STUDY OF EUROPEAN GOVERNMENT SUPPORT TO CIVIL AERONAUTICS R&D

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August 15, 2005

Prepared for the National Aeronautics and Space Administration under Contract No. NNH04CC62C.

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Executive Summary

The study of government support for civil aeronautics research was performed at the highest possible level of detail for the European Commission, U.K., France, Germany, Belgium, Netherlands, Italy, Spain, Austria, Sweden and for Eurocontrol. While the level of detail available varied widely by country, information on the full scope of each country's civil aeronautics research program was obtained. It shows that total government support in 2002 for all entities covered by the study was approximately €2.9 billion to €3.0 billion. (This does not include research support provided by the Spanish government in the form of zero-interest loans, an unknown part of which is directed at research). The amount of government support is certainly growing and all countries covered by this study support civil aeronautics research on the basis of industrial policies.

The study revealed that industry participates in the vast majority of European civil aeronautics research programs on a cost-sharing basis. With the exception of France and Spain, industry contributes about 50% - 55% of total cost, on average. In France and Spain, industry contribution is reduced to 22% and 40%, respectively. Thus, total research expenditures are nearly doubled, greatly exceeding total spending on civil aeronautics research in the U.S. In return for making substantial cost-sharing contributions to research, industry, in all cases where it participates, has a decisive voice in defining the research and determining which, if any, research results may be publicly released.

European aeronautics research is increasingly guided by the strategic direction provided by "Vision 2020" and by the resulting Strategic Research Agenda (SRA) This is reflected in the fact that each country's research program has adopted the SRA objectives. The "country" entities are pursuing these common goals on an increasingly coordinated and cooperative basis, thereby reducing unnecessary duplication of effort and increasing the ultimate effectiveness of the various aeronautics research programs.

The most fundamental goal of the European aeronautics research agenda is to wrest world leadership from the U.S. by 2020. Consequently, all research programs are explicitly aimed at enhancing the "competitiveness" of the European aeronautics industry. The combination of a high level of funding for aeronautics research by both government and industry and its rapidly growing effectiveness from better coordination and cooperation on the basis of common research objectives lends credibility to the European goal of surpassing the U.S. in aeronautics by 2020.

If Europe reaches its goal of becoming world leader in aviation, the implications would be substantial and durable. Consideration of the following consequences of European success can guide future U.S. aeronautics policy:

- Reduced U.S. ability to translate technical leadership into high-quality jobs, intellectual capital, and innovation;
- Lost technical leadership, which would undermine the U.S. role in setting aviation standards for new technologies and affects adoption and implementation schedules and costs;
- Reduced positive contributions of the aeronautics industry to the U.S. balance of payments;
- Diminished rewards associated with a first-to-market position with products embodying innovative technology; higher long-term profits will also be jeopardized.

The examination of European aeronautics research clearly indicates that goals to reduce environmental impact from emissions and noise, improved aircraft safety, and increased operational capacity and safety are keys to the EU's strategic path to industry leadership. Especially those research areas that principally address externalities are difficult for the private sector to fund. Public resources are clearly required and justifiable in such cases. As for the other research areas, there is often insufficient appropriability for the private sector and at least some public resources may be required. It is noteworthy that in contrast to European effort, recent U.S. public funding for all such research has been in decline.

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Chapter 1

Introduction

This study was produced to inform NASA as to government-supported research programs in civil aeronautics undertaken in the European Union (EU). Public support by the European Commission (EC) as well as at the national level of each relevant EU member country was investigated. Since Europe is presently the only site of substantial aeronautics research outside the U.S., the data and analysis contained in the study make an important contribution to the knowledge of world-wide aeronautics research activities NASA needs in order to define its own research agenda. Among the benefits and ramifications of this work are that it should --

- Reduce the likelihood of unnecessary duplication of R&D efforts in those cases where the outcomes of publicly-supported research are shared with the U.S.
- Identify possible areas of mutual concern where cooperation would be more efficient and yield results in a more timely manner.
- Identify possible areas of mutually-beneficial standardization, especially where inter-operability is important (e.g. air traffic management).
- Identify future threats to U.S. competitiveness in fields of critical importance to U.S. economic and social well-being. (This item could be of special relevance in defining NASA's long-term research goals).
- Improve NASA's guidance for allocation in the U.S. of both public and private resources to civil aeronautics research.
- Develop an effective counter-strategy to the European approach to funding R&D and assisting U.S. industry to become increasingly competitive as a counter to Europe's stated aspirations.

The approach to acquiring and analyzing the data as well as the countries and time periods covered are addressed in Chapter 2, while a detailed description of each country's civil aeronautics research programs is provided in Chapter 3. Chapters 4 through 6 cover analysis of the data and a summary of findings. Detailed project information on research programs sponsored by the EC and Germany, the only two instances where such detailed information was found, is provided in the Appendices.

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Chapter 2
Approach and Methodology

The study covers the civil aeronautics research programs of the two relevant European Union organizations, the European Commission and Eurocontrol, as well as of each European Union member nation with a significant aeronautics research effort. The European organizations and countries studied are, in order of discussion in Chapter 3[1]:

- European Commission
- United Kingdom
- France
- Germany
- Belgium
- Netherlands
- Italy
- Spain
- Austria
- Sweden
- Eurocontrol

A separate section on Eurocontrol was added when it became apparent during the performance of the study that Eurocontrol had recently assumed a central role in defining, coordinating, directing and sponsoring research in air traffic management for all European Union member nations. The Eurocontrol research programs are discussed in as much detail as was found.

For each entity an attempt was made to identify research in the following subject areas:

- Civil transport aircraft – structures, aerodynamics, systems
- Aircraft engines
- Rotorcraft
- Air traffic management
- General aviation

The study team, in collecting information for this study, drew on its own direct contacts with European government entities and industrial sources as well as on the support of two subcontractors, both of which are well connected to industry and governments in the countries under study. The study team directly covered the research programs sponsored by the European Commission, Eurocontrol and

[1] The European Commission is placed first because its research program has become the template for most national programs. Eurocontrol is discussed last because it is highly interactive with the national air traffic management-related research. Placing it last helps it provide a summary of all important work in this field.

the U.K. while the subcontractors covered the remaining countries, with assistance from the study team, which also performed the entire data analysis.

Data sources were:

- Government ministries and research laboratories
- Appropriations bills
- Records of parliamentary debate
- Reports on major government-supported research laboratories and programs
- Company annual reports
- Information from national aerospace trade groups
- Personal contacts in government and industry

The quality, completeness and accessibility of the data varied widely between the countries. The most complete records were kept by the European Commission and Germany. The greatest difficulties in assembling a full understanding of the country's aeronautics research programs were encountered in Italy and Spain. The manner in which countries report on their aeronautics research programs is not uniform. A few provide detailed information at the project level; most only report at higher program or top budget levels.

This variability in the level of detail of available information made it impossible to organize the data by the above-mentioned subject areas. Instead, it had to be arranged—and needs to be examined—on a country-by-country basis. A discussion of the information and data is presented following the country reports.

All budget figures were taken from publicly available information. This does not mean that the information was always readily available; frequently, personal contacts were needed for help in obtaining the desired information. In those countries where the publicly accessible records did not provide much, if any, detailed information on research programs, personal contacts became the only means of filling in the details. In some countries, notably France, such detailed information could only be obtained from industry sources (indicative of a close collaborative working relationship between government and industry), some in the form of unrestricted company information (such as annual reports), some as estimates by personal contacts.

A further complication was that some countries do not explicitly separate aeronautics from astronautics research, but combine them in an "aerospace" category. In all such cases the aeronautics component is very dominant and an estimate of the aeronautics part could be made with reasonable accuracy. Also, all national programs contain a "dual-use" (for military and civil applications) research component funded out of each country's defense budget. The study team learned that there are significant benefits for the civil sector deriving from military-funded research in aeronautics. There are two reasons: First, most countries cannot afford to fund separate defense and civil sector companies; the same company supplies both. Second, cross-fertilization is made possible by the fact that none of the countries has the sort of stringent legal restrictions on mixing defense and civil work that apply in the U.S. Very little information could be found on such dual-use research. It is typically excluded from the listing of a country's civil research programs. Thus, the study undercounts to some degree the amount of government support to aeronautics research from which the civil sector benefits.

The study revealed that the institutions and nations of the European Union are increasingly cooperating on aeronautics research in support of and compliance with the strategic agenda summarized in "Vision 2020" and detailed in the European Strategic Research Agenda (SRA). Some of the resulting cooperative programs are funded from multiple sources, typically involving major contributions by the European Commission (EC) and smaller national ones. There is also increasing cooperation between national programs with the governments from several European nations contributing funds to such cooperative programs, both with and without EC participation. In all such cases, where available, each nation's contribution is noted in the discussion of its research programs, thus avoiding under- or over-counting total budgets. For example, if a program had funding from the EC and one or more national governments, each contribution is either explicitly listed by program (or even project, where the information was available) in the respective country report or included in the individual country's overall research budget if detailed project information was unavailable.

The discussion for each "country" entity includes an overview of the funding structure as well as of the importance of its aeronautics industry to its economy. Also, the approach to funding the research is described, including the extent of cost-sharing between government and industry which was found to be a common practice.

As for the time period covered in the discussion of the various government programs, the goal was to select the most recent one for which detailed information is available. This turned out to be the year 2002 in most cases. Since nearly all programs and projects are multi-year, program histories prior to 2002 are provided as well as what has been revealed about the time since 2002. In general, following the history of each country's aeronautics research program, its future direction is considered.

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Chapter 3
Information and Data on European Government-Supported Civil Aeronautics Research, by Country

EUROPEAN COMMISSION FUNDING

EUROPEAN COMMISSION "FRAMEWORK PROGRAMMES"

Through its Framework Programmes (FPs), the European Commission (EC) meets one of the key responsibilities imposed on the European Union by the Treaty of Rome; that of enhancing the competitiveness of the industries of its member nations through research in all relevant areas. The EC has supported aeronautics research since 1990, starting with its 2nd FP. This support was initiated in response to a study, published in 1988, by the European aeronautics industry. The study provided the basis for a strategic approach to pre-competitive research and technology development at the European level. While the initial "pilot phase" took up only the second half of the 2nd FP, subsequent aeronautics research has occupied the full duration of each FP. The time periods for the Framework Programmes are shown below in Table 1, along with overall budget information.

The time periods shown in Table 1 indicate the periods during which funds were committed. There is some overlap between successive FPs; some of the work effort funded under one FPs extends for at least a year into the next.

From the beginning, in all cases where industry participated, the funds provided by the EC have been matched by industry, which typically contributes an equal amount. As a result, the EC-supported R&D projects tend to have a near to mid-term time horizon and to be supportive of industry's product plans.

Overview and History of EC Civil Aeronautics-related Research

Start-up phase (1990-1991, as part of Second Framework Programme)

In 1988 the European aeronautics industry prepared a study (European Cooperative Measures for Aeronautical Research and Technology – EUROMART). This formed the basis for a strategic approach to R&D at the European level.

A “pilot phase” was conducted during 1990-1991, as part of the 2nd FP, with a budget of 66 million ECU[2] (European Currency Units; 1 ECU = €1). In accordance with general EC policy, the EC commitment was matched nearly 100% by industry to provide a total budget of 122 million ECU. Civil aeronautics research was conducted under the 2nd FP as part of the BRITE-EURAM I Programme (Basic Research in Industrial Technologies for Europe – European Research in Advanced Materials). BRITE-EURAM continued through the 4th FP. BRITE-EURAM III was part of the 4th FP. Starting with the 5th FP, aeronautics research has been given its own separate research category.

Table 1. EC Commercial Aeronautics-related R&D Budgets

Programme	Time Period	Total Aeronautics related R&D (€ millions)	Total Aeronautics R&D with industry contribution (€ millions)
Pilot Phase, 2nd FP	1990-1991	66	122
3rd FP	1991-1994	129	240
4thFP	1994-1998	400	800
5th FP	1998-2002	700	1,346
6th FP	**2002-2006**	**980[3]**	**1.840**

Third Framework Programme (1991 - 1994)

During this phase, EC support for aircraft- and engine-related research grew to €107 million plus an additional €22 million for research addressing energy efficiency, environmental concerns, aircraft safety, “telematics” (i.e. communication, navigation and surveillance) and air traffic management, for a total of €129 million[4]. Again, industry was required to match the EC’s funding.

Fourth Framework Programme (1994 - 1998)

The EC’s research budget for aircraft, rotorcraft and engines was increased to €245 million. In addition, €97 million was allocated to avionics, airports and air traffic management and €58 million to environmental and information technologies, resulting in a total EC contribution of €400 million. Matching funds from Industry brought total available research funds to €800 million.

[2] All funding figures are in Euros or ECUs because of the fluctuations in the dollar exchange rate over the period of time covered by the study. The average annual exchange rate in terms of $ per € for the last nine years have been:

1997	1998	1999	2000	2001	2002	2003	2004	2005
1.14	1.15	1.09	0.94	0.90	0.95	1.15	1.27	1.26

[3] Estimate of aeronautics research part of total budget for aeronautics and space, which is €1.18 billion.
[4] Funding flow in any given Framework Programme starts with a delay and extends into the next FP.

Fifth Framework Programme (1998 – 2002)

The EC's total aeronautics research budget grew to €700 million. Industry continued to match costs at about an equal level for 95% of the budget. (5% of the budget went to academia for programs not requiring cost sharing.) The total €1.35 billion for aeronautics research includes all areas related to aviation, including information technology and communication systems.

The 5th FP was not only more generously funded than its predecessors, it also marks the beginning of a serious effort at integration between the EC and national research programs. Both the larger budget and the more highly-integrated approach made it more effective than anything previously undertaken. It is also noteworthy that industry is not only sharing research costs, but takes a leading role in selecting and defining the research subject for all projects in which it participates. While this industry influence appears to be necessary to assure that the required cost match is made available, it also closely couples the expenditure of EC resources to the commercial interests and needs of industry.

Another important first for the 5th FP is that it establishes, for the first time, a separate stand-alone research category for aeronautics by combining all aeronautics-related research into the category "New Perspectives in Aeronautics." In all previous FPs aeronautics research had been distributed over several research categories (e.g., materials, production, information technology).

The research objectives are being defined quantitatively, with a clear bias toward improving the competitiveness of European aircraft, their systems and components, their manufacturers and their suppliers. This is illustrated by the following explicit objectives taken from the 5th FP[5].

1. **Reducing aircraft development cost and time-to-market.** Over the next ten years, from 1998, development time-to-market is to be reduced by 15 to 30%, development cost by 35% and manufacturing cost by 30%.
2. **Improving aircraft efficiency.** Over the next decade, aerodynamic drag is to be reduced by 20% and structural weight by 20% without increasing manufacturing cost. Fuel economy is to be improved by 20% (partly through lower airframe weights and aerodynamic improvements) with an equal reduction in emissions of greenhouse gases. Power consumption of on-board systems is to be reduced by 10% and the weight of such systems by 20%. Maintenance costs are to be reduced by 40% through application of state-of-the-art technologies.
3. **Improving the environmental friendliness of aircraft.** The research objectives are to reduce engine emissions of NOx and particulates to specific targets, reduce external perceived noise by 10 dB, and reduce

[5] "New Perspectives in Aeronautics", 1998-2002 Project Synopses, European Commission, Community Research, ISBN 92-894-2078-2.

internal cabin noise by 5 to 10 dB for turbofan and 10 to 15 dB for turboprop aircraft.

4. **Improving the operational capability and safety of aircraft.** The objectives are to increase airspace and airport capacity through the more autonomous operation of aircraft consistent with the future European Air Traffic Management (ATM) concept. Additionally, overall maintenance costs are to be reduced by 25% over 5 years and by 40% over 10 years while improving the reliability of maintenance operations. Finally, the aircraft "accident rate" is to be reduced by at least the same factor as the growth in traffic. For example: in order to prevent the number of accidents from increasing, a 30% increase in air traffic is to be compensated by 30% decrease in the accident rate.

Each of these key research objectives addresses important competitiveness issues for the EU's aeronautical industry. They were adopted by the "Group of Personalities", which was formed in late 2000 to develop the European vision for aeronautics in the year 2020, as stated in the group's report "European Aeronautics: A Vision for 2020." Based on recommendations in the report, an Advisory Council for Aeronautics Research in Europe (ACARE) was formed. It was given the primary mission of defining a European Strategic Research Agenda (SRA) which is to provide guidance to the planning of future aeronautics research in Europe at both the EC and national levels.

Sixth Framework Programme (2002-2006)

The selection of the main research objectives of the 6th FP and of its programs and projects has been guided by the "Vision 2020" report and the SRA defined by ACARE. The top-level research goals are defined as follows:

- To meet society's needs for a more efficient, safer and environmentally friendly air transport system.
- To win global leadership for European aeronautics, including a competitive supply chain and the promotion of small and medium-size enterprises (SMEs).

It was also influenced by the Lisbon European Council of March, 2000, at which the European Union member nations resolved that the combined economy of the European Union should become the worlds most competitive by 2010. The 6th FP is designed to help the EU move toward that goal through

- Greater integration between all research programs at the EC and national levels;
- Larger and more co-operative projects;
- Encouragement of innovation.

In the language of the European Union, aiming for such an integrated research approach is referred to as creating a "European Research Area" (ERA). The 6th FP is the EC's current main financial and legal instrument for implementing the ERA, in conjunction with national research initiatives.

Aeronautics research is covered by the "Thematic Priority", one of seven, labeled "Aeronautics and Space." It has a total budget of €1.18 billion over five years. By various estimates, about 80% of this budget, €980 million, is allocated to aeronautics. The research is primarily focused on civil aircraft, including their systems and components. The categories covered are large transport, regional and business aircraft as well as rotorcraft, engines and avionics. Ground-based and on-board avionics equipment related to air traffic management are also covered, on a "gate-to-gate" basis.

The scope of work is structured into the following four research areas:

1. Strengthening the global competitiveness of the European aeronautics manufacturing industry by delivering more economical, higher performing and better quality products and services.
2. Reducing the environmental impact of emissions and noise and for meeting society's demand for sustainable transport.
3. Improving aircraft safety and security to the extent that the accident rate will be reduced at least to the same extent as the rate of increase in air traffic.
4. Increasing the operational capacity and safety of the air transport system through a seamlessly integrated European air traffic management system which meets the goals of the "Single European Sky" initiative.

At this writing the EC has not yet published a list of projects funded under the 6th FP, let alone any project details (such as research topic, funding level, participants and duration). According to the EC, this information will not become publicly available before late 2005. (This increased propensity to withhold such information likely reflects EC's and European national governments' clear intention to maximize the contributions their support of aeronautics research can make by enhancing Europe's "competitiveness"). A very limited listing of projects which came to the attention of the authors through informal channels is provided in Appendix 1. Consequently, the 5th FP, being the most recent FP for which detailed information is available, is discussed in detail.

5th Framework Programme Details

Aeronautics research in the 5th FP was divided into two major categories, development of critical technologies and technology integration and validation. A total of 126 Critical Technology and eight Technology Platform projects were funded under the 5th FP. A project list is provided in Appendix 2. More detailed project information is provided in Reference 5 and at EC websites[6].

[6] http://europa.eu.int/comm/research/growth, www.cordis.lu/growth

Development of Critical Technologies - Takes a medium- to long-term perspective with the objective of extending and improving the European technology base in those critical disciplines which are perceived to be most important to reaching the socio-economic goals of the ERA (European Research Area).

Technology Integration and Validation - Takes a short-term perspective. Intended to reduce the risk inherent in applying new, innovative technologies. This is most relevant to aeronautics "products", which tend to be a combination of multiple systems and technologies. The so-called "Technology Platform" projects are specifically designed to deal with the integration and validation issues of such complex combinations by means of test rigs, flying test beds and simulators. Such projects are typically larger than those in the critical technologies category.

Critical Technologies

(1) Reducing Aircraft Development Cost and Time to Market

Research in this category was aimed at improvements in design systems and tools, manufacturing and quality control.

Advanced Design Systems and Tools. Research goals were reduction in time-to-market by 15-30% and of development costs by 35%. Research was focused on:

- Development of concurrent engineering environments.
- Development and validation of multi-disciplinary optimization methods.
- Advanced modeling and simulation tools, including virtual reality, in support of virtual prototyping.
- Knowledge-based systems to support design activities.

Manufacturing. Manufacturing cost was to be reduced by 30% through the following research activities:

- 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. Improvements through continuous quality and cost control measures in the design and manufacturing stages by means of the following research activities:

- Development of new inventory and configuration control procedures to be deployed across the supply chain.
- Advanced in-process inspection and test techniques.
- Development of knowledge-based diagnosis techniques.

(2) Improving Aircraft Efficiency

Direct Operating Cost (DOC) was to be improved through a substantial reduction in fuel consumption, while maintaining or improving safety, on the basis of the following research objectives:

5. Drag reduction and improved lift-to-drag ratio through improved aerodynamic designs.
6. Reduction in aircraft Operating Empty Weight (OEW) through increased use of advanced, lightweight, cost-efficient structures and of power-optimized and safer integrated flight controls, systems and equipment.
7. Improved engine efficiency with higher performance propulsion systems and propulsion controls.

Aerodynamics. The overarching goal is a reduction in aerodynamic drag by 20% in ten years from 1998 and the improvement of the overall aerodynamic efficiency of aircraft in all phases of flight. Research was focused on:

- Development and validation of high-performance technologies, systems and support tools for drag reduction.
- Theoretical and experimental methods for the prediction and control of boundary layer behavior.
- 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. The objective is a reduction in weight by 20% in ten years at no increase in manufacturing cost and without reduction of structural life. This is to be accomplished through research:

- Development and validation of improved theoretical tools for the simulation of structural behavior.
- New structural concepts for increased use of advanced materials in primary structure.
- Tools and technologies for the application of “smart materials.”
- Realization of “smart structures” integrating the sensors-structure-control-actuator chain.

Propulsion. A 20% increase in fuel economy is sought over ten years with commensurate reduction in the emissions of greenhouse gases as well as improvement in engine thrust-to-weight ratio by 40%. The research addresses:

- New and improved engine cycle concepts.
- Numerical aero-thermodynamic methods for the design of turbine engine 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. For on-board systems, reduction in power consumption by 10% and in weight by 20% is the goal while maintaining the current level of safety, cost-effectiveness, reliability and maintainability. Research being conducted includes:

- Power generation and other technologies in support of a more electric aircraft.
- Low-power and other advanced flight control systems.
- Improved modeling and design methods for landing gear and braking systems.
- Techniques for improved reliability of fuel management systems.
- Application of fiber optics to cabin utility systems, passenger services and avionics.
- Development of underlying technologies and procedures for implementing integrated modular concepts.
- Utilization of multimedia passenger services through application of advanced displays and sensors related to cockpit functions.

Design and Interdisciplinary Aspects. The task is the development of the analytical capability to assess improved and novel aircraft configurations through research into:

- 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 and rotorcraft).
- Improved analytical tools for the prediction, and technologies for the prevention of, static and dynamic aero-elastic phenomena.

(3) Improving the Environmental Friendliness of Aircraft

Research is aimed at reductions in emissions and external and cabin noise as well as at improving the overall cabin environment.

Low Pollutant Emissions. Reduction in engine emissions of NOx and particulates is sought as well as improvement of the composition of emissions. The specific targets for NOx emissions are: 80% in the LTO cycle, emission index of 8 g per kg of fuel burned in cruise/climb. Supportive research:

- Tools and technologies for low-NOx combustors and efficient combustions systems.
- Measurement and modeling 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.
- Acquisition of the technical background to define new emissions parameters covering all aircraft operations.

External Noise. Reduction in perceived noise of 10dB in ten years is to be achieved through research:

- Predictive methods and tools for reduction of noise at the source.
- Modeling of far-field noise radiation.
- Development of the technical background to improve noise certification parameters and procedures.
- Modeling of sonic boom patterns.

Cabin Environment. In the medium term, the objective is a reduction of cabin noise levels by 5-10 dB for turbofan-powered aircraft and 10-15 dB for turboprop and rotary-wing aircraft. The research undertaken:

- 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 cabin environment technologies for cost-effective cabin climate control including humidification and other aspects of air quality.
- Human-centered utilization of multi-media 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. With the expected growth in air traffic, the probability of an accident must be reduced. Research and technology development has therefore been aimed at providing a better understanding of the causes of accidents and of the human-machine interface. Also, the crashworthiness of aircraft is to be improved.

Air-Traffic Management (ATM)-related Airborne System. The need is to increase airspace and airport capacity through more autonomous operation of aircraft consistent with the future European ATM concept (see also Chapter 3, EUROCONTROL). Research is addressing:

- Advanced on-board flight management functions, optimizing 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 communications and surveillance technologies.

Operational Maintenance. Reducing maintenance costs by 25% in the medium term and 40% in ten years is the objective while improving the reliability of maintenance operations; associated research includes:

- Improved maintenance systems.
- Development of "smart" maintenance systems with self-inspection and self-repair capabilities.
- Improved non-destructive testing and analytical methodologies aimed at maintaining the integrity of aging aircraft.

Accident Prevention. The goal is to reduce aircraft accident rates by at least the same factor as the growth in air traffic. The research required includes:

- 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 strikes and single radiation upset effects.

Accident survivability. Reduced passenger casualties or injuries in the case of survivable accidents is the objective. Research covers the development of prediction tools as well as design techniques and structural concepts for improved airframe crashworthiness and also methodologies for the prediction and mitigation of on-board fires.

Technology Platforms

Technology platforms (TPs) have been used for technology integration and validation. Each TP brings together a multiplicity of advanced technologies within a single project. The purpose is to support high priority efforts related to the development of future aircraft. The following eight TPs were established:

- Low-cost, low-weight primary structures.
- Efficient and environmentally friendly aero-engine.
- More highly autonomous aircraft in the future air traffic management system.

- Power-optimized aircraft.
- Low external-noise aircraft.
- Friendly aircraft cabin environment.
- Advanced wing configuration.
- Integrated and modular aircraft electronic system.

EUROPEAN REGIONAL DEVELOPMENT SUPPORT

The European Commission disburses large amounts of economic-assistance funding to economically disadvantaged regions in member nations. For example, by far the largest of such program is the Common Agricultural Policy, which distributes more than €40 billion annually to farmers throughout the EU. Two such economic assistance programs provide funds for research. They are the European Regional Development Fund (ERDF) and the European Social Fund (ESF). These resources are often allocated in coordination with national economic development funds. They channel millions of euros annually into certain geographical regions for support of research, industrial innovation, technical training, manufacturing improvements and education. Details are discussed for individual countries receiving such funds and which support aeronautics research.

UNITED KINGDOM

INTRODUCTION

The U.K. aerospace industry, with total revenue of $30 billion in 2002, is the second largest in the world, after that of the U.S. Information about government support for civil aeronautics R&D in the United Kingdom has proven difficult to acquire. Most of the government's funding for civil aeronautics research is now in the form of direct product support, so-called "launch aid"[7]. The increase in launch-aid funding was accompanied by a decrease in other forms of public support for aeronautics research. In fact, U.K. Government support for all civil R&D has declined by 82% in constant British Pounds over the last twenty years.

Overall U.K. aerospace R&D was 8% of industry revenue in 2001, which is low by the standards of the other European countries analyzed in this study. Around 50% of the total was funded by U.K. industry. The U.K. aerospace R&D growth rate has lagged behind its major competitors both in Europe and elsewhere. A comparison between the U.S., Germany and the U.K., in terms of Government funding allocated specifically for civil aerospace R&T[8] (which is pre-dominantly aeronautics R&T), shows that in 1998 (latest available comparative data) the U.S.

[7] Launch aid consists of loans at preferred interest rates for the development of new products. These loans only have to be repaid if the products succeed in the market. It is referred to as "direct support" in the 1992 Agreement on Trade in Large Civil Aircraft.
[8] The British designation R&T is the equivalent to R&D elsewhere.

Government provided about $1 billion, compared to $200 million in Germany and only $32 million in the U.K.[9]

Government support for research is funded by the U.K. government, also referred to as Her Majesty's Government (HMG). Economically distressed regions receive support from HMG and from the European Commission's Regional Development Fund (ERDF) and the European Social Fund (ESF). An unknown fraction of this support is allocated to civil aeronautics research. Most of government's aeronautics research support is allocated to the defense sector in the U.K..

Launch aid has been primarily provided to support the development of new Airbus aircraft, Westland helicopters and Rolls Royce engines. Since this form of government support is directly aimed at the development of new commercial products, it falls outside the scope of this study.

RESEARCH GRANTS FROM U.K. GOVERNMENT

Aeronautics Research Programme (formerly Civil Aircraft Research and Demonstration)

Over the years, the U.K. has consistently provided modest amounts of financial support for civil aeronautics research in the form of grants. Starting in 1990, the Department of Industry and Trade (DTI) managed this function through the Civil Aircraft Research and Demonstration (CARAD) program. In April 2001 it was renewed for a further five years, under the new name of Aeronautics Research Programme (ARP).

ARP is part of the U.K.'s nationally integrated research effort in aeronautics. It supports collaborative, pre-competitive research and technology demonstrations by industry, at universities and in research organizations. It also encourages industry to work with QinetiQ, which was split out of the former Defence Research and Evaluation Agency (DERA) in order to build upon the latter's capabilities for the benefit of civil industry, with the aim of improving the long term technological competitiveness of the U.K. industry. The ARP supports a nationally-integrated program in the technology areas shown in Table 2, along with their budgets for 2002[10]. The budget for ARP (and CARAD before it) has been level over the past several years.

ARP support comes in the form of direct grants to industry projects or programs. The work is led by industry, in collaboration with universities and research institutions. ARP provides up to 50 percent of total project funding. The rest is contributed by industry. Support levels are negotiated case-by-case. The program funds basic and applied research but does not provide assistance for direct product development, which is funded through "launch aid." ARP also contributes funds to some dual-use (civil/defense) programs inpartnership with the Ministry of Defence (MoD).

[9] An Independent Report on the Future of the U.K. Aerospace Industry, DTI, June 2003
[10] "Government Support to Rolls Royce U.K. for Aero Engine R&D", TECOP report, 11/18/03

Table 2. 2002 Aeronautics Research Programme Budget Line Items

Technology	**2002 Budget ($ millions)[11]**
European Transonic Wind tunnel	0.3 (1%)
Aerodynamics	4.0 (13%)
Propulsion Systems	13.4 (42%)
Structures & Materials	8.3 (26%)
Aircraft Systems	5.9 (18%)
TOTAL	**32.0 (100%)**

To cite some examples of the type of research supported by CARAD, the following two important initiatives were launched in 2000-01:

1. "More Electric Engine and Wing Systems Programme" to develop and demonstrate "more electric" technologies that will eventually replace hydraulic and pneumatic aircraft control systems with the promise of delivering significant cost savings in manufacturing and maintenance, and

2. "Flight Deck Technologies for Enhanced Safety Programme" to address technologies specifically aimed at minimising pilot error, thus contributing to a reduction in the rate of aircraft accidents.

Engineering and Physical Sciences Research Council

Engineering and Physical Sciences Research Council (EPSRC) grants are primarily directed at universities. They support aerospace-relevant research there through "Responsive Mode" (making key experts available) and "Managed Programmes" (collaboration with industry). The latter require industrial contributions in the form of either direct cash or in-kind contributions (up to 50 percent of total cost, depending on the program). The former, Responsive Mode, provides continual access to experts in the field for more generic research, often attracting industrial collaboration.

A confidential report, published in April, 2003 by EPSRC "Aerospace and Defence Sector Report", represents

- An overview of HMG's R&D spending,
- How such spending divides between civil and defense sectors,
- Its distribution among the largest recipients of such spending.

This reports indicates that total HMG spending on research in aeronautics and defense is around $800 million per year. 91.1% of this, or $728 million, was

[11] At the exchange rate of £1 = $1.6 current in 2002.

provided by MoD. The rest was assigned to civil research. It is shared between DTI (4% of total, or $32 million - which is consistent with the figure in Table 1) and EPSRC (approximately 5%, or $40 million). $19.4 million and $19.2 million of total (civil and defense) EPSRC-funded support was allocated to Rolls Royce and BAE for engine-related and large transport aircraft-related research, respectively, accounting for 72% of the EPSRC R&D budget for aeronautics collaborative (with industry) research.

The total EPSRC budget has been rising steadily over the last ten years at a compounded rate of roughly three percent per year, from $591 million in 1994-95 to $808 million in 2003-04. EPSRC provides information on their main collaborative projects in aeronautics research in 2001-02, shown in Table 3[12].

Table 3. Main Collaborative Projects Supported by EPSRC in 2001-02

Company	**Number of projects**	**Grant value ($ millions)**
Rolls Royce	60	19.4
BAE	52	19.2
QinetiQ	37	9.8
Others	15	5.1
TOTAL	**164**	**53.5**

Local Regional Aid

The Regional Development Agencies (RDAs) are the key strategic drivers of economic development in economically disadvantaged U.K. regions. They were created to co-ordinate regional economic development and regeneration so the regions can improve their relative competitiveness and reduce imbalances within and between regions. They are in part funded by contributions from the European Union regional aid programs. The following is a list of the regions[13]:

- Advantage West Midlands
- East of England Development Agency
- East Midlands Development Agency
- London Development Agency
- North West Development Agency
- One North East
- South East of England Development Agency
- South West of England Regional Development Agency
- Yorkshire Forward

RDAs play an important role in helping DTI meet its goals for regional productivity growth. In the 2000 Spending Review, the RDAs were given both

[12] Ibid
[13] DTI

extra resources and new financial autonomies through the ‘Single Pot’ to meet regional needs. As the lead sponsoring department, DTI’s funding specifically for the RDAs has been increased from $254 million in 2002-03 to $453 million by 2005-06. This additional funding equips the RDAs to implement their enterprise agenda by engaging industry in projects directed at fostering innovation, by developing key sectors and clusters, supporting the economic rejuvenation of coalfield communities and stimulating workforce development among local employers.

East Midlands Regional Development Agency. A key RDA for aeronautics research, the East Midlands Regional Development Agency (EMDA), was established in April 1999. The EMDA aims “to take the East Midlands into Europe’s Top 20 regions by 2010 where people want to live, work and invest because of our vibrant economy; healthy, safe, diverse and inclusive society; and our quality environment.” Its role “is to work with partners by focusing on learning and skills; enterprise and innovation; harnessing the revolution in information and communications technology (ICT) and providing a climate for investment.”

EMDA’s budget for 2002/2003 was $166 million, including $24 million from EC economic development funds. The amount applied to aeronautics research is not specified.

Aerospace Innovation and Growth Team

Launched on May 16, 2002 by Patricia Hewitt, the Secretary of State, the Aerospace Innovation and Growth Team (IGT) is a partnership venture to improve innovation and competitiveness in the aerospace industry. The team, including representatives from industry, government and other stakeholders, was led by Sir Richard Evans, former Chairman of BAE Systems. Its aim is to secure agreement between government and industry on a shared vision and strategy for the future.

In June 2003 the U.K. Government outlined plans to support the aerospace industry through the IGT initiative. The team recommended that defense research and technology (R&T) support levels be maintained at then-current levels but with increased emphasis on making the programs more relevant to industry’s product strategies. The recommendations included that DTI funding be increased by $80 million per year, from $32 to $112 million.

European Union Local Regional Aid

East Midlands Region

The European Commission (EC) provides support through its Framework Programmes (FP) and regional aid programs. Support provided through the EC’s FPs is covered in the Chapter on the EC. The European Regional Development

Fund (ERDF) runs a program called "Supporting Technological Development and Business Innovation." The East Midlands Region, including the city of Derby (Rolls Royce engines), qualifies for such grant aid under the European Union's "Objective 2" program for helping areas of economic deprivation.

The whole East Midlands region has been a major beneficiary of Regional Development and Social Funds and indeed has had access to Objective 2 funding for the last 12 years, receiving some $330 million over the period 1993-1999. In the current seven-year period, 2000-2006, it has access to EU ERDF and ESF resources of some $643 million, or $91.9 million per year, on average. The amount going to civil aeronautics research could not be identified.

South West Region

The prosperous South West Region, surprisingly, has also been a recipient of ERDF funds to the tune of about $445 million over the period 2000 – 2006, on average $63.6 million per year. The South West Region is home to major facilities of BAE Systems (Airbus wings), Agusta Westland (helicopters), Rolls Royce (engines) and Smiths (avionics). Approximately half the funds, $31.8 million, are dedicated to the development of innovative technology at regional SMEs[14]. An unspecified fraction of this amount is allocated to civil aeronautics research, but it is likely to be significant because of the importance of the aeronautics industry to the Region.

France

Introduction

The aerospace sector is a very important part of France's industrial capability and makes a key contribution to its Gross Domestic Product and exports. According to GIFAS, the French Association of Aerospace Industries, total revenues from the aerospace sector were €24.6 billion ($24.6 billion[15]) in 2002, of which the civil aeronautics sector represented €16 billion (65%). It has been nurtured and kept competitive since inception by the French government.

France is the one large European nation with the most highly centralized national government. It is not a federal republic like Germany or Austria and has not devolved any significant power to local governments as the U.K. has to Scotland and Wales. Its administrative regional governments have no power outside their limited territory. They do not independently decide on issues such as support for industrial research or any other aspects of industrial policy.

[14] Mid-Term Evaluation of the South West Objective 1 & 2 Programmes 2000-2006, Final Inception Report, Dec. 2002.

[15] Based on an exchange rate of 1:1, which applied in 2002. The dollar hit a lowest point of 1€ = $1.35 in early 2005.

In addition to its tradition of a powerful central government, France has a long history of strong involvement by the central government in industry, insurance and banking. The last time that industry and finance in France were nationalized was as recently as the mid-nineteen eighties. Although government began a privatization process in the second half of the eighties, the aerospace sector remained largely nationalized until the founding of EADS in 2000. To this day, government retains a strong position of influence on the board of EADS through its 15% ownership stake and through a long cultural tradition of state control and influence in all sectors of public life. It is also a shareholder in most of the other significant aeronautics companies, OEMs as well as suppliers.

The tradition of government ownership, industrial policy and continuing tight government control of the aerospace sector means that there is neither a clear demarcation line between government and industry nor much transparency or accountability in the ways in which government provides funding to industry, how much or for what purpose. Consequently, a top-down analytical approach was required for France, starting with the annual appropriations budgets for 2002 (the most recent year for which such information was available) and supplementing it with details based mostly on personal contacts in government and industry who wish to remain anonymous, particularly at this time of heightened tension between the European Union and the U.S. on the issue of subsidies to Airbus and Boeing. French government spending on research support has been nearly flat since 2002, thus the 2002 figures should be representative of those of subsequent years.

Government Funding of Civil Aeronautics Research in 2002 – a Top-Down Analysis

The French government supports industry in both pre-competitive research, as well as research directed at specific near-term products, in the pursuit of its policy objective of ensuring the long-term competitiveness of the French civil aeronautics industry. This industry contains four main clusters of aircraft manufacturers and their suppliers: Airbus for large transport aircraft, Eurocopter for rotary aircraft, SOCATA for small general aviation aircraft and Dassault for business jets. Dassault appears to get little if any research support for development of the airframes of its business jets, but is the recipient of subsidies for research aimed at its electronic/avionics and design software businesses.

In 2002, the total expenditure on all areas of research, not only in aeronautics, by government and industry was €9.09 billion[16], of which 78%, or €7.09 billion[17], was provided by government. Of this, government spent approximately €1.96 billion**,** or 28%, on civil aeronautics. The actual amount is probably higher because of contributions by the Ministry of Defense which may not be fully represented by this study because of restricted access to the relevant information.

[16] Ministry for the economy, finance and industry.
[17] GIFAS.

It is important to note that the government's relative share of research expenditures is much higher – and industry's contribution much lower – in France than in the U.K, Germany or in the EC model. The €1.96 billion budget for civil aeronautics research breaks down as follows (all amounts in € million). Industry beneficiaries are noted where information was available:

	(€ millions)
Research Support to Industry (2002 annual)	**416.0**
Aircraft engines (SNECMA, Hurel-Hispano, Turbomeca)	20.6[18]
Avionics (Thales, Dassault Electronique, Sagem)	21.9[19]
Civil aircraft (Airbus and its subcontractors)	210.2[20]
Rotary wing aircraft (Eurocopter)	30.0[21]
Lab & test equipment purchases	113.3[22]
Related labor services	14.8[23]
Taxes (mostly value-added tax)	5.2[24]
"Targeted Calls"[25] Support to National Research Institutions	**375.9**
ONERA (Office Nationale d'Etudes Aerospatiales)	170.0[26]
Fixed wing aircraft	*96.0*[27]
Rotary wing aircraft	*12.0*
Engines	*21.0*
Materials	*14.0*
Civil part of dual use research	*27.0*
CNRS (Centre National de la Recherche Scientific)	130.0
CEA (Commisariat de L'Energie Atomique) for materials testing and electronics	3.5
CNES (Centre National d'Etudes Spatiales) for materials and atmospheric drag studies	35.0
INERIS (Institut National de l'environment industrielle) For studies of environmental impact of aircraft	15.0
Research subject aircraft safety	0.8[28]
Research subject small civil aircraft	21.6[29]
Research Support to Academia	**26.6**
Universities and national laboratory use by universities	14.3[30]
Test equipment	12.3[31]
Salaries, Wages and Indirect Cost Burdens for Management and Administration at Government Institutions (e.g. National Labs)	**1,144.2**[32]
Annual Grand Total:	**1,962.7**

[18] Ministry for Equipment, Transport and Tourism.
[19] Ibid.
[20] Ibid. (Airbus alone received €168.2 million, which was almost entirely assigned to the A380 project.)
[21] Private communication with industry sources.
[22] Ministry for the Economy, Finance and Industry.
[23] Ibid.
[24] Ibid.
[25] "Target Calls" programs and projects have clearly defined goals and objectives.
[26] Ministry for Primary and Secondary Education and Research.
[27] Breakdown represents estimates based on private communications with industry sources.
[28] Ministry for Equipment, Transport and Tourism.
[29] Ibid.
[30] Private communication.
[31] Ministry for equipment, transport and tourism.
[32] All ministries except for Defense

MAIN RESEARCH GOALS AND FUNDING CHANNELS

Government funds supporting civil aeronautics research are channeled through the following institutions:

- Ministry of the Economy, Finance and Industry (primary source for industry support)
- Ministry of Primary and Higher Education and of Research (plays a coordinating role)
- Ministry for Equipment, Transportation and Tourism (primarily air traffic management)
- Defense Ministry (contributions to dual-use programs)

The overarching research objectives are:

- Improving safety
- Improving aircraft performance
- Improving aircraft cabin comfort
- Improving propulsion performance
- Lowering the cost of designing and manufacturing aircraft

Funding contributions to air traffic management and air navigation-related research to programs under Eurocontrol's responsibility are excluded from this compilation of research support. They are listed in the Chapter 3 section on Eurocontrol. Air navigation and traffic management are the responsibility of the Direction de la Navigation Aérienne (DNA), which, in coordination with Eurocontrol, defines and funds research performed at the Centre d'Etudes de la Navigation Aérienne (CENA). This work is France's contribution to Eurocontrol and is included in the latter's budgets. DNA also supervises the French air traffic management service, Service Technique de la Navigation Aérienne (STNA). CENA and STNA are cooperating closely with the military sector and have full access to military research results. For security reasons their research budgets, apart from those contributed to Eurocontrol, are classified.

DNA is also engaged in joint research with the French intelligence services and the military into aviation security matters. All such research is designated classified.

FUNDING FOR AERONAUTICS RESEARCH BY THE EUROPEAN INVESTMENT BANK

The European Investment Bank (EIB) provided funds to two aeronautics research programs for:

- "Development of civil aeronautics": EADS France received $700 million in 2002 for Airbus (A380) R&D.

- "Research development and industrial application of advanced aeronautical propulsion techniques" - at centers located mainly in France. SNECMA R&D received $300 million in 2003.

These funds are spent over an unknown number of years.

GERMANY

INTRODUCTION

In 2003, the aerospace industry in Germany generated approximately €16 billion in total revenues and employed about 72,000 workers. The member companies of the German Aerospace Industries Association (BDLI), invested 17.2% of total industry revenues in R&D. 71.7% of revenues were exported, making the industry a key contributor to Germany's export-led economy. The German aeronautics industry has been the recipient of relatively modest levels of government research support, mostly federal, compared to the size of the industry. The objective of government funding at the federal and state levels has been to enhance the domestic aeronautics industry's competitiveness within the European Union as well as internationally.

FEDERAL FUNDING

In Germany's federal government structure, most government support for civil aeronautics research comes from the federal government. Only the three federal states in which the German aeronautics industry is clustered contribute any significant funding intended to enhance the competitiveness of their "home" industry. Cost sharing by industry is a standard feature in all such government-supported research programs.

Research Foundations, Societies and Research Centers

Germany has long provided relatively modest levels of government support to civil aeronautics research programs through its Federal Research Center for Aeronautics and Astronautics, DLR, as well as through contributions to the German Research Foundation, DFG, the German Aeronautics Information Service, DFS, the German Society for Aeronautics and Astronautics, and contributions to German universities. Federal support for these programs has consistently run at about €20 million ($20 million[33]) per year, on average.

The responsibility for funding universities generally lies with the federal states; it is their constitutional responsibility to fund academia.

[33] At an exchange rate of 1€ = $1, which was the average over the period 2000-2003.

Aeronautics Research Programs

Starting in 1995, the federal government provided additional and much more significant aeronautics research funding through its Aeronautics Research Programs (ARPs, called "Luftfahrtforschungsprogramme" "Lufo" in German). The ARPs are patterned after the EC's Framework Programmes (FPs) in order to encourage and facilitate the participation of German research institutions and industry in the FPs (with EC funding) and to improve coordination between German and EC research programs. They are organized and supervised by DLR[34].

Since 1999, the states have been asked to contribute funding to the ARPs. The states of Bavaria, Brandenburg and Hamburg answered the call with sizeable contributions while the remaining states play only a minor role. The three dominant states play host to most of Germany's aeronautics industry and have a history of providing research support in order to enhance the "home" industry's competitiveness.

Industry Cost Sharing and Coordination with EC Research

Industry cost-sharing is a key feature of the German aeronautics research programs. Large companies contribute 60% of total cost while small and mid-size business concerns (SME) provide 40%. Industry's contribution can be reduced somewhat if certain special criteria are met, e.g. if the company is located in an area that qualifies for regional development assistance or if the project is a co-operative one with several partners. On average, German industry contributes about 55% of total research cost, slightly higher than industry's contribution under the European Commission's (EC)Framework Programmes (FP).

In the spirit of the EC's "Vision 2020" and the European Research Agenda (ERA), since 2001, the German research program has been increasingly coordinated with the EC FPs as well as with the aeronautics research programs of other EU member nations. The overall goals of ERA, which have been adopted by Germany, are to enable Europe to:

- Meet society's needs for a more efficient, safer and environmentally friendlier air transport system.
- Win global leadership for Europe's aeronautics industry.

Co-operative research projects, including projects with cross-border co-operation, have been favored since 2000.

Historical Overview of Aeronautics Research Programs

Since its inception in 1995, a total of more than €1.25 billion[35] had been spent through 2003 on the German ARPs by government (federal and state) and

[34] www.dlr.de
[35] No equivalent dollar value was calculated due to the fluctuations in the exchange rate over the years.

industry. The program is currently in its third phase. A budget overview for the program, consisting of three ARP phases from inception through 2007, is provided in Table 4[36]. The figures for industry funding are estimates. They are based on the rule that, on average, 95% of the government funding supports projects in which industry participates with cost sharing (industry contributed roughly 55% of total cost in ARP II and III, 50% in ARP I, on average), while 5% goes to academic projects, without cost-sharing.

Table 4. Funding of German Aeronautics Research Programs Since Inception

Program	Time Frame	Federal Funding (€ millions)	State Funding (€ millions)	Industry Funding (€ millions)	Total Funding (€ millions)
ARP I	1995-1998	310	0	300	610
ARP II	1999-2002	120	80	210	410
ARP III	2003-2007	160	160	335	655
TOTALS	**1995-2007**	**590**	**240**	**845**	**1,675**

ARP I (1995-1997): In this phase the foundation for collaborative research involving government-funded research agencies, industry and academia was established. From the start, participation of SMEs (Small and Medium-size Enterprises) has been encouraged. Key projects were “Megaliner” (research preparatory to the eventual A380), “Eurojet 2010” and “Regioprop 2010” (regional turbine jet and turbo prop aircraft, respectively), “Helicopter 2010” and “Engine 3E 2010” (engines with lower emissions, greater efficiency and better fuel economy). 80% of the government funding came from the Federal Ministry of Education and Research (BMBF) and 20% from the Ministry of Economics and Labor (BMWA). There was no contribution by any of the federal states to ARP I.

ARP II (1998-2002): The high cost of German re-unification, coupled with persistent low economic growth since the mid-nineties, caused the Federal Government to severely reduce its funding contribution both in absolute and in relative terms; the federal contribution was reduced to about 30% of total cost, while 20% was contributed by the states and about 51% by industry. This was the first time that the federal states were asked to contribute funding to the ARP. A more detailed discussion of funding provided by the states is provided below. All federal funding came from BMWA[37].

ARP III (2003-2007): The federal government provides funding through BMWA with funding increased by 33% over that of ARP II. The states nearly match the

[36] www.bmbf.bund.de and www.bmwa.bund.de
[37] The reduction in German government support was in part offset by a significant increase in funding allocated to Germany from the EC’s 5th FP.

federal contribution. Total government funding is €300 million over five years, or €60 million annually, on average.

Research is mainly focused on the following three areas:

- Air traffic control and environmental factors (65%);
- Aircraft safety and air cabin environment (25%);
- Economic efficiency, value creation and competitiveness (10%).

A breakdown by technical discipline gives the following funding distribution:

Aircraft structures	18%
Aircraft aerodynamics	18%
Aircraft interiors	16%
Engines	26%
Rotorcraft	8%
Avionics/flight controls	3%
Air traffic control	11%

Detailed Discussion of the Current Research Program, ARP III

As in the earlier ARPs, the federal government strongly continues to promote close collaboration between industry (including SMEs), national research centers and academia, as well as with research efforts in other European Union member nations, and the EC FPs. An extensive list of research projects is provided in Appendix 3. The list is unlikely to be complete since no database could be found that claimed to track comprehensively all German federally-funded aeronautics research projects.

Key research goals to be reached by 2020 are quantitatively expressed as follows:

- Reduction of 50%.in CO2 emissions
- Reduction of 80% in NOx emissions relative to the ICAO CAEP2 levels.
- Noise level reduction of 60-65db near airports.
- Lowering of aircraft life cycle cost by 30%.
- Reduction of 50% in development time and cost for new aircraft designs.
- Reduction of 30-40% in manufacturing and maintenance costs.
- Improvement of air transportation system efficiency by 60%.
- Reduction of in flight accident rate by 80%.

For the period 1998-2004 (ARP II and part of III), the distribution of expended funds between the various aeronautics research areas is shown in Table 5. It is interesting to note that nearly two thirds has been allocated to large aircraft coincident with the concept development and design of the A380.

Table 5. Distribution of Government and Industry Funding for Aeronautics Research in ARPs II and III for 1998-2004.

Research Area	1998-2004 Total Funding ($ millions) (government plus industry)	Percent Share
Large Aircraft	383.1	64.4%
Rotorcraft	31.9	5.4%
Engines	124.5	20.9%
Avionics	31.0	5.2%
Air Traffic Management	24.3	4.1%
Total	**594.8**	**100%**

DLR, German Research Center for Aeronautics and Astronautics

DLR provides planning and managerial support to the BMWA-funded ARPs by managing the definition of the scope of work, entire proposal process and supervising the technical work. It is performing these same functions for the aeronautics research programs of the states. Following the example set by the EC, DLR promotes cross-border collaboration with research teams from other European Union members and with the EC FPs.

DLR is funded by the German Ministry for Education and Research (BMBF) and the Ministry of Defense (BMVg). While BMBF funding is directed at the civil sector and the main emphasis of BMVg funding is on defense, the latter covers dual-use technologies in all aeronautics research areas. This is inevitable given the cost-sharing participation of industry in research activities and considering that the same companies typically address both civil and defense markets. The civil and defense markets are too small to support separate companies. The BMBF, through DLR, has contributed about €16 million annually over the last five years for contract aeronautics research. An additional combined €4 million per year is contributed by the German research foundation, DFG, the German aeronautics information service, DFS, and the German Society for Aeronautics and Astronautics, for a total of €20 million, as noted above.

In addition, the DLR receives from BMBF, on average, €49 million per year of institutional funding for in-house aeronautics research. Among the major programs at DLR are those involving research into supersonic transport aircraft, blended wing body aircraft, adaptive wing technology, and “triple-surface” aircraft.

DFG, German Research Foundation

The DFG promotes long-term research in a variety of areas. In aeronautics it supports research in materials, engines and advanced concepts. It is funded to 58.7% by the federal government and 40.8% by the states. The remaining 0.5% is provided by various foundations and private sources. It's annual budget for civil aeronautics research is a modest €12 million out of its total budget of €1.3 billion.

GERMAN STATE PROGRAMS

German aeronautics industry and supporting research facilities and universities, are concentrated in three distinct clusters; the states of Bavaria, Hamburg (city state plus surrounding area) and Berlin-Brandenburg. They are referred to as Aeronautics Regions.

Aeronautics Region Bavaria

Bavaria has the most comprehensive range of aeronautics industry and research activities. It is home to the EADS Eurofighter Typhoon program, the military helicopters from Eurocopter, a large Airbus plant, headquarters of MTU[38] aero engines supplier, and a long list of suppliers ranging from large companies to SMEs. Total aerospace employment in Bavaria is about 26,500 (37% of total German aerospace sector), spread over about 25 companies with total annual revenues in 2003 of about €6 billion[39]. It has spent more than €180 million since 1990[40] in support of industry, research facilities (mostly DLR), the Technical University of Munich and a center for satellite navigation. In addition, under its High-Tech Initiative, it established a €8 million fund (for 2000-2003 - €2 million/year average) to strengthen the competitiveness of the Bavarian aeronautics industry and promote stronger collaboration between industry and academia. Industry would cost-share at a level of 60% of the total cost for large companies and up to 50% for SMEs. Research is focused on the development of innovative composite structures and three-dimensional display technology.

Also, the University of Stuttgart, though located in a neighboring state, is tied to the Aeronautics Region Bavaria and its technical base. In addition to Bavarian research money, it is the recipient of other government funding in the following major research programs.

- *Project CLEAN[41] (Component validation for environmentally friendly aero engines) – 2000–2005:* This $65 million project is funded 50:50 by DLR and NLR (Dutch research center for aeronautics and astronautics). It works closely with DNW (German-Dutch Wind tunnel consortium). It supports the research objectives of the EC FPs and German ARPs for cleaner, quieter and more fuel-efficient engines.
- *High-altitude Platform[42] – 1999–2004:* With government funding of $975 million this large program is directed at developing very-high-altitude

[38] U.S. ownership has had no discernable impact on the level of government support to MTU.
[39] Bavarian Ministry of Economics, Infrastructure, Transport and Technology, Briefing on Aerospace and Navigation, July 15, 2004
[40] Ibid
[41] www.luftfahrtstandort-hamburg.de/relaunch2/
[42] www.isd.uni-stuttgart.de

platforms for broadband communication in lieu of satellites. Each such platform is to cover a 125 mile-radius surface area.

- *Project AIRCHAIN*[43] - Development of a system test bed ("Iron Bird") for high-altitude platforms which enables operation of all flight systems in real time while on the ground. At first, many subsystems will be simulated, however, the most important systems will be tested as hardware.

Aeronautics Region Hamburg

This region has the largest concentration of aeronautics industry (Airbus and its suppliers) in Germany. With annual revenues of €9.4 billion it employs more than 34,000 people, second only to Toulouse in Europe. Airbus plays a dominant role in the region. Consequently, aeronautics research is oriented toward supporting Airbus' needs. In fact, Airbus is the prime sponsor of research at its own research and technology development center at Hamburg-Finkenwerder and at the region's academic institutions. It has maintained a public-private joint research effort with the Technical University Hamburg-Harburg (TUHH) and its affiliated private sector organization TUHH-Technology GmbH for more than ten years as its primary channel of working with academia. TUHH-Technology is chartered to promote and facilitate technology transfer. Other academic institutions in the region which play a role in aeronautics research, albeit to a lesser degree, are the University for Applied Sciences Hamburg (HAW Hamburg), University of the Armed Forces, and the University of Hamburg.

Examples of technologies which have been developed in the Region with partial government support are laser welding of aluminum stringers to aluminum fuselage panels, the composite pressure bulkheads for the A340-500/600 and A380 and the composite wing box for the A380.

In addition to its contribution to the ARPs, the City State of Hamburg (Free and Hanseatic City of Hamburg) launched a program of research support (Aviation Technology Program) in early 2001 patterned after the federal ARPs (i.e. 50-60% industry cost-sharing participation, multi-party collaborative projects). It allocated €18.3 million over the time period 2001-2005 with a further €4 million earmarked for 2005-2006[44]. This corresponds to an average annual government funding rate of about €3.7 million. Industry cost sharing doubles those amounts. A program started in 2002 (CASIV, "Cabin System Integration and Verification") performs research into A380-specific cabin designs and performance issues; cabin air quality research and on-board systems research, in general, is funded under this program.

[43] www.isd.uni-stuttgart.de/airchain/institute/index.html
[44] www.luftfahrtstandort-hamburg.de/relaunch2/

Aeronautics Region Berlin-Brandenburg

The aeronautics industry is among the most important growth industries in the region. In 2003, industry employment was 3,500 and annual revenues were €650 million. The region has a heavy concentration of aero-engine industry and associated research with both Rolls Royce and MTU maintaining design and production facilities there. Both also cooperate with local academic institutions on research.

The regional government launched its support program in 1999 in close cooperation with the federal ARP II. The government's contribution to aeronautics research is limited to its constitutional obligation to fund its academic institutions – with emphasis on education, training and research in aero-engine technologies. The bulk of government funding for aeronautics research comes from the federal ARPs, the DLR, the EC FPs and EC subsidies for economically disadvantaged regions, a category for which this former communist region qualifies. Cost-sharing participation by local industry in such disadvantaged regions is encouraged by reducing the industry contribution to as low as 40% (from normally 60%) for large companies and 35% (from 50%) for SMEs.

One of the region's universities, Brandenburg Technical University Cottbus (BTU) was chosen by Rolls Royce as its one and only Rolls Royce University Technology Centre (UTC)[45] for aero-engine research. The centre is the recipient of generous federal and EU subsidies to economically disadvantaged regions, which help fund research of benefit to Rolls Royce at the UTC.

Brandenburg qualifies for assistance under the EU's European Regional Development Fund (EFDF)[46], which is designed to promote economic and social cohesion by correcting major regional imbalances and supporting the development and improvement of regions. For the period 2001-2005, Brandenburg received a budget of €1.5 billion (82% ERDF and 18% State of Brandenburg). This money helped Brandenburg make its contribution to ARP III. Beyond that, a further, unknown, amount was allocated to universities and industry in Brandenburg for aeronautics research.

Brandenburg is also a recipient of European Social Fund (ESF)[47] aid, which is primarily directed at improving the population's employment skills through training and education. Some of these resources have been allocated to support aeronautics research at universities.

[45] www.tu-cottbus.de/triebwerktechnik/pdf/bentzinger.pdf
[46] http://europa.eu.int/scadplus/leg/en/lvb/60015.htm
[47] http://europa.eu.int/comm/employment_social/esf2000/Index.htm

SUMMARY OF ANNUAL GOVERNMENT FUNDING LEVELS

Annual government funding in Germany of civil aeronautics research consists of the following elements (amounts marked with asterisk (*) are in addition to ARP contribution):

Research foundations, societies and centers	€20.0 million
ARP III	€64.0 million
DLR institutional funds	€49.0 million
State of Bavaria	€2.0 million*
State of Hamburg	€3.7 million*
EC regional development aid	unknown
Total	**€138.7 million***

BELGIUM

INTRODUCTION

Belgium is a small country where government has been providing only a modest amount of support for aeronautics research. Belgium has the challenge of being a country inhabited by different ethnic groups speaking different languages. This has led to the – self-inflicted - problem of fragmentation and duplication of research across the board. While Belgium was unified in the past under a monarch, over the last 50 years, as the country has become more democratic, the different ethnic and language groups have increasingly asserted their separate identities. Lack of cooperation between the groups has meant that the effectiveness of research in Belgium is even less than the modest amounts of government support might suggest.

Over the last 50 years the country has evolved into a state where increasingly the power of the central government has devolved to the federated entities: the language Communities (French, Flemish and German-speaking) and the ethnic Regions (Walloon, Brussels-Capital and Flemish regions). While the Communities are in charge of education and culture, the Regions are responsible for transportation, economic policy, energy policy (except for nuclear power, which is set at the federal level), public works and the environment. The Regions also provide general support for industrial and technological research and are the primary government funding source for civil aeronautics research.

The Federal Authority handles all overarching concerns such as foreign policy, national defense, justice, social security and research conducted in co-operation with other countries and the EC. The resulting fragmentation of authority for research and its devolution to local levels means, among other things, that there is a lack of detailed information and transparency compared to the records kept by, for example, the European Commission and the German authorities.

As for aeronautics research, the Communities fund academic research while the Regions support industrial research and innovation. The Federal Authority encourages coordination for larger programs (such as A380 development and production), provides financing for participation of Belgian organizations in international research programs and facilitates participation in the European Commission (EC) Framework Programmes (FPs). It also distributes EC subsidies to economically depressed areas, primarily Wallonia, which used to be a major coal and steel-producing region.

AERONAUTICS INDUSTRY AND RESEARCH CENTERS IN BELGIUM

The Belgian aeronautics activities are concentrated in the Walloon and Brussels-Capital regions, both of which are French-speaking and have close cultural ties to France. The Flemish region (Flanders) has become the core for Belgium's space-related activities. Total revenue in 2002 from the aeronautics industry in the Walloon region was €613 million[48] and in the Brussels-Capital region €50 million. The Flemish Region produced revenues of €502 million from aerospace in 2002, most of which was for space-related work.

The Federal government contributes a modest level of support to the Center of Excellence in Aeronautics Research (CENAERO) and other research centers.

AERONAUTICS RESEARCH PROGRAMS

Federal Programs

The Federal Government implements its responsibility for national and international research programs through its Federal Science Policy Office with the objective of harnessing all of Belgium's scientific and technological potential in the competition for such programs. These programs, typically multi-year, are called Federal Research Actions (FEDRAs).

The Federal Science Policy does not explicitly identify an aeronautics research program, but it does fund individual projects in advanced materials, manufacturing processes for such materials, coatings, computational fluid dynamics, etc. Judging from the project descriptions, they should be considered as aeronautics research. In 2003, the total annual budget (for support to academia, research laboratories and industry) for such aeronautics research-related projects was in the range of €20 million to €30 million.

With this budget, the Federal Government provides incentives for collaboration between universities and research organizations in its various language Communities and ethnic Regions through two so-called "Attraction Poles" programs, the Interuniversity Attraction Pole (IAP) and Technology Attraction Pole (TAP) programs.

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[48] Funding figures in € because the €/$ exchange rate has been variable, ranging from €1=$0.82 in 2001to €1=$1.36 in early 2005. The dollar has strengthened somewhat since May, 2005, but the future outlook is uncertain.

The above-cited budget figure excludes Belgium's contribution to the development of the Airbus A380. The Federal Government separately coordinated and managed the country's contribution to the development of the A380 as part of a risk-sharing arrangement with Airbus. In this collaborative agreement, the total amount was €120 million, all contributed by the Regions (Wallonia 58%, Brussels-Capital 21 % and Flanders 21%). In return, Belgian industry is guaranteed a certain level of supplier contracts as well as sharing in future A380 profits as they may materialize. In general, federal support to industry ranges from 100% of project cost for pre-competitive research to 50% to product-related research

IAP (Interuniversity Attraction Pole)Programs: These five-year programs promote collaboration between university research teams from all Communities by financially supporting the formation of multi-university "teams of excellence" in basic research. They run concurrently with the EC's FPs. The total budget for the current phase (2002-2006) is €111.6 million. Of this, the budget for aeronautics research in the current program (2002-2006) is estimated at approximately €7.5-10 million, or €1.5-2 million annually, on average.

TAP (Technology Attraction Pole) Programs: This four-year program (2002-2005) encourages collaboration between university research teams, research laboratories and industry from throughout the country with the objectives of making research relevant and of promoting innovation and technology transfer to industry. Its budget for aeronautics research is estimated at €2-2.5 million for the four-year period, corresponding to an annual average of €500,000 to 630,000. TAP's total budget for 2002-2005 is €8.9 million.

Regional Programs

Walloon Region

This region used to be the country's industrial heartland with its coal mining, steel-making and metal-working industries. It has become Belgium's key region for its aeronautics industry, home to its six largest aeronautics companies, as noted above. Regional government support for aeronautics research is primarily channeled through the programs CENAERO, RESEAUX 1 and FIRST.

Center of Excellence in Aeronautics Research (CENAERO): CENAERO is a non-profit applied research center with a focus on the development of multidisciplinary simulation technologies for aeronautics. It also provides technical consulting support to industry. Founded in 2002, its staff of 26 highly-skilled staff members is specialized in computational fluid dynamics (CFD) , acoustics, structural mechanics, virtual manufacturing, numerical methods, physics and applied mathematics. CENAERO is primarily funded by the Walloon Region and EC structural funds in support of regional development. The central government makes a small contribution, the exact amount of which could not be determined.

CENAERO has strong ties to industry and academia in the Walloon Region. It is partnered with all of Belgium's six major aerospace companies (all located in the Walloon Region) Sonaca, Sabca, Alcatel-Etca, Techspace Aero, Samtech and Free Field Technologies (FFT), as well as with three universities in the Region and the Von Karman Institute for Fluid Dynamics. It focuses on the following five major research areas:

- CFD multi-physics
- Multi-scale materials
- Numerical methods and optimization
- Thermal analysis
- Virtual manufacturing

RESAUX 1: As the name implies (it means transportation networks) it is concerned with networks; in this case Networks of Excellence for research in the EC's Sixth Framework Programme. Specifically, it is designed to assist Walloon universities and industry to compete successfully for participation in the EC program. In 2003 it provided a total of €5.1 million to universities for two multi-year (of unknown duration) aeronautics projects. There was no industry contribution. The projects are:

- LASEF – LIDAR based on fiber optics. €2.47 million.
- CORONET – micro- and nano-structured surfaces with auto-wetting characteristics for anti-corrosion. €2.65 million.

FIRST: This program, the acronym of which stands for "development and promotion of scientific and technological research", is designed to promote cross-fertilization between researchers in academia and industry through funded projects and the exchange of scientists. In 2003 it funded a single project: the modeling of shock impact on structures (e.g. bird ingestion by turbine engines) with €59,500 from government and an equal amount from industry.

Flemish Region

Aerospace in the Flemish Region is primarily oriented toward defense and space applications. Regional government research support is provided through the Institute for the Advancement of Innovation in Science and Technology in Flanders (IWT). Its budget in 2002 was €190 million for all research. An unknown fraction was devoted to aerospace research, mostly in defense and space.

Brussels Capital Region

Research in this region is oriented toward information technology, electro-mechanical engineering, biotechnology and life sciences, environmental technology and the medical field. Aeronautics research plays a relatively minor role.

Funding by the European Investment Bank

The company SABCA S.A. recently obtained European Investment Bank (EIB) funds of $56 million under the EIB's i2i program to stimulate innovation in industry for the development of advanced metallurgical and metal-forming processes for the A380 program. The company is contributing an equal amount.

INDUSTRY COST SHARING

It is standard practice in all government-supported research programs with industry participation which are product-related, that industry normally bears half the total cost. Exceptions are made for SMEs (Small and Medium-size Enterprises), which only have to contribute 40% of total cost. As an incentive for industry to engage in research in aeronautics and astronautics, government can increase its share of funding by 10% if certain criteria are met. For pre-competitive research programs, government may pay up to 100% of total cost.

NETHERLANDS

INTRODUCTION

Total annual revenues for the aeronautics industry in the Netherlands in aircraft production, MRO and research is €2.4 billion, about three times that of Belgium despite the similar size of the two countries. The Dutch aeronautics industry has made an international name for itself in the past through the aircraft manufacturer Fokker. While Fokker is no longer a manufacturer of aircraft, its successor company, Stork, has established itself as a supplier of advanced structural materials for airframes (e.g. GLARE for fuselage panels and thermoplastics for wing leading edges). The government-supported national research capability which under-girded Fokker's success has been continued. The Netherlands, which is governed by a central government, has a long tradition of supporting aeronautics research and innovation through its Central Planning Agency not only because of the direct benefits flowing to its indigenous aeronautics industry, but also because it is convinced that other industries as well as society as a whole benefit from the aeronautics-related "knowledge infrastructure."

With the demise of Fokker, the Dutch civil aircraft manufacturing industry has become focused on Airbus for civil aircraft, i.e. on the A380 since 2000, for all practical purposes. For military aircraft the focus is on the F-35 (formerly JSF). In order to enable its industry to compete for participation on these and future international aircraft programs, the government has targeted four priority areas for research support:

- Advanced materials along with advanced manufacturing technology.
- Integration of design, production and automated assembly of structural and subsystem parts.
- Integration of engine components into modular subsystems.

- New concepts and technology in the areas of maintenance, repair and overhaul (MRO) services.

These priorities areas mesh well with the top-level goals of the European Research Area of lowering design and manufacturing costs, reducing energy consumption and CO2 emissions through lower aircraft weight and strengthening the competitiveness of the European aeronautics industry.

Government Support for Aeronautics Research

The primary government-funding source for civil aerospace research, except in the areas of airspace and airport capacity, is the Ministry of Economic Affairs. Airspace and airport capacity-related research is funded by the Ministry of Transportation. The Ministry of Economic Affairs manages its research support program through the Dutch Agency for Aerospace Programs (NIVR). The agency is responsible for executing government aeronautics policy, including acting as project manager, policy consultant to government and intermediary between government on one side and the recipients of funds, i.e. research institutions and industry, on the other. NIVR also receives some minor funding from the Ministry of Education, Culture and Science and the Ministry of Transportation.

As an aside, NIVR also supervises the Dutch participation in the F-35/JSF System Design and Development program as a risk-sharing partner.

Government support, managed by NIVR, is provided through two channels: the Basic Research Program (BRP) and the Civil Aircraft Development (CVO) arrangement. Government support is available in the form of grants and repayable loans.

Basic Research Program

Availability of Basic Research Program (BRP) funds is limited to research institutions, including universities, for civil programs. In practice this means that they flow to the Netherlands' Aerospace Laboratory (NLR), Netherlands' Organization for Applied Science (TNO) and the Technical University Delft (TU Delft). BRP covers 100% of costs. They are focused on promoting innovation in the Dutch aeronautics community. Two research areas are addressed: (1) Fiber metal laminates (BRP-VML) such as GLARE and (2) everything else. In the 2000-2003 period, a total of €12.3 million was allocated to development of GLARE alone.

BRP projects are to lead to deployment of new technology in the mid-term. Research results are shared with the entire Dutch aerospace sector. A breakdown of BRP budgets by major research area for the period 1998-2003 is shown in Table 6[49]. All funding figures are presented in €x1000.

[49] Ministry of Economic Affairs: Evaluation of the Aviation Cluster Final Report, September, 2004, www.minez.nl

Civil Aircraft Development Arrangement

Civil Aircraft Development (CVO) projects are intended to help Dutch industry, research institutions and universities contribute to the development and production of subassemblies and components of civil aircraft. CVO grants pay for 50% of the total cost of research and technology development ("from the laboratory to the factory") for aircraft and 75% for avionics and engine components. For industrial product development they come in the form of loans at the level of 40% of total cost for aircraft systems and engines.

Since 2000 CVO efforts have been entirely focused on the development of the A380. The government set aside €145 million in 1997 for participation in the A380 program as a 2.5% risk-sharing partner. When Dutch industry was unable to deliver value corresponding to 2.5%, the A380-related subsidy was reduced to €100 million. The unapplied €45 million were diverted to the F-35/JSF program.

Table 6. BRP Budgets for Period 1998-2003

Research Area	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Total**
Structural A/C components	170	340	450	450	380	0	1,790
Materials	70	45	70	70	70	315	640
Mechanical systems	135	45	90	70	90	0	430
Avionics	280	270	270	160	315	335	1,630
Engines (subsystems, comp)	340	340	410	330	635	0	2,055
Software	0	0	0	0	0	200	200
Training & Simulations	0	0	0	105	70	160	335
Design & Dev. Techniques	340	320	320	240	500	180	1,900
Production technologies	230	470	290	395	670	435	2,490
Total BRP	*1,560*	*1,830*	*1,900*	*1,820*	*2,730*	*1,625*	*11,470*
Total BRP-VML (GLARE)	*0*	*0*	*3,990*	*4,530*	*1,870*	*1,900*	*12,290*
Total (€x1000)	**1,565**	**1,830**	**5,890**	**6,350**	**4,600**	**3,525**	**23,760**

The actual and planned annual government budgets for CVO and other civil aeronautics research, apart from basic research, for the period 2002-2007 are shown in Table 7[50]. NLR receives additional funds, at an annual level of €465,000, from the Ministry of Defense for basic research.

[50] Ministry of Economic Affairs: Survey on innovation-related funding (Extract). www.minez.nl

Table 7. Actual and Planned Budgets for Aeronautics Research (€x1000), excluding BRP

Ministry	Goal	Instruments	2002	2003	2004	2005	2006	2007
Ministry of Economic Affairs	Stimulation of knowledge in strategic areas	Civil Aircraft Development (CVO)	4,266	19,924	21,496	15,494	3,629	7,328
		Aerospace institutes NIVR, NLR	4,942	5,838	5,794	6,443	6,393	6,393
Ministry of Transport	Airspace/ Airport capacity	Research NLR	14,000	14,000	14,000	14,000	14,000	14,000
		Investments NLR	5,400	5,400	5,400	5,400	5,400	5,400

Netherlands' Organization for Applied Science

In addition to the above-noted CVO budgets for civil aeronautics research and innovation, Netherlands' Organization for Applied Science (TNO) obtains funding from the Ministry of Economic Affairs, Ministry of Transportation and Ministry of Education at levels shown in Table 8. TNO's focus is on technology validation and deployment.

Table 8. Actual and Planned Funding for TNO for Period 2003-2009 (€ million)

Year	Budget (€ millions)
2003	31.1
2004	29.5
2005	28.5
2006	28.2
2007	28.2
2008	28.2
2009	28.2

TNO is a non-profit organization which supports the technology needs of industry and government. It offers support in the form of contract research and consultancy services. It performs product testing and certification services and issues independent quality evaluation assessments. TNO also assists start-up companies market their innovations.

At TNO, aeronautics-related activities fall within its Science and Technology Division, which is one of five divisions. The Division targets the national and international manufacturing and process industries as well as supporting research organizations.

Regarding aeronautics, TNO concentrates on equipment for ultra-precise manufacturing and measurement, smart manufacturing, innovative materials and optimizing the performance of the process industries. In addition, it is engaged in the following efforts:

- Advanced aircraft control and automated flight control
- Components for low-emission engines with low fuel consumption
- New processes for producing "intelligent" materials
- Computer analysis and testing methods for flutter control
- Nozzle molding of polymer micro components
- Micro-laser production

Innovation Clusters

The NIVR has stimulated the establishment of "Innovation Clusters" to encourage cooperation between the key players in the research community and between it and industry. Four such clusters have been defined:

- The Fiber Metal Laminate Centre of Excellence (FMLC)
- The Dutch Aero Engine Cluster (DAEC)
- The Aerospace Software and Technologies Institute (ASTI)
- The Netherlands Foundation for Industrial Scientific Cooperation on Simulation (SimNed).

A brief description of each follows.

FMLC – was founded in 2001. It builds upon 25 years of research into fiber metal laminates (FMLs). Its mission is to develop FMLs for a wide range of applications, promote new applications of FMLs, support customers worldwide in engineering and manufacturing of FMLs and to act as the central repository of knowledge on design, manufacturing and application.

DAEC – since its founding in 2001 it has focused on becoming a supplier of components for the A380 engines, the Trent 900 by Rolls Royce and the GP 7000 by the GE/P&W Engine Alliance. It is a risk-sharing partner in the latter. DAEChas received CVO funding since 2003.

ASTI – was founded at TU Delft in 2003 with TNO, NLR, University of Twente and several industrial organizations as partners. Its work is directed at applications of software in an aerospace context. Like Dutch organizations in general, it has an international outlook; for example, it has developed software tools for the U.S. Eclipse 500 micro-jet. ASTI is focused on five strategic areas of research:

- Model synthesis and identification,
- Vision-based autonomous flight controls
- Worst-case analysis and envelope clearance,
- Graphic and human factors man-machine interface,
- Smart integrated sensor systems.

SimNed – Founded in 1995, is dedicated to enhancing the competitive strength of the Netherlands worldwide in the field of simulation.

ITALY

INTRODUCTION

Italy's aerospace industry is the fourth largest in Europe, after the U.K., France and Germany. It generated €6.3 billion[51] in revenues for 2002, 50% of which were for export. Most of the revenue comes from aeronautics. For its contribution to Italy's GDP and for its role in stimulating innovation and technological development, it is considered a key national industry. Italy has a history of supporting the industry through an extensive program of public-private research and industrial ventures.

Italy is governed by a central government which sets policy for the whole country. Its regional governments have an administrative function. Similar to the situation found in France, there is a lower level of transparency of government funding programs than was found at the EC, in Germany, the Netherlands, Austria and Sweden.

THE ITALIAN NATIONAL RESEARCH PROGRAM

The Italian aeronautics research program is part of the National Research Program (PNR), which covers all areas of research and is aligned with national industrial policy and coordinated with the European Commission's Framework Programmes. The PNR contains ten Strategic Programs[52], three of which are relevant to aeronautics. They are:

- "Shipyards, Aeronautics, Helicopters with their potential to penetrate foreign markets" (Program no. 6).
- "Advanced Manufacturing Systems" (Program no. 4).
- "Advanced Materials" (Program no. 7).

In order to utilize the country's resources better and stimulate economic development throughout the nation, the NPR for 2005-2007 assigns strategic technology focal points to different political or geographic regions. The regions of interest for aeronautics are:

- Region Lazio for aerospace and defense.
- Region Campagnia for composites and polymers
- Region Lombardia for advanced materials
- Region Venetto for nanotechnology

[51] ILA 2004: The Italian Aerospace Industry. www.ditt.de/katalog_ILA1.pdf
[52] PNR 2005-2007 Executive Summary. www.miur.it/userfiles/2001.pdf

The central government, through the PNR, funds research in general through the following funding channels:

- Universities (FFO)
- Academic research (CFIN)
- Public research institutions (FOE)
- Basic research investments (FIRB) to public institutions
- Research grants to industry to:
  - Strengthen competitiveness through closer cooperation between public and private sector research institutions.
  - Promote industrial spin offs of innovation and assist start-up companies.
  - Promote research at SMEs (Small and Medium-size Enterprises).

The total PNR budget for all research (of which aeronautics is only a part) was €14.6 billion in 2002, with the following breakdown:

Universities	€4.80 billion
Major public research institutions	2.10 billion
"Other public institutions"	0.45 billion
Private non-profit institutions	0.19 billion
Industry	7.06 billion
Total	**€14.60 billion**

In the Italian system the National Research Council (CNR) is assigned the responsibility for implementing the PNR. It does so through coordination with and delegation of responsibility to other research organization as well as through direct control of certain research programs. CNR's legal definition as a public organization is "A national research organization with general scientific competence and with scientific research institutes distributed throughout Italy, whose primary function is the promotion of science and progress of the Country." It typically works through three-year plans.

Direct CNR programs

CNR has direct control over the aeronautics-related research programs[53] shown in Table 9.

Table 9. National Institute for Aerospace Technology

Enabling Technology	2003 (€ millions)	2004 (€ millions)	2005 (€ millions)
Materials technology: Structures and Functions	48.8	51.2	51.8
Fluid dynamics and combustion technology	33.1	34.7	35.1
Aeronautics and space in EC priority areas	45.2	47.4	48.0
Total	**127.1**	**133.3**	**134.9**

[53] Extract CNR P T 2003-2005

National Institute for Aerospace Technology (CIRA) was established in 1984 to define and implement a national aerospace program. It is the key agency through which CNR implements those aeronautics research programs in the PNR which it does not directly control. One of CIRA's main responsibilities is promoting innovation, developing know-how and transferring technology to industry with the objective of enhancing the competitiveness of the Italian aerospace industry. It promotes cooperation among the various national research centers and with international programs, particularly the European Commission's Framework Programmes. CIRA is a joint-stock consortium. Majority owners are the Italian Space Agency (ASI) and CNR. Regional governments and the major Italian aeronautics companies are minor shareholders

CIRA covers the following research areas:

Fluid Dynamics

- Aircraft aerodynamics
- Aerodynamics and aero-acoustics of rotorcraft
- Experimental aerodynamics methodologies
- Instrumentation and data acquisition
- Ice accretion prediction
- Aerodynamics of space vehicles
- Computational aerodynamics
- Experimental aerodynamics

Air Vehicle Structures

- Vibration and acoustic noise
- Environmental acoustics
- Computational mechanics
- Smart structures
- High-energy impact, crashworthiness
- Mechanical testing

Flight Systems

- Flight systems
- Aerospace vehicle dynamics
- Flight automation and control
- Hardware-in-the-loop simulation
- On-board system management

Computer Science

- Information technologies
- Virtual reality
- Parallel computing

National Aerospace Research Program (PRORA)

CIRA is also tasked with defining and implementing the National Aerospace Research Program (PRORA), which is part of the PNR as well. PRORA is funded by the Ministry of Education, Universities and Research (MIUR). Total annual PRORA funding for 2003 and 2004 was €247.6 million and €282.9 million, respectively..

The following are examples of research activities under CIRA/PRORA

Support to Boeing's B787 Program

Alenia is receiving €68 million in 2005 from the government for support of its role as a risk-sharing partner in Boeing's 787 program. Alenia, in an alliance with the U.S. company Vought, has been selected by Boeing as a supplier of composite fuselage sections. The government research support to the program, through CIRA, is intended to help Alenia develop advanced manufacturing and assembly capabilities.

The information source used for this study indicates that, in addition to the €68 million to Alenia, the Estel Group is receiving €33 million and that the total amount of government support to Alenia and Estel, combined, may end up being as high as €200 million over two years. It could not be determined if the companies contribute private funds to the project on a cost-sharing basis and, if so, how much.

Advanced Materials

Since 1987, CIRA has supported research into advanced materials in partnership with industry. Emphasis has been placed on advanced polymers, including some incorporating nanotechnology. Funding for the period 2003-2005 is estimated at €450,400 from the Italian government, €64,000 from the 6th EC Framework Programme and €1 million from Italian industry.

During the same period, a program investigating nanotechnology applications to metal coatings has received €275,000 from the Italian government and €448,000 from industry. A further €325,000 has been contributed by the EC. The program addresses applications of nanotechnology to all metal-using industrial sectors, including aeronautics.

One of the currently-active programs in advanced materials research, called MBDyn, began in 1991. MBDyn is a MultiBody Dynamics analysis code, which was jointly developed by NASA Langley, Agusta and the Milano Polytech Institute.

UAVTEC

Since 2002, CIRA has supported, as a top priority for aeronautics research, a program for the development of an unmanned aerial vehicle (UAV) as an innovation platform. The program is called UAVTEC. Under a related, but separate, program, an unmanned space vehicle (USV) will be developed as a platform for space research.

UAVTEC is expected to be extended to 2010. A UAV platform under this program will serve as a test bed for defense technologies needed for reconnaissance, surveillance and combat applications. In addition, the program addresses innovative dual-use technologies such as electric propulsion, heavy-fuel propulsion and pneumatic systems. Among the research projects with civil applications started in 2002 are:

- Active wing flow control
- Filament-wound composite fuselage sections
- Shape memory alloys
- Fully autonomous and automated take off and landing operations.

The annual government funding level of UAVTEC has been held roughly constant in inflation-adjusted terms. It was €3.8 million for a twelve-month period in 2002-2003 and is expected to continue at this level. No industry contribution is recorded.

General Aviation

CIRA is supporting the development and testing of a single-engine turbo-prop aircraft together with Vulcanair S.p.A. The aircraft has short take off and landing capability and can carry up to eleven passengers. No financial data could be obtained on this research program.

Rotorcraft

In the past, government support played a significant role in the development of the Agusta Westland triple-engine EH-101 helicopter. (This aircraft was chosen earlier this year by the U.S. Navy as the next presidential helicopter, designated US-101). CIRA is building a new wind tunnel for testing rotorcraft, called SAWT.

CIRA continues to support rotorcraft research under the ARCO (Advanced Rotorcraft Concepts) in cooperation with Agusta.

Engines

Avio is CIRA's key industrial partner for turbine engine-related research. To support the research, CIRA is financing the construction of a new engine test facility called COLDFLOW with funds from MIUR.

Avionics and Air Traffic Management

Italy's avionics industry is oriented toward military systems and thus gets research support from the Ministry of Defense which does not divulge any information about its programs. As is common in each European country with an Air Force, the results of military-sponsored research tend to flow into civil products, for two reasons. First, in each country, the same companies (often only a single company) supply both markets because the civil and defense segments are too small to support completely separate approaches. Second, European contract regulations do not have the same strict barriers between defense and civil research and production as does the U.S. In the U.S., government contract regulations require that funding of both research and production for defense and civil programs be kept separate. Such a strict separation does not exist in Europe. Moreover, this applies to all aeronautics research, not only to avionics.

Additional government research funding for air traffic management and related avionics is assigned to the Eurocontrol research program, which is discussed in a separate section of this chapter.

Regional Programs

As noted above, Italy has designated certain regions as focal points for specific research subjects. The objective of this approach is to promote industry innovation and foster industry competitiveness by forming clusters consisting of non-profit research institutions, universities and industrial partners in designated regions. Providing financial support to SMEs in the region is a top priority. The Lazio and Campania Regions are the key regions for aeronautics research.

Funding is provided by the Ministry of Education, Universities and Research (MIUR) and the Ministry of the Economy and Finance (MEF). The regional financial development and investment agency, FILAS, provides administrative and additional funding support. Each region has is own department of economic planning to coordinate the cluster formation.

Lazio Region: Aerospace

This is the heartland of Italy's aerospace industry, with about €5 billion of annual industrial revenues. A public investment of €60 million for the period 2004-2008 (€12 million annual average) is expected to generate a €72 million contribution from industry, for a total of €132 million over five years.

In addition, the region is receiving €200 million from the European Investment Bank (EIB) for multi-year support for development of its composite industry. A total of €1.1 billion from industry and government augment the EIB funding.

Campania Region: Polymers and Composites

In January, 2004 the Campania Technology District for Polymers and Composite Materials, Engineering and Structures, IMAST Scarl, was formed as a consortium between industry, academia and government research institutions. It is headquartered in Naples.

Veneto Region: Nanotechnology

This region is included because of the future contribution nanotechnology is expected to make to aeronautics. Founded in 2003, it is funded with €26 million from MIUR and €15.9 million from the Veneto Region

SPAIN

INTRODUCTION

Spain's aerospace industry, which is 91% aeronautics and 9% space-oriented, represents a very important part of the country's industrial base. 70% of its revenues are attributable to export. Because of its role as a driver of innovation and advanced technologies, many of which are transferred over time into other industrial sectors, the full importance and value of the contribution of aeronautics to Spain's economy is considerably greater than it would appear if judged solely on the basis of its annual revenues of €3.2 billion (in 2003). The aerospace industry's annual investment in R&D in 2003 was 13.9% of revenue, or €444 million, all in aeronautics. Of this, aircraft-related research was €298 million (67%), engines €106 million (24%) and equipment/systems €40 million (9%). (While industry invests its own capital in aeronautics research, space research is fully funded by the government.)

Government has, for many years, been contributing to aeronautics research with amounts significantly exceeding the industry's annual R&D investment. Spain has a centrally-managed national research plan; some of its regional governments also contribute resources to aeronautics research.

CENTRAL GOVERNMENT SUPPORTED RESEARCH

National Plan for Science, Research and Technological Innovation

The central government manages aerospace research through its National Plan for Science, Research and Technological Innovation (PNIDI), of which it is but one element. The plan is structured to be consistent with the European Commission's (EC) Framework Programmes (FP), starting with the 5th FP, and the European Commission's program of regional structural development support.

The Ministry of Science and Technology (MCYT) has overall responsibility for PNIDI. It draws on the *Center for Industrial Technological Research (CDTI)* for evaluation and funding of research involving industry. It offers zero-interest loans to industry for up to 60% of the total research project cost, provided a business analysis indicates that the end-product is technically and economically viable. In case the end-product turns out to be a failure in the market, the loans do not have to be repaid.

Scientific and technical support is provided by the *National Institute for Aerospace Technology (INTA[54])*, a public research organization which is primarily funded by the Ministry of Defense. It is involved in both defense and civil research.

Aeronautics research is part of PNIDI. An overview of all aeronautics research budgets, identified as such, for 2002 is shown in Table 10[55].

Table 10. Aeronautics R&D in 2002, Number of Projects and Budgets.

Organizational Category	**No. of Beneficiaries**	**Grants (€ millions)**	**Loans[56] (€ millions)**
Large Companies	16	218.0	2,217.6
SMEs	8	60.0	2,060.0
Universities and other non-profit Research Organizations	4	384.0	0
Non-gvt. Institutions	1	90.0	0
Total	**29**	**752.0**	**4,277.6**

Aeronautics is also benefiting to a further, if unknown, extent from two other research areas in PNIDI; the National Plan for Design and Industrial Production and the National Plan for Materials.

The civil aeronautics research program under PNIDI covers the following subject areas:

- New aircraft concepts
- Aerodynamics, fluid dynamics and aeroacoustics
- Structures, materials and processes
- Engines and power systems
- Avionics and equipment
- Advanced methods and procedures for engineering, production and maintenance
- ATM, ground operations and ground support systems

[54] http://www.inta.es
[55] Extract. Memoria de Actividades de I+D+I2002; www.madrimasd.org/informacionIDI/indicadores/documumentos/doc/Memoria_I+D+I2002.pdf
[56] The zero-interest loans are guaranteed by the government, which assumes ultimate liability for re-payment.

The PNIDI for 2004-2007 contains the research category of "Qualified Industrial Projects", which covers R&D specific to various aircraft projects (e.g. A380, A400M, helicopters), as well as the maintenance-related category referred to as New Detection Systems, which is related to health monitoring.

Aeronautics research in PNIDI is made up of several major programs which fund aeronautics research, as follows:

Plan for Aeronautical Technology II

Contained in the aeronautics research plan is the Plan for Aeronautical Technology II (PTA II), which, during the period 1999-2003, had €240.4 million of funding (about €48 million per year on average). The funding was allocated to different aeronautics research areas as follows:

Aerodynamics:	27%
Propulsion Systems:	25%
Materials & Structures:	23%
Equipment & Systems:	13.8%
Air Traffic Management:	4%
Automated Maintenance:	3%
Simulation Tools:	3%
Testing & Inspection:	1%

PTA II research is focused on the following major areas:

Advanced Structures

- Composite fuselage structures and turbine engine blades
- Manufacturing of large metallic structures
- Intelligent structures
- Aircraft interiors
- Non-destructive inspection
- Failure prediction methods
- Development of specialized machine tools

Advanced Aeronautics Systems

- Feasibility studies of UAVs
- Feasibility studies of advanced avionics and systems
- Studies of more-electric-aircraft technology
- Simulation capability
- Data management.

Air Traffic and Airport Management

- Research into means to increase air space capacity and air traffic management efficiency
- Development of advanced CNS/ATM concepts
- Development of advanced simulators

Aerodynamics and Propulsion

- Improved aerodynamic lift designs
- Research into low pressure turbines and compressors based on improvements in aerodynamic design
- Lowering of production and maintenance costs of turbine engines
- Reduction of CO_2 and NO_x emissions.

Program to Foster Technical Research

Program to Foster Technical Research (PROFIT) is another program under PNIDI. Directly controlled by the Ministry of Science and Technology, it provides public funding to stimulate industrial innovation through research. It distributes most of its support through zero-interest loans.

Center for Industrial Technological Research (CDTI) and National Institute for Aerospace Technology (INTA)

Also under PNIDI, CDTI supports research through zero-interest loans only., while INTA uses both grants and loans. INTA's priorities are set by the Ministry of Defense. However, it is actively involved in both civil and defense sector processes related to aircraft certification.

REGIONAL AERONAUTICS RESEARCH PROGRAMS

Table 10 above showed the total government support to aeronautics research broken down by recipient category. Table 11 shows how these funds are distributed over the various regions of Spain.

Table 11. Government Aeronautics R&D Budgets in 2002, Distribution by Region.

Region	No. of Projects	Grants (€ millions)	Loans (€ millions)
Baleares	0	0	0
Castilla-La Mancha	1	0	212.0
Cataluna	1	30.0	0
Galicia	1	0	193.9
Madrid	25	636.0	3,871.7
Basque	1	86.0	0
Total	**29**	**752.0**	**4,277.6**

The key regions for research are:

Basque Region

25% of Spain's total revenues from the aeronautics sector come from this region. The Basque regional government supports the sector's competitiveness through a variety of program, the most important among which are the following:

- SPRI – Society for the Promotion and Re-invigoration of Industry.
- HEGAN – Aeronautics and Space Cluster.
- CTA – Center for Aeronautics Technology. It specializes in testing and certification of aeronautics products.
- INTEK – Supports advanced research, development and innovation
- PROINTER 2005 – Promotes international co-operative research

Region Castilla – La Mancha

As shown in Table 2, this region received €212 million in loans in 2002 from the central government. The regional government distributed these research funds through its Economic Development Agency.

Region Madrid

The University of Madrid (UPM) represents the focal point of basic academic research in aeronautics in Spain. In addition, with its Polytechnic University and broad industrial base, it is by far the largest recipient of government support for aeronautics research, as indicated in Table 11.

AUSTRIA

INTRODUCTION

Austria's government support to aeronautics research is primarily directed at enhancing the international competitiveness of its aeronautics industry, which is playing a considerably stronger role in international civil aeronautics programs than its modest size, and the relatively small size of Austria, would lead one to expect. Austria's aeronautics industry has been on a strong growth trajectory, with annual revenues growing from €30 million in 1988 to €380 million in 2002. Given its small domestic market, Austria's aeronautics industry is heavily dependent on exports. Austrian companies are suppliers to the world's top civil aeronautics industrial programs, including Airbus' A380 as well as Boeing's B-787. Specialization is found in the following:

- Metal and composite parts for large aircraft, business jets and general aviation aircraft.
- Development of general aviation aircraft.
- Engines for general aviation aircraft.
- Large aircraft engine components and subsystems.
- On-board communications and flight management systems.

- Flight simulators and software for flight training and planning.

The competitiveness of Austria's aeronautics industry is strongly dependent on research support provided by the Federal Government, as well as on industry's internal investment in R&D of approximately 12% of revenues, corresponding to €46 million in 2002[57]. Since the publication of "Vision 2020" in 2001, Austria's government-supported research programs in aeronautics have been more closely coordinated with EC Framework Programmes and those of other EU nations.

RESEARCH SUPPORT BY THE AUSTRIAN GOVERNMENT

Austrian Space Agency

In 1972, the Austrian Federal Government founded the Austrian Space Agency[58] (ASA) as the focal point for national and international coordination of aeronautics and space-related research (mostly aeronautics research). In addition to its coordinating role, ASA is chartered to promote and support Austrian science and technology as well its aeronautics industry.

In response to "Vision 2020", the Federal Government started a new program in 2002, called TAKE OFF, which supports aeronautics research with the objective of strengthening the competitiveness of the country's industry. ASA was initially tasked with managing TAKE OFF.

TAKE OFF was initiated in 2002 by the Federal Ministry of Transport, Innovation and Technology (BMVIT). As noted, the goal is to strengthen the international competitiveness of Austria's aeronautics industry. TAKE OFF supports research spanning a broad range from applied research to prototype development; it emphasizes long-term research strategy and promotes strategic partnerships to secure better access to international markets. TAKE OFF was managed by ASA until late 2004. It has since been managed by the Agency for the Advancement of Research (FFG).

TAKE OFF is currently in its second phase (Phase 2). Phase 1, the two-year start-up phase in 2002-2003, was funded with €10.1 million, of which €1.4 million was re-allocated from a pre-existing Innovation & Technology Fund. In 2004, TAKE OFF received €3.6 million for the first year of the three-year Phase 2 (2004-2006). An additional €6.3 million has been allocated to the program for the two-year period 2005-2006, resulting in total funding of €20 million for the five-year period 2002-2006. TAKE OFF support has been a key factor in the recent growth of Austria's aeronautics industry and in its successful quest for supply contracts from the A380 program.

[57] Aeronautics Research in Austria: www.mariazell.at/gespraeche/technologie/geissler.pdf
[58] www.asaspace.at

Phase 1 (2002-2003). The start-up phase established longer-term programs with the overall objective of doubling the annual revenues of Austria's aeronautics industry by 2010. It defined six major activity areas:

- Foster strategically important research programs by providing slightly more than 50% government contribution to total research cost.
- Develop advanced Computer-Based Training (CBT) tools and promote technology transfer, training and advanced education.
- Develop a framework for efficient certification of aviation products, compatible with the regulations of EASA (European Aviation Safety Agency – the new European Union equivalent of the FAA).
- Develop a long-term financing model for risk-sharing technology development projects and arrange for guaranteed loans to such projects.
- Manage offset programs[59] through coordinating research to benefit long-term industrial goals.
- Facilitate access by Austrian industry to international research networks.

Phase 2. The following major thrust areas have been defined for long-term research:

- Aero engines: materials, components, systems.
- Aircraft structures and interiors: materials, components, systems.
- Computer-based modeling solutions for aeronautics.
- Innovative systems and processes for General Aviation, MRO, ground facilities and test facilities.

Agency for the Advancement of Research

Agency for the Advancement of Research (FFG) was established in September, 2004 to better coordinate Austrian research programs in support of industry across a broad range of technical disciplines and industry sectors and to better coordinate its research with that of the EC and other European nations.

One of its four divisions, Division 3, Aeronautics and Space, covers aeronautics research, with a budget of €10.2 million for 2004, out of a total budget for all research activities of €325.6 million and €352 million for 2004 and 2005, respectively[60]. FFG is funded in equal shares by the BMVIT and the Ministry of Commerce and Labor (BMWA). Its functions include providing guidance on the selection of research programs to be funded, supporting such programs and representing Austria on international committees and working groups. It has also assumed management responsibility for TAKE OFF from ASA.

[59] As a buyer of Eurofighter Typhoon fighter aircraft, Austria negotiated a €400 million offset arrangement with plane maker EADS on the A380 program. I.e. Austria's industry gets €400 million worth of supply contracts from the A380 program as an offset to Austria's purchase of Eurofighter aircraft.

[60] www.ffg.at/doc/location_austria_en.pdf

FFG Research Funding Policy. FFG defines funding policy for research support by the Austrian Government. It continues the long-established policy of funding approximately half of total research costs – the other half being borne by industry – with a few refinements, as follows[61]:

During the earlier stage of applied research (i.e. closer to basic research), government covers at least 50% of total cost. Government's share can grow to a maximum of 75% if certain conditions are fulfilled -- such as if the industry partner is an SME (+10%), the project is in compliance with EC Framework research goals (+15%), it is a co-operative project involving several partners (+10%), and if the project is performed in a region qualifying for EC Regional Aid (+5 to 10%).

During development at the later stages, including prototype development, government covers at least 25% of total cost. An increase to a maximum of 50% is possible, based on the same factors as those above.

Government support is provided as grants, zero or very low interest loans or a combination of the two.

MAJOR RESEARCH PROJECTS

The following is a summary of current major research projects:

Aircraft Structures

- A380 structural components (composites and ultra light-weight Al alloys). Key industrial partner is Fischer Advanced Composites Components AG (FACC), a supplier to both the A380 and B787 programs.
- Development of aerodynamically sensitive composite parts (e.g. flap track fairings) – with FACC.
- Liquid molding of composites. Key industrial partner is Airbus Germany.

Rotorcraft

- Development of a next-generation unmanned rotorcraft for aerial surveillance ("UAV Camcopter S-100"). Key industrial partner is Schiebel.

Engines

- "INTERMET" – Inter-metallic materials and structures for "revolutionary" performance improvements for turbine jet engines. Key industrial partners are Plansee AG, Böher Molding Techniques, Tyrolit Schleifmittelwerke, Swarowski.
- Development of a quiet engine for general aviation. Key industrial partner is Bombardier-Rotax.

[61] TAKE OFF Presentation BMVIT and FFG 2002. http://ffg.co.at

- "D-JET" – Design of a modern single-engine general aviation aircraft. Key industrial partner is Diamond Aircraft.
- Development of cryogenic test methods.
- « DIBINE » – Rapid, accurate non-contact dimensional measurement of turbine blades.
- Mixed convection boundary flow over a horizontal plate.
- Laminar boundary layer separation in BZT fluids.

Avionics and ATM

- Integrated avionics system Brightline iNAV300. Key industrial partner is Brightline Avionics.
- "CDM@airports" – Application of operations research and artificial intelligence to improvements in co-operative decision making. Key industrial partner is Frequentis Nachrichtentechnik.
- Mapping of navigation signals received by on-board antennas in critical flight phases. The objective is to develop technology to enable properly equipped aircraft to land under poor visibility conditions with the aid of Galileo signals.
- "AIRBORNE" - Development of internationally recognized qualification standards for the certification of avionics equipment.

Austrian Research Centers and Knet for Austrian Aeronautics Research

Austrian Research Centers (ARC), a network of research centers, perform contract research for industry and government. ARCs are often linked with industry and academia in so-called "Knets" (competence networks) which bring collective expertise to bear on specific research areas. One such example is the Knet for Austrian Aeronautics Research (Knet AAR or AAR). Established in 2000, it represents a national initiative to enhance the technology base and industrial potential of the Austrian aeronautics industry. It is managed by ARC Seibersdorf with government support of €10.68 million for the five-year period 2001-2005. This support covers 50% of total research project cost with industry providing the other half. Knet AAR's main focus is on lightweight materials (composites and ultra light alloys). It addresses the following major research areas:

- Simulation and modeling
- Structural performance and fatigue failure
- Test and validation methods
- Materials and processes

Materials testing is performed at ARC Seibersdorf's AMTT testing facility (Europe's only large scale testing facility for materials and components).

In addition to engaging in research, AAR is involved in promoting Austria's aeronautics industry on a global basis.

SWEDEN

INTRODUCTION

Sweden has a long tradition of maintaining an internationally competitive domestic aeronautics industry. The key companies are:

- Saab, previously a manufacturer of civil aircraft (Saab-2000 and 340)and, currently, of military aircraft (Gripen combat aircraft), is also supplier of components to Boeing and Airbus.
- Volvo Aero, which provides engine components to all major engine manufacturers.
- Ericsson Microwave Systems, a supplier of avionics.

In 2004, total annual revenues of Sweden's aeronautics industry were about $2.5 billion, roughly evenly split between defense and civil sectors. Most of the civil revenues were for export, while nearly all defense revenues were domestic.

Government support to aeronautics research has played an important role in attaining and maintaining the strong contribution made by Sweden's aeronautics industry relative to the country's size. In line with common European practice, government research support in Sweden encourages cooperation between academia, industry and research institutions. Industry typically contributes half of total research cost.

Although Sweden is a member of the European Union, it has not adopted the Euro as its currency. Instead, it has continued to use the Swedish Kronor (SEK). All funding figures are shown in U.S. dollars at an exchange rate of $1 = SEK7.4, which represents the average for 2003 and 2004.

SWEDISH GOVERNMENT SUPPORT FOR AERONAUTICS RESEARCH

Government support for aeronautics research in Sweden is channeled through several programs. The "Vision 2020"-induced trend to better coordination between in-country programs as well as with EC programs and those of other European nations is clearly evident in Sweden (just as it is in all the other European nations studied) as will become apparent in the discussion below.

National Aeronautics Research Program (NFPP)

The NFPP is the only Swedish research program exclusively dedicated to aeronautics research. Several other programs also support aeronautics research. However, in these programs, aeronautics research is embedded in broader topics such as materials research and development of better production systems. NFPP started in 1993. It has continually operated since then at a total annual government contribution of $4.1 million, two thirds of which ($2.7 million per year) goes to defense-related, including dual-use, research and the remaining $1.4 million per year of government funding is allocated to the civil sector. Industry contributes matching amounts to the defense as well as the civil research programs. Funding for defense-related research comes from the Ministry of Defense and for the civil program from the Swedish Agency for Innovation Systems (VINNOVA), (see below).

NFPP runs in multi-year phases of varying duration (the only exception being 2004). The current phase, NFFP4, spans four years, from 2005 through 2008. It focuses on the following research areas:

- Systems analysis: Concept development, systems-of-systems architecture, optimization, supplier networks
- System technology: Mission planning, power generation, avionics systems, information systems, MSI interaction, signature, simulations.
- Aircraft technology: Aerodynamics, aero-acoustics, flight mechanics, structural dynamics, materials technology.
- Service-based systems: Service development, integrated solutions, lifecycle management, product support, MRO technology.
- Innovative technologies for future aircraft systems: Engines, design, power generation, avionics, communications, nano materials.

Swedish Agency for Innovation Systems

As mentioned above, the Swedish Agency for Innovation Systems (VINNOVA) is funding the civil research component of the NFPP. It provides support to aeronautics research through a number of channels. It also coordinates and integrates R&D for technology in all modes of transportation as well as for the work environment in other industries. Its mission is to promote economic growth by financing R&D and by developing effective "innovation systems" designed to facilitate the process of maturation of technology from basic to applied research, to product development and deployment. In 2002, its budget was $135 million.

An important tool used by VINNOVA for strengthening collaboration between academia, industry R&D and research institutions is the so-called Competence Center Program[62]. It currently comprises 28 Competence Centers at eight universities. It is managed by VINNOVA in collaboration with the Swedish Energy Agency (STEM). In addition to the government agencies VINNOVA and STEM, all parties to a Competence Center, including industrial companies and universities, contribute to the Center's research program in the form of cash or in-kind contributions. The total funding (public and private) for all 28 centers is currently $78 million per year, ($2.8 million per year per center, on average). Generally, on average**,** industry annually contributes 40% ($1.1 million), academic partners and VINNOVA/STEM 30% ($840K) each.

[62] http://publiceng.vinnova.se/main.aspx?ID=e9846286-4ec1-403b-8fd3-10cc6b38c005

The following Competence Centers are of particular relevance to aeronautics research:

- Combustion Engines Research (CERC), Chalmers Institute of Technology (CTH).
- Integrated Product Development, Polhem Laboratory, Lulea Institute of Technology.
- Combustion Processes, Lund University (LU).
- Customer-driven high performance production systems, Woxencentrum, Royal Institute of Technology (KTH).
- Advanced Software Technology, Uppsala University (UU).

Assuming that all centers are funded at roughly the same level, government funding for these five centers totals $4.2 million per year, not all of which, of course, is dedicated to aeronautics research. It represents an upper bound for aeronautics research funding through the VINNOVA Competence Center Program.

To promote interdisciplinary research and integration among the Competence Centers and their partners, VINNOVA has defined a total of 18 so-called growth areas for funding. They cut across traditional boundaries of industrial sectors and scientific disciplines. Six of these are relevant to aeronautics.

- Materials design, including nanomaterials
- Lightweight materials and design
- Micro- and nano-electronics
- Software products
- Information technology
- Complex assembled products

Swedish Foundation for Strategic Research

The Swedish Foundation for Strategic Research (SSF) was founded in 1994 with the brief of supporting research in the natural sciences, engineering and medical science in order to enhance Sweden's competitiveness in international markets. Its total annual budget has held steady at about $108 million[63]. Two of its defined research areas are relevant to aeronautics: Material Science, which gets $14 million annually and Manufacturing and Production, with $16 million, for a combined total of $30 million. Not all of this support is necessarily assigned to aeronautics; it was impossible to determine any further breakdown of these budgets. Again, the total of $30 million per year has to be regarded as an upper bound for SSF support to aeronautics research.

Another data point indicating how much funding SSF is directing to aeronautics research is to look at what portion of its budget is assigned to the three academic institutions most important for aeronautics research. They are: Royal Institute of

[63] SSF: www.stratresearch.se/pdf/activity%20report%202003.pdf

Technology (KTH), 19% of total budget, or $20.5 million, Chalmers Institute of Technology (CTH) and Lund University (LU), each receiving 17%, or $18.4 million. These three academic institutions, which dominate aeronautics research, between them receive more than half of total annual SSF funding (53%, or $57.3 million). Each of these three universities is host to at least one research center important to aeronautics research. The Royal Institute of Technology and the Gas Turbine Center, the Chalmers Institute of Technology and the Combustion Engine Research Center and Lund University's Swedish Center for Aviation Research. More details on these centers is provided below.

Based on these two data points, the annual public funding through SSF to aeronautics-related research projects is estimated at between $20 million and $25 million.

Swedish Research Council

Swedish Research Council (SCI) is an agency under the Ministry of Education and Science[64]. Its three main areas of responsibility are: formulation of national research policy, funding of research and communication between the various elements of the scientific community. It emphasizes basic research. It is organized into three Scientific Councils: humanities and social sciences, medical science, and natural sciences and engineering. The latter is relevant to aeronautics research. Taking a snapshot of 2003, SCI was funding at least eight programs in aeronautics research, most of them multi-year. For 2003, the total was about $802,000. Most of the programs were conducted at the Royal Institute of Technology (KTH). One of the aeronautics research programs by SCI at KTH is the operation of a test facility for interior aero-acoustics.

The Knowledge Foundation

The Knowledge Foundation (KK), which was established in 1994 shortly after the founding of NFPP, is supporting education[65]. At an average annual funding level of $67.6 million, it co-funds research at universities and promotes development of competencies in industry as well as at universities and non-university research institutions with the objective of strengthening Sweden's competitiveness. It supports research across a wide spectrum of technical areas, not only in aeronautics.

MAJOR AERONAUTICS RESEARCH INSTITUTIONS

Swedish Center for Aviation Research

The Swedish Center for Aviation Research (SCFF) is a collaborative effort between Lund University and the Swedish Civil Aviation Authority (LFV); it stresses R&D and education in air traffic and airport control management.

[64] www.vr.se/english

[65] www.kks.se/templates/StandardPage.aspx?id=84

Emphasis is placed on human factors research. The center is located at Lund University.

Gas Turbine Center

The Gas Turbine Center (GTC) is a consortium of three universities (Chalmers, Royal and Lund) and industry (Alstom and Volvo Aero). Half of its research cost is borne by government (Swedish National Energy Administration - STEM) and half by industry (Alstom and Volvo Aero). Its research is focused on the compressor, turbine and combustor elements of a turbine engine. The Royal Institute of Technology (KTH) is the host.

Wallenberg Laboratory for Research on Information Technology and Autonomous Systems

Located at Linköping University, the Wallenberg Laboratory for Research on Information Technology and Autonomous Systems (WITAS) is currently focused on only one large project: development of information and control technology for UAVs. The objective of the program is to develop the capability for a UAV to make autonomous decisions on the basis of data from on-board sensors.

KEY AERONAUTICS RESEARCH PROGRAMS

Aircraft Structures. The main research objective in structures-related research has recently been to help Saab AB be a competitive supplier of aircraft structural components made of Al alloys as well as composites. Saab is a risk-sharing partner on the A380 program to which it supplies complete sets of mid- and outer wing leading edge (MOLE) units. It also supplies the forward fuselage structure for the Eurocopter NH-90 helicopter. Saab has leveraged government support into obtaining supplier positions on these programs.

Rotorcraft. Current research is focused on the development of a small, unmanned helicopter. Saab again is the industrial partner.

Engines. The industrial partner, Volvo Aero, is a supplier of engine components. Volvo Aero parts and components are installed on 80% of all engines powering aircraft larger than 100 seats. This includes the latest designs; for example, it is a component supplier to the GEnx program.

By far the largest research project, called VITAL for Environmentally Friendly Aero Engine, is a four-year program with a total budget of $109 million. The EC 6th FP contributes $61 million, Volvo Aero $11.5 million, other Swedish companies $5.5 million and the Swedish government, primarily through the Ministry of Defense, $31 million. The program was launched on January 18, 2005. Its technical goals are identical to those of the EC's Vision 2020 plan: 50% reduction in noise and CO2 emissions and 80% reduction in NOx emissions, by 2020. Chalmers University is a key partner in the program.

Avionics. The industrial partner is Ericsson Microwave Systems (EMW). Its government research support comes primarily from the Ministry of Defense. It also works on dual-use programs, which include air traffic control and radar technology.

Air Traffic Control. In recent years ATM-related research has been focused on preparing the Civil Aviation Authority (LFV) for the installation and start-up of a Thales air traffic management system, model Eurocat 2000E. This advanced system controls all of Sweden's airspace. It was successfully put into operation on March 19, 2005.

Funding Summary

As shown in the above discussion, Swedish government support to civil aeronautics research flows through a number of separate channels. To complicate the analysis further, the most significant contributors, VINNOVA and SSF, do not separately identify aeronautics research support as such. Their figures represent estimates. This relatively complex funding arrangement is summarized in terms of current annual budgets as follows:

Swedish Government Support	**$ Millions**
National Aeronautics Research Program (NFPP):	1.4
Agency for Innovation Systems (VINNOVA):	less than 4.2
Swedish Foundation for Strategic Research (SSF):	$20 – 25
Swedish Research Council:	0.8
Ministry of Defense contribution to 6th FP on engines (VITAL)	31 (spread over several (unknown number of) years)

EUROCONTROL

Introduction

EUROCONTROL is the European organization responsible for the safety of air navigation for both civil and military air traffic in the European airspace of the 41 member nations of the European Civil Aviation Conference (ECAC). Of these, 34 nations are members of EUROCONTROL (22 of which are members of the EU). EURONTROL'S primary objective is the development of a seamless, pan-European air traffic management (ATM) system. It formulates, coordinates and implements short-, medium-, and long-term strategies and action plans in collaboration with national authorities, air navigation service providers, civil and military air space users, airports, industry and relevant European institutions, primarily the European Commission (EC). Its control covers the entire range of activities required for gate-to-gate "navigation."

AIR TRAFFIC MANAGEMENT RESEARCH & DEVELOPMENT

EUROCONTROL manages research in pursuit of its primary objective of a seamless Air Traffic Management (ATM) system with sufficient capacity across the 41 ECAC member states under the EUROCONTROL Performance Enhancement in European ATM Programme (EATMP), which got started in 2004. The first task has been to develop initial strategies, concepts and roadmaps for improving ATM over the entire time horizon, from short- to long-term. The strategies are to generate agreement on a portfolio of implementation programs and services with involvement of participants and stakeholders.

The strategic direction of EATMP is provided by the European ATM Master Plan. It is based on the EUROCONTROL ATM 2000+ Strategy which in turn responds to the "Vision 2020" objectives, the Single European Sky Initiative and their updates. R&D is performed under EUROCONTROL primarily at its EUROCONTROL Experimental Center (EEC) and externally under the EC's Framework Programmes (FPs), at national research establishments and by industry. With EATMP, EUROCONTROL demonstrates that it has taken on the lead role for the development of the future pan-European ATM system. The increase in EUROCONTROL's responsibilities for Europe's future ATM system started in 2001 as a consequence of the long-term strategic plan embodied in "Vision 2020." Since then, sponsorship of ATM research has increasingly shifted from national to European organizations.

The European ATM Master Plan identifies the following major milestones on the path to achieving the "Vision 2020" objectives:

- 2012 – Single European Sky implementation. Technical implementation is performed under the new SESAME program[66].
- 2017 – Collaborative High Performance concept, "an evolutionary step toward an expected paradigm shift" (i.e. away from controller-centric ATM).
- Finally, by 2020, the ATM system is required to handle a traffic increase of more than 90% compared with today's capacity limit and do it safely and cost-effectively while providing airspace users with greater in-flight efficiency.

To achieve these objectives, the ATM R&D program is organized into five main research areas, as follows:

Sector Safety and Productivity (SSP) – Concerned with all aspects of air traffic control related to controller-centric sector-level planning and separation management functions.

[66] EUROCONTROL website

Network Capacity and Demand Management (NCD) -- Addresses airspace management, demand and capacity management and traffic management issues consistent with the European Single Sky Initiative.

Airport Throughput (APT) -- Focuses on capacity issues facing airports and their immediate environments.

Innovative Research (INO) -- Investigates and coordinates initial feasibility studies on long-term goals identified in the ACARE's (Advisory Council for Aeronautics Research in Europe) SRA (Strategic Research Agenda), which in turn are based on "Vision 2020."

Society-Environment-Economics (SEE) -- Addresses issues identified by ACARE as being related to the sustainability of growth.

AIR TRAFFIC MANAGEMENT RESEARCH & DEVELOPMENT FUNDING

The annual budget for EATMP and its forerunner was €200 million ($200 million[67]), on average, over the years 1996 – 2003, with slight up and down variations from year to year. EATMP's budget is expected to continue at this level through 2006, after which it is to at least double. Of the €200 million about 20%, or €40 million is spent on R&D infrastructure, the rest on research personnel in government and industry research organizations.

Of the €200 million, on average, 60% (€120 million) per year is contributed by EU institutions: €70 million by EUROCONTROL and €50 million by the EC's Framework Programmes (FPs). The remaining 40% (€80 million) comes from national governments (€60 million, on average) and industry (€20 million, on average), for cost-shared, co-operative projects. On cooperative programs, industry participates and contributes through the EC Framework Programmes. Since FP projects are multi-year, annual fluctuations in recorded contributions, such as shown in Table 1, are mainly caused by the accounting procedures employed. In sum, total annual government funding, by the EU and national governments, has been running at about €200 million. It is expected to double from 2007 on.

The average distribution by the origin of the funds is as follows:

Industry:	10%
National governments:	6%
National user charges:	23%
EC:	24%
EURONTROL user charges:	37%

[67] An average exchange rate of 1€ = $1 is used. It applies for the years 2001-2003.

The funding provided by the participants is shown in Table 12 for the years 2002 (actual) and 2003 (budget plan)[68].

Table 12. ATM R&D Budgets for 2002-2003, by Sponsors

Country	**Organization**	**2002 actual (€ millions)**	**2003 plan (€ millions)**
All	industry	20.3	12.0
EC	FPs	54.4	42.3
EUROCONTROL	EEC	72.7	68.7
France	DNA	16.0	15.5
Germany	DFS+DLR	9.5	13.2
Netherlands	LVNL+NLR	6.6	8.5
U.K.	NATS+DERA	4.4	0.5
Spain	AENA	7.2	7.1
Sweden	LFV	1.5	2.7
Italy	ENAV+SITCA	10.6	9.9
Other	Other	6.3	3.3
TOTAL		**209.5**	**183.9**

The acronyms shown in Table 12 for national government organization are defined as follows:

Country	**Government Organization**
France	DNA – French Air Navigation Agency
Germany	DFS – German Air Traffic Management Corp. DLR – German Aeronautics and Astronautics Research Institute
Netherlands	LVNL – Dutch Air Traffic Management Agency NLR – National Aerospace Laboratory
U.K.	NATS – National Air Traffic Services Ltd. DERA - Defence Evaluation and Research Agency
Spain	AENA – Spanish Airports and Air Navigation Agency
Sweden	LFV – Civil Aviation Administration
Italy	ENAV – National Organization for Assistance to Air Traffic SITCA – Innovative Systems for Air Traffic Control

The EATMP research program is spread over a large number of projects, 268 and 534 in 2002 and 2003, respectively. The typical project has about 4 partners, pointing to a high level of collaboration. Only about 18% of the projects are in

[68] ARDEP ("Analysis of Research and Development in European Programmes") 2003: Overview, via EUROCONTROL Website

excess of €1 million, which indicates a somewhat fragmented research program with attendant inefficiencies.

In addition to the funds provided by industry shown in Table 12, firms spend an additional estimated €50 million annually on go-it-alone proprietary projects the results of which companies do not want to share with their competitors. Total annual research budgets approximate €250 million. All such industry projects are coordinated with EATMP.

The planned distribution of funds by research area for 2003 is shown in Table 13[69]:

Table 13. Planned Funding Distribution by Research Area for 2003

Research Area	No. of Projects	€ millions	% of Total
INV – Innovative Studies & Technology Assessment	12	2.4	1.3
OVA – Overall ATM issues	85	26.7	14.5
AMG – Airspace Management	28	9.4	5.1
FCM – Flow and Capacity Management	13	4.6	2.5
HUM – Human Factors	30	7.2	3.9
VAL – Validation	25	11.2	6.1
COS – Communications Systems	33	11.8	6.4
NAS – Navigation Systems	20	9.0	5.0
SUS – Surveillance Systems	30	12.4	6.7
DSS – Decision Support Systems	65	26.3	14.3
AVN – Avionics	41	15.9	8.6
APT – Airports	44	12.3	6.7
ALO – Airline Operations	5	0.8	0.4
MET – Meteorological Systems	13	3.5	1.9
SPT R&D – Infrastructure	52	19.4	10.5
RDM R&D – Management & Coordination	20	8.3	4.5
ENV – Environment	18	2.3	1.3
Totals	**534**	**183.5**	**101.6**

[69] ARDEP 2003: Overview

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Chapter 4
Relationship of European Aeronautics Research to "Vision 2020"

A common thread running through both EC research programs and those of each European country identified in Chapter 3. is the long-standing commitment by governments to committing public resources to enhance the competitiveness of the aeronautics industry at both the European and national levels. Also common to the European and national research programs is the recent trend toward increased cooperation between the European and national programs and among the national programs themselves. Underlying this trend is a shared commitment to a common set of key research objectives. The research objectives were initially adopted for application throughout Europe by the "Group of Personalities", which was formed in late 2000 to develop the European concept for attaining a dominant competitive position in aeronautics by the year 2020. This is reflected in the group's report "European Aeronautics: A Vision for 2020." Based on recommendations in the report, an Advisory Council for Aeronautics Research in Europe (ACARE) was formed. It was given the primary mission of defining the Strategic Research Agenda (SRA), which provides guidance to the planning of aeronautics research in Europe at both the EC and national levels. The discussions of the aeronautics research programs of the European Union and its member states show that the strategic goals expressed in "Vision 2020" and the SRA are providing the guidance intended and are the drivers underlying the growing cooperation and coordination of Europe's aeronautics research programs.

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Chapter 5

Role of Industry and Government-Industry Cooperation

All European research programs also have in common that they share the cost of the research with industry; this is accomplished through various forms of public-private partnerships. This European "paradigm" for funding aeronautics research is characterized by the following key features:

- All European countries practice "industrial policy" relative to the aeronautics sector to a greater (e.g. France) or lesser (e.g. Germany) extent.
- Strong industry involvement in defining and performing research as well as in paying for about half the cost in most countries. Industry's share is lower in France, where government pays 78% of total research cost, and in Spain with a 60% government share.
- Any one industry partner in a cost-shared research program can veto the public dissemination of research results. Thus, results from such research projects are typically not shared outside the European community.
- Emphasis on enhancing European industry's international competitiveness, both in terms of each country's "home" industry as well as of Europe's as a whole.
- Support for industry's product development endeavors with emphasis on short- and mid-term time horizons.
- Support for activities which promote and assist technology transfer and deployment.
- Strong and wide-spread research support for Airbus programs; this reflects the strong Europe-wide political support for the industrial policy aimed at enhancing the international competitiveness of Airbus.
- Allocation of a share of European Commission and national regional development funds to economically disadvantaged regions for programs supportive of aeronautics research goals, primarily in the form of funding new research facilities as well as education and training programs designed to improve the skill level of the local population. Such programs are coordinated with industry, which derives benefits from them.

An important consequence of the role European industry plays in both setting research agendas and carrying out aeronautics research is that such research tends to be biased to support the next major industry program. This implies a near- to mid-term time horizon. Comparatively little investment has been made in long-term research outside of academic institutions. With the increasing coordination of research in the common pursuit of "Vision 2020" goals, the time horizon is gradually lengthening.

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Chapter 6

Implications for U.S. Competitiveness and Economic Well-Being

Europe's well-funded aeronautics research programs challenge U.S. long-standing primacy in civil aeronautics technology. The European initiative is characterized by private-sector investments alongside the public investments by the European Commission and national governments. All this is in furtherance of the goal set out in "Vision 2020": to overtake the U.S. and become the world leader in aeronautics.

While Europe's civil aeronautics research programs are not only growing but also becoming more effective, in the U.S. such research appears to be on a downward slope (See Table 14). Unless this situation is reversed, Europe may well succeed in gaining world leadership in aeronautics technology. Such a development would be detrimental to U.S. interests for the following reasons:

- U.S. industry, shorn of its leadership position, will lose market share. Two studies of the economic implications of aeronautics research and the respective roles of the private and public sectors in funding it ([70]) ([71]), concluded that sustained government research support was needed because the private sector tends to under-invest in aeronautics research. This is a direct result of an individual company's inability to derive ("appropriate") sufficient benefits from the research results unless government shares the cost of requisite research. A related factor is that a sizeable fraction of even privately-funded aeronautics research leads to results which end up being broadly shared by industry -- by those who invested in it as well as those who did not. The 1992 study also specifically addressed Airbus as an example of the then-new "Strategic Trade Theory" and concluded that, unless Europe's governments were convinced to abandon their substantial public support for R&D beneficial to Airbus, the most effective U.S. response would be to aid U.S. industry with similar types and magnitudes of financial support.
- Loss of market share will diminish the significant positive contribution by aeronautics to the U.S. balance of payments.
- In place of the U.S., Europe will increasingly be able to set aviation standards for new technologies and do so to its own advantage. This is a particularly urgent concern in the area of air traffic management. (It is

[70] Gellman Research Associates, Inc., Economic Analysis of Aeronautical Research and Technology, August 30, 1982

[71] Gellman Research Associates, Inc., Economic Analysis of Aeronautical Research and Technology – An Update, April 9, 1992

appropriate to note here that the FAA Administrator recently stated[72] that NASA had to a significant degree become the source of R&D outcomes required by the FAA. Certainly this is the case where ATM is concerned. With the ATM system so in need of revamping[73], can the nation tolerate any withdrawal of R&D resources in this area?)

- Loss of first-to-market position with new-technology products means U.S. industry will not capture the higher long-term profits that usually reward the market leader. The "Framework Programs" put U.S. industry at a further disadvantage because the final results of European research are not publicly disseminated and remain unavailable, unlike most publicly-funded civil aeronautics research in the United States.

Table 14. NASA Aeronautics Research Annual Budgets in Full Cost[74]
($ millions)

Fiscal Year						
2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1056.8	962.1	852.3	727.6	730.7	727.5	717.6

[72] Comments by Marion Blakey at REDAC meeting of September 20, 2005.
[73] Presentation by Jerry Thompson on air traffic management research at REDAC meeting of September 20, 2005.
[74] Full cost funding figures reflect all costs associated with workforce, facilities, overhead, and funding for university and industry partnerships. FY 2004 and FY 2005 reflect the operating plans for those years. Funding levels for FY 2006 and beyond reflect the proposed FY 2006 President's Budget. Data obtained from the NASA website (http://www.nasa.gov/pdf/107489main_FY06_1_sae.pdf).

Chapter 7
Summary

Civil aeronautics research in the European Union is benefiting from substantial amounts of support from government at all levels; the European Commission, national and regional governments. Table 15 provides an overview of estimated funding levels during the year 2002. Also presented in the Table are the total aerospace revenues for each country. The revenue information gives an indication of the relative ranking of each country's aerospace industry. It is important to note that the aerospace revenue figures consist of both the civil and defense parts of the aeronautics and space industries whereas the figures for government research support are limited to civil aeronautics. Despite this limitation, they do lead to the following observations:

- The governments of the U.K., Germany and Sweden expend the smallest amounts on civil aeronautics research relative to total aerospace revenues, ranging from 0.2% for the U.K. to 1% for Sweden. The U.K. government spends much more on aeronautics research for defense than for the civil sector.
- France, Belgium, the Netherlands and Austria provide government research support to civil aeronautics at about the same level of roughly 3.3% to 4.3% of the revenues of their respective aerospace industries. France supports a sizeable defense research effort in addition to its civil research[75].
- Italy, at 6.1%, is the next highest. This is consistent with Italy's concerted effort to make its research capabilities and infrastructure competitive internationally in order to attract business for its aeronautics industry and its research institutions not only from within the European Union, but also from the U.S. Winning a significant share of the Boeing 787 airframe production as a risk-sharing partner is a sign of the success of this policy.
- Spain, at 23.4%, not counting zero-interest loans to industry, provides by far the highest level of government support of the countries studied relative to the total revenues of its aerospace industry. The zero-interest loans cover product development support as well as research leading up to product definition. Only the latter is of interest for this study. Unfortunately, the research component was not separately reported.

Table 15 only shows the amount of government support to civil aeronautics research. The actual total amount is significantly larger because most of European

[75] It is highly likely that a substantial portion of the defense aeronautics research France sponsors is, from its inception, targeted at civil aviation. To minimize the risk of such funding being identified as "subsidy" for the French civil aeronautics industry, the defense "cover" is used. To the extent this is done, it makes France's support for civil aeronautics research greater than shown here.

research, for most “country” entities, involves industry participation where industry bears about half the cost. Exceptions are France and Spain, where governments provide 78% and 60% of cost, on average, respectively.

Civil aeronautics research in the European Union receives substantial amounts of support from government at various levels excluding the European Commission and national and regional governments. Approximately 95% of government research support is allocated to projects in which industry participates, in most cases sharing half the total cost. Exceptions are France and Spain, where governments provide 78% and 60%, respectively, on average, of the total cost of an R&D endeavor. The remaining 5% is provided to universities and non-profit research institutions, without cost sharing. Government funds are often made available as grants or no-interest loans. The latter do not have to be repaid if the products which result from the research do not produce a profit.

The level of EU government involvement in aeronautics research, from funding and industrial policies to the scope of coordination and implementation of strategic research is properly a concern for U.S. industry and government, particularly as U.S. aeronautics research is shrinking. Project information on the 5^{th} Framework Program, which ended in 2002 (Appendix 2), shows how extensive EU aeronautics research has become in many areas of interest to the U.S. industry. If the strategy adopted to pursue “Vision 2020” goals continues unchallenged, the European Union will be able to attain its objectives more readily.

Table 15. Estimated Annual Government Aeronautics Research Support and Aerospace Revenues for the year 2002

(Note: EIB loans are not included.)

Political Entity	**Programs**	**2002 Govt. Support for Civil Aeronautics R&D**	**2002 Total Aerospace Industry Revenues**
EC	6th FP	€245 million	
	Regional Development Aid	~€100-200 million	
U.K.	ARP and EPSRC	$72 million	$30 billion
France	All programs, excluding expenses for management and admin.	€ 818.5 million	€24.6 billion
Germany	All programs	€140 million +	€16 billion
Belgium	All programs	€20-30 million	€800 million
Netherlands	All programs	€80 million	€2.4 billion
Italy	All programs	€390 million	€6.3 billion
Spain	grants	€752 million	€3.2 billion
	(Zero-interest loans	€4.3 billion)	
Austria	All programs	€16.4 million	€380 million
Sweden	All programs	$25-30 million	$2.5 billion
EUROCONTROL		€200 million (€400 million from 2007 on)	
Totals[76]	**(excluding Spanish loans)**	**~€2.9-3.0 billion**	**~€83 billion**
Totals	**(including Spanish loans)**	**~€7.2-7.3 billion**	**~€83 billion**

[76] An $:€ exchange rate of 1:1 was used

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Appendices

APPENDIX 1 – SIXTH FRAMEWORK PROGRAMME

LIMITED LISTING OF 6TH FP PROJECTS, WHICH HAVE COME TO THE AUTHOR'S ATTENTION THROUGH INFORMAL COMMUNICATIONS CHANNELS. (OFFICIAL INFORMATION NOT AVAILABLE BEFORE LATE 2005)

- FAME – Functionalised Advanced Materials and Engineering: Hybrids and Ceramics. FAME is a Network of Excellence organized to maximize the use of European research infrastructure. It consists of 18 universities, University of Liège (Belgium) and University of Bordeaux (France) leading, and 28 companies (12 large companies and 16 SMEs).
- COCOMAT – Improved Material Exploitation at Safe Design of Composite Airframe Structures by Accurate Simulation of Collapse. Program lead: DLR (Germany). Major participants: Agusta, Israel Aircraft Industries, Swedish Defense Research Institute.
- WAKENET 2 – EUROPE – Thematic Network on "Wake Turbulence." The following research subjects are covered:
  - Wake vortex risk assessment validation, including incident reporting (EUROCONTROL)
  - Meteorological aspects of the wake vortex problem (DLR)
  - Integration of wake vortex warning system in ATM environment, novel wake turbulence avoidance procedures (DFS)
  - Characterization of wake vortex strength and decay (UCL) and encounter parameterization (DLR)
  - Simulating wake turbulence effects: aircraft response and pilot's perception (Airbus)
  - LIDAR developments and applications to Wake Vortex Research and Airport Applications (QinetiQ)
  - Principles of vortex alleviation systems (ONERA)
- COMPOSITN – Composite Material Research Requirements of the Aerospace Industry. This is a Thematic Network led by EADS with university and industry participation
- EWA - European Windtunnel Association – Network of Excellence. It addresses wind tunnel testing for aeronautical applications and related advanced measuring technologies.
- CAATS – Cooperative Approach to Air Traffic Services. Program Lead: ISDE, S.A. (Spain).

Appendix 2 - Complete list of Fifth Framework Programme Projects

Advanced Technology Development Projects – Critical Technologies

Aircraft Development Cost and Time to Market

Advanced Design Systems and Tools

- CASH – Collaborative Working within the Aeronautical Supply Chain
- FLOMANIA – Flow Physics Modelling: An Integrated Approach
- M-DAW – Modelling and Design of Advanced Wing Tip Devices
- MOB – A Computational Design Engine Incorporating Multi-Disciplinary Design and Optimization for Blended Wing-Body Configuration
- SYNAMEC – Synthesis Tools for Aeronautical Mechanisms Design

Manufacturing

- ADFAST – Automation for Drilling, Fastening, Assembly, Systems Integration, and Tooling.
- AGNETA – Advanced Grinding of New Aircraft Engine Materials
- BASSA – Bond-assisted Single Step Assembly of Aircraft Structural Components
- DUTIFRISK – Dual Material Titanium Alloy Friction Welded BLISK
- OPTISPRAY – Optimization of Spray-Forming of Advanced High-Quality Components of Superalloys for Aeronautical Applications
- TITALUM – Improvement of Tools for the Machining of Aeronautic Aluminum and Titanium Alloys
- WAFS – Welding of Airframes by Friction Stir

Product Quality Control

- INDeT – Integration of Non-Destructive Testing
- MANHIRP – Integrating Process Controls with Manufacturing to Produce High Integrity Rotating Parts for Modern Gas Turbines
- MMFSC – Manufacturing and Modelling of Fabricated Structural Components
- QUALISTIR – Development of Novel Non-Destructive Testing Techniques and Integrated On-line Process Control for Robotic and Flexible Friction Stir-Welding System

Aircraft Efficiency

Aerodynamics

- AEROMEMS II – Advanced Aerodynamic Flow Control Using MEMS
- AEROSHAPE – Multi-Point Aerodynamic Shape Optimization

- ALTTA – Application of Hybrid Laminar Flow Technology on Transport Aircraft
- EPISTLE – European Project for Improvement of Supersonic Transport Low-Speed Efficiency
- EUROLIFT – European High-Lift Programme
- EUROPIV 2 – A Joint Programme to Improve PIV Performance for Industry and Research
- HELIX – Innovative Aerodynamic High-Lift Concepts
- HiAer – High-Level Modelling of High-Lift Aerodynamics
- HiReTT – High Reynolds Number Tools and Techniques for Civil Transport Aircraft Design
- TILTAERO – Tilt Rotor Interactional Aerodynamics

Structures and Materials Application

- ADMIRE – Advance Design Concepts and Maintenance by Integrated Risk Evaluation for Aerostructures
- AGEFORM – Age-Formable Panels for Commercial Aircraft
- BOJCAS – Bolted Joints in Composite Aircraft Structures
- DOLSIG – Development of Lightweight Stiff Static Sheet Structures in Gamma Titanium Aluminide
- FALCOM – Failure, Performance and Processing Prediction for Enhanced Design with Non-Crimp Fabric Composites
- FASTWing – Foldable, Adaptive, Steerable Textile Wing Structure for Heavy Load Delivery
- FUBACOMP – Full-Barrel Composite Fuselage
- IARCAS – Improve and Assess Repair Capability of Aircraft Structrures
- IDA – Investigation of Damage-Tolerance Behaviour of Aluminum Alloys
- INCA – Improved NDE Concepts for Innovative Aircraft Structures and Efficient Operational Maintenance
- LiSA- Light-Weight Low-Cost Surface Protection for Advanced Aircraft Structures
- POSICOSS – Improved Postbuckling Simulation for Design of Fibre Composite Stiffened Fuselage Structures

Propulsion

- ADCOMB – Advanced 3D Compressor Blade Design
- ADSEALS – Investigation in Advanced High Temperature Turbine Seals
- AEROHEX – Advanced Exhaust Gas Recuperator Technology for Aero Engine Applications
- AITEB – Aerothermal Investigation of Turbine Endwalls and Blades
- ATOS – Advanced Transmission and Oil System Concepts
- AWFORS – Advanced Welding Techniques for Repair and Salvage of High-Valued Engine Components on Nickel and Titanium-Based Alloys
- CERES – Cost-Effective Rotordynamics Engineering Solutions
- CFD4C – Computational Fluid Dynamics for Combustion
- HORTIA – Heat and Oxidation Resistant Titanium Alloys Application

- ICAS-GT2 – Fluid Flow and Heat Transfer with the Rotating Internal Cooling Air System for Gas Turbines 2
- MAGFLY – Magnetic Bearings for Smart Aero Engines
- ORDICO – Oxidation Resistant Al and PtAl Diffusion Coatings with Improved Oxidation and Thermomechanical Fatigue Life
- RAMGT – Robust Aerofoils for Modern Gas Turbines
- SEAL-COAT – Abradable Seal Coatings and Claddings for Compressor Applications
- SiA-TEAM – Soot in Aeronautics – Towards Enhanced Aero Engine Combustor Modelling
- TBC PLUS – New Increased Temperature-Capability Thermal Barrier Coatings
- UTAT – Unsteady Transitional Flows in Axial Turbomachines

Systems and Equipment

- ACT-TILT – Active Control Technologies for Tilt-rotor
- ADFCS-II – Affordable Digital Fly-by-Wire Control System for Small Commercial Aircraft
- AEROFIL – New Concept for High-Pressure Hydraulic Filter for Aeronautics Preserving Environment
- AIR FREIGHT CONTAINER – Development of Temperature-Controlled Air Freight Containers.
- AIRSCAN – Development of Stabilization, Route Guidance, Propulsion and Ground Segment Control System for the Autonomous Operation of Unmanned Surveillance/Scanning Airships
- ANAIS – Advanced Network Architecture for In-Flight Cabin Systems
- ASL – Aircraft Service Logistics
- AUTAS – Automating FMECA for Aircraft Systems
- COCOPAN – Advanced Digital Network for New Cockpit Overhead Panel
- DART – Development of an Advanced Rotor for Tilt-rotor
- EECS – Efficient and Economic Cabling Systems
- EHA – Electro-Hydraulic Actuators
- GIFT – GNSS – Inertial Future Landing Techniques
- IMCAD – Improving the Cockpit Application Development Process
- LOADTNet – Low-Cost Optical Avionics Data Networks
- MALVINA – Modular Avionics for Light Vehicles in Aeronautics
- MCUBE – Highly Dissipative Integrated Modular Electronic Packages
- MESA – Magnetorestrictive Equipment and Systems for More Electric Aircraft
- MOTIFES –Multimedia Optical-Plastic Technologies for In-Flight Entertainment
- NATACHA – Network Architecture and Technologies for Airborne Communication of Internet High-Bandwidth Applications
- NEWSCREEN – Three Large-Display Cockpit Approach

- PAMELA – Prospective Analysis for Modular Electronic Integration in Airborne Systems
- SmartFuel – Third-Generation Digital Fluid Management System
- TRISYD – Tilt-Rotor Integrated Drive System Development

Configurational and Interdisciplinary Aspects

- 3AS – Active Aeroelastic Aircraft Structures
- ADTurBII – Aeroelastic Design of Turbine Blades II
- CAPECON – Civil UAV Application and Economic Effectiveness of Potential Configuration Solutions
- CRYOPLANE –Liquid Hydrogen-Fuelled Aircraft-System Analysis
- RHILP – Rotorcraft Handling, Interactions and Loads Prediction
- TAURUS – Technology Development for Aeroelastic Simulations on Unstructured Grids
- VELA – Very Efficient Large Aircraft

Environmental Friendliness of Aircraft

Pollutant Emissions

- AERO2K – Global Aircraft Emissions Data Project for Climate Impact Evaluation
- CYPRESS – Future Engine Cycle Prediction and Emissions Study
- ICLEAC – Instability Control of Low-Emission Aero Engine Combustors
- LOPOCOTEP – Low-Pollutant Combustor Technology Programme
- MENELAS – Minority Exhaust Measurements of Aircraft Engine Emissions by Infrared Laser Spectroscopy
- MOLECULES – Modelling of Low Emissions Combustors Using Large Eddy Simulation
- MUSCLES – Modelling of Unsteady Combustion in Low-Emissions Systems
- NEPAIR – Development of the Technical Basis for a New Emissions Parameter Covering the Whole Aircraft Operation
- PARTEMIS – Measurement and Predictions of the Emissions of Aerosols and Gaseous Precursors from Gas Turbine Engines

External Noise

- ADYN – Advanced European Tilt-Rotor Dynamics and Noise
- AROMA – Acoustic Radiation of Small Turbomachines
- ENABLE – Environmental Noise Associated with Turbulent Boundary Layer Excitation
- HeliNOVI – Helicopter Noise and Vibration Reduction
- JEAN – Jet Exhaust Aerodynamics and Noise
- ROSAS – Research on Silent Aircraft Configuration
- SOBER – Sonic Boom European Research Programme: Numerical and Laboratory Experimental Simulation

- TURBONOISECFD – Turbomachinery Noise-Source CFD Models for Low-Noise Aircraft Engine Designs

Cabin Environment

- ASICA – Air Management Simulation for Aircraft Cabins
- CABINAIR – Improving Air Quality in Aircraft Cabins Using 'Measurements in the Sky' and Innovative Designs and Technologies
- HEACE – Health Effects in the Aircraft Cabin Environment
- PARVIS – High Performance Anti-vibration Material for Aeronautical Use

Operational Capability and Safety of Aircraft

Air Traffic Management (ATM) Related Air Borne System

- INTENT – The Transition towards Global Air and Ground Collaboration in Traffic Separation Assurance
- SHINE – Smart Hybrid Integrated Navigation Equipment

Accident Prevention

- ACIDS – Air Conformal Fibre Optic Ice Detection System
- ADAMS 2 – Human-Centred System for Aircraft Dispatch and Maintenance Safety
- C-WAKE – Wake Vortex Characterization and Control
- EM-HAZ – Methods and Technologies for Aircraft Safety and Protection against Electromagnetic Hazards
- ESACS – Enhanced Safety Assessment fro Complex Systems
- I-WAKE – Instrumentation System for On-board Wake Vortex and Other Hazards Detection, Warning and Avoidance
- ISAWARE II – Increasing Safety by Enhancing Crew Situation Awareness
- ROBAIR – Development of a Robotic System for the Inspection of Aircraft Wings and Fuselage
- S-WAKE – Assessment of Wake Vortex Safety
- SAFE SOUND – Safety Improvement by Means of Sound
- USICO – UAV Safety Issues for Civil Operations
- VINTHEC II Visual Interaction and Human Effectiveness in the Cockpit, Part II

Accident Survivability

- CAST – Crashworthiness of Helicopters on Water: Design of Structures Using Advanced Simulation Tools
- CRAHVI – Crashworthiness of Aircraft in High-Velocity Impact
- FIREDETEX – New Fire/Smoke Detection and Fire Extinguishing Systems for Aircraft Applications
- HELISAFE – Helicopter Occupant Safety

TECHNOLOGY PLATFORMS

- AFAS – Aircraft in the Future Air Traffic Management System
- AWIATOR – Aircraft Wing with Advanced Technology Operation
- EEFAE – Efficient and Environmentally Friendly Aircraft Engine
- FACE – Friendly Aircraft Cabin Environment
- MA-AFAS – More Autonomous Aircraft in the Future Air-Traffic Management System
- POA – Power Optimized Aircraft
- SILENCE(R) – Significantly Lower Community Exposure to Aircraft Noise
- TANGO – Technology Application to the Near-Term Business Goals and Objectives
- VICTORIA – Validation platform to Integration of standardized Components, Technologies and Tools in an Open, modulated and Improved Aircraft electronic system.

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