream of the combustor exit plane. The special needs of the teams engaged in the measurement will need to be taken into account, and therefore will require close collaboration between WP2 and WP4 teams.

Expected results

The outputs are of value to those engaged in engine design, performing studies of the effects of aircraft on the upper atmosphere, and to technologists and policy-makers responsible for future air transport strategy.

The programme will deliver:

- a transformation model for detailed estimates of the change in trace species during their transport from principal generation centres in the combustor to the engine exhaust plume;
- a database relating to the characterisation of trace species and aerosols from aircraft engines;
- a deeper and broader understanding of the formation of aircraft emissions and the factors affecting them;
- an advance in instrumentation techniques used to measure trace species in a representative engine environment.

Title: Measurement and Predictions of the Emission of Aerosols and Gaseous Precursors from Gas Turbine Engines

Acronym: **PARTEMIS**

Contract N°: G4RD-CT-2000-00207

Proposal N°: GRD1-1999-10891

Total cost: €4 310 697

EU contribution: €2 699 805

Starting date: 01/04/2000

Duration: 36 months

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Paul Scherrer Institut	CH
Rolls-Royce plc.	UK
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Universität Gesamthochschule Essen	D
Universität Wien	A
Université Louis Pasteur, Strasbourg 1	F
University of Leeds	UK

1.3. Environmental Friendliness of Aircraft

External Noise

Project objectives

The project objectives are to:

- Provide, at European level, an exhaustive knowledge, both computational and experimental, of the Whirl-flutter phenomenon that may occur in tiltrotors both in the airplane mode and in the conversion corridor.
- Provide a validated code to predict Whirl-flutter.
- Provide a validated code to predict rotor noise and performance in specific tiltrotor flight conditions.
- Acquire blade design and manufacturing techniques to optimise rotor external noise.
- Final recommendations for the design of a full-scale tiltrotor demonstrator (ERICA).

Description of the work

The project is structured to address the following four main areas:

1. Whirl-flutter: Requirements and preliminary calculations.
   Existing analytical codes will be rearranged to numerically simulate tiltrotor whirl-flutter behaviour. An investigation on major design parameters will be performed. A critical comparison of the results of the different codes will be carried out to assess the wind tunnel model requirements.
2. Whirl-flutter: Model preparation and Test
   A Mach- and Dynamically-scaled half-span wind tunnel model will be designed and manufactured. The test campaign will be in a high speed wind tunnel and the investigation will address Whirl-flutter stability margin detection, both in high speed airplane mode and the conversion corridor.
   Experimental database will be used in the validation of computational tools.
3. Aeroacoustic assessment and optimisation.
   The rotor used in the TILTAERO project will be tested in the wind tunnel to explore its noise characteristics at specific flight conditions (e.g.: low speed descent, hover, etc.). The first step towards the design and manufacture of a new blade with improved noise characteristics (including BVI) will be a numerical prediction study. At the same time a non conventional noise reduction strategy for rotor blades will be assessed. The new blades will be manufactured and tested as well. Experimental database will be used in the validation of computational tools.
4. High speed performance assessment.
   The rotors will be tested in a speed wind tunnel and the measured performance will be used to confirm the validity of the noise optimised blade design also in these flight conditions.

Expected results

The project is intended to enhance the EU knowledge on tiltrotor technologies by deeply analysing Whirl-flutter, an aeroelastic instability of the rotor/pylon system occurring at high inflow speeds typical of tiltrotors. The research effort involves the comparison of analytical and experimental results. Tests will be conducted in a high-speed wind tunnel facility using a half-span scaled model. The availability of a wind tunnel model that is useful also for aeroacoustic analysis will help optimize the rotor blade design for low external noise and at the same time a performance assessment in wind tunnel will demonstrate the validity of this design in all flight conditions. The project will provide final recommendations for the design of a full-scale tiltrotor flight demonstrator (ERICA).

Title: Advanced European Tilt-Rotor Dynamics and Noise

Acronym: **ADYN**

Contract N°: G4RD-CT-2002-00773

Proposal N°: GRD1-2001-40126

Total cost: €7 423 463

EU contribution: €3 799 753

Starting date: 01/05/2002

Duration: 48 months

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Eurocopter S.A.	F
Eurocopter Deutschland GmbH	D
IDS Ingegneria dei Sistemi S.p.A.	I
National Technical University of Athens (NTUA)	EL
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Politecnico di Milano	I
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Acoustic Radiation of Small Turbomachines

Project objectives

Research on aircraft noise is primarily focused on fixed-wing aircraft powerplant noise. Large research projects/technology platforms are devoted to the investigation of various technologies for further reducing aircraft engine noise. AROMA focuses on the specific requirements of small high-speed turbomachines used for powering helicopters and for the air-conditioning of fixed-wing aircraft. AROMA's main purpose is the development and validation of an integrated aeroacoustic design environment for turbomachines, based on existing commercial CFD and CAA codes. The work will focus on three areas:

- development and enhancement of three turbomachine source models that convert CFD results into acoustic sources to be used in acoustic propagation and radiation codes;
- enhancement and coupling of leading commercial CFD and acoustic codes in a seamless simulation, optimisation and design tool for turbomachinery noise;
- experimental validation of the various components of the simulation tools.

Description of the work

Predicting the noise produced by turbomachines requires three essential modelling components:

- an accurate description of the flow through the turbomachine (WP1);
- a model predicting the amplitude of the acoustic source from the results of the CFD calculation (WP2);
- a prediction of the propagation of the source in a lined duct, taking into account the flow field in the duct (WP3).

The different components must then be seamlessly integrated and connected to an optimisation tool (WP4). Finally each component of the loop and the integrated system must be validated against experimental results (WP5).

In order to be successful, the project must be managed and its results disseminated and exploited (WP6).

The project will involve several different codes. In terms of CFD, the following codes will be used and enhanced:

- a commercial CFD code dedicated to the modelling of turbomachines (FINE/Turbo by NUMECA);
- an in-house special-purpose CFD tool dedicated to the modelling of turboshaft engines (Turbomeca).

In terms of source modelling, the following codes will be used and enhanced or developed:

- a code based on a surface-integration method used by the turboshaft engine manufacturer (SIM);
- a code based on the surface Ffowcs-Williams-Hawkings (FWH) model and developed by Liebherr Aerospace;
- a code based on the volume Ffowcs-Williams-Hawkings (FWH) model, to be developed jointly by NUMECA and Free Field Technologies (VFWH).

A cross-comparison of these complementary approaches will be performed.

In terms of acoustic propagation, the finite element/infinite element-based solver of Free Field Technologies will be used.

Expected results

- Improved aeroacoustic design methodology for small turbomachines.
- New integrated aeroacoustic simulation tool for the prediction of the tonal component of turbomachine noise.
- Improved and optimised turbomachine concepts.

Title: Acoustic Radiation of Small Turbomachines

Acronym: **AROMA**

Contract N°: G4RD-CT-2001-00606

Proposal N°: GRD1-2001-40212

Total cost: €1 552 545

EU contribution: €776 271

Starting date: 01/12/2001

Duration: 24 months

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Liebherr Aerospace Toulouse S.A.	F
Numerical Mechanics Applications International (NUMECA)	B
Turbomeca S.A.	F

Environmental Noise Associated with Turbulent Boundary Layer Excitation

Project objectives

The ENABLE project addresses the interior noise generated by the turbulent boundary layer around an aircraft, which usually constitutes the most important source of cabin noise during cruise. The random character of the pressure distribution induced by the boundary layer has a major effect on the noise transmitted through the fuselage. More particularly, the cross-spectral density of the loading pressure plays a major role in determining the effective force that causes motion to the structure. The project will provide the designer with predictive tools for the boundary layer-induced noise. The ENABLE project is intended to deliver enhanced models of the pressure fluctuations beneath a turbulent boundary layer (including the effects of pressure gradients), and to couple these models with structural transmission codes. Then it will validate the overall methodology against experiments undertaken during the project. Finally, guidelines will be derived for industrial use.

Description of the work

The technical work carried out in ENABLE is organised in four work packages.

WP1. The focus is on finding models that will describe the pressure fluctuations generated by a turbulent boundary layer. The cross-spectrum and wall-pressure fluctuations will be studied, taking into account the effect of pressure gradient and surface irregularities.

WP2. Generic methods will be developed and validated for predicting the vibrational response of the fuselage and the effective transmission loss through the fuselage side wall due to the excitation of a turbulent boundary layer. 'Generic methods' means those methods that can be applied to any structure encountered on the fuselage of an aircraft, and that are able to deal with pressurisation and curvature, in particular.

WP3. This work covers the experimental tests (wind-tunnel as well as in-flight tests) needed to assess, update and validate source models, together with the consequent vibration and sound-radiated level of well- characterised structures.

WP4. The methodology will be validated and guidelines produced for industrial applications.

Expected results

The expected results are:

- updated models for the wall pressure fluctuations induced by a turbulent boundary layer;
- generic techniques for the prediction of the skin response and the transmission loss of the fuselage under a turbulent boundary layer;
- a validated methodology and insight for practical industrial use.

Title: Environmental Noise Associated with Turbulent Boundary Layer Excitation

Acronym: **ENABLE**

Contract N°: G4RD-CT-2000-00223

Proposal N°: GRD1-1999-10487

Total cost: €3 358 440

EU contribution: €1 996 000

Starting date: 01/04/2000

Duration: 36 months

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DaimlerChrysler AG Stuttgart	D
Dornier GmbH	D
Ecole Centrale de Lyon	F
Instituto Superior Técnico (IST) Lisboa	P
Integrated Aerospace Sciences Corporation O.E.	EL
Kungliga Tekniska Hoegskolan (KTH) Stockholm	S
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Swedish Defence Research Agency (FOI)	S
Trinity College Dublin	IRL
Università Degli Studi di Napoli 'Federico II'	I
University of Southampton	UK

Project objectives

Reduction of helicopter noise by at least 7 EPNdB.
Doubling of the lifetime of critical aircraft components with respect to vibration.
Improvement of passenger comfort for helicopters in emergency and medical services (EMS).
Creation of high-fidelity work environment for helicopter pilots.

Description of the work

- Adaptation and refinement of prediction design tools for detailed quantification of the effects on unsteady loads and noise of the main-rotor wake and the main rotor to tail rotor interaction, including aeroelastic modelling.
- Improvement of the noise-prediction codes, with emphasis on the tail rotor with/without fuselage- scattering effects.
- Definition of the appropriate wind tunnel test matrix and model instrumentation requirements.
- Performance of pre-test predictions of rotor wake(s) unsteady air loads, vibration analysis and noise emissions.
- Carrying out of tests and dissemination of data to partners.
- Analysis of Particle Image Velocimetry (PIV) results, blade/airframe pressure and air loads, acoustics, rotor hub and balance loads, and blade strain data.
- Validation of the pre-test calculations by measuring PIV, pressure, strain, and noise pressure.
- Evaluation of the noise-reduction potential by modifying important design parameters: position of the tail rotor, its sense of rotation and rotation speed, and the main rotor-to-cabin distance.
- Substantiation of means to reduce vibration by modifying the same design parameters as above.
- Documentation and dissemination of results.

Expected results

- Achievement of high-resolution results with respect to detailed noise and vibration predictions of the complete helicopter configuration.
- Unique wind tunnel database, with special emphasis on parameter variation for exploring interactional phenomena and on the evaluation of transferability to full-scale applications.
- Validated advanced design tools with respect to noise and vibration calculations.

Title: Helicopter Noise and Vibration Reduction

Acronym: **HeliNOVI**

Contract N°: G4RD-CT-2001-00667

Proposal N°: GRD1-2001-40113

Total cost: €4 582 423

EU contribution: €2 493 399

Starting date: 01/04/2002

Duration: 36 months

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Eurocopter S.A.	F
Eurocopter Deutschland GmbH	D
National Technical University of Athens (NTUA)	EL
Office National d’Etude et de Recherches Aerospatiales (ONERA)	F
QinetiQ Ltd.	UK
SENER Ingenieria y Sistemas S.A.	E
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
University of Manchester Institute of Science and Technology (UMIST)	UK
Vibratec	F

Project objectives

The objectives of JEAN are to develop methodologies for the prediction of noise generated by jets, including the effects of mixing enhancement and co-axial configurations. The long-term aim is to provide design tools for the development of low noise nozzles for HBR engines.

The specific technical objectives of the project are:

- to identify and develop optimal CFD methods for the calculation of the velocity characteristics of jet flows of relevance to aircraft technology;
- to develop aeroacoustic methods which use the CFD results as input to predict the acoustic fields generated by exhaust flows;
- to validate the prediction techniques thus developed;
- to identify the optimum prediction methodologies for particular applications.

The work is of a fundamental nature and the complementary skills of the partners, together with the capacity to work in a synergistic manner, will ensure that the project's success in achieving the principal objectives, which are:

- to develop predictive tools to assess future jet noise reduction techniques;
- to quantify the effects of flow distortion and co-axial configurations.

Description of the work

Despite the tremendous progress which has been made in the development of CFD solvers, most noise prediction methods currently in use for jet flows are correlations based on empirical databases. These are of very limited practical use for assessing the impact of novel noise reduction techniques on aircraft noise. A more explicit approach is required in which changes to the flow are explicitly predicted and properly linked to the production of noise. The innovation in this project is linked to the development of an experimentally validated suite of techniques for the prediction of Jet Noise. This project's methodologies for the prediction of noise generated by jets will be developed and validated, and their applicability assessed by comparison of its predictions with available data for the effects of mixing enhancement and co-axial configurations.

The project is divided into a management task and four work packages as follows:

- CFD Prediction Techniques
- Acoustic Source & Propagation Modelling
- Experimental Validation of CFD & Acoustics
- Application to Advanced Configurations

The project's output will be a set of validated techniques for the prediction of noise, not only from simple jet configurations but from coaxial jets, and will include advanced concepts such as mixing. It is expected that each of the approaches for the CFD predictions will have advantages for particular applications, as will be the case for the source and propagation models. The work will recommend the use of a particular suite of techniques for specific applications.

The major milestones are as follows:

1. Validated CFD models for jet flow predictions
2. Validated noise source & propagation models
3. Multi-point measurements in jet flows
4. Validated methodologies for jet noise predictions

Expected results

The overall objective of the project is to develop and validate numerical techniques that will predict the noise generated by a jet with an accuracy of 3dB across the frequency range 50-10,000 Hz for distances of 40-100 diameters from the jet exit. This goal is to be achieved by month 36 of the project.

Title: Jet Exhaust Aerodynamics and Noise

Acronym: **JEAN**

Contract N°: G4RD-CT-2000-00313

Proposal N°: GRD1-2000-25679

Total cost: €2 222 223

EU contribution: €1 519 270

Starting date: 01/02/2001

Duration: 36 months

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Dassault Aviation S.A.	F
Ecole Centrale de Lyon	F
Instituto Superior Técnico (IST) Lisboa	P
National Research & Development Institute for Turboengines Comoti RA	RO
Office National d’Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Rolls-Royce Deutschland GmbH	D
SNECMA Moteurs	F
Université de Poitiers	F
University of Southampton	UK
Volvo Aero Corporation AB	S

Project objectives

As a complement to SILENCER, the general target of ROSAS projects is to develop, within the European aeronautical community, the necessary capabilities for the evaluation and selection of innovative silent aircraft concepts. Starting with alternative installation concepts of advanced turbofan engines, the project tackles two main critical disciplines, acoustics and aerodynamics, with the following objectives:

- generation of an experimental database on noise-shielding effects in order to calibrate noise prediction methods,
- analytical investigation of noise diffraction by shielding surfaces,
- identification of the key aerodynamic phenomena and CFD investigations of the feasibility issues for the shape design of alternative engine installations.

The outcome of these tasks, and the analysis of the impact of the new installations on the aircraft structure, weight, handling qualities and performance, will lead to a homogeneous comparison of the new concepts with the reference conventional configuration. In conclusion, recommendations will be issued for future investigations and development of associated tools.

Description of the work

The ROSAS technical content is structured into four work packages (WP).

WP1. The reference airframe and advanced turbofan, in the Under Wing Nacelle configuration (UWN), will be identified in detail, together with the two innovative silent-aircraft concepts: the Rear Fuselage Nacelles (RFN) and the Over Wing Nacelles (OWN). The consequences of the new engine installations on the aerodynamics, acoustics, handling qualities and structure will be analysed, and the constraints and parameters for these installations will be defined.

WP2. Aerodynamics. CFD-based investigations of the aerodynamic phenomena in the area of the new engine installations will cover both low-speed and high-speed conditions, allowing the precise identification of the key aerodynamic issues and associated risks, the design of efficient external shapes in the power-plant area, and the determination of the essential aerodynamic data for aircraft performance and handling qualities.

WP3. Acoustics. In order to validate and calibrate semi-empirical methods for the prediction of noise-shielding effects, an experimental database will be produced through a comprehensive wind-tunnel campaign. A new model support and rear fuselage with shielding empennage will be manufactured and adapted to the existing aircraft model used in the RAIN programme. Aan existing TPS will be used for to simulate shielded fan noise and a new exhaust nozzle representing an advanced very high by-pass ratio engine will be designed and manufactured for jet noise simulation. Several rear-fuselage and over-wing engine positions will be tested. The test results will be combined with the analytical investigation of the noise diffraction by a shielding surface and the modelling of advanced engine-noise sources to assess the far-field noise benefit of the RFN and OWN concepts versus the UWN reference.

WP4. On top of the results obtained for the critical disciplines in WP2 and WP3, a multi-disciplinary analysis will include structural definition and weight assessment, handling qualities, overall aircraft performance, refined assessment of regulatory noise levels and economic evaluation. This will enable a fair comparison of the OWN and RFN concepts with the reference UWN. Finally, recommendations will be issued for future investigations and associated tools development.

Expected results

- Generation and exploitation of wind-tunnel experimental database on noise shielding and calibration of methods for the prediction of noise levels of silent-aircraft concepts, featuring innovative installations of advanced turbofans.

- Identification of the aerodynamic phenomena and related risks for these innovative concepts and design of efficient external shapes.
- Multi-disciplinary investigations of silent-aircraft concepts to achieve a fair comparison with the reference underwing configuration.
- Recommendations for future investigations and tools development.

Title: Research on Silent Aircraft Configurations

Acronym: **ROSAS**

Contract N°: G4RD-CT-2001-00633

Proposal N°: GRD1-2001-40147

Total cost: €5 016 959

EU contribution: €2 599 432

Starting date: 01/01/2002

Duration: 36 months

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Hurel-Hispano	F
Instituto Superior Técnico (IST) Lisboa	P
Office National d’Etudes et de Recherches Aérospatiale (ONERA)	F
Rolls-Royce Deutschland Ltd. & Co KG	D
Rolls-Royce plc.	UK
SNECMA Moteurs	F
Stichting Nationnal Lucht-en Ruimtevaartlaboratorium (NLR)	NL
Trinity College Dublin	IRL

Sonic Boom European Research Programme: Numerical and Laboratory-Scale Experimental Simulation

Project objectives

While supersonic commercial transport (SCT) can satisfy the demand for reduced long-range travel times, it must be proved to be environmentally friendly, a key point for the launch decision. The sonic boom issue could be a show-stopper for the whole SCT programme: since sonic boom may restrict supersonic exploitation to overseas flights, it could impair the overall project profitability should supersonic flights be pushed too far away from coastlines.

The main SOBER objective is to provide a tool to help decide on acceptable operating routes, based on a comprehensive modelling of all types of sonic booms that could provoke protests near coasts, islands or wildlife colonies. This would be achieved through an innovative combination of advanced physical and numerical modelling, covering all phases of flight, laboratory-scale simulation, and meteorological statistical analysis.

Description of the work

The SOBER workplan is divided into five workpackages (WP). One, built on the partners' experience, is dedicated to the management and updating of numerical codes. Thematic work packages will investigate the numerical and experimental simulation of three critical situations:

- focused boom due to acceleration (small geographical impact, but high amplitude and potential damage),
- lateral extent of sonic boom in shadow zone influenced by ground or sea-surface absorption and atmospheric turbulence (low amplitude, but possibly large geographical impact),
- secondary boom after propagation in the upper atmosphere (very low amplitude, but continental-wide extent of effect).

Laboratory-scale experimental simulations in a controlled environment will provide the required validation of numerical codes that cannot be achieved by test flights. Finally, one WP will conduct a statistical analysis on the influence of meteorological variability by coupling the numerical code to a meteo database for selected flight configurations (cruise or accelerated) and target areas, in order to provide the information for the exploitation plan and industrial objectives. By combining the knowledge and skills in physical modelling, numerical and experimental simulation, meteorology and aircraft design from six universities, two research institutes and two major aeronautics manufacturers from four countries, the successful execution of the project will be assured. The universities will contribute the necessary fundamental background, advanced numerical capacities and state-of-the-art experimental installations. The research institutes will provide the indispensable meteorological and atmospheric physics expertise. Numerical codes, operating configurations and product know-how brought by industrial partners will ensure that practical constraints and cross-discipline aspects are taken into account. Existing co-operation arrangements will be reinforced by sharing PhD students, young researchers and experimental facilities to guarantee a transnational synergy.

Expected results

The main milestones will monitor code evolution, qualify experimental facilities and validate the physicalmodelling. The main outputs will be:

- software for sonic boom prediction in the most general configurations,
- large database of experimental and numerical results, cross-correlated to meteo data,
- a methodology for modelling sonic boom in yet unexplored cases.

This will enable the industrial partners to check the compatibility of sonic boom with environmental constraints.

Title: Sonic Boom European Research Programme: Numerical and Laboratory-Scale Experimental Simulation

Acronym: **SOBER**

Contract N°: G4RD-CT-2000-00398

Proposal N°: GRD1-2000-25189

Total cost: €3 391 077

EU contribution: €2 482 505

Starting date: 01/01/2001

Duration: 36 months

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Ecole Centrale de Lyon	F
Ecole Supérieure de Physique et Chimie Industrielles de la Ville de Paris	F
Institut für Atmosphärenphysik an der Universität Rostock	D
Université Pierre et Marie Curie – Paris VI	F
University of Bergen	NO
University of Hull	UK
University of Oxford	UK

Turbomachinery Noise-Source CFD Models for Low-Noise Aircraft Engine Designs

Project objectives

The European aircraft-engine manufacturing industry is facing increasing pressure to reduce engine noise levels. The community expectations of improved quality of life (through reduced noise levels) and the current growth in air traffic together present a major socio-economic problem. A long-term solution is proposed here to create a new method for designing low-noise turbomachinery components through the exploitation of existing Computational Fluid Dynamics (CFD) software. If the technical challenges such as dispersion and excessive memory and computational times can be overcome, this project could enable CFD software to be used for the prediction of noise. Then, if successful, the results of this project could be commercially exploited in the same way as the CFD codes for turbomachinery aerodynamics. The aim of this project is to contribute to the achievement of the Work Programme RTD objective of a 10 dB reduction in ten years in external perceived noise from aircraft.

Description of the work

WP1. Noise requirements of CFD codes. To identify the key features required of unsteady CFD codes to model numerically the tone-noise source for each type of fan, compressor and turbine, and also blade-row transmission effects for tones and broadband noise. A special study will be conducted on the feasibility of CFD modelling of the fan broadband-noise sources.

WP2. Matching, propagation and radiation. To develop rules for defining the CFD domain for the fan, compressor and turbine noise sources and for the matching of CFD solutions to current propagation and radiation model(s), to produce source-to-far-field models for each source type.

WP3. Model Testing and Benchmarking. To test and benchmark the methodology and application rules from WP1 and WP2. This will include application-to-test cases for which experimental data is available for (1) rotor/stator viscous wake interaction, (2) potential interaction tone generation, (3) fan rotor-alone and buzz-saw noise generation and (4) rotor and stator transmission and reflections.

WP4. Low-Noise Design Evaluation and Improvement. To prove and refine the new methodology through a case study of low-noise design concepts identified in RESOUND and elsewhere to develop the tools in a working environment prior to exploitation and to recommend low noise concept improvements.

Expected results

1. A methodology for using unsteady CFD codes and propagation/radiation models to predict the dominant engine tone noise sources, and its cost-effective application to low-noise design concepts on current computing platforms over timescales compatible with both ‘component design’ and ‘analysis’.
2. Validation results for each type of tone-noise source and recommendations for the low-noise design concept improvements.
3. An assessment of the feasibility of using CFD to model fan broadband noise sources.

Title: Turbomachinery Noise-Source CFD Models For Low-Noise Aircraft Engine Designs

Acronym: **TURBONOISECFD**

Contract N°: G4RD-CT-1999-00144

Proposal N°: GRD1-1999-10509

Total cost: €4 783 496

EU contribution: €2 997 673

Starting date: 01/03/2000

Duration: 36 months

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Eindhoven University of Technology	NL
FFA – The Aeronautical Research Institute of Sweden	S
Industria de Turbo Propulsores S.A.	E
MTU Motoren- und Turbinen-Union München GmbH	D
National Aerospace Laboratory (NLR)	NL
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Société Nationale d'Etudes et de Construction de Moteurs d'Aviation (SNECMA)	F
Technische Universität Berlin (TUB)	D
Turbomeca S.A.	F
Université Pierre et Marie Curie – Paris VI	F
University of Cambridge	UK
University of Southampton	UK

1.3. Environmental Friendliness of Aircraft

Cabin environment

Air Management Simulation for Aircraft Cabins

Project objectives

ASICA aims to enhance cabin air quality for the health and comfort of passengers and good working conditions for the crew. This can be broken down as follows:

- producing a set of quantitative criteria relative to air quality;
- providing each partner with validated simulations for their development process equipment, including cabin-interior analysis;
- building both a modular integrated Air Cabin System (ACS) management simulation and a communication infrastructure between partners, using available High Performance Computers; thus enabling collaborative work between firms on future aircraft programmes for global optimisation purposes;
- validating new technical concepts for future aircraft programmes, capable of handling criteria for air quality.

Description of the work

The first task is to improve air quality on the basis of available know-how, and to determine criteria for safety and health (such as gas concentrations, system failure), including subjective criteria related to passenger comfort and crew working conditions. A specific study will then compare critical points of existing ACS against these criteria.

The efficient approach to this enhancement process is to consider ACS management holistically, taking into account interactions between subsystems, including fuel consumption effects. The best technical approach would require a modular global ACS simulation, which would combine a simulation of its components/subsystems with the new comfort criteria (pressure, temperature, humidity, pollutants concentrations). Therefore, models specific to component/subsystems will be created or upgraded for integration in the global ACS simulation. Experiments will be carried out to validate the reliability of these simulations, including specific tests in a cabin mock-up.

To solve critical points, and with selected criteria in mind, new technical solutions (managing humidity in cabin, CO_2 regenerative filters etc.), will be compared for possible trade-offs and the most promising ones selected for validation in experiments against the selected criteria.

A special work package is devoted to research in algorithm and HPCN fields to find an efficient global ACS simulation as a key point of the improvement process. Another research effort will focus on the improvement of controller design and failure detection processes in order to improve safety on board.

Exploitation is planned one year after the end of the project; the results may be applicable to any future large or small aircraft programme.

Expected results

- Analysis of criteria for on-board Air Quality
- Advanced global and modular ACS simulation models, based on simulations for each partner
- A new communication infrastructure between partners, using available High Performance computers
- Introduction of pollutants in CFD simulations, in order to analyse airflow in cabins
- New system concept for Cabin Pressure Control System to avoid uncomfortable conditions
- New regenerative filters, e.g. for CO_2
- New technology for managing humidity
- New solutions for air ducting and recirculation fans, to reduce noise.

Title: Air Management Simulation for Aircraft Cabins

Acronym: **ASICA**

Contract N°: G4RD-CT-1999-00056

Proposal N°: GRD1-1999-10396

Total cost: €10 099 966

EU contribution: €5 049 981

Starting date: 01/02/2000

Duration: 36 months

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Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (CERFACS)	F
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
CTT Systems AB	S
DaimlerChrysler AG	D
Lhottelier Montrichard SA	F
Liebherr Aerospace Lindenberg GmbH	D
Nord-Micro Elektronik-Feinmechanik AG	D
Pall Europe Ltd.	UK
Pica SA	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technofan SA	F

Improving Air Quality in Aircraft Cabins Using 'Measurements in the Sky' and Innovative Designs and Technologies

Project objectives

The key objectives of Cabinair are as follows.

1. To establish the current air quality and the extent of the problem in commercial passenger aircraft.
2. To produce comprehensive information on the relationship of cabin air quality with the performance of the environmental control systems (ECS), filtration systems, the distribution of air in the cabin, and energy consumption and external environmental impact as it relates to fuel burn.
3. To provide innovative designs and technical solutions in the areas of the ECS, the filtration system, and cabin air distribution and control system.
4. To optimise cabin air quality and minimise fuel consumption and external environmental impact.
5. To develop performance specification for the components and propose a draft European Prestandard that will be both technically feasible and economically justifiable, and will address the needs of the EU.

Description of the work

The project comprises five work packages (WPs). The extent of the problem and current air quality in commercial passenger aircraft will be addressed primarily in WP1 ('measurements in the sky'), through a comprehensive cabin air-quality monitoring programme for four generic aircraft types. This programme will also monitor ventilation system performance, allowing the impact of ECS, filtration systems and air distribution systems on cabin air quality to be determined. Analyses will also be made of the operating cost, fuel energy use and external environmental impact arising from the provision of cabin ventilation.

WP2, WP3 and WP4 will address design and technology development of the ECS, filtration systems and cabin air-distribution systems respectively to achieve a cabin environment that is safe, healthy and comfortable. These developments will address priorities arising from the monitoring exercise of WP1, with due consideration for cost, energy use and external environmental impact. Each work package will also tackle the innovations required for the design requirements of future aircraft. These three work packages will review existing design strategies and technologies in detail, and will develop new strategies and technologies through a combination of design assessments, models and technology demonstrators.

WP5 will address the development of performance specifications for the three components and draft a European Prestandard. New performance indices developed in this work package will be measured during the monitoring process in WP1. Guidelines on standards and on certification of innovative technologies will be provided to inform WP2, WP3 and WP4.

Expected results

The most significant results expected are as follows:

- comprehensive survey of cabin air quality of aircraft types that represent the current commercial fleet;
- innovative designs and technical solutions in the areas of the ECS, the filtration system and the cabin air-distribution and control system;
- impact assessment of new designs and technologies on current methods;
- guidelines for draft European Prestandard in the areas of cabin environments in commercial airlines.

Title: Improving Air Quality in Aircraft Cabins Using 'Measurements in the Sky' and Innovative Designs and Technologies

Acronym: **CABINAIR**

Contract N°: G4RD-CT-2000-00366

Proposal N°: GRD1-2000-25033

Total cost: €7 405 621

EU contribution: €3 796 361

Starting date: 01/01/2001

Duration: 36 months

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Centre Technique des Industries Aérauliques et Thermiques	F
Civil Aviation Authority	UK
Fairchild Dornier GmbH	D
Honeywell Normalair-Garrett Ltd.	UK
KLM Royal Dutch Airlines	NL
Netherlands Organisation for Applied Scientific Research	NL
Norges Byggforskningsinstitut	NO
Pall Europe Ltd.	UK
QinetiQ Ltd.	UK
Rolls-Royce Deutschland GmbH	D
Scandinavian Airlines System	S
Universität Gesamthochschule Essen	D

Project objectives

The proposal aims to achieve a better understanding of the health and comfort of the working environment inside aircraft for both crew and passengers through the development of an advanced Human Response Model. This understanding will be translated into improvements that will be promoted through the definition of appropriate schemes and measures for aircraft design (e.g. improved guidelines). European manufacturers and airlines will thus be provided with clearer concepts and design tools with respect to the cabin/cockpit environment, in order to increase the friendliness of this workplace. This will bring direct benefits in relation to health and comfort, achieved by improving the overall quality of the cabin environment for crew and passengers. In addition, indirect benefits are expected through reduction of errors due to poor environments, thus reinforcing the safety of passengers and crew in this important means of transport.

Description of the work

HEACE will evaluate the multidimensional state of comfort perception, in particular with respect to health, well-being, and crew performance in the cabin/cockpit environment. The requirements for a supportive travel environment are reviewed and end-user needs at the workplace identified. Health-related environmental input and output data will form the basis for in-flight and mock-up test settings. In-flight data will be produced for mock-up refinements. A series of measurements with test-subjects, cabin crew and flight crew are to be carried out under flight conditions, particularly in mock-ups, to determine the relevant physical, psychological and medical sets of parameters that define health, comfort and performance in an aeronautical workplace. After pre-processing the data, a statistical analysis and training of ANN structures will be performed in order to develop a Human Response Model. The investigation will support improved tools for the design of a better and safer workplace in aeronautics, and will foster the definition of metrics and guidelines for a general improvement of the cabin/cockpit-environment inside the aircraft.

Expected results

- Review of environmental effects on health and comfort with respect to the travel environment.
- Identification of end-user requirements and constraints on test settings.
- Evaluation of environmental and health-related data for in-flight and mock-up test procedures.
- Tests conducted in mock-ups and in-flight conditions, providing an experimental database.
- Evaluation of data with statistical tools and ANN structures, to develop a Human Response Model.
- New methodology to produce guidelines, evaluation and design tools for the comfort and health of the cockpit/cabin environment.

Title: Health Effects in the Aircraft Cabin Environment

Acronym: **HEACE**

Contract N°: G4RD-CT-2001-00611

Proposal N°: GRD1-2001-40118

Total cost: €4 897 845

EU contribution: €3 288 229

Starting date: 01/12/2001

Duration: 36 months

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EADS Deutschland GmbH	D
Institut für Technische und Angewandte Physik GmbH	D
Institute for Environmental Health, University of Vienna, Austria	A
Paragon Ltd.	EL
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High Performance Anti-vibration Material for Aeronautical Use

Project objectives

The PARVIS (PARallel VIScoelastic) proposal accepted in the framework of the FP5 Growth Programme aims at offering a new vibration damping system based on the SPADD® (for Smart PAssive Damping Device) passive technology already validated in noise attenuation. Indeed, aircraft manufacturers know there is a growing concern about aircraft passenger and crew comfort. The latter is dependent on several issues, although most of the nuisance comes from the level of cabin noise which is generally the consequence of a lack of vibration and noise source efficient attenuation.

The aim of the project is to develop a new damping material which maintains high damping performance under large variations of temperature and aircraft lifespan, with a minimum or no maintenance. This material will be at the root of innovative damping devices, SPADD®, designed by ARTEC Aerospace for structure damping applications. In conjunction with both the innovative material and ARTEC Aerospace's damping technology, which is currently using this kind of material, safety and passenger comfort could be greatly improved.

Description of the work

The 18-month project comprises the design and synthesis of three new polymer materials with characteristics (damping properties) and objectives (performance stability in a large temperature range) which will be clearly defined depending on the potential applications for which this material will be developed.

The project will depend on the collaboration between six European partners, each of them bringing specific knowledge and competencies to their specific fields of expertise:

1. ARTEC Aerospace company (France) meets the requirements of industrialists and manufacturers on a daily basis. The company will provide the user requirements and will be the first end-user of this new material since the material will be embedded in its passive damping devices SPADD®.
2. ISMANS laboratory (France) has acquired an extensive know-how of polymer design and has all the CAD software needed for such activity.
3. IQS team (Instituto Químico de Sarria, Spain) will work together with ISMANS to design and synthesise three new polymers.
4. MAKROSS, a German engineering office, will work on developing theoretic approaches for predicting the dynamic behaviour of those materials.
5. Ultimately, JEVSA, a Spanish rubber manufacturing company, will terminate the project by performing a manufacturing process study once ARTEC Aerospace has conducted a mechanical characterisation of the material (i.e. mechanical tests and experimental validation of the predicted properties). Materials pre-series will be initiated and ARTEC Aerospace, the material end-user, will validate them.
6. Throughout the project, the assistant contractor EURO-INTER, will give technical advice and disseminate information.

Expected results

The new developed material in the framework of this Shared Cost Project will eventually respond to present societal needs, in particular the improvement of passenger and crew comfort as this issue is becoming more and more important and norms are becoming more and more stringent. Actually, combined with ARTEC Aerospace's SPADD® damping devices, the inner noise perceived by aircraft passengers could be greatly decreased despite the broad temperature variations surrounding the devices. In addition, this project will respond to Community added value by creating an inexpensive European-made viscoelastic damping material to replace the current material which is US-made and costly.

Title: High Performance Anti-vibration Material for Aeronautical Use

Acronym: **PARVIS**

Contract N°: G4RD-CT-2001-00495

Proposal N°: GRD1-2000-25105

Total cost: €614 900

EU contribution: €419 800

Starting date: 01/04/2001

Duration: 18 months

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ISMANS – Institut Supérieur des Matériaux du Mans	F
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1.4. Operational Capability and Safety of Aircraft

Air Traffic Management (ATM) related air borne systems

The Transition towards Global Air and Ground Collaboration in Traffic Separation Assurance

Project objectives

The objective of the INTENT project is to link 'information about the aircraft intention' (calculated by the aircraft's Flight Management System (FMS) and sent out to other aircraft and the ground Air Traffic Management (ATM) system) to the traffic separation assurance process (either airborne or ground-based) and the resulting airspace capacity. The central research question of INTENT is defined as follows:

"How does the level of aircraft INTENT information, shared among ATM users and actors, relate to the air traffic system capacity, the avionics system design and ATM system design?"

The objective of INTENT is to answer this question, providing a technology roadmap and implementation plan for airborne and ground-based equipment to increase airspace capacity. For that purpose, a relationship between aircraft intent information, the place of responsibility for the traffic separation assurance process (air, ground) and airspace capacity has to be found

Description of the work

Linking the aircraft intent information, the place of responsibility for the traffic separation assurance process and airspace capacity would normally require extensive and expensive real-time simulations. The approach in INTENT, however, is to use off-line, compressed-time simulations to generate the required objective data and to use real-time simulations to develop the compressed-time models and validate the outcome of the compressed-time simulations.

Within INTENT, the following three-dimensional experiment-matrix will be considered:

- Four levels of intent information (aircraft current state (0 − 5 minutes ahead) and aircraft flight plan information (10, 15, 20 minutes ahead).
- Three operational concepts with two locations of the traffic separation assurance process:
  - airborne traffic separation assurance, unstructured airspace (no routes),
  - ground traffic separation assurance, unstructured airspace (no routes),
  - ground traffic separation assurance, structured airspace (fixed routes).
- Three traffic samples (today, 2 x today, 4 x today).

Compressed-time simulations will include air-traffic controller characteristics and pilot characteristics derived from real-time human-in-the-loop part-task simulations. The compressed-time simulations will collect data on the number of controller and pilot actions (indication of workload), ATC sector throughput, safety (separation violation) and efficiency (fuel used), using capacity metrics identified within the INTENT project.

The compressed-time simulations, addressing the complete experiment-matrix, are expected to demonstrate where (air/ground) and when (traffic scenario) the different levels of intent information can best be used to increase airspace capacity.

Following the compressed-time simulations, the results of the compressed-time simulations will be verified during real-time human-in-the-loop simulations. These simulations are intended to confirm the compressed-time simulation results, adding confidence to the results.

Expected results

The main project output is a roadmap of technologies associated with the implementation of an ATM system, showing considerable increase in capacity. This result is expected to include the use of information available from the aircraft in the air-traffic management process, either in an autonomous way, or as part of a co-operative scheme. An implementation plan will be drafted in INTENT in which technologies will be identified that relate to increased airspace capacity and the extent to which the market will be prepared to invest in their implementation, as a function of time.

Title: The Transition towards Global Air and Ground Collaboration in Traffic Separation Assurance

Acronym: **INTENT**

Contract N°: G4RD-CT-2000-00394

Proposal N°: GRD1-2000-25326

Total cost: €3 233 521

EU contribution: €1 621 760

Starting date: 01/12/2000

Duration: 24 months

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Delft University of Technology	NL
EUROCONTROL – European Organisation for the Safety of Air Navigation	INT
KLM, British Airways and SAS (AEA)	INT
Office National d’Etudes et de Recherches Aérospatiales (ONERA)	F
QinetiQ Ltd.	UK
Rockwell-Collins France	F
Smiths Industries	UK
Vereniging voor Nederlandse Verkeersvliegers	NL

Smart Hybrid Integrated Navigation Equipment

Project objectives

The SHINE project (Smart hybrid Integrated Navigation Equipment) aims to improving air transport efficiency and quality by offering new navigation and attitude sensors at low cost, enabling aircraft to fly and land in a more dense European airspace with the same or better level of safety. Allowing helicopter and regional aircraft to have Head Up Guidance or CAT I landing capability at a low cost also makes a major contribution to the reduction of operating costs, allowing a reduction in number of diversions to other airports in case of bad weather conditions.

The main goal is to make progress at European level in the following domains:

- Requirement identification for future AHRS/GNSS system,
- Low-cost inertial technology by evaluation of one technology singled out as best candidate,
- Self-redundant inertial sensor equipment,
- GNSS signal-processing technique for attitude determination applied to aircraft environments,
- Improved AHRS/GNSS hybridisation techniques,
- GNSS1 EGNOS receiver performance, including promotion of EGNOS system through Fly Tests,
- GNSS receivers transition to different augmentations and constellations (GBAS, GALILEO/GNSS2),
- GNSS techniques for enhanced robustness to environmental interference.

Description of the work

The approach selected in SHINE is to build on progress already made in two areas (GNSS integrity and low-cost inertial sensor technology) and add in advanced processing techniques in order to design equipment that will deliver navigation and kinematics parameters that are smaller and cheaper than current configurations, while maintaining at least equivalent performance. In one low-cost low-weight configuration, the equipment will provide all positioning, attitude and kinematics parameters required by control, guidance and navigation avionics systems.

The work plan is structured around the key research area (low-cost IMU, GNSS based attitude) and includes development of the prototype equipment (base-line design, prototyping, flight test, etc). The project aims to define, manufacture and test in flight an airborne prototype equipment based on this new concept, to assess what performance can be achieved. The project also aims to define the future product, with preliminary safety and certification analysis and analysis of user requirements. The work programme is divided into eight work packages. Each key component of the SHINE concept is associated with a dedicated work package.

WP1 : Baseline Design	WP5 : Prototype Manufacturing
WP2 : Low-Cost Inertial Measurement Unit	WP6 : GNSS extension studies
WP3 : GNSS Attitudes	WP7 : Flight Testing
WP4 : AHRS/GNSS Hybridization	WP8 : Management & Conclusions

Expected results

The following expected results have been identified for the complete SHINE project:

- Definition of the whole system taking the variety of potential users into account, from light helicopters to heavy airline carriers.
- Definition and testing of the self-redundant inertial sensor architecture and of sensor fusion algorithms
- Definition and validation of basic inertial sensor technologies
- Prototype Development, Laboratory and flight tests.

Title: Smart Hybrid Integrated Navigation Equipment

Acronym: **SHINE**

Contract N°: G4RD-CT-2000-00227

Proposal N°: GRD1-1999-10370

Total cost: €4 979 836

EU contribution: €2 651 267

Starting date: 01/05/2000

Duration: 36 months

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Eurocopter S.A.	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technische Universiteit Delft	NL

1.4. Operational Capability and Safety of Aircraft

Accident prevention

Air Conformal Fibre Optic Ice Detection System

Project objectives

The major scope of the project aims to deliver complete wind tunnel-tested integrated sub-systems embedded in real structures working in concert with distributed de-icing computer algorithms in order to eliminate the formation of various types of ice on aircraft efficiently and with point specificity. Secondary objectives include the simultaneous monitoring of the influence of stress factors on all sensor architectures and modules. This requires a proper characterisation of the optical properties of ice during ice accretion on critical surfaces such as rotor blades and wing leading edges, and of the manufacture and integration of fibre sensors in such structures for the detection of ice formation and real-time data acquisition algorithms.

Description of the work

It is well known that a number of aviation accidents involving aircraft may have been due to ice. The major concern is with ice accretion during holding patterns in airports in adverse weather conditions, and for all-weather helicopters. Although ice detection is not mandatory in general aviation, the Federal Aviation Authority (FAA) is pressing for all aircraft to be equipped with an icing alert system, which is also likely to be adopted by the European Joint Airworthiness Authorities (JAA). To this end, in 1996 the FAA initiated a 13-point In-flight Aircraft Safety Plan. For helicopters and some types of aircraft, localised ice accretion can be a major safety issue, but to date no air conformal ice detection systems are commercially available.

The ACIDS proposal aims to develop and test a system in a wind tunnel under icing conditions which will be capable of detecting the presence, thickness and type of ice accreted on the leading surfaces of rotary and fixed wing aircraft. The system will be capable of measuring ice formation directly on leading surfaces, raising an alarm and automatically activating localised de-icing (DI) elements. The capability of the system is designed to reducing engine power consumption normally diverted to DI in difficult flying conditions, and hence it will make a substantial contribution to aircraft safety.

The project will bring together innovative European SMEs, major European helicopter and aircraft manufacturers and research institutes to work on a safety aspect of aviation industry which crosses national and company boundaries and addresses an issue that is becoming ever more critical.

Efforts will be concentrated in three main areas:

1. determination of appropriate optical sensor detection architectures in fibres;
2. their integration in existing rotor blade and wing structures;
3. miniaturisation and integration of the optical modules with the data acquisition hardware and algorithms interfaced with localised de-icing procedures.

Expected results

A number of significant milestones and results include fibre-based sensor architectures for the detection of ice accretion on airfoil surfaces, fibre sensor integration in rotor blade composite structures, integrated sensor and data acquisition modules for rotor blades and wing edges, wind tunnel evaluation profiles of modules and stress monitoring. Such results will be evaluated in collaboration with the FAA and JAA authorities for future exploitation actions.

Title: Air Conformal Fibre Optic Ice Detection System

Acronym: **ACIDS**

Contract N°: G4RD-CT-2001-00612

Total cost: €3 027 865

Proposal N°: GRD1-2001-40170

EU contribution: €1 617 731

Starting date: 01/01/2002

Duration: 36 months

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Cambridge Optical Services	UK
Eurocopter Deutschland GmbH	D
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University of Limerick	IRL

Human-Centred Systems for Aircraft Dispatch and Maintenance Safety

Project objectives

ADAMS-2 will develop an analysis of the human role in reliability and effectiveness in the systems and processes of aircraft maintenance – at the level of the task, the individual and group, events and incidents, and the organisation. This will support the development and evaluation of tools and methodologies to improve practice in design, quality management, and the management of risk. Organisational change requirements for successful implementation and costs and benefits of these interventions will be examined. The project aims to achieve the following innovations:

- Design guidelines and tools to enable the aircraft and avionics manufacturer to measure the impact of maintainability issues during the design phase;
- New methodologies for auditing and assessing tasks, situations and organisations;
- A comprehensive approach to managing the risks associated with incidents;
- Analysis of organisational change to overcome barriers to effective implementation
- Cost-benefit case studies.

Description of the work

ADAMS-2 comprises a systematic approach to integrating human factors requirements in aircraft maintenance systems from the design of aircraft to ensuring the safety, reliability and cost effectiveness of operations. The first stage defines the requirements to achieve this and is divided into four distinct levels of analysis. These are the task (Task analysis); the person and working group (Professional skills); incidents and events (Event information management); and the organisation (Organisational systems). A methodology for undertaking cost-benefit case studies will also be developed at this stage (Cost benefit evaluation criteria).

The basic research accomplished in these work packages will be brought together in a specific integration activity (Stage 2) in order to ensure that the work supports the development of truly complementary methodologies and tools in Stage 3 of the project.

Stage 3 (Development and pilot implementation) develops and tests tools and methodologies in the following spheres of activity: aircraft design for maintainability (Design guidelines and tools); auditing (Quality auditing) and the management of risk associated with incidents and events (Events and organisational learning). The requirements for organisational change involved in the implementation of these tools and methods are the subject of a specific workpackage (Organisational change). Case studies of cost-benefit analysis will be based on the activities of Stage 3 (Cost benefit case studies).

Stage 4 (Evaluation and Review) comprises two work packages which evaluate the products and deliverables which are relevant to the aircraft manufacturer and maintenance organisation respectively. The Finalisation work package concludes the project's work taking into account the results of Stage 4.

Expected results

- Design for maintainability guidelines integrating both physical and cognitive aspects of tasks.
- Auditing and assessment tools for Task and Professional skills.
- Organisational Auditing tools for safety and reliability systems and organisational culture.
- Operational Incident Reporting and Risk Assessment System.
- Guide to Human-Centred Management for Aircraft Maintenance.
- Methodology for cost-benefit analysis of human-centred interventions.

Title: Human-Centred Operations in Aircraft Dispatch and Maintenance Safety

Acronym: **ADAMS 2**

Contract N°: G4RD-CT-2001-00502

Proposal N°: GRD1-2000-25751

Total cost: €4 545 018

EU contribution: €2 701 259

Starting date: 01/04/2001

Duration: 36 months

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Sabena Technics S.A.	B
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
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Wake Vortex Characterisation and Control

Project objectives

The C-Wake project addresses physical aspects of aircraft-generated wakes through characterisation. It aims to provide application guidelines for the European aircraft industry through the treatment of wake control; it also synthesises findings from various critical technology projects and other related sources with the eventual goal to arrive at a validated method of predicting wake characteristics of Large Transport Aircraft with sufficient accuracy. C-Wake results are intended to contribute to flight safety, to enhance the competitiveness of the European aircraft industry, and to provide input to approaches to increasing capacity.

Description of the work

The C-Wake project will advance Wake Vortex characterisation and control in future applications of large passenger transport aircraft. This is to be accomplished within two main work packages, one experimental and one numerical, in which various high-standard tools are employed to address wake vortex topics in complementary schemes. A third work package will summarise results, provide a wake vortex database structure and issue guidance to industry.

Work package 1 focuses on experimental investigations, first measuring and then characterising the flow field generated by aircraft models in experimental facilities (wind tunnel, catapult, towing tank) or by real aircraft flying over a facility that measures their wakes. The main objective will be the characterisation of aircraft vortex wakes and the effects which a particular aircraft configuration – or a single component – has on wake behaviour.Experiments are expensive. Hence it has become mandatory to employ less expensive numerical approaches.

Work package 2's goal is wake *modelling* which emerged as a challenging topic aiming to provide realistic descriptions of vortex wakes. The tools employed are high-end computers, with results from experiments serving to validate codes. The greatest *added value* could be achieved through a combination of both numerical and experimental approaches complementing each other. Interrelated activities between both work packages will become mandatory to meet the objectives set out in the programme.

A prime goal of the C-Wake project is to describe the *unsteady* effects in a wake which are believed to be a key to understanding wake decay.

The focus of the whole C-Wake research effort is to put forward the methodologies which industry could use as guidance for designing large transport aircraft which shed benign vortex wakes. A unique *database* will be established which will for the first time allow access to others to draw on the resources obtained in the C-Wake Project and elsewhere.

Work package 3 will try to assemble these findings into workable methods. The exchange of data between these work packages will be vital to efficiency, and also forging links with C-Wake's sister projects, I- Wake and S-Wake. Before air traffic separation distances can be safely reduced, viable solutions from these critical wake-oriented Technology Projects have to be provided.

Expected results

- Wind tunnel tests of realistic large aircraft model in near field will provide data on the effect of wake-modifying devices. A parametric database will be available from near field testing.
- In catapult tests an Airbus-type model and a very large aircraft model will be tested with the PIV operating with up to ten CCD cameras. That will open up a new dimension for the PIV application. A database from this testing will be made available and deliver inputs to WP2.
- Towing tank experiments will provide data on realistic wake decay and through this open up a new dimension to access the far field.

- Flight tests of Airbus A340 overflights will be measured by ground-based LIDAR systems. The analysed data will deliver datasets for the database.
- The Numerical Assessment of far field simulations will deliver inputs to the databank.

From the synthesis of the established database the required inputs will be used to produce validated recommendations for acceptance by industry.

Title: Wake Vortex Characterisation and Control

Acronym: **C-WAKE**

Contract N°: G4RD-CT1999-00141

Proposal N°: GRD1-1999-10332

Total cost: €14 647 682
EU contribution: €7 573 854
Starting date: 01/01/2000

Duration: 36 months

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Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
CFD Norway A.S.	NO
Debis Systemhaus Solutions for Research GmbH	D
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Hamburgische Schiffbau-Versuchsanstalt GmbH (HSVA)	D
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Instituto Superior Técnico (IST) Lisboa	P
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QinetiQ Ltd.	UK
Société d'Ingéniérie, de Recherches et d'Etudes en Hydrodynamique Navale S.A. (SIREHNA)	F
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Methods and Technologies for Aircraft Safety and Protection against Electromagnetic Hazards

Project objectives

The technical and scientific objectives of EM-Haz are to develop and validate efficient methods and techniques to improve aircraft safety and protection against electromagnetic (EM) hazards, including direct lightning effects. New configurations are being considered, including equipment, system and airframe, and also new materials. The methods and techniques developed will be targeted to handle the different EM aspects throughout the aircraft life-cycle, from threat specification to design, certification and in-service operation issues. The innovative aspects are state-of-the-art development regarding methods and techniques for assessing different EM properties and protection strategies during aircraft development, and also new methods for the efficient combination of these techniques in the verification/certification and maintenance phases.

Description of the work

Throughout EM-Haz, the scientific methodology that will be used in developing new methods and techniques is the constant verification of these methods and techniques against validated models and physical theories, and also against measurements and experiments that are performed under controlled and reproducible conditions. The project will be strongly based on the results and techniques from the preceding EC projects, CATE and FULMEN, that are ongoing.

First, the external electromagnetic environment is being reviewed, and the external electromagnetic and lightning threats to aircraft are being updated. Potential new electromagnetic threats (due to emerging technologies such as portable electronic devices (PEDs) and potential terrorist threats) are also under consideration. Then, the CATE and FULMEN results are critically analysed. Based on this analysis, efficient means are developed to predict the internal response in complex aircraft system configurations. Methods are established for the efficient determination of internal threat levels in order to derive equipment specifications. The following step is to develop optimised protection techniques for direct lightning effects on composite structures, and to identify and improve available ways to use airframe protection techniques to reduce the indirect electromagnetic effects on internal structures, installation and equipment.

Then, a process for electromagnetic hazard protection and qualification of modular avionics systems will be defined. Protection strategies for interference from PEDs will be evaluated and validated.

Finally, the qualification/certification process for aircraft will be reviewed, including an investigation of the need for new regulations (e.g. PEDs) and the establishment of new compliance demonstration methods and strategies.

Expected results

The main exploitable outputs from EM-Haz will be the Lightning Zoning Tool, the in-flight Lightning measurement system, as well as the methods and techniques for concept evaluation, protection design and compliance demonstration for structures, systems and equipment.

Title: Methods and Technologies for Aircraft Safety and Protection against Electromagnetic Hazards

Acronym: **EM-HAZ**

Contract N°: G4RD-CT-1999-00093

Proposal N°: GRD1-1999-10020

Total cost: €7 989 051

EU contribution: €3 994 524

Starting date: 01/03/2000

Duration: 40 months

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Culham Electromagnetics and Lightning Ltd.	UK
Dornier GmbH	D
Eurocopter S.A.	F
Eurocopter Deutschland GmbH	D
GIE EADS CCR France	F
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F

Enhanced Safety Assessment for Complex Systems

Project objectives

The technical and scientific objectives of ESACS are: to define a methodology to improve safety analysis practice for complex systems development; to set up a shared environment based on tools that support the methodology; to validate the methodology through its application to case studies. The environment between design and safety will consist of tools to generate parts of the safety analysis, using information extracted directly from the system model, and also a repository that will include all the safety information related to the Complex System under development.

Description of the work

The ESACS technical work is divided into six work packages (WP).

WP1 deals with the identification of the requirements for complex systems safety/certification process through the analysis of the actual procedures in order to find out the points/development phases where the safety analysis process could be improved and better integrated with the design/development process.

WP2 represents the core of the project. It deals with the development of an enhanced safety analysis methodology and environment. It will provide a closer link between system modelling tools (like STATEMATE, SCADE) and the safety analysis techniques (classical ones like FTA or FMEA as well as the new ones developed within ESACS), and it will provide novel powerful analysis techniques based on formal verification methods, together with the development of failure mode models.

WP3 deals with the definition of case studies which will be used to validate the outputs of WP2.

WP4 represents the application of the methodology and of the environment in case studies.

WP5 will handle the exploitation and dissemination of the results

WP6 will provide the project management.

Expected results

Methodology and enviroment with tools for supporting the safety process of complex systems.

Innovations and benefits:

- enhanced integration of safety and design/development processes;
- improved traceability of safety issues during the complex system development;
- computer-aided analysis helps to master complexity;
- worst-case considerations in FMEAs and FTA avoided;
- weak points revealed in early points of design.

Title: Enhanced Safety Assessment for Complex Systems

Acronym: **ESACS**

Contract N°: G4RD-CT-2000-00361

Proposal N°: GRD1-2000-25060

Total cost: €6 014 276

EU contribution: €3 348 255

Starting date: 01/02/2001

Duration: 30 months

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Kuratorium Offis e.V.	D
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Prover Technology AB	S
Saab AB	S
Societa' Italiana Avionica	I

Instrumentation Systems for On-board Wake Vortex and Other Hazards Detection Warning and Avoidance

Project objectives

The overall objective is to improve the operational capacity and safety of air transport by developing on-board integration of a system for the remote detection, warning and avoidance of wake vortices and other atmospheric hazards (dry wind shear, clear air turbulence, volcanic ashes). The system will principally provide on-board remote detection of wake vortices during approach phases. In this way, the required level of safety can be guaranteed during approaches with reduced separation distances, or by flying behind a very large transport aircraft without the need to apply extended separation, while the aircraft is autonomously flown by the pilot.

Description of the work

The work is organised with a view to making steady progress in system definition, integration capability and airborne performances:

Work package 1000 System Definition is dedicated to defining the airborne I-WAKE system and its integration in aircraft, including assessment of the system's safety and benefits.

Work package 2000 Flight Simulation Tests contributes to validate WP 1000 studies on wake-vortex avoidance manoeuvres definition and to test appropriate Man Machine Interface concept.

Work package 3000 Flight Tests intends to fly a prototype of airborne LIDAR, to perform in-flight measurements behind a leading aircraft and to analyse wake-vortex detection capabilities. Longer range detection capabilities for detection of dry wind shear and clear air turbulence will also be tested. Additionally, to prove the feasibility and the efficiency of an airborne system, WP 3000 in-flight recordings -will be compared with previous ground results.

Work package 4000 Techniques and Technologies is oriented towards European development of the techniques and technologies required for a compact, reliable, efficient and affordable future industrial airborne system. The LIDAR optics used for flight test in WP 3000 is based on high-technology components from a USA company. I-WAKE aims to develop European capability to provide similar, hopefully more compact, components. Development of processing algorithms for automatic wake-vortex pattern recognition in real time, to be integrated in the future equipment, also presents a challenge, to be demonstrated in this work package.

Work package 5000 Management and Final Synthesis. Synthesis is the convergence key point of all the other projects, allowing their conclusions to be updated. Definitions will be drawn up of the future airborne equipment, its perspectives, and the necessary complementary activities.

Expected results

- availability of major system definition inputs, of installation constraints for equipment to be flight-tested and first results from laboratory mock-up of LIDAR;
- availability of most input elements for final on-board system definition and update of benefits;
- project conclusions concerning progress made on techniques and technologies during I-WAKE, and final definition of on-board system and benefits.

Title: Instrumentation Systems for On-board Wake Vortex and Other Hazards Detection Warning and Avoidance

Acronym: **I-WAKE**

Contract N°: G4RD-CT-2002-00778

Proposal N°: GRD1-2001-40176

Total cost: €5 903 737

EU contribution: €3 292 522

Starting date: 01/05/2002

Duration: 36 months

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Université Catholique de Louvain	B

Increasing Safety by Enhancing Crew Situation Awareness

Project objectives

The density of air traffic is increasing steadily, and the resulting local congestion is becoming more and more of a problem. These increasing traffic demands call for new innovative system solutions on-board aircraft to improve the current safety and reliability standards. ISAWARE II will make a major contribution to solve the issue of improving both safety and efficiency of flight operations. It consists of a new and unique way to present to the pilots information on the terrain, surrounding traffic, weather and airport conditions that will be consistent with their natural perception. This comprehensive presentation will provide not only a totally new quality of crew situation awareness but will also enables pilots to play proactive and co-operative roles in Air Traffic Management. Therefore, ISAWARE-II fulfils the Growth programme objectives 4.4.3 'accident prevention' objectives completely.

Description of the work

The following technical innovations will be developed and evaluated by airline pilots on flight simulators during ISAWARE II:

- Interactivity concept, applied to the use of surveillance system, that will enable pilots to customise their display presentations, introducing more flexibility through pop-up menus to be selected by a novel Crew Control Device, and to build non-dedicated control panels which will reduce the number of control panels required, and thus also reduce the overall cost of the aircraft.
- Proactive system enabling the pilot to prepare his route planning, thanks to the interactivity with both cockpit display system and the FMS.
- An Intelligent Crew Support (ICS) system to assist the crews in high workload and critical situations, when flight operations are found most difficult and prone to human errors.
- A novel exocentric Navigation Display presentation that will greatly enhance the crew's vertical awareness during approach and departure, in order to enhance safety during these phases of flight that are prone to CFIT accidents.
- Situation-awareness during the ground phases (taxiing, take-off and landing) will be further evaluated by using a taxi display, which is to be integrated with the navigation display.

Furthermore, following the ISAWARE studies done on workstations, ISAWARE II will address the integration and certification aspects of such a system by developing and experimenting a mock-up based on embedded hardware.
The ISAWARE II mock-up will be tested in a fixed base-flight simulator with test pilots to have a first evaluation of the work and to test the various HMI and other system options available. Finally, the mock-up will be installed in a moving base-flight simulator to be evaluated by airline crews.

Expected results

ISAWARE II project is aimed at improving the safety level, as planned for 2010, by bringing down the current CFIT-related Approach-and-Landing Accident rate for civil transport aircraft by about 5% per year. Furthermore, as terrain, weather and other traffic are presented in a natural way, take-off and landing intervals may become the same under IMC conditions as they are today under VMC conditions. This will bring the European industry not just abreast but ahead of US competitors.

Title: Increasing Safety by Enhancing Crew Situation Awareness

Acronym: **ISAWARE II**

Contract N°: G4RD-CT-2002-00800

Proposal N°: GRD1-2001-40169

Total cost: €7 534 587

EU contribution: €4 075 512

Starting date: 01/07/2002

Duration: 36 months

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Diehl Avionik Systeme GmbH	D
Eurocopter S.A.	F
Skysoft Portugal, Software e Tecnologias de Informaçao, SA	P
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

Development of a Robotic System for the Inspection of Aircraft Wings and Fuselage

Project objectives

The objective is to develop a robotic inspection system which will walk over large areas of an aircraft structure and carry out automatic data collection and interpretation to identify defects without the need to dismantle components. At present, most Non-Destructive Evaluation (NDE) inspections are undertaken manually with limited coverage that attracts the following drawbacks: high maintenance penalty due to slow rate of inspection; reduced probability of detection; high cost and erroneous results (false calls) due to subjectivity and fatigue of the operator.

Technically, the objectives are to overcome the above limitations by developing a robotic NDE inspection system capable of rapid automatic scanning of large and complex structures. This will be achieved by developing novel NDE techniques that can be deployed using a robotic system. The economic objectives are to reduce the cost of aircraft inspections and increase EU competitiveness when compared to foreign enterprises. The social objectives of this project are:

1. elimination of labour-intensive and monotonous inspection tasks,
2. elimination of the need for operators to work in confined and dangerous spaces,
3. elimination of subjective data interpretation,
4. enhanced reliability of aircraft inspection.

Description of the work

In addition to using conventional NDE sensors, the project involves development in four new technology areas: an acoustic camera, phased arrays, thermography and dry coupling. A robotic system, consisting of a mobile vehicle and a scanning module, is also being developed. Hence nb the project conveniently lends itself to division into two major research and development areas:

1. **Novel NDE techniques.** The RTD performers will deliver novel NDE techniques and peripherals specifically for robotic deployment. This will increase ability to detect defects and decrease inspection time. The defects to be detected will be: cracks around fasteners, bond quality in bonded structures, areas of corrosion, and impact damage. The peripheral instrumentation will be further developed to: miniaturise NDE sensors, eliminate or reduce wiring, and reduce sensor weight. The selected techniques will be refined to be easily interfaced and deployed by a robotic system.
2. **Robotic system.** The robotic system for deploying NDE sensors will consist of a mobile vehicle able to travel vertically and horizontally on large structures (which may be curved) using pneumatic suction cups for adherence. The vehicle will be capable of climbing heights of up to 20 m. It will carry a mechanical 'XYZθ' scanner module to the inspection surface, controlled automatically or by an operator using visual feedback. The scanner will then manoeuvre the NDE sensor in the specified inspection routine. This could involve skewing the probe, rotating the probe, or maximising signals by iterative movements etc. Finally, once the robotic system is taking readings on the aircraft surface, defect visualisation software will provide the necessary information to the operator and display/store the defect data for real-time or future reference.

The multi-tasking robotic NDE system will be developed in six work packages (WPs):

WP-A. System specification and provision of defect samples.
WP-B. NDE techniques.
WP-C. NDE sensors and systems.
WP-D. NDE scanner module.
WP-E. Mobile climbing vehicle.
WP-F. System Integration and testing.

As the project mid-term point approaches, the stages of system specification, collection of defect samples, design of the vehicle/scanner and development of NDE techniques have been completed. More than half of WP-C work has been completed and the final integration and testing phase, which depends on the output of prior WPs, is due to start on schedule.

Expected results

The final result will be a field prototype one-stop inspection system, operating in the aircraft industrial inspection environment and establishing the automation of inspection tasks that previously have been performed either with limited automation or, in some cases, entirely manually. Full operator manuals will be available for this robotic system, which will be fully modular in conception. This will facilitate the exploitation of individual elements such as the NDE sensors and systems, mechanical scanner module and the mobile climbing vehicle as stand-alone items, as well as the entire ROBAIR one-stop inspection system.

Title: Development of a Robotic System for the Inspection of Aircraft Wings and Fuselage

Acronym: **ROBAIR**

Contract N°: G4ST-CT-2000-50028

Proposal N°: CRAF-1999-70040

Total cost: €1 910 612

EU contribution: €954 000

Starting date: 01/01/2001

Duration: 24 months

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Technical University of Sofia	BG
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ZENON SA – Industrial Automation	EL

Assessment of Wake Vortex Safety

Project objectives

1. Improve the physical understanding of wake vortex evolution and decay in the atmosphere under various weather conditions.
2. Classify the weather in predictable classes of wake vortex safety.
3. Improve and validate wake vortex and decay models.
4. Improve and validate existing models for aerodynamic forces and moments during wake vortex encounter.
5. Improve flight simulation capabilities for realistic wake vortex encounter safety studies.
6. Establish a validated probabilistic safety assessment environment for wake vortex safety studies.
7. Analyse the wake vortex safety aspects under current wake vortex separation rules.
8. Define possible new ATM concepts, which allow a safe mitigation of the current separation rules under certain conditions (e.g. weather).
9. Analyse the wake vortex safety aspects of a new very large transport aircraft like the A380.

Description of the work

The S-Wake project aims to develop, validate and apply tools for addressing appropriate safe wake vortex separation distances. The short-term needs of the aircraft industry are addressed by studying the potential hazard from a new A380-like aircraft in comparison to that from existing heavy aircraft (B747). The S-Wake project also addresses the airport congestion problems caused by the current strict wake separation rules. The influence of weather conditions on wake vortex evolution and decay is studied. Attempts will be made to define predictable wake vortex safety weather classes in order to allow a mitigation of the current strict separation rules under certain circumstances. Advanced numerical methods and existing databases with wake vortex behaviour in real atmosphere will be used to improve and validate simple models for wake vortex evolution and decay.

Wake vortex encounter models to predict the aerodynamic forces and moments on an aircraft during wake vortex encounter will be improved and validated against flight test data. Realistic flight simulation environments will be developed and validated against the flight test results. Afterwards, wake encounters will be simulated for a range of aircraft sizes, wake topologies (strengths) and wake interception conditions, including worst case scenarios. The pilots' perceptions of aircraft handling quality and level of safety during the encounter will be compared with the risks of flying through the wake of a B747-400.

In order to analyse the safety levels under current operating conditions near airports, a probabilistic method for wake vortex safety studies will be developed and validated against results from a large collection of data based on Flight Data Recording (FDR) data. This database will be collected and processed with an automatic detection and classification algorithm that will be developed in the S-Wake project. Data from most incoming aircraft at Heathrow airport will be collected and analysed during a period of one year. A statistical analysis of the data will be made, which will allow a verification of the probabilistic modelling approach. Results from the probabilistic risk assessment and the FDR data analysis will be used to explore the possibilities for reduced separation rules under certain operational or weather conditions. The S-Wake consortium combines the expertise of civil aircraft manufacturers, aeronautical research institutes, flight mechanical experts from universities, meteorological institutes, aircraft safety regulation and ATM experts in a highly multi-disciplinary project dedicated to the assessment of wake vortex safety. It is run in close co-operation with the related C-Wake project and the Thematic Network WakeNet.

Expected results

- assessment of levels of safety for flying into the wake of different aircraft, including new A380-like aircraft;
- assessment of the effectiveness of so-called 'low-vortex' designs;
- assessment of levels of wake vortex safety for current ATM practice;
- a classification of wake vortex safety weather conditions that may allow a safe mitigation of separation rules;
- definition of possible new concepts for a safe mitigation of wake vortex separation rules.

Title: Assessment of Wake Vortex Safety

Acronym: **S-WAKE**

Contract N°: G4RD-CT-1999-00099

Proposal N°: GRD1-1999-10695

Total cost: €5 678 812

EU contribution: €3 007 452

Starting date: 01/01/2000

Duration: 36 months

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Météo-France	F
National Air Traffic Services Limited	UK
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Spirent Systems	UK
Technische Universität Berlin (TUB)	D
Technische Universität Braunschweig	D
UK Met Office	UK

Project objectives

The project has set up four concrete objectives, for each of which a major project output will be delivered. The key project objectives and their associated outputs are:

- quantitative validated data to assess the actual benefits and safety gains of the projected audio system, derived from part-task evaluations and rigorous tests during full flight simulations;
- complete specifications of a cockpit audio system, including distant voice input and output (DVI, DVO) and 3D-sound, compatible with one aircraft system;
- a certification memo proposing and documenting solutions to certification issues for regulation authorities and airframers;
- a documented audio system mock-up that achieves the required performances.

Description of the work

SAFE SOUND is structured in five work packages:

1. operational requirements,
2. human factors studies,
3. system definition and certificability,
4. technological developments,
5. evaluation of safety gains in a full-flight simulator.

Operational requirements are the first step to build on. The participation of a major European airframer, a European organisation for the Safety of Air Navigation, a major European avionics supplier, and a major European airline guarantees an adequate identification of line-orientated requirements.

The second step is the identification of functional requirements and procedures: how to transform operational demands into user-centred (crew) requirements while ensuring that advanced audio features will lead to increased crew situation awareness and safety. Here the Human Factor is essential for identifying the most promising uses of advanced audio and to assess the long-range usability of candidate technologies. Three partners have extensive experience in performing quantitative human factor experiments in the aviation domain.

The third step addresses the system and certificability aspect, while the fourth is about the adaptation of off-the-shelf technology to avionic applications. Two partners have a wide experience in certification, and three partners have a wide experience in advanced audio technology. The participation of the airline partner is also important because airline operations are essential to the final success of the advanced audio system.

Finally, the advanced audio concepts will be subject to rigorous testing. The use of a full-flight simulator will allow a comprehensive and objective assessment of the actual safety gains and the crew reactions and performance.

Expected results

The main expected results are:

- full specifications of the enhanced audio system,
- a certification memo that provides answers to main certification issues,
- a complete mock-up of the audio system.

The results will be disseminated through presentations made at a final symposium. The project will focus on the domain of commercial transport aircraft.

Title: Safety Improvement by Means of Sound

Acronym: **SAFE SOUND**

Contract N°: G4RD-CT-2002-00640

Proposal N°: GRD1-2001-40178

Total cost: €5 362 804

EU contribution: €2 681 400

Starting date: 15/05/2002

Duration: 36 months

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EADS France S.A.S.	F
EUROCONTROL – European Organisation for the Safety of Air Navigation	INT
Netherlands Organisation for Applied Scientific Research (TNO)	NL
Risoe National Laboratory	DK
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL

UAV Safety Issues for Civil Operations

Project objectives

Unmanned aerial vehicles (UAV) are increasingly being seen as the next step in aircraft evolution, with the potential to replace manned aircraft over a broad range of civil roles. Within the next few years, Civil Unmanned Aerial Vehicles will be ready to operate in civil airspace. Europe has the opportunity to benefit in many ways from their utilisation. There are numerous applications where it is preferable to use Civil UAV in circumstances where manned flight would be too dangerous, expensive or monotonous, such as environmental data collection or 'Eye-in-the-sky' surveillance for the better protection of citizens and integrity of borders.

The technology needed for UAV applications is already available. However, before the Civil UAV can be fully exploited, permission must be given to operate them in non-reserved airspace. In order to satisfy future demand, there is a pressing need to develop the regulatory framework. To make faster progress in developing agreed European/Global regulations and ATC/ATM integration concepts, the consortium will recommend certification and operational procedures for applicable airworthiness. For various Civil UAV missions operational concepts based on ATM/ATC integration and 'See&Avoid' will be developed and proved by realistic computer simulations. The findings will be disseminated to regulation bodies and the Civil UAV user community.

Description of the work

The technical/scientific work starts with the analysis of **future commercial applications** (e.g remote sensing, surveillance, surveying, air transportation, communications) versus UAV missions, possible platform concepts, expected society-induced aspects, all of which are compiled in representative future mission scenarios.

For **airworthiness** certification issues, a practical approach to the certification of Civil UAVs (considering all safety-relevant system aspects), is defined essentially to relate to the criteria to be set in order to design and develop an UAV with the appropriate safety measures.

Safe operations operational procedures, based on existing regulations, are to be defined for UAV flight in non-reserved air space. Technologies such as ATC/ATM integration of UAV and 'See&Avoid will be investigated to improve safe operations.

Finally, an overall **safety concept evaluation** will take place, using realistic computer simulations based on representative future UAV mission scenarios to access the practicability and performance of the developed safety concepts.

The **dissemination and exploitation** of project results will be done in parallel to all other research activities.Regulation bodies are being continuously informed. A user group is to be installed as a discussion forum. Finally, implementation strategies for the concept will be outlined

Expected results

The project will produce several results, including a better understanding of the role of UAV in civil applications. For the first time, the complete life-cycle aspects of UAVs are being considered in order to improve the safe operation of these new and innovative platforms. In detail, the results are:

- An assessment report on civil UAVs and their commercial missions.
- A practicable airworthiness certification process, considering the complete life cycle of an UAV.
- An operational safety concept based on ATC/ATM integration of UAVs and use of see & avoid technologies.
- A strategy for implementation of the developed safety concept with near-term, mid-term and long-term objectives. The consortium will ensure that these results are also usable by other parties, such as certification bodies on European and national level, and finally will open the market for Civil UAVs in Europe.

Title:	UAV Safety Issues for Civil Operations
Acronym:	**USICO**
Contract N°:	G4RD-CT-2001-00635
Proposal N°:	GRD1-2001-40123
Total cost:	€4 574 389
EU contribution:	€2 487 117
Starting date:	01/05/2002
Duration:	30 months
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Foersvarshoegskolan (English: Swedish National Defence College)	S
Israel Aircraft Industries Ltd. (IAI)	IL
Marconi Mobile S.p.A.	I
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Swedish Space Corporation	S
Università Degli Studi di Napoli 'Federico II'	I

Visual Interaction and Human Effectiveness in the Cockpit, Part II

Project objectives

Situation awareness (SA) is increasingly recognised as a critical element for safe operation on the civil flightdeck. Until now, research has mainly been directed toward understanding individual SA. However, it is becoming increasingly clear that team SA or shared SA is an important concept, especially in the context of sophisticated automated flightdecks, on which automation itself can be perceived as an extra crew member.

Recently, cognitive theories have matured in parallel with a revolution in psychophysiological methods that have enabled researchers to study, in a non-invasive manner, various aspects of non-overt human performance. Eye point-of-gaze (EPOG) and other ocular indicators may reveal fundamental aspects of human visual perception and information processing.

VINTHEC II's main objective is to develop, assess and evaluate an objective measurement methodology, centred around EPOG, that can be used to assess flightdeck crew co-ordination in terms of both the crew's shared SA and their interaction with automated flightdeck systems. The project also seeks to develop guidelines for the use of EPOG in SA assessment in other (i.e. non-flightdeck) domains.

Description of the work

VINTHEC II is being carried out in a series of seven substantive work packages. Firstly, a literature review is being conducted to identify the theoretical and practical state-of-the-art in three areas: Situation Awareness theory and assessment; Cockpit Resource Management (CRM); and computer modelling. (e.g. task analytic). Next, the project is focusing on exploring and refining the techniques for measuring and analysing EPOG data. This includes both the assessment of ergonomic aspects of data collection, and also the development of novel techniques for analysing EPOG and related psychophysiological measures, including new means of data pre-processing and analysis. This is being accomplished through a series of small-scale experiments. Next, a flight scenario is being developed for use in later pre-testing (WP5) and – ultimately – in a high-fidelity, motion-based flight simulation (WP7) that will permit the consortium to draw conclusions about the use of physiological measures in the assessment of team SA.

In parallel, a task-analytic modelling effort is being made, not only to help sharpen the flight simulation scenario, but also to serve as a comparison for the result of the empirical data (i.e. from the motion-based simulation).

The results of VINTHEC II will have implications for many domains outside the civil flightdeck. It is explicitly intended that the project knowledge will be transferred to these other fields that share fundamental aspects of performance (e.g. team setting, interaction with complex human-machine systems, etc.). For this reason, the project is convening two Expert User Groups comprising representatives of various domains (e.g. air traffic control, maritime bridge operations, medicine, and military aviation). This will help ensure that the results of VINTHEC II will be exportable to various domains.

Expected results

The chief exploitable product of this project will be a universal, validated, and standardised methodology for assessing crew co-ordination in operationally-relevant scenarios, which can benefit crew training (e.g. Line Oriented Flight Training, or LOFT), especially with respect to intercrew co-ordination (Crew Resource Management, or CRM) training. The project aims not only to provide a methodology for assessing team interaction and shared SA, but also guidelines for its use in various domains (including practical aspects of measurement, analysis, and interpretation).

Title: Visual Interaction and Human Effectiveness in the Cockpit, Part II

Acronym: **VINTHEC II**

Contract N°: G4RD-CT-2000-00249

Proposal N°: GRD1-1999-10543

Total cost: €2 750 162

EU contribution: €1 672 990

Starting date: 01/04/2000

Duration: 36 months

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Linköping University	S
QinetiQ Ltd.	UK
Risoe National Laboratory	DK
Swedish Defence Research Agency (FOI)	S
Technion – Israel Institute of Technology	IL

1.4. Operational Capability and Safety of Aircraft

Accident survivability

Crashworthiness of Helicopter on Water: Design of Structures Using Advanced Simulation Tools

Project objectives

The overall objective of the project is to develop a set of simulation tools and a design methodology, which will permit cost-effective design and entry-into-service of crashworthy (including impact on water) helicopters.

The helicopter design community requires a simulation system which is able to predict the behaviour of a helicopter structure when impacting water. In support of this, the simulation tools will be improved so that they would capable of more accurate handling of the complex response of metal and composite materials and fluid structure interaction in the water-impact analysis problem.

The major objectives for the industrial members of the consortium are to:

- Achieve a better and more effective design capability for the manufacture of safer helicopters at reduced cost through the use of advanced simulation tools
- Gain an international advantage with respect to non-European industry
- Transfer and exchange new technology between commercial partners
- Transfer simulation technology to project partners
- Improve and validate structural simulation capability of commercial packages
- Produce design and simulation guidelines for helicopter impact on water

Description of the work

The work programme is divided into seven main tasks each with a Task Leader and co-ordinated by the Prime Contractor together with a Steering Group. These tasks are directed at the design environment, the development of improved simulation methods, the design and manufacture of demonstrator structures, and the conducting of a test programme. The tasks map onto the following main activities:

1. **Survey.** This activity covers the collection of existing data on: helicopter accidents on water; metallic and composite materials used in helicopter structures; critical analysis of existing simulation codes for crash simulations; existing test procedures and the standardisation of materials data.

2. **Testing.** Generation of new data on:

- materials through coupon and small structural component tests to provide the basis for improvement of material models;
- structural joints through coupon tests for development of new simulation tools;
- helicopter substructure and full scale response to impact on water for methods validation and design improvements.

3. **Methods development.** The development of improved simulation tools for:

- modelling of fluid/structure interaction in impact on water;
- strain rate dependent orthotropic material models metal and composite;
- modelling of delamination failure for chosen composite material system.

4. **Design.** Within this activity new simulation aided design methodology and design guidelines for crashworthy design for impact on water will be developed and applied to the design of a demonstrator, a new ‘crashworthy’ structure.

5. **Manufacture.** The specimens used for the basic coupon, substructure and demonstrator tests will be manufactured by the consortium according to a defined manufacturing programme. A helicopter fuselage for the full scale test will be provided by one of the helicopter manufacturers taking part in the project.

6. **Validation.** Validation of the newly developed tools, design methodology and the new design ‘philosophy’ will be done using experimental data from the demonstrator impact on water tests.

The method of working will exploit:

- team-based workshops for rapid development of ideas;
- team-based approach to individual tasks which will involve combining effort across the consortium;
- the setting of clear validation targets, and the dynamic creation of new design methods and philosophies.

Expected results

Based on the objectives set out above, the project intends to produce the following results:

- To develop a new design methodology and simulation tools for improving the safety of European helicopters.
- To provide a platform for the industrial helicopter partners to enter new segments of the market.
- To promote the increased use of very advanced simulation tools within Europe's Aeronautical Industry.
- To develop new simulation methods which can subsequently be developed and incorporated into an existing European commercial software packages.

These results will be in the form of:

- Requirements and specification for a 'crashworthy' helicopter structure
- New design philosophy and methodology
- Design guidelines
- New improved simulation tools for simulation of impact on water.

Title: Crashworthiness of Helicopter on Water: Design of Structures Using Advanced Simulation Tools

Acronym: **CAST**

Contract N°: G4RD-CT-2000-00178

Proposal N°: GRD1-1999-10651

Total cost: €3 587 988

EU contribution: €2 172 144

Starting date: 01/04/2000

Duration: 36 months

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Deutsches Zentrum für Luft-und Raumfahrt e.V (DLR)	D
Engineering System International SA	F
Eurocopter Deutschland GmbH	D
Israel Aircraft Industries Ltd. (IAI)	IL
Mecalog SARL	F
National Technical University of Athens (NTUA)	EL
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Politecnico di Milano	I
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Westland Helicopters Ltd.	UK
Wytwornia Sprzetu Komunikacyjnego 'PZL-Swidnik' SA	PL

Crashworthiness of Aircraft for High-Velocity Impact

Project objectives

The aim is to develop methods and tools to predict the behaviour of aircraft structures that are subjected to high-velocity impacts. Implementation of such methods will enhance aircraft safety through damage-tolerance of aircraft design and the development of crashworthy aircraft concepts. The impact scenarios considered in CRAHVI are bird strike on leading edge structures, debris hits (tyre and engine debris on access panel and front spar), hailstones on composite structure, fuselage impacts on water and hill slopes, and flight into obstacles. Objectives include the development of reliable and usable FE methods, in order to reduce testing, hence also the time and cost of development, and also to enable the incorporation of composites into the primary structure to optimise weight reduction, for example through innovative design for energy-absorption of composite leading- edge structures. The project will also contribute to the EU goal of reducing accident rates, thus effectively reducing the number of casualties or passengers injured in survivable crash scenarios.

Description of the work

High-velocity impacts on aircraft due to flying objects (birds, hailstones, tyre and engine debris) and also due to the shock of survivable crash landings on different surfaces (rigid, inclined surfaces (slopes) and water with different sea states) are complex phenomena because of the high number of variables involved. In order to develop FE methods to predict the behaviour of aircraft structures that have been subjected to these impact scenarios, it is important to establish material properties that take a number of effects into account: high strain rate, the derivation of material models and failure criteria, the derivation of models and failure criteria for joints, the development of the impactor models, the development of models and methodologies for impacting different surfaces. These models will be developed in WP1 and incorporated in the FE simulations in WP2, WP3 and WP4. In WP2, FE methods will be developed for bird strike on composite and metallic leading edge structures, using various theoretical approaches i.e. current Lagrangian approach, as well as state-of-the-art approaches such as Smoothed Particle Hydrodynamics and coupled Lagrangian/Eulerian. FE methods will also be developed for flying debris (soft :tyre and hailstone and hard: engine debris) against metallic access panels. In WP3, in conjunction with the FE simulation results, stochastic methods will be applied to the impact and crash simulation of aeronautical structures. The application of these methods will complement the development of FE models for the simulation of impact events in WPs 2 and 4. The uncertainty which is inherent in such deterministic simulation (due to variations in material properties, load conditions and manufacturing defects) will be taken into account through the use of stochastic methods.

Local/global and FE methods will be developed in WP 4 to determine the loading on several generic aircraft under realistic crash conditions, such as impact on different surfaces. This will provide a load database for the cabin environment which can be used for the design of innovative cabin safety features with the aim to improve passenger safety. To validate the FE methods, bird strike tests will be performed on composite (commuter) and metallic (airliner) leading edges. Flying debris tests will be performed on metallic access panels and front spars. A substitute material simulating birds will be developed in order to overcome the inconsistency of bird strike test results obtained from using real birds. Impact tests on metallic joints will also be performed. Project synthesis takes place in WP 6, where the design tools developed will be assessed, and design guidelines generated from the analyses and tests will be documented.

Expected results

Bird models and substitute bird material for use in bird-strike simulations; improved FE methods for predicting the response of aircraft structures to various impact scenarios; stochastic methods for use in high-speed impact and survivable crash scenarios; innovative design methods for energy absorption of composite leading edge structures; local/global and FE methods for determining structural loading of a complete aircraft under realistic crash conditions. A load database (accelerations, velocities, displacement, forces) for the cabin environment will be created for use in designing innovative cabin safety features with the aim of improving passenger safety.

Title: Crashworthiness of Aircraft for High-Velocity Impact

Acronym: **CRAHVI**
Contract N°: G4RD-CT-2000-00395
Proposal N°: GRD1-2000-25242
Total cost: €5 117 688
EU contribution: €2 887 959
Starting date: 01/02/2001
Duration: 36 months

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Alenia Aeronautica S.p.A.	I
CAD – FEM Gesellschaft für Computerunterstützte Konstruktion und Berechnung GmbH	D
Centre d'Essais Aéronautique de Toulouse (CEAT)	F
Cranfield Impact Centre Ltd.	UK
Deutsches Zentrum Für Luft-und Raumfahrt e.V (DLR)	D
Devtec Ltd.	IRL
Engineering System International SA	F
Mecalog SARL	F
Office National d'Etudes et de Recherches Aérospatiales (ONERA)	F
Principia Ingenieros Consultores S.A.	E
Rheinisch-Westfälische Technische Hochschule Aachen (RWTH)	D
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
University of Limerick	IRL
University of Liverpool	UK
University of Oxford	UK
University of Patras	EL

New Fire/Smoke Detection and Fire Extinguishing Systems for Aircraft Applications

Project objectives

The overall objective is the enhancement of aircraft fire protection to achieve a higher safety level. Today's aircraft detection technologies are not adequate to detect several kinds of fire. The aim is to increase aviation safety through the early detection of fire and/or smoke. This project investigates advanced detection technologies in order to identify the proper fire signatures to drastically reduce the rates of false alarms of smoke detectors in aircraft applications. Fire detection objectives will include smouldering fires, advanced sensor performance to reduce false alarms, new means for the visualisation of fires in unoccupied and inaccessible areas, and also a new generation of fire and smoke detectors for use in cargo compartments.

Another important objective is to make advances in the field of fire suppression. The main objective here is the development of an advanced fire-suppression system using environmentally friendly extinguishing agents (water mist and nitrogen). Fire suppression work aims to achieve an environmentally friendly suppression system (non-halon) based on water mist and nitrogen, together with technology for on-board inert gas generation (OBIGGS) for cargo compartments.

Description of the work

Based on an in-depth analysis of the aircraft environment and associated fire situations, the most appropriate kinds of new sensor technologies for fire detection and visualisation will be studied and validated with respect to aircraft application. At the end of the project, a validated technology test stand will be established that will proven under full-scale conditions.

After setting the design requirements for the new fire suppression system, different possible system concepts will be weighed up (water/nitrogen capabilities, full flood or zonal suppression system, fall-back position). On that basis, small- and medium-scale tests are performed to deliver input for the requirements of the final full-scale test rig, fire scenarios and test plan. Once the requirements have been adapted or optimised, full-scale fire suppression tests will be performed by the water mist/nitrogen generating system. Comparison with a halon system is planned for the better understanding/classification of the results obtained, in order to advise on the feasibility of the new system for new aircraft programmes, and eventually for retrofitting existing aircraft.

Expected results

One of the main results expected will be a technical validaton, in which the performance of the new fire- detection and suppression methods and technologies will have to pass the test fire scenarios prepared by the International Aircraft Systems Fire Protection Working Group's (IASFPWG) Minimum Performance Standards (MPS). The newly developed and tested technologies will be designed in way that will enable them to be fitted and operated in an aircraft environment. When these new technologies are implemented in all future aircraft, this project will prove its benefit to the European industry that is implementing the next-generation fire protection systems. Thus it will help preserve today's level of absolute safety, in spite of increases in the overall air traffic that could otherwise be expected to result in higher numbers of fire-related accidents.

Title: New Fire/Smoke Detection and Fire Extinguishing Systems for Aircraft Applications

Acronym: **FIREDETEX**

Contract N°: G4RD-CT-1999-00057

Proposal N°: GRD1-1999-10342

Total cost: €10 258 637

EU contribution: €5 346 657

Starting date: 01/02/2000

Duration: 36 months

Coordinator: AIRBUS DEUTSCHLAND GmbH
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Aliachem AS	CZ
AOA Apparatebau Gauting GmbH	D
Civil Aviation Authority	UK
Fraunhofer Gesellschaft – ICT	D
Kidde Graviner Ltd.	UK
Latécoère SA	F
MAN Technologie AG	D
National Technical University of Athens (NTUA)	EL
Siemens Cerberus SA	F
Universität Giessen	D

Project objectives

Helicopter fatalities are at a level ten times higher than those from fixed wing aircraft. This is partly due to the inherently risky operation of helicopters close to ground and to the high complexity of the aircraft.

The objective of HeliSafe is to improve the survivability of occupants of both cockpit and cabin in helicopter crashes, and to minimise the risk of injury. A 25% to 50% reduction in crash fatalities is envisaged compared with the case for current helicopters. This will be achieved by an advanced cabin Safety System concept based on interacting safety features (airbags, seats, belt restraint systems, etc.) HeliSafe will develop and validate a numerical simulation tool concept to predict typical crash scenarios reliably and simulate the response loads on the human body with respect to the interaction of safety equipment.

Description of the work

A generic geometry of the helicopter area which creates the space of survival for the occupant during a crash will be defined, and a 3D-CAD database generated. Crash scenarios will be defined, for example by analysing available helicopter crash data. The loads corresponding to the scenarios active in the cockpit and cabin area will be determined. Definitions will also be found for the most frequent injuries in helicopter crashes for the different crash scenarios, the instrumentation needed to assess the level of injury in a dummy, and for the injury criteria, which could be used to measure the effectiveness.

There will also be definition and prototyping of the hardware and software tools necessary to assess occupant safety through crash tests and computer simulation. This will include the development and validation of design methodology and simulation software for predicting cabin/cockpit and occupant safety during crash loading of the helicopter structure.

A future passive occupant safety concept for helicopters will be developed. This approach will rely heavily on safety components and concepts developed and successfully employed in the automotive industry. Parameter studies will be performed with the simulation tools HOSS to assess different layouts and equipment concepts for cabin safety. A principal layout of a sensor concept and the necessary crash detection algorithm will be defined. The potential to achieve flight approval in future will be evaluated.

Validation tests will be performed on the proposed simulation tool in order to obtain data for the response loads and the final tests. The capability of the proposed safety equipment technology to enhance the occupant crash survivability in a significant way will finally be demonstrated.

Expected results

1. Validated HOSS software concept for use in 3.1 available.
2. Definition and assessment of advanced system technology for occupant restraint.
3. Definition and assessment of advanced seat technology for minimised acceleration in crash situations.
4. Final aerospace dummy with enhanced injury assessment.
5. Airworthiness recommendation report.

Title: Helicopter Occupant Safety

Acronym: **HELISAFE**

Contract N°: G4RD-CT-1999-00071

Proposal N°: GRD1-1999-10361

Total cost: €4 009 329

EU contribution: €2 107 921

Starting date: 01/02/2000

Duration: 36 months

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Eurocopter S.A.	F
Martin-Baker Aircraft Company Ltd.	UK
Netherlands Organisation for Applied Scientific Research (TNO)	NL
Politecnico di Milano	I
Siemens Restraint Systems GmbH	D

2.0. Technology Platforms

Aircraft in the Future Air Traffic Management System

Project objectives

The growth of commercial aviation over the years has been accompanied by growth in the capacity of the services on which it depends, but traffic delays continue at a rate, which is expensive for the airlines and politically difficult to accept for governments and the travelling public. The single largest source of insufficient capacity (and consequent delays) is Air Traffic Control, responsible for about 50% of total delays once knock-on effects have been taken into account. In a word, there is a clear need to improve the situation at European level and to propose a solution, that should meet the following objectives:

- Improve air transport capacity while maintaining – or even enhancing – a high level of safety.
- Build a European solution, which involves all stakeholders in the problem: industry, airlines, airworthiness authorities, ground and air segments, standardisation bodies, airports and service providers.
- Propose a solution that can demonstrate clear objectives and quantified results, and can prove to be acceptable to stakeholders and solve their problems.

In the meantime, this solution will help to improve the competitiveness of European industry compared with that of the US, and will allow Europe to create highly qualified jobs.

Description of the work

The work to be developed in AFAS has been divided in three work packages:

Review of CNS/ATM projects and operations (WP1)- Operational Concept Definition will first identify the environment within which the A320 avionics package will need to be employed, based on forthcoming standards, current and planned research, and strategic and economic drivers such as reduction of delays. Having identified the available facilities and ATM functions, this work package will define a representative set of operational scenarios that will exercise the air and ground aspects, demonstrate interoperability, and prove the performance of the ATM avionics system. These scenarios will focus on three representative European airports and three airlines operating Airbus A320 aircraft between these airports. These operational scenarios will be reviewed by users (pilots, airlines, controllers and ATM service providers) during User Forums to gain their acceptance.

Avionics package (WP2). This will define, design, develop and integrate an experimental Avionics Package, targeted for the Airbus A320 family aircraft (A318/A319/A320/ A321), it will support functionalities selected in WP1 and approved by users during user forums. This package will be built according to usual quality and airborne software-development rules, in the perspective of post-AFAS certification. Then intensive experimentation will be performed on revenue service flights during 2003–2004 to assess the economic, environmental and social benefits when deploying new CNS/ATM functionalities.

Air-Ground Validation (WP3) will aim to demonstrate the benefits of the AFAS services defined in WP1 and developed in WP2. For this purpose, the AFAS ground stakeholders will update their own ground platform to support the new AFAS services. The work will be split into two main phases –first, interoperability tests between air and ground systems for technical validation, followed by fast-time and real-time simulations to demonstrate the operational benefits of the AFAS concept.

Expected results

In terms of exploitable results, AFAS will generate:

- a validated CNS avionics package that will meet the requirements of a high-density airspace ATM system, ready for the certification process, to be exploited by avionics suppliers *as a first release in their new CNS product line*.
- an operational concept, supported by this avionics package;

- studies of the cost benefits of these operational concepts, aiming to demonstrate their potential benefits to encourage airlines and ATM Service Provider decision-makers to apply these new concepts;
- an assessment of the impact of such requirements on current airborne systems. This will help airframe manufacturers integrate these systems in the cockpit, and assist airworthiness authorities responsible for certifying CNS systems and aircraft
- a definition of the crew's role and of the allocation of responsibilities between pilot and controller, as well as human factor aspects.

Title: Aircraft in the Future Air Traffic Management System

Acronym: **AFAS**

Contract N°: G4RD-CT-2000-00229

Proposal N°: GRD1-1999-10300

Total cost: €34 518 716

EU contribution: €17 259 361

Starting date: 01/04/2000

Duration: 36 months

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EADS – ATR	F
Entidad Publica Empresarial Aeropuertos Españoles y Navegacion Aerea (AENA)	E
EUROCONTROL – European Organisation for the Safety of Air Navigation	INT
Lufthansa	D
Skysoft Portugal, Software e Tecnologias de Informaçao, SA	P
Smiths Industries Aerospace and Defence Systems Ltd.	UK
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Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (LNR)	NL
THALES – ATM	F
THALES Avionics S.A.	F
Westland Helicopters Ltd.	UK

Project objectives

The overall target of this project is the integration of advanced technologies into novel fixed wing configurations, aiming at a further significant step in improving aircraft efficiency and reducing far-field impact. To achieve this target, the following specific industrial objectives have been identified:

- Reduce the vortex hazard, thereby decreasing the separation distance behind a large aircraft by 1 nm.
- Apply specific flight procedures using new devices validated in this project, thereby reducing noise by 2 EPNdB.
- Increase cruise performance (L/D + 2%, Fuel Burn -2%) through new devices and load control strategies.
- Increase low-speed performance by using new devices and load control strategies, and in detail increase L/D by 2.5%
- Decrease the structural weight of new aircraft by applying new load-control strategies, thereby reducing weight by 5% through the use of existing devices and by 10% when using new devices.

Aerodynamic characteristics, systems and structures will be optimised in a multi-disciplinary approach by controlling lift distribution, wake vortex, and wing loads.

Description of the work

Within AWIATOR, three technical work packages will address the technologies which have been identified to help to cope with the new requirements:

- In **Far-Field Impact**, vortex hazard reducing devices will be identified, selected and tested in ground tests as well as in flight. Furthermore, new inboard spoilers will be used in-flight in order to find greater efficiency in drag increase during approach without influencing the flow around the vertical tailplane. Finally, specific flight procedures will be investigated, taking the devices of this work package and the others into account regarding noise, vortex, capacity etc.
- In **Near-Field Flow**, work will focus mainly on the effect of very large winglets (with height as some 15% of half span). Furthermore, the wing flow will be investigated, with and without any device, for pressure distribution, deformation, and loads.
- In **Flow, Load and Aircraft Control**, the effect of new load control strategies will be addressed including the application of a gust/turbulence sensor, and the addition of new adaptive elements for load control. Finally, devices to suppress separation on flaps will be integrated in order to increase low-speed performance still further.

The validation of each individual technology, and also all the technologies together in combination, will be done in a work package called **Integration**. Here all flight clearance issues for all technologies will be co-ordinated, harmonised test programmes for wind-tunnel and flight tests will be set up, and the assessment of all technologies will be made using project tools.

The outcome of AWIATOR will be a down-selection of the most promising individual devices, and also the best combination of different devices at aircraft level with respect to their improvements of aircraft performance and noise. All this will be done for the different requirements applicable when these requirements become subject to official certification.

The whole work is highly interdisciplinary. The background of this work may be seen as flight physics, but systems, structure, and manufacturing disciplines must combine their efforts in an optimised, concurrent engineering way to reach the ambitious targets.

Expected results

The key milestones will be two flight test campaigns. In the first campaign, main parameters of large winglets will be looked at, a down-selection of vortex-reducing devices will be made, and the gust sensor will be pre-tested. In the second flight test campaign, the integral performance of all technologies will be validated. In parallel, tests in wind and water tunnels, catapults, rigs and ground tests will guarantee the flight clearance needed. As a final milestone, all data will be fed into project tools for the final assessment of the different technologies for the test aircraft and also for all new aircraft.

Title: Aircraft Wing with Advanced Technology Operation

Acronym: **AWIATOR**

Contract N°: G4RD-CT-2002-00836

Proposal N°: GRD1-2001-40160

Total cost: €79 105 027

EU contribution: €39 941 630

Starting date: 01/07/2002

Duration: 48 months

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Centre National de la Recherche Scientifique – Délégation Provence	F
Deutsches Zentrum Für Luft- und Raumfahrt e.V. (DLR)	D
DMECS Development of Mechatronics Systems GmbH & Co.KG	D
DNW German-Dutch Wind Tunnels	NL
EADS Deutschland GmbH – Corporate Research Centre Germany	D
Gie Airbus Industrie	F
GKN Aerospace	UK
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QinetiQ Ltd.	UK
Schledal Simulation GmbH	D
SENER Ingenieria y Sistemas S.A.	E
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Subcontratacion Proyectos Aeronauticos, S.A.	E
Technische Universität Berlin (TUB)	D
Technische Universität München – Lehrstuhl für Fluidmechanik	D
Université Catholique de Louvain	B
Université de la Méditerranée (Aix-Marseille II)	F
Université de Provence (Aix-Marseille)	F

Efficient and Environmentally Friendly Aircraft Engine

Project objectives

Future aero engines will need to be more reliable, have lower operating costs and have significantly lower environmental impact than those currently in service. The EEFAE technology platform will test advanced technologies capable of providing significant improvements to future generations of aero engines.

The EEFAE project engages all of the major European aero engine companies and a number of suppliers, supported by universities and research establishments (19 partners in total) in a four-year collaborative project. The project will build two vehicles to integrate and test a range of new aero engine technologies with the objective of:

- reducing fuel consumption and CO2 emissions by 12% to 20%
- reducing NOx emissions (relative to ICAO 96 standard) by 60% to 80%
- reducing cost of ownership by 20% to 30%
- improving reliability by 60%
- reducing life-cycle cost by 30%

Description of the work

The two vehicles will be built and tested as described below:

ANTLE (Affordable Near Term Low-Emissions Engine)

ANTLE will test a range of technologies suitable for implementation in new three-shaft engines in the thrust range of 50 to 110 klbs thrust. Once validated in this project, these technologies will be available for use in new engines that enter service from 2008 onwards. The technologies planned for validation within ANTLE are:

- **HP Compressor.** A high-pressure-ratio HP Compressor is being developed by Rolls-Royce Germany. Advanced aerodynamic methods and rotor manufacturing technologies will enable higher pressure ratios than existing compressors, while also reducing the number of stages.
- **Combustor.** A low-emissions combustor is being developed by Rolls-Royce and Rolls-Royce Germany. The selected concept will incorporate staged combustion and lean modules. The final design will undergo emissions evaluation as part of the ANTLE test programme.
- **HP Turbine.** An advanced turbine is being developed by Rolls-Royce. The turbine will be demonstrated on the ANTLE vehicle.
- **LP Turbine.** This is being developed by ITP of Spain. The concepts being considered are aimed at facilitating a high-load LP Turbine which should lead to reduced costs and mass via reduced number of stages and the exploitation of advanced materials.
- **IP Turbine.** FIAT Avio of Italy, supported by the University of Florence, will develop an advanced aerodynamic IP Turbine design. A number of mechanical concepts are under consideration to optimise both the structural and aerodynamic definition and to reduce whole engine costs and weight.
- **Controls System.** A novel distributed engine-control system is being developed by TRW with the support of Rolls-Royce. This concept should enhance the reliability of the control system by providing more accurate diagnostic capabilities for each control unit.
- **Tail-Bearing Housing.** The Volvo Aero Corporation, together with the University of Luleaa, is developing an advanced turbine rear frame utilising novel methods for manufacturing modelling and construction. These advances will enable significant reductions in cost and manufacturing lead time.
- **Oil System.** Techspace Aero of Belgium is leading the development of an optimised oil system for the ANTLE demonstrator vehicle. Technologies under consideration include enhanced oil-system modelling, leading to optimised pump definition and sealing arrangements.

- **Advanced Accessory Gearbox.** Hispano-Suiza is developing an advanced accessory gearbox incorporating optimised breather, bearing and sealing arrangements. Together with a low-mass drive shaft, these technologies will reduce emissions, weight and costs.

CLEAN (Component Validation for Low-Emissions Aero Engine)

CLEAN is the first application of technology initially developed for a geared turbofan engine and in the longer term for an inter-cooled recuperative aero engine. It is expected that this technology will be available for service between 2010 and 2015.The technologies planned for validation within CLEAN are:

- **Active surge control.** An innovative active surge-control system is being developed by Snecma Moteurs. It will be based on an early detection of surge onsets from unsteady pressure measurements (algorithm defined in the frame of a nationally funded programme) and two kinds of actuators for avoiding the surge.
- **HP Compressor.** The highly efficient/highly loaded HP Compressor is based on an existing Snecma Moteurs design and is being designed and manufactured by Snecma Moteurs.
- **Combustor.** An innovative combustor is being developed by Snecma Moteurs and FiatAvio, based on an Axially Staged Combustor (ASC) architecture. The pilot stage will be an optimised conventional combustor, while that for the main stage will be a Lean Premixed Prevaporised (LPP) model. This last component, allowing a very low level of NOx emissions, will take advantage of the results of the LOWNOXIII EC-funded programme.
- **HP Turbine.** An existing advanced design from Snecma Moteurs is being used for the CLEAN HP Turbine. This high-efficiency adapted component will be completely designed and manufactured by Snecma Moteurs.
- **Control System.** Snecma Moteurs and MTU Aero Engines will utilise existing equipment for the development of the vehicle control system.
- **LP Turbine.** A new high-speed low-pressure turbine is being developed by MTU Aero Engines. Using new materials and advanced aerodynamics derived in earlier technology programmes, the CLEAN engine will allow the validatation of mechanical integrity and a high adiabatic efficiency through reduced life-cycle costs and minimised turbine noise generation.
- **TEC.** Volvo is responsible for design and manufacturing of the turbine exhaust casing (TEC). The TEC will be exposed to higher temperatures than normally experienced for similar components. Advanced state-of-the-art high-temperature materials will be used in the application.
- **Heat Exchanger.** A new heat exchanger segment developed by MTU Aero Engines is aimed at validating the technology which could be applied to a future IRA engine (Inter-cooled Recuperative Aero-engine). The first stage of testing this concept will be the inclusion of a heat exchanger in the CLEAN engine.

Expected results

The project is currently on target to achieve the results listed in the objectives. It is anticipated that the technologies validated by this project will be available in new aero engines that enter service from 2008 onwards.

Title: Efficient and Environmentally Friendly Aircraft Engine

Acronym: **EEFAE**

Contract N°: **G4RD-CT-1999-00224**

Proposal N°: **GRD1-1999-10403**

Total cost: **€101 397 582**

EU contribution: **€50 820 043**

Starting date: 01/03/2000

Duration: 48 months

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Engineering Solutions International Ltd.	IRL
Fiat Avio S.p.A.	I
Hispano-Suiza SA	F
Howmet Ltd.	UK
Industria de Turbo Propulsores S.A.	E
Instituto Nacional de Técnica Aeroespacial 'Esteban Terradas'	E
Luleä University of Technology (LTU)	S
MTU Aero Engines GmbH	D
Rolls-Royce Deutschland GmbH	D
Société Nationale d'Etudes et de Construction de Moteurs d'Aviation (SNECMA)	F
Techspace Aero S.A.	B
TRW Ltd. Aeronautical Systems Lucas Aerospace	UK
University of Florence	I
Volvo Aero Corporation AB	S

Friendly Aircraft Cabin Environment

Project objectives

The Proposal is focused on improving the Aircraft Environmental Comfort in the aircraft cabin and cockpit of the future European turbofan aircraft. It addresses the Environmental Comfort parameters affecting noise, vibration and air-quality technology, and includes evaluation of comfort effects on/from multimedia utilisation within the limitation of the environmental parameters indicated above. Composite fuselage structural-acoustic behaviours, considered the most important for future fuselage application, to be treated within the acoustic area, will be studied utilising TANGO and FUBACOMB composite fuselage barrels, addressed to civil turbofan application. The Environmental Cabin Comfort issues leads to any turbofan aircraft application from Business jet to Large civil transport. The activity has been planned under the "aircraft research activity strategy" provided by the European Industry. It has been split in two steps: – The first focuses on the selection of the more promising technology concepts for comfort achievements. – The second addresses integration and validation of the selected concepts by appropriate Technology Platforms experimentation. An Environmental testing facility will be properly prepared to perform validation tests, in various simulated cabin environments, with the scope of validating useful criteria for the cabin comfort evaluation. Finally an extrapolation of results to real aircraft in flight environment will be, carried out and supported by the large experience of the airframer partners.

Description of the work

FACE is a Technology Platform focused on the Environmental Aircraft Cabin Comfort in civil turbofan aircraft. The scope is to provide advanced know-how for the main environmental behaviours linked to the noise & vibration as well as the air-quality control in aircraft cabins. The improved knowledge of the interaction of the Noise and Vibration and Air-Quality will improve the capability to design and manufacture aircraft with improved comfort standards; improvements to health and safety standard for the passengers as well for the crewmembers will be obtained also. The optimisation of the impact on weight, cost and performance will be taken into account all along the project, as important design parameters. The impact of the comfort items on the utilisation of the multimedia devices, and the opposite influence of such devices on the passenger is also included in this proposal. The better knowledge of comfort issue and materials behaviour will help the European Aircraft Industry to improve its share in the world market. The competitiveness of the European aeronautical industry will be strengthened, while ensuring the development of air transport with regard to comfort and safety. The definition and validation of new advanced criteria for the cabin comfort judgement will help the aircraft operators and the aircraft manufacturers to understand better and finalise requirements for passenger comfort satisfaction. The project activities target some of the key needs in this field: (i) Broadband noise component reduction for light weight composite fuselage. (ii) Cabin air-quality improvement by reducing the contamination and improving the thermal and humidity comfort parameters. (iii)friendly utilisation of the on-board multimedia system. It is proposed to address integration and validation activities through the use of Technology Platforms:

- Selection of vibro-acoustic concepts (limited to broadband frequency components), to be validated for composite structural-acoustic transmission loss and integrated control measures: passive and active solutions and their optimised integration will be considered. Air-quality issues: humidity, airpurity and thermal concepts will be treated. Multimedia equipment concept will be assessed with the purpose of evaluating the impact of their use on passenger comfort, wish limiting the analysis to the environmental comfort parameters.

- Concepts identified and expected to provide technological improvement, shall be used in selected cases. These will provide integration and validation of concepts through the use of appropriate Technology Platforms. The final stage of optimised technology for application on aircraft composite structures will be analysed by means of new properly developed criteria for comfort judgement: Environmental Comfort Indexes.
- Finally the use of an appropriate Environmental testing facility, capable to simulate different cabin environmental contests, will be prepared and used for tests addressing the evaluation and assessment of the comfort criteria defined within the Project, providing reliable and validate solutions.

Expected results

- Improve the acoustic/vibration know-how related to light composite structures for future turbofan application;
- Improve the cabin air quality supporting comfort and safety of the passenger and crewmembers, the achievements of improvements in these technology areas will directly provide positive effects on the human health conditions on board.
- TANGO and FUBACOMP composite fuselage will be the technology platforms allowing large co-operation among the consortia.
- Improved air-quality concepts will be integrated and validated by large scale cabin mock-up.
- The effects of multimedia on and from the environmental parameters as affecting the human comfort shall be evaluated.
- New comfort criteria for evaluating the passenger comfort, “Environmental Comfort Index”, will be developed and validated by an independent team of comfort experts in co-operation with the industrial partners providing aircraft requirements and support into test validation activity.

Title: Friendly Aircraft Cabin Environment

Acronym: **FACE**

Contract N°: G4RD-CT-2002-00764

Proposal N°: GRD1-2001-40205

Total cost: €34 717 021

EU contribution: €17 995 064

Starting date: 01/03/2002

Duration: 48 months

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Carl von Ossietzky Universität Oldenburg	D
Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
CTT Systems AB	S
Dassault Aviation SA	F
EADS Deutschland GmbH	D
EADS France - CCR	F
Eurocopter S.A.	F
Eurocopter Deutschland GmbH	D
Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V.	D
Hellenic Company for Space Applications	EL
Integrated Aerospace Sciences Corporation (INASCO)	EL
Kungl. Tekniska Hoegskolan (KTH) Stockholm	S
Labinal	F
Leuven Measurements and Systems Int. NV (LMS)	B
Liebherr-Aerospace Lindenberg GmbH	D
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More Autonomous Aircraft in the Future Air-Traffic Management System

Project objectives

The civil avionics market is in the early stages of a major revolution which is being driven by the inexorable growth of civil air traffic (5% in time of recession, 8% last year). This growth is pushing the current ATM systems to breaking point. Within Europe the situation means long delays for passengers, inefficient routeing for operators and unacceptable stress for controllers.

The More Autonomous Aircraft in the Future ATM System (MA-AFAS) programme addresses the requirements of Key Action 2.4 New Perspectives in Aeronautics, Technology Platform 4. It aims to transform European research results into practical operational Air Traffic Management (ATM) procedures with the potential to improve the European ATM scenario radically in the near term (from 2005 onwards). By selecting and validating key airborne elements of CNS, and defining their economic benefits and certification requirements, this research will enable more autonomous aircraft operation in the European ATM system.

Description of the work

The improvements developed under MA-AFAS must be capable of being fitted to existing aircraft so this project will focus on the ATM solution required for aircraft retrofit. It shall use the ATM and ground requirements, ground infrastructure and operational scenarios, as defined and reviewed by users (such as airlines and ATS providers) in WP1 – Operational Concept, as a basis. The retrofit avionics solution will be designed and developed to meet this baseline (under WP2 – Avionics Package) and demonstrated within representative future ATM environments (under WP3 – Validation). The capabilities to be validated will be :

- Validation of GNSS (with ground and space based augmentation) procedures for approach using 4D flight path control.
- Evaluation of airborne 4D flight path generation for integration with ground based flight path planning
- Validation of ADS-B (using VDL Mode 4) with airborne display of traffic (CDTI) and separation assurance algorithms
- Integration of airborne taxiway map and data linked clearances
- Improving AOC fleet management through use of improved data link communication
- Evaluation of flight deck HMI improvements to support 4D flight path generation and monitoring in a more autonomous environment
- Integration of the ATN stack (using VDL Mode 2 and/or VDL Mode 4) in the airborne environment to support AOC and ATC communications using ODIAC defined standards

WP4 – Operational Support will be used to identify the steps required to transition from the trials demonstration of the avionics package to in-service pre-operational validation, by providing cost benefit analysis, operational procedures, new and modified standards, and implementation, exploitation and certification plans.

Expected results

The MA-AFAS milestones will be:

- Formulation of an achievable common operational concept which builds upon EC and Eurocontrol research in the functional areas of Air-Ground and Air-Air datalinks, SBAS and GBAS approaches, 4D flight-path generation and guidance, CDTI and ASAS;
- Validation by Avionics Package Definition and trials;
- Verification of communication loop using MA-AFAS defined Operational Procedures;
- Verification that ground infrastructure can support mixed-capability aircraft;
- Establishment of a safe strategy implementation, based on economic benefit, standards and world-wide agreements;
- Development of user buy-in.

The MA-AFAS team includes avionics and communication suppliers, research centres, SMEs, service providers, policy-makers and airlines, therefore ensuring that all key parties are represented in the design and development of this avionics package. The team encompasses a good mixture of nationalities, including Austrian, British, Dutch, German, European, French, Irish, Italian, Portuguese, Spanish and Swedish.

The EU Added Value will be obtained by bringing together expertise from different companies across different countries in Europe – which otherwise would not occur – to permit the design, development and validation of an avionics package for the European ATM system. The results will lead to increased airspace capacity and reduced environmental damage through greater route efficiency. Exploitation routes include new avionic systems for potentially all the European air transport fleets, to enable both modern and classic aircraft to operate in the new airspace environment. Further progress in improving European technology will be achieved through developing the combined community knowledge and experience on future avionics solutions for the global ATM environment, and ensuring that emerging solutions will have a strong European focus.

Title: More Autonomous Aircraft in the Future Air-Traffic Management System

Acronym: **MA-AFAS**

Contract N°: G4RD-2000-00228

Proposal N°: GRD1-1999-10516

Total cost: €27 928 441

EU contribution: €13 964 223

Starting date: 01/03/2000

Duration: 36 months

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Alenia Marconi Systems	I
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)	D
Euro Telematik GmbH	D
EUROCONTROL – European Organisation for the Safety of Air Navigation	INT
FREQUENTIS Nachrichtentechnik GmbH	A
Indra Sistemas	E
National Air Traffic Services Ltd. – (NATS)	UK
QinetiQ Ltd.	UK
Saab AB	S
Skysoft Portugal, Software e Tecnologias de Informação, S.A.	P
Société Française d'Etudes et Réalisations d'Equipements Aéronautiques (SOFREAVIA)	F
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Thales – ATM	F

Power Optimised Aircraft

Project objectives

For many years, hydraulic, pneumatic and electrical power supply in commercial aircraft had been sufficient to meet the demands from Technical Loads (pumps, avionics, actuators, air systems; in general all of the equipment required to operate the aircraft) and Commercial Loads (in-flight entertainment, galleys; in general all of the equipment required to increase passenger comfort and satisfaction). Modern aircraft have demanding Technical Loads, whilst market trends and increasing flight duration have resulted in increasing Commercial Loads. The aerospace industry has identified a potential deadlock, where power needs will eventually exceed the maximum available power supply. Over the past decade, members of the POA consortium have been developing more electrical aircraft equipment systems to solve this problem. In POA, the required technological breakthrough will be achieved by implementing these state-of-the-art technologies in novel ways.

Therefore, the target of POA is to validate, at aircraft level and both qualitatively and quantitatively, the ability of next generation systems equipment to enable the reduction in consumption of non-propulsive power. The Project Objectives by wich POA will reach this target are the achievement of:

- A reduction of aircraft peak non-propulsive power consumption by 25%
- A reduction of aircraft total non-propulsive power consumption
- A reduction of aircraft fuel consumption by 5%
- A reduction of aircraft total equipment weight

Additional objectives are a reduction of aircraft operational maintenance costs, no increase in aircraft equipment production costs and an increase in system reliability and safety. These will all be measured against a Reference Aircraft, which has been defined as a wide-bodied, 300 passenger, twin engine ETOPS (Extended Twin Engine Operation) rated civil aircraft.

Description of the work

POA will address the objectives by using 7 Work Packages (excluding management) and the three phase approach shown here over a total of four years.

Phase I – The Validation of Systems

In four equipment level Work Packages, the equipment industry will implement individual equipment systems solutions in order to contribute to the Project Objectives. These four Work Packages will then optimise and validate this equipment and their equipment systems models at the systems level.

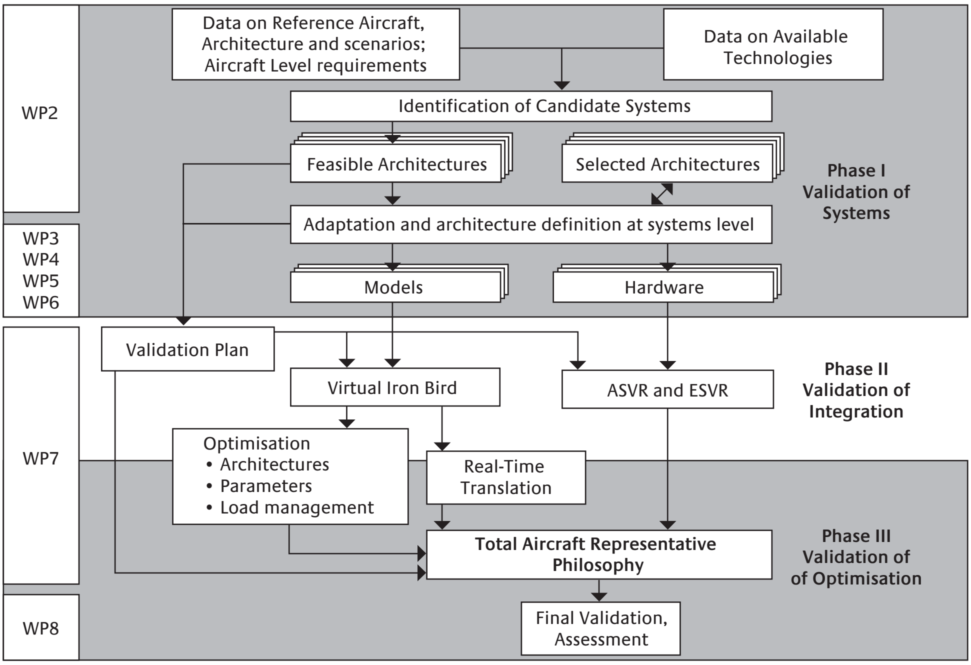
Phase II – The Validation of Integration

A *Virtual Iron Bird* (VIB) will be able to use the software models to describe the all of the Feasible Architectures and the Selected Architectures. The Project Objectives will then be used as criteria against which to perform the following optimisations:

1. Architecture Optimisation – all the feasible architectures which satisfy the Project Objectives will be selected as the optimised ones.
2. Equipment Parameter Optimisation – within the optimised architectures, parameters of the constituent equipment systems will be optimised to provide further compliance with the Project Objectives
3. Load Management Parameter Optimisation – the Load Management algorithm will be optimised to provide even further compliance with the Project Objectives

The equipment systems hardware will be integrated into an Engine Systems Validation Rig (ESVR) and an Aircraft Systems Validation Rig (ASVR). These Rigs will be used to:

- Validate the VIB models at integrated systems level
- Validate the physical integration of the Selected Architecture



Phase III – The Validation of Power Optimisation

The VIB will provide a theoretically optimised Architecture, Parameters and Load Management Parameters, and these results will be further qualified and validated by the use of the ASVR and ESVR. The combined use of these three instruments is what constitutes a Total Aircraft Representative Philosophy (TARP). This is effectively a combination of results from the ESVR, ASVR and a real-time translation of the VIB.

Results from these three elements will be assessed as a single aircraft, and will demonstrate that the expected achievements of the Project Objectives are realised.

Expected results

I – Validation of Systems. The main outputs from this phase will be

- Equipment systems models for the Reference Aircraft and Feasible Architectures
- Equipment systems hardware for the Selected Architecture

In the short term, the results from the first phase of the work can be used to understand how alternative equipment technologies can be implemented in aircraft. This is the first step towards eventual use of these technologies on aircraft.

II – Validation of Integration. The main outputs from this phase will be

- A Virtual Iron Bird (VIB) with validated equipment model integration
- An Engine Systems Validation Rig (ESVR) with validated engine equipment integration
- An Aircraft Systems Validation Rig (ASVR) with validated aircraft equipment integration
- An Optimised Architecture with optimised parameters and optimised load management
- Guidelines for a process for Optimisation of Architectures, Parameters and Load Management
- Design guidelines for, and validation of, the Integration of Equipment Systems

In the medium term, the lessons learned from technology integration will lead to the possibility of retrofitting aircraft with alternative equipment as a first stage in the realisation of the next generation aircraft.

III – Validation of Optimisation. The main outputs from this phase will be

- A validated aircraft equipment architecture for next generation aircraft, satisfying the Project Objectives
- An aircraft manufacturers assessment of the validated aircraft architecture and equipment

In the medium to long term, the optimised architectures and load management from POA will be used in the design of next generation aircraft. Furthermore, the presence of the Equipment, Aircraft and Engine sectors in POA means that the Virtual Iron Bird will be used by European aircraft and equipment manufacturers to examine all the possibilities and consequences of future technological developments at aircraft level.

Title: Power Optimised Aircraft

Acronym: **POA**

Contract N°: G4RD-CT-2001-00601

Proposal N°: GRD1-2001-40136

Total cost: €99 202 340

EU contribution: €50 747 133

Starting date: 01/01/2002

Duration: 48 months

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Dunlop Aerospace Ltd.	UK
Ecole Normale Supérieure de Cachan	F
ESW-Extel Systems Wedel Gesellschaft für Ausrustung GmbH	D
FCS Control Systems B.V.	NL
Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung e.V.	D
Hispano-Suiza S.A.	F
Institut National des Sciences Appliquées, Mechanical Engineering Department Mechanical Engineering Laboratory	F
Institut National Polytechnique de Grenoble	F
Institute of Structures and Advanced Materials	EL
Instituto Nacional de Técnica Aeroespacial (INTA)	E
Intertechnique S.A.	F
LABINAL	F
L'Equipment de la Construction Electrique	F
Liebherr Aerospace Toulouse S.A.	F
Messier-Dowty Ltd.	UK
Messier-Dowty S.A.	F
MICROTECNICA S.R.L.	I
MTU Aero Engines GmbH	D
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Rolls-Royce plc.	UK
Sener Ingeneria y Sistemas S.A.	E
SNECMA Moteurs	F
Société Anonyme Belge de Constructions Aéronautiques (SABCA)	B
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
Technofan SA	F
Techspace Aero S.A.	B
THALES Avionics S.A.	F
THALES Avionics Electrical Systems S.A.	F
TRW Limited	UK
TUHH-Technologies GmbH	D
Universita' Degli Studi di Padova	I
Université Catholique de Louvain	B
University of Kassel	D
Volvo Aero Corporation AB	S

Significantly Lower Community Exposure to Aircraft Noise

Project objectives

SILENCE(R) addresses the issue of aircraft noise. The noise environment around airports is a major cause of concern within Europe, with many local communities subjected to high levels of aircraft noise. Unless noise-reduction technology can be developed and validated to reduce aircraft noise, aircraft fleet growth is likely to be restricted because of noise restrictions. This would have a direct impact on the aircraft industry and indirectly affect general economic growth.

SILENCE(R) has three major objectives:

- Validation of the noise-reduction technologies, the development of which was initiated by EU and National programmes in or around 1998.
- Assessment of the applicability of these technologies for improvement in noise levels of current and future European products, with minimum cost, weight or performance penalties.
- Determination of the noise reduction that could be achieved by the realistic exploitation of validated technologies.

Description of the work

A number of noise-reduction concepts will be validated, including: CFD-designed low-noise fans and LP turbines (designed for the 'Efficient and Environmentally Friendly Aero Engines' (EEFAE) Technology Platform); negatively-scarfed intakes; novel intake; bypass and hot-stream liners; nozzle-jet noise suppressors; active control techniques, and airframe noise reduction technologies.

A two-phase approach is being used for the validation of the novel noise-reduction concepts explored in earlier EU and nationally funded programmes. In Phase 1, technical work has been organised into groups of technologies allowing parallel development of technology elements and identification of the most efficient noise-reduction strategies. These groups comprise: low-noise engine component design; nacelle low-noise features; low-noise engine nozzle design; hot-stream liner technology; active systems technology and low-noise airframe design. This will lead to down-selected noise-reduction strategies for full-scale validation in Phase 2.

Phase 2 is structured (i) to provide consistent information on the noise benefit versus the impact on cost, weight and performance (so that technology efficiency can be extrapolated for all appropriate types of aircraft/engine combination), (ii) to reflect the availability of suitable validation test vehicles, and (iii) to achieve cost-effectiveness in two potentially expensive areas, namely flight tests and technologies requiring the integrated redesign of engine or aircraft parts for large-scale validation. Tests will be conducted statically on three aero engines, in-flight on two aircraft, and on a number of large-scale component rigs.

In addition, SILENCE(R) will conduct a thorough noise evaluation of the two EEFAE concepts, namely: a performance-improved, low cost-extrapolation of current engines (BPR 7-9), and an advanced-cycle Ultra High Bypass Ratio (UHBR) engine (BPR 10-15).

Expected results

Key milestones will be tests conducted statically on three aero engines, flight tests on two aircraft and a number of large-scale component rig tests, supported by Preliminary Design and Critical Design Reviews for each technology area, and the Mid-term assessment with all partners and the European Commission's representative.

The main deliverables are noise-reduction technologies validated by tests on full-scale prototypes, a cost/benefit analysis of the application of these technologies, and assessments of the noise-reduction levels achievable with these technologies.

Title: Significantly Lower Community Exposure to Aircraft Noise

Acronym: **SILENCE(R)**

Contract N°: G4RD-CT-2001-00500

Proposal N°: GRD1-2000-25297

Total cost: €111 547 036

EU contribution: €55 929 806

Starting date: 01/04/2001

Duration: 48 months

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ATECA – Application des Technologies Avancées S.A.	F
Brüel & Kjær Sound & Vibration Measurement A/S	DK
Centre National de la Recherche Scientifique (CNRS)	F
Centre de Transfert de Technologie du Mans – Association pour les Transfert de Technologies du Mans	F
Dassault Aviation S.A.	F
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)	D
Dornier GmbH	D
EADS France S.A.S.	F
EADS Deutschland GmbH	D
Ecole Polytechnique Fédérale de Lausanne	CH
Fokker Aerostructures BV	NL
Fundacion Centro de Tecnologias Aeronauticas	E
Fundacion INASMET – Asociacion de Investigation Metalurgica del Pais Vasco	E
Hispano-Suiza Aerostructures S.A.	F
INBIS Technology Ltd.	UK
Industria de Turbo Propulsores S.A.	E
Institut National des Sciences Appliquées de Lyon	F
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Metravib Recherche Développement Service SA	F
MTU Motoren- und Turbinen-Union München GmbH	D
National Aerospace Laboratory (NLR)	NL
National Research & Development Institute for Turboengines Comoti R.A.	RO
Office National d'Études et de Recherches Aérospatiales (ONERA)	F
Plansee AG	A
QinetiQ Ltd.	UK
Rolls-Royce plc.	UK
Rolls-Royce Deutschland GmbH	D
Saab AB	S
Short Brothers Plc	UK
Sener Ingeniería y Sistemas S.A.	E
SIEGEL S.A.	E
Sonaca S.A.	B
Subcontratacion de Proyectos Aeronauticos S.A.	E
Technical Research Centre of Finland	FI
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Turbomeca S.A.	F
University of Southampton	UK
Vibratec S.A.	F
Walcher Elektronik GmbH	D

Project objectives

The key technological challenges confronting airframe manufacturers arise from the need to reduce the environmental impact of aircraft, increase their operational competitiveness, and improve their safety. Lighter structures offer a direct means of raising fuel efficiency and thus reducing emissions of carbon dioxide and nitrogen oxides. Structures also account for a large proportion of the cost of the aircraft. This means that reductions in manufacturing cost may significantly influence competitiveness. For airline customers, this potentially translates into a three-fold benefit in terms of lower fuel costs, lower maintenance costs and lower acquisition costs.

TANGO is the first opportunity to address the challenge of producing low-cost low-weight primary structures on a large scale. The elements most likely to generate significant cost and weight reductions have been selected and packaged as platforms; a composite lateral wing-box, a composite centre wing-box, a composite fuselage section, and an advanced metallic fuselage section.

In order to obtain the required levels of operating performance improvements for future aircraft, aggressive targets have been set:

- 20% weight reduction in comparison to structures in service today,
- 20% cost reduction in comparison to current manufacturing processes and state-of-the-art designs.

Description of the work

The TANGO work plan consists of the four physical platforms, a simulated join-up of two of the platforms and a cost-weight trade study. Each platform involves the design, manufacture, assembly and test of a large structure that integrates many component parts and advanced technologies.

The Cost-Weight-Trade package is fundamental to the overall process, and will ensure that the technologies integrated into the fuselage programme are selected as the most likely to achieve the overall project targets for weight, cost and operating costs.

The work plans of the four physical Platforms follow the same general pattern:

- Specification of platform structure including geometry and loading conditions.
- Creation of a finite element model used to produce component loading.
- Design schemes based on geometry and component loading.
- Specification of platform test programme.
- Preliminary view of the ‘build sequence’.
- Evaluation and selection of technologies for the platform structure.
- Derivation of design and stress data from coupon and small element tests.
- Detailed design and manufacture of parts using selected technologies.
- Assembly of platform structure, instrumentation and test rigs.
- Testing of full platform structure and analysis of results.

A multidisciplinary approach is being taken to ensure that additional issues are considered, such as environmental aspects, human factors with respect to assembly and in-service maintainability, repair issues, and provisioning for systems.

Each of the platforms possesses specific characteristics, which may be summarised as follows:

Composite Centre Wing-Box

The composite centre wing-box platform will be representative of a highly loaded structure and will include one aluminium dummy box representative of the lateral wing-box. Two other steel dummy boxes will enable loads to be introduced.

Lateral Composite Wing Box

The lateral wing-box Platform will consist of inner metallic wing-box components, outer-wing composite components and a mid-span interface. The mid-span interface, the composite outer wing-box structure and a representative inner metallic structure will be manufactured, assembled and undergo full scale structural testing.

Advanced Metallic Fuselage

This platform will include all the structural features such as the window surround structure, load introduction areas, and the interfaces and joints. The general definition of the metallic fuselage structure will be based on long-range aircraft structure of the rear fuselage. Structures that are not subjected to testing, (e.g. the floor structure) may be taken directly from long-range aircraft series production lines.

Composite Fuselage

This platform will have a similar diameter and frame pitch to a single-aisle aircraft. A composite door- surround structure will be included, although the door will be a dummy. This includes all the structural features such as the stringer profiles and pitches, door surround structure, interfaces and the type and location of the longitudinal joints and the circumferential joint. The loading conditions and the sub-component and panel test requirements will be defined.

Technologies being applied to the platforms include:

Fibre Metal Laminates, Friction Stir Welding, Laser Beam Welding and Advanced Bonding, RTM, RFI, LRI, RTI, ATL, Hybrid Material Drilling, Advanced Joining and Assembly techniques, Innovative re-inforcements and Fabrics and Simulation Techniques.

Expected results

The more tangible deliverables include the delivery of four structurally tested platforms (lateral wing-box, centre wing-box, metallic fuselage and composite fuselage), including a full suite of design, manufacture and test reports including recommendations for future technology applications.

There is no doubt that the technologies validated in TANGO will find their way into future European products, and enhance the competitiveness of European manufacturers of large aircraft; however, the programme will also increase the capability of equipment, component and material suppliers. By participating in technology selection, design and manufacture of cost-effective structures, suppliers will see where to direct their investment for the future. Experience gained by universities and institutes will be disseminated naturally into other business sectors and, at the same time, they too will have a better understanding of the future research needs of industry.

Title: Technology Application to the Near-Term Business Goals and Objectives

Acronym: **TANGO**

Contract N°: G4RD-CT-2000-00241

Proposal N°: GRD1-1999-10806

Total cost: €84 616 599

EU contribution: €42 631 311

Starting date: 01/04/2000

Duration: 48 months

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Centro Italiano Ricerche Aerospaziali S.C.p.A. (CIRA)	I
Centro Ricerche Fiat S.C.p.A	I
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Israel Aircraft Industries Ltd. (IAI)	IL
Istituto per le Ricerche di Tecnologia Meccanica e per l'Automazione S.p.A.	I
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Materials Research Centre	I
National University of Ireland, Galway	IRL
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Short Brothers plc.	UK
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Société de Construction des Avions Hurel Dubois	F
Sonaca S.A.	B
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
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Università degli Studi di Napoli 'Federico II'	I

Validation platform for Integration of standardised Components, Technologies and Tools in an Open, modulaR and Improved Aircraft electronic system

Project objectives

Typical electronics systems on board current European aircraft consist of a large number of different «black boxes», each tailored in terms of hardware and software technologies or engineering design to the specific function performed, this has the following drawbacks:
- rather «conservative» technologies for flight-critical systems
- crude implementations of new information and communication technologies in the non-flight-critical applications for crew and passenger
- typically, expensive development and evolution for equipment.

The VICTORIA project is intended to help the European aircraft electronic industry prepare a new generation of electronic systems, featuring modular, reusable and reconfigurable components with the integration of several functions onto common resources. Also importantly a seamless engineering process and tool suite providing:
- harmonised and optimised connection between the different domains of aircraft electronics
- optimised weight, power consumption, and operational cost
- scalability and growth potential to cope with ever increasing functional requirements,
- reduced time and cost to market.

This necessitates the use of the best available technologies; both for hardware/software components and engineering methods/tools applied extensively in a framework of open standards.

To support this, the Victoria objectives are:
- to validate technically these new technologies and tools
- to establish the interoperability standards, the development processes and the certification material to use them in further programs
- to assess the expected benefits on the overall competitiveness of our industry

Description of the work

The Victoria project centres, around a core team of 6 European airframers and suppliers but the extended team consists of: airframers, equipment and system suppliers, specialised SME's, universities and research centres, a total of 33 partners.

The project is organised in 8 work packages, namely:
- Preparation of new standards and certification material (WP1),
  This WP will run during the three years of the project. It is focused on preparing those standards and certification materials that are absolutely necessary for further successful deployment and cost-effective use of the new technologies envisaged.
- Preparation of new development tools and means (WP3)
- Definition (WP2), realisation (WP4 for resources and WP5 for applications), and integration (WP6) of a comprehensive validation testbed
- Project assessment, exploitation and dissemination (WP7)
- Overall project management (WP8)

The testbed covers a representative set of the different domains of aircraft electronics: cockpit avionics and aircraft control systems, emerging on-board crew information systems, passenger information and communication systems. Its goal is to validate:

- interoperability standards of WP1,
- development / integration means and tool chains of WP3,
- efficiency of functional performance, due to the integration of applications onto the resources of each domain.

The project schedule spreads over 3 years, broadly organised as follows:

- the first year devoted to the initial setting of standards, the definition of the overall test objectives, the testbed definition, with its process and tools and the integration and validation plan. Also the commencement of the longer lead or first needed items
- the second year concentrates on the implementation and adaptations of the tools, the resources and the applications
- the third year integration of the different items, perform the validation tests, and the overall assessment of the project, including the refinement of the standards.

Expected results

VICTORIA will culminate in the setting up of an experimental validation platform, which will bring the hardware and software together. It will consist of sets of experiments assembled and tested in Filton, Hamburg and Toulouse. The most important expected results are:

- validation of the new technologies and tools
- progress on essential interoperability standards in avionics, selected at the beginning of the project,
- validation of a development processes and of certification material, to be used in further programs
- assessment of the benefits of the new system compared to existing ones

Although the focus of energies is on air transport needs the requirements and results are assessed against the regional and rotorcraft needs by the partners.

Title: Validation platform for Integration of standardised Components, Technologies and Tools in an Open, modulaR and Improved Aircraft electronic system

Acronym: **VICTORIA**

Contract N°: G4RD-CT-2000-00399

Proposal N°: GRD1-2000-25209

Total cost: €83 039 784

EU contribution: €42 144 943

Starting date: 01/01/2001

Duration: 36 months

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BAE SYSTEMS Avionics Ltd.	UK
Diehl Avionik Systeme GmbH Frankfurt	D
Diehl Avionik Systeme GmbH Überlingen	D
Eurocopter S.A.	F
Fokker Elmo B.V.	NL
Gesellschaft für Angewandte Informatik und Mikroelektronik mbH	D
Institute of Communication and Computer Systems	EL
Intertechnique S.A.	F
KID-SYSTEME GmbH	D
Liebherr Aerospace Lindebergh GmbH	D
Messier-Bugatti S.A.	F
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SAGEM S.A.	F
Sinters	F
Skysoft Portugal, Software e Tecnologias de Informaçao,S.A.	P
Smiths Aerospace Ltd.	UK
Stichting Nationaal Lucht- en Ruimtevaart Laboratorium (NLR)	NL
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TERMA Elektronik A/S	DK
THALES Communications S.A.	F
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Universität Bremen	D
University of York	UK
Westland Helicopters Ltd.	UK

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