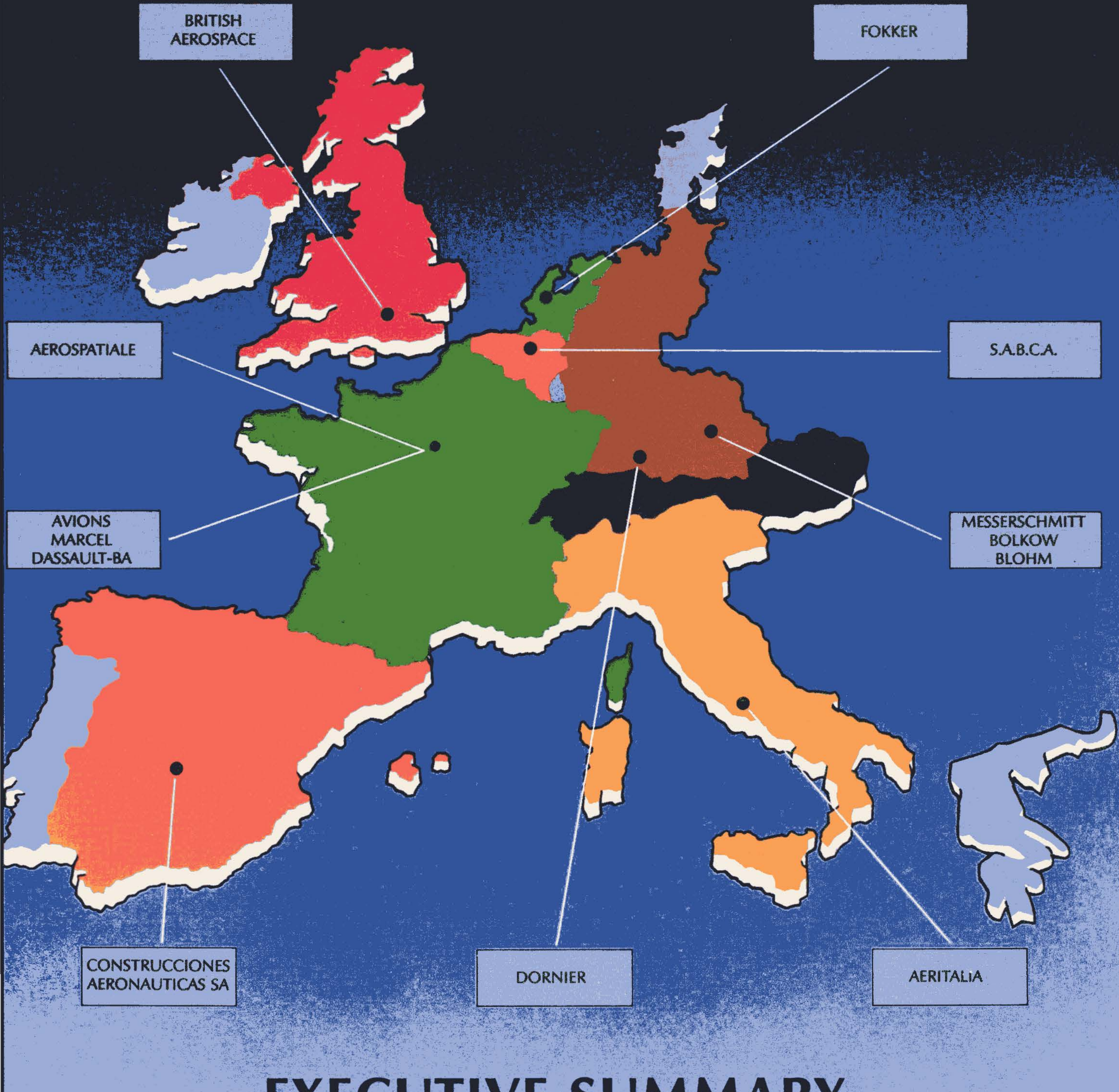
EUROMART STUDY REPORT



EXECUTIVE SUMMARY

Published
April, 1988

COMMERCIAL-IN-CONFIDENCE

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CONTENTS

PREFACE

This Executive Summary forms part of the final report of the EUROMART Study Group. The other parts — that is, the Main Report and its associated Annexes — are published concurrently under separate cover.

The Group, comprising representatives of the following companies

AERITALIA SPA
AEROSPATIALE SNI
AVIONS MARCEL DASSAULT – BREGUET AVIATION
BRITISH AEROSPACE PLC
CONSTRUCCIONES AERONAUTICAS SA
DORNIER GmbH
FOKKER AIRCRAFT BV
MESSERSCHMITT-BÖLKOW-BLOHM GmbH
SOCIETE ANONYME BELGE DE CONSTRUCTIONS AERONAUTIQUES,

conducted the Study under the terms of an EC contract (Ref. ECI-1539-B7210-B).

The EUROMART Study report is published in response to, and in formal satisfaction of the requirements contained in Annex 1 of that contract.

SYNOPSIS

1. REASONS FOR THE STUDY

1.1 Over the last three decades the European Aeronautics Industry (EAI) has recorded a number of major successes. The build-up of a powerful capability in the field of large transport aircraft, through cooperative working on the Airbus programme, and the inroads made into the United States domestic market by EAI products (not only large transports but also commuter aircraft, helicopters, etc.) are well-known examples in the civil sector. Similarly, there have been successes in the military field, such as the major export programmes based on the Tornado and Mirage aircraft. These achievements have encouraged the expectation of a bright and successful future for the industry.

1.2 Early in 1986, however, the Commission of the European Community observed a number of developments in the world aviation scene which appeared to pose a threat to the continuation of the industry's success. In particular, it noted a marked resurgence in aeronautical research and exploratory development activity in the USA, allied to declarations of their Administration support for a new national thrust to reassert US leadership in world aeronautics. Other matters, notably the emergence of government-backed aeronautical industries in newly industrialised countries, and a recent major fall in dollar exchange rates, have subsequently given further cause for concern.

1.3 These observations prompted the Commission to approach the heads of nine major European aircraft companies to seek industry's views on the situation and on the question whether some action should be taken at Community level. It transpired that the Commission's perception of events coincided with the growing apprehension of the industrialists. As a result, it was decided that all the companies should work together to make an initial assessment of the situation. Later discussion between the Commission and the companies in the light of that joint assessment led to the decision to undertake the present EUROMART* study.

**Joint Study of EUROpean Cooperative Measures for Aeronautical Research and Technology.*

1.4 It was agreed that the study should concentrate on research and technology, with the following objectives:

"Against the background of an analysis of the market prospects and business strategy of the European Aeronautics Industry:

- To examine the essential technological capabilities which will be needed by that industry to meet a future competitive challenge in the world market place; and
- To determine the nature of major shortfalls, if any, which can be foreseen between those needs and the fruits of existing national and co-operative actions, both governmental and industrial; and
- To identify actions which might be appropriate to take at European level to repair the previously identified shortfalls; and, if justified by the results of this analysis,
- To provide a first-order definition of a coherent programme to perform the needed actions, including consideration of the necessary relationships to concurrent national and international actions."

2. CONDUCT OF THE STUDY

2.1 In February 1987 the nine aeronautical companies, (AERITALIA, AEROSPATIALE, AVIONS MARCEL DASSAULT – BREGUET AVIATION, BRITISH AEROSPACE, CASA, DORNIER, FOKKER, MESSERSCHMITT-BÖLKOW-BLOHM and SABCA) formally launched the EUROMART Study under shared funding by these companies and the Commission.

The work undertaken during the study (Fig.S1) covered:

- The current posture of the industry, and in particular the general problems it faces in the light of the recent changes in its competitive environment.
- The present and future market offered to the industry under the condition of an appropriate competitiveness.
- The requirements for such a competitiveness, and particularly the role of advanced technology in it.
- The identification of common requirements to acquire the technologies needed to ensure adequate competitiveness.
- The key technology areas and, in particular, those suitable for co-operation.
- The current European research and technology co-operations, in order to assess their merits and to determine if they adequately cover the perceived needs.
- The requirements for improved, enhanced and expanded co-operations, and the new measures which could meet these.

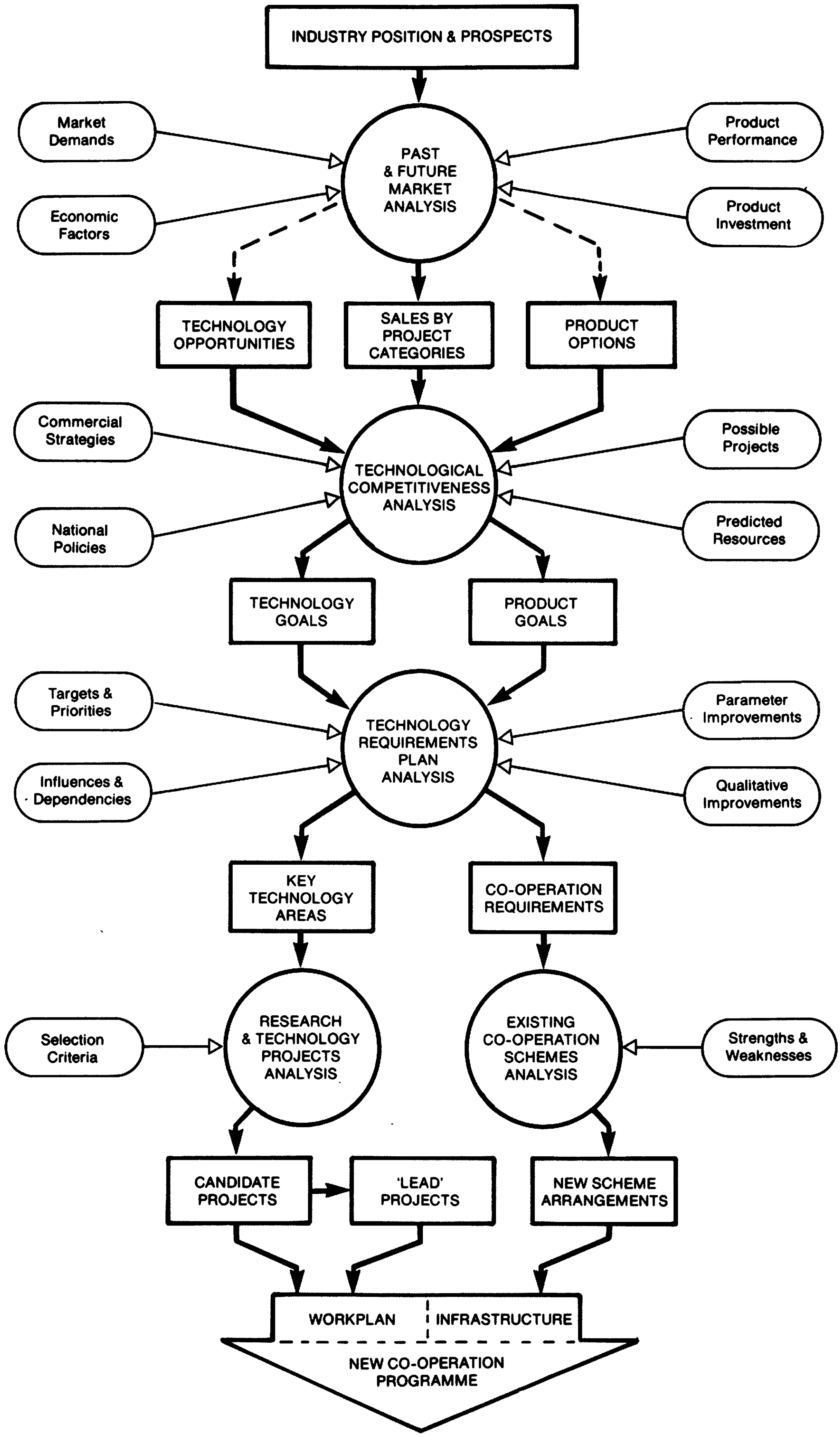

Fig.S1 EUROMART Study methodology

3. FINDINGS OF THE STUDY

3.1 A strong, prosperous aeronautics industry is a major asset to Europe, its economy, strength, the welfare of its people, and its culture.

3.2 In recent years, the industry has organised itself to compete strongly in world markets. Over the period 1980—1986 it obtained 23% and 28% of the world markets in civil and military aircraft, respectively. This represents an average annual delivery value of ECU 9,900 million, and a total value of ECU 69,500 million (1987 prices).

3.3 The industry aims to increase its overall share of the markets, which have been analyzed for the period 1987—2010. This aim, if realised, would represent a major increase in business with an average annual delivery value during the period of ECU 14,800 million and a total value over the 24 years of ECU 356,000 million (1987 prices). There will be a shift in emphasis to the civil market (32% share) from the military market (23% share).

3.4 Exports will continue to play a vital role in the future of the industry since the European home-market as a proportion of world demand is unlikely to increase greatly over the next twenty years. The United States industry will continue to have the substantial benefit of a very large home market.

3.5 The study confirms that there *is* substantial cause for concern about the future. In particular, the competitiveness of the industry in world markets is threatened by the intensification of technological competition resulting from the powerful drive underway in the United States, particularly in research and technology, which expresses a positive national determination to try to sustain its historical pre-eminence into the next century. A further factor adversely affecting European competitiveness is the decline in the value of the dollar.

3.6 There is a crucial relationship between technological competitiveness and commercial success in the aeronautics business and it is now clear that the EAI will be unable to maintain a state-of-the-art competitiveness under present conditions for the conduct of research and technology activities (funding, organisation, etc.). More and improved cooperation is essential. Furthermore, these joint efforts must be concentrated on those areas which analysis of future technological opportunities and product options has shown to be of key importance. The work of the study has yielded an inventory of such key areas. It remains now to find ways and means of securing and deploying the resources necessary to make such cooperative work effective.

3.7 In short, an improvement, enhancement and expansion of the technological capabilities of the European Aeronautics Industry is necessary if the industry is to continue to thrive. This can be achieved by adopting a consistent and interdependent set of common measures, the first two separately and jointly ensuring the cost-effectiveness of the third measure, namely:

- Increase co-operation in research and technology activities
- Concentrate on key technology areas identified in new joint requirements
- Provide additional funding resources to support this increased effort.

3.8 Specific proposals for cooperative work are contained in this report. Some sixty outline projects have been identified as candidates for new near-term and medium-term cooperative programmes, nine of these being in a sufficiently detailed programme proposal form for work to start. The experience and expertise built up within the industry during successful collaboration in the past should provide a firm basis for the extension of cooperation in research and technology now being proposed.

3.9 To give a reasonable prospect of success, the present level of expenditure on research and technology (excluding development) within the European Aeronautics Industry, excluding engine and equipment companies, needs to be built up well above the current ECU 370 million per year. This is best done in stages:

- Immediately, there is an urgent need to raise yearly expenditure by 25%
- Over the next five years there is a clear need for the build-up to continue such that, by the end of this period, expenditure will be 50—60% higher than it is at present
- By the end of the next decade it is foreseen that a doubling of expenditure will be necessary and should be prepared by further studies.

Industry cannot meet this level of funding from available resources.

3.10 The proposed changes must be coordinated with the plans and funding arrangements of the national government administrations concerned and with those of the European Community.

4. RECOMMENDATIONS

4.1 The companies who have conducted the EUROMART study submit this report to the EC Commission for its consideration. They invite the Commission:

- To take note of the report and its conclusions
- To take these conclusions into account in the formulation of its future programmes to encourage the competitiveness of Community industry and strengthen the Community science and technology base
- To take the initiative necessary to secure implementation of the needed actions.

EUROMART STUDY REPORT

EXECUTIVE SUMMARY

FOREWORD

This is the Executive Summary of the report on the work and findings of a study carried out by a group of nine European aircraft companies in the period from February 1987 to February 1988. The main focus of attention in the study was the status of, and future need for, research and technology acquisition in the European Aeronautics Industry. It is important to emphasise that in referring to "research and technology" this report confines itself to research and technology activities which are not project-specific and which precede the "development" phase during which the design and proving of a new or modified aircraft is carried out: technology demonstration activities are included in this definition of research and technology.

1. INTRODUCTION

Over the last three decades the European Aeronautics Industry (EAI) has recorded a number of major successes. The build-up of a powerful capability in the field of large transport aircraft (Fig.1), through cooperative working on the Airbus programme, and the inroads made into the United States domestic market by EAI products (not only large transport aircraft but also commuter aircraft, helicopters, etc.) are well-known examples in the civil sector. Similarly, there have been successes in the military field, such as the major export programmes based on the Tornado and Mirage aircraft. These achievements have encouraged the expectation of a bright and successful future for the industry.

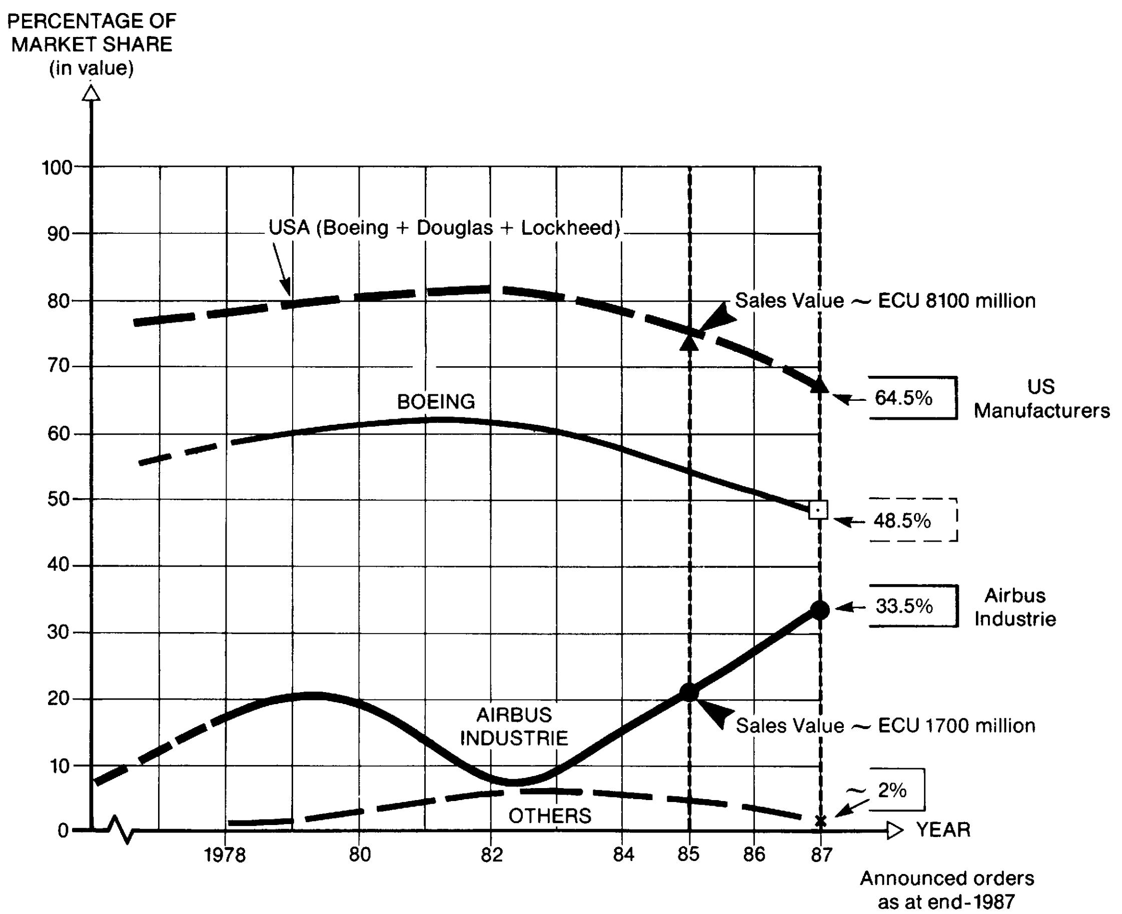

Fig.1 The market for large civil jet transport aircraft (more than 100 passengers) over the past ten years (1987 prices)

Early in 1986, however, the Commission of the European Community observed a number of developments in the world aviation scene which appeared to pose a threat to the continuation of the industry's success. In particular, it noted a marked resurgence in aeronautical research and exploratory development activity in the USA, allied to declarations of their Administration support for a new national thrust to reassert US leadership in world aeronautics. Other matters, notably the emergence of government-backed aeronautics industries in newly industrialised countries, and a recent major fall in dollar exchange rates, have subsequently given further cause for concern.

These observations prompted the Commission to approach the heads of nine major European aircraft companies to seek industry's views on the situation and on the question whether some action should be taken at Community level. It transpired that the Commission's perception of events coincided with the growing concerns of these industrialists. As a result, the companies decided they should work together to make an initial assessment of the situation. Later discussion between the Commission and the companies in the light of that joint assessment led to the joint decision to undertake the present (EUROMART*) study.

It was agreed that the study should concentrate on research and technology, with the following objectives:

"Against the background of an analysis of the market prospects and business strategy of the European Aeronautics Industry:

- To examine the essential technological capabilities which will be needed by that industry to meet a future competitive challenge in the world market place; and
- To determine the nature of major shortfalls, if any, which can be foreseen between those needs and the fruits of existing national and co-operative actions, both governmental and industrial; and
- To identify actions which might be appropriate to take at European level to repair the previously identified shortfalls; and, if justified by the results of this analysis,
- To provide a first-order definition of a coherent programme to perform the needed actions, including consideration of the necessary relationships to concurrent national and international actions."

In February 1987 the nine aeronautical companies (Aeritalia, Aerospatiale, Avions Marcel Dassault-Bréguet Aviation, British Aerospace, CASA, Dornier, Fokker, Messerschmitt-Bölkow-Blohm, SABCA) formally launched the joint EUROMART Study under shared funding by these companies and the Commission.

The work of the study was planned and subsequently managed by an Industry Management Group (IMG) composed of senior representatives of all participating companies, assisted by a project co-ordinator, as shown in Appendix A. The IMG has also undertaken the synthesis of

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**Joint Study of EUROpean Cooperative Measures for Aeronautical Research and Technology.*

overall conclusions. The detailed work of the study was performed by a number of expert working groups composed of senior staff drawn from the companies, as listed in Appendix A.

In the text which follows, Section 2 summarizes the main work of the expert working groups. Section 3 discusses the underlying features which the study indicates must be taken into account. Section 4 presents the perceived implications of the study findings, leading to a statement of the principal conclusions and recommendations in Section 5.

2. THE INDUSTRY'S STATUS AND PROSPECTS

2.1 The European Aeronautics Industry (EAI)

The companies which make up the EAI are involved in the design, manufacture and marketing world-wide of:

- Civil aircraft, covering commercial and regional transports, business jets, utility and light piston-engined aircraft
- Military aircraft, covering combat aircraft, military transports and trainers
- Rotary-wing aircraft for both civil and military uses
- Space and missile systems
- Associated "spin-off" endeavours.

These activities, in conjunction with those of the engine and equipment companies, form an overall aerospace industry (Fig.2). The EUROMART Study addressed the mainstream

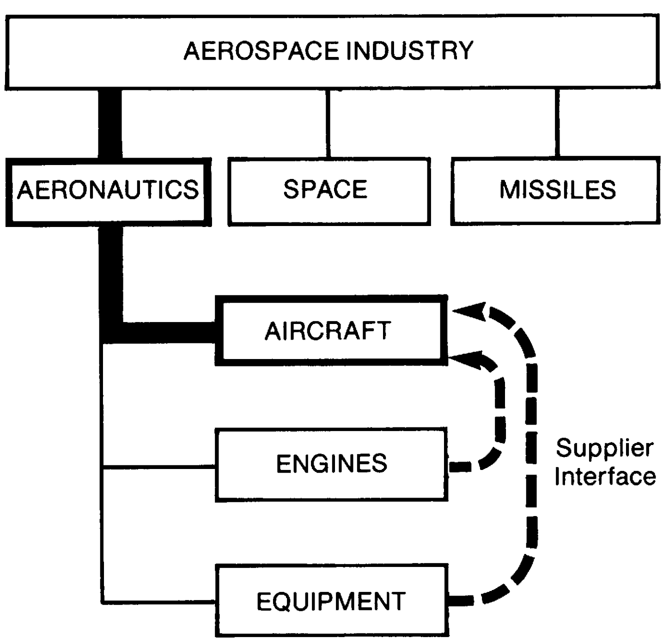


Fig.2 Aeronautics within the aerospace industry

AERONAUTICS part of the industry covering all AIRCRAFT-based activities, but excluding activities on space and missile systems. However, aircraft-based vehicles which will operate partly in space (trans-atmospheric aircraft, for example) were included. Some main aircraft configuration and technology opportunities are illustrated in Fig.3.

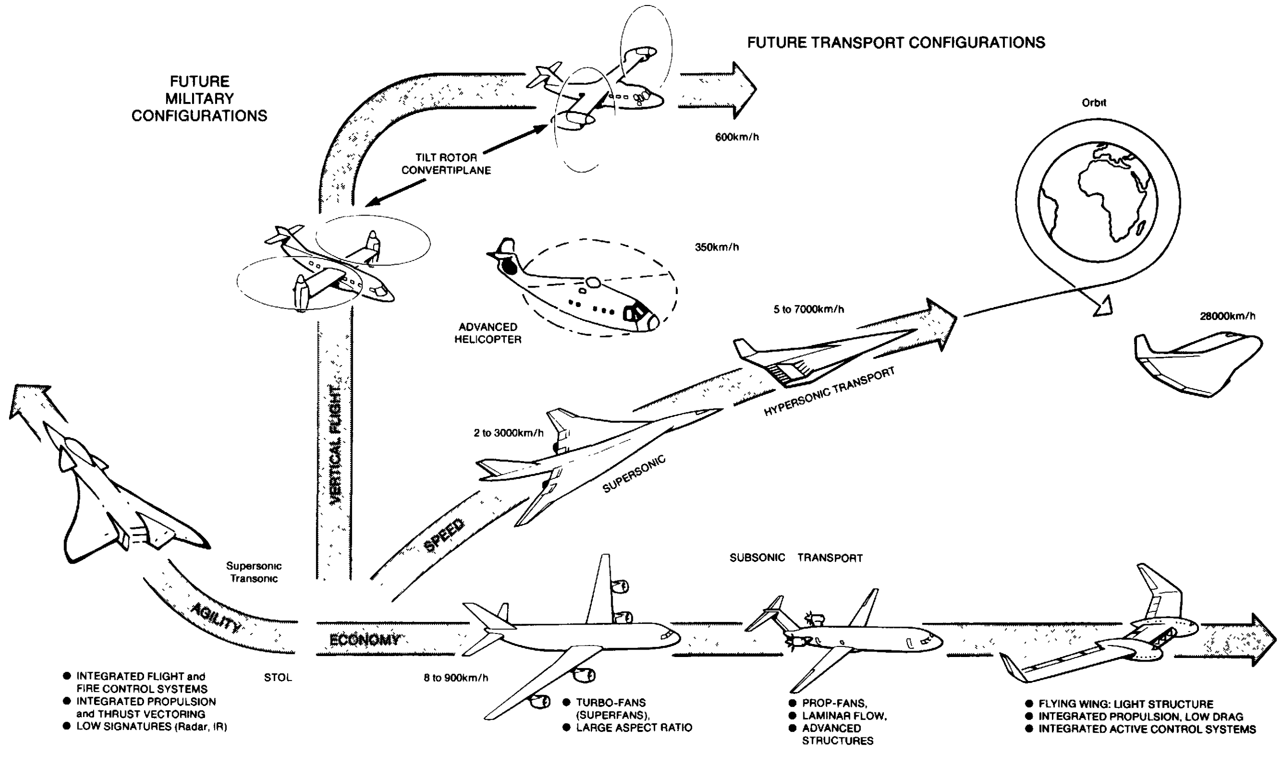
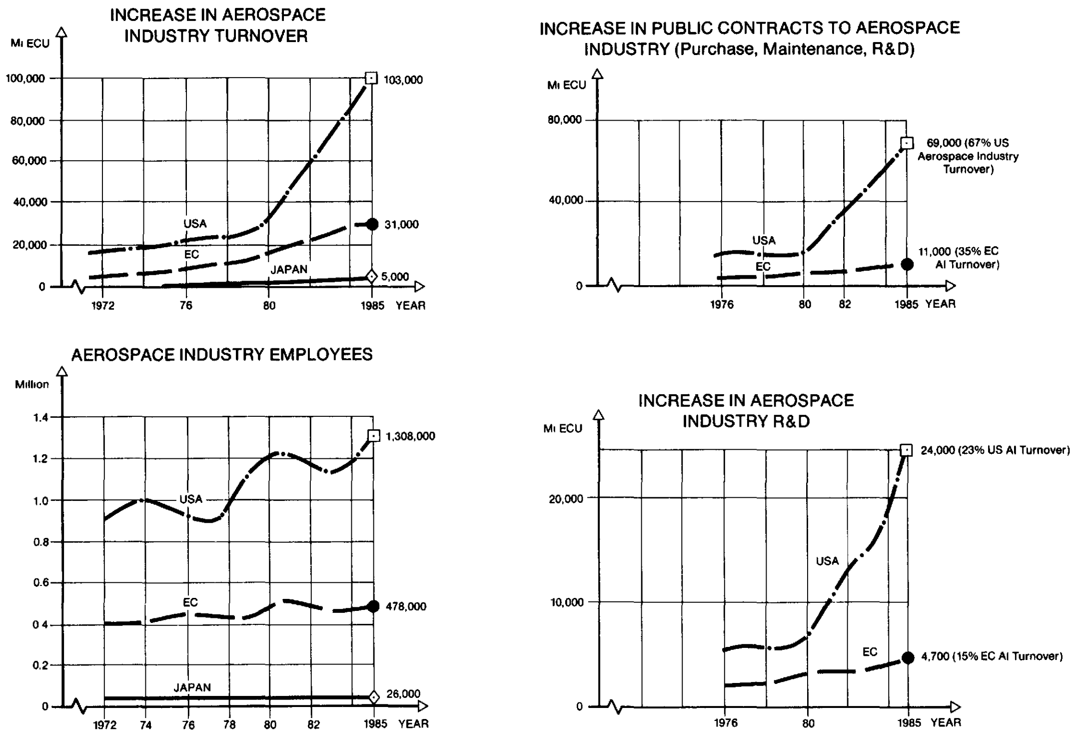


Fig.3 Some of the challenges and opportunities for the future

Strictly speaking, the aeronautics industry encompasses not only the aircraft manufacturers but also the aircraft engine and equipment companies, who have a large measure of design and development autonomy at the level of their products; it is therefore appropriate to treat them as a separate entity. But the customers of these companies are the aircraft manufacturers who have an integrating role and an overall responsibility for design, manufacture, and marketing of the complete end-product. Therefore, although the EUROMART Study concentrated on the aircraft 'part' of the industry, it took full account of the research and technology interfaces with the supplier 'part' of the industry, in line with its integrating role.

To set the study in context, it is appropriate first to consider the overall AEROSPACE industry (Fig.4) This industry in Europe employs some 480,000 persons. The equivalent US figure is around 1.31 million. The consolidated turnover of the European industry exceeds ECU 30,000 million, a six-fold increase since the early 1970s. The equivalent US industry turnover is ECU 103,000 million. EAI exports outside Europe represent 30% of turnover (the figure for the aircraft sector alone is about 40%). The average ratio of R & D expenditure to the European Aerospace Industry turnover is near 15%. The US industry ratio is markedly higher, at about 25%. (These values are based on 1985 data.)



Ref. — The European Aerospace Industry - EC Commission/Rep III/53788EN - Brussels, 1/02/1988
— National Science Foundation - USA.
— Patterns Of Resources Devoted To Research & Experimental Development - OECD Study

Fig.4 Surge in United States aerospace industry

Turning to the EUROPEAN AERONAUTICS INDUSTRY, as previously defined (that is, aircraft interests, but excluding engine and equipment companies), the Study Group's estimates for the current (1987) situation, based on EC 1985 data, are:

	European Aeronautics Industry
Number employed	† 200,000
Annual turnover	ECU 16,000 million
Annual R&D expenditure	ECU 2,400 million
*Annual research and technology expenditure	ECU 370 million

Over the last thirty years the EAI has successfully built up both separate and joint capabilities in research, design, testing, manufacturing and marketing which has enabled it to establish its present position as a major world supplier, rather than deteriorating into the role of a license-build or sub-contractor industry. Furthermore, based in large part on the successful major collaborative ventures indicated in Figure 5 the industry has over the last two decades produced technically proficient products which have achieved strong penetration (25%) of the highly

*Research and Technology excludes the project-specific development content of R&D.
†Depending on assumptions made, this figure could be 180,000.

competitive civil aircraft world market. A similar level of market penetration has been achieved with military aircraft, again including major export successes.

	AS	AMD-BA	AIT	BAe	CASA	DORNIER	FOKKER	MBB	SABCA	OTHERS
CIVIL AIRCRAFT										
Airbus A300/310/320/330/340	●			●	●	●	●	●	●	
ATR 42/72	●		●							
Concorde	●			●						
Fokker F.27/Fo-50, F.28/Fo-100		●					●	●	●	●
MILITARY AIRCRAFT										
Jaguar		●		●						
Tornado			●	●				●		
Alpha Jet		●				●			●	
EFA			●	●	●	●		●		
Transall	●							●		
Atlantic -1/-2	●	●	●			●	●		●	
HELICOPTERS										
Puma	●								●	●
Gazelle	●									●
Lynx	●									●
EH 101									●	●●
HAP - HAC/PAH 2	●							●		●
NH 90	●						●	●		●
A129 LAH					●		●			●

OTHERS: SHORTS AGUSTA WESTLAND

Fig.5 Some of the European Aeronautics Industry's collaborative programmes

The acquisition and application of new technology has played a key role in these developments with the increasing complexity and sophistication which is necessary to achieve competitive performance on a cost-effective basis.

A very important characteristic of the EAI, when compared with other industries, is its long product cycle length (10—30 years) together with a long cycle of new technology development (5—15 years); thus, long-term projections and long-term commitments are key business factors, as Figure 6 indicates. These factors, together with involvement in defence and space projects, will continue to require the close relationship with governments which has long been a distinctive feature of the industry.

There are new threats to the EAI which can seriously affect its future. The very success which the industry has built up has been a major contributory factor in stimulating the vigorous US national determination to secure its own dominance in aeronautics into the next century, with aeronautics research and technology playing a key role. A further danger, which should not be underestimated, is of the EAI being squeezed between the USA, the world leading power in

THE AERONAUTICS INDUSTRY'S
VERY LONG PRODUCT-CYCLE LENGTH DEMANDS

LONG-TERM PLANS + SUBSTANTIAL LONG-TERM INVESTMENTS, ON

because it requires -----

5-10 YEARS
to develop a new
technology, based on ------------------- ADVANCED RESEARCH,

+

5 YEARS (approx.)
to apply the technology ------------------- DEVELOPMENT,
to a new product

+

10 YEARS (approx.) AND PRODUCTION
of production, to yield a ------------------- proper return on investment

Figure 6

terms of allocation of resources and general support to its aeronautical industry, and emerging newcomer industries in developing countries, relying on the firm resolution of their governments and enjoying advantageous operating conditions. Indications of this "sandwich" effect can be seen in the pressures on Airbus Industrie from the USA, the indirect support provided to US civil aircraft manufacturers, and the promotion of American fighter aircraft sales in Europe on the one hand, and the penetration of military trainer aircraft from South America into Europe on the other hand.

The European Aeronautics Industry is poised to continue its present success into the future. But the special factors just outlined, when coupled with other contributory effects such as the falling dollar exchange rate, US legislation limiting technology transfer, and different conditions for financing sales, make it evident that this future success is not certain. This report concentrates on the research and technology aspects of this problem and is structured on the study methodology illustrated in Fig.S1, in the Synopsis.

2.2 Analysis of Aircraft Markets — Past and Future

Any consideration of the future prospects of the European Aeronautics Industry must start from an analysis of its market. The EAI market necessarily encompasses the whole of the world (although Warsaw Pact countries and China were not included in the detailed analysis), since the European domestic market is too small relative to the size of aeronautical investment to give a proper return on investment. In this context, sales performance over the period 1980—1986 was reviewed in terms of units, value, and market share, and the analysis then extended to forecast the same breakdown for the next 24 years (1987—2010), all values being taken at 1987 prices. The results of the analysis are shown in Figure 7.

AIRCRAFT CATEGORIES	AIRCRAFT DELIVERED 1980—1986					FORECAST DELIVERIES 1987—2010				
	All Manufacturers		EEC Manufacturers only			All Manufacturers		EEC Manufacturers only		
	Units	Value (Bln ECU 1987)	Units	Value (Bln ECU 1987)	Value of Market Share (%)	Units	Value (Bln ECU 1987)	Units	Value (Bln ECU 1987)	Value of Market Share (%)
CIVIL										
Commercial Transports										
>360 Seats	228	19.03	0	0	0	1450	148	0—200	0—20	0—14
281—360	211	13.20	0	0	0	1650	109	550	36	33
201—280	438	21.56	283	14.77	68.5	1600	84	650	34	40
141—200	734	17.43	0	0	0	3250	79	1150	30	38
81—140	764	13.02	160	2.00	15.4	2050	34	750	12	35
51—80	2	0.02	0	0	0	2000	16	1250	10	63
20—50	794	3.46	530	2.07	59.8	2350	11	1050	5	45
15—19	967	1.80	226	0.50	27.8	1900	5	750	2	40
Supersonic						0—120	0—25	0—50	0—10	0—40
General Aviation										
Business Jet	2401	15.10	504	4.42	29.3	8600	60	2150	21.5	36
Private	16000	2.00	n.a.	n.a.	n.a.	70000	10	10500	0—1.5	0—15
Utility	n.a.	n.a.	n.a.	n.a.	n.a.	1600	5.4	800	3.5	65
Helicopters	5210	9.23	1980	2.69	29.1	12000	22	4800	8.5	40
Convertiplanes	—	—	—	—	—	600	9	150	1.5	17
CIVIL SUB-TOTALS		115.85		26.45	22.8		592—617		164—196	28—32
MILITARY										
Combat	6870	105.80	1650	27.65	26.1	22000	420	4800	74.0	18
Trainers										
Jet	1207	5.88	936	5.08	86.4	4000	30	2400	21.6	72
Turboprop	786	0.67	32	0.01	1.9	4000	4	0—500	0—0.5	0—13
Piston	596	0.15	344	0.09	60.0	1500	1	0—400	0—0.3	0—30
Transports										
Heavy	58	3.62	0	0	0	270	30	0	0	0
Large	209	2.90	25	0.33	11.4	1050	30	250	9.4	31
Medium	115	1.16	69	0.67	57.8	400	4	250	2.5	63
Light	452	1.07	153	0.36	33.6	1650	6	750	2.5	45
Special-purpose	785	13.87	142	0.73	5.3	1900	55	450	6.3	11
Helicopters	4010	17.30	1820	8.10	46.8	19200	93	7700	37.4	40
Convertiplanes	—	—	—	—	—	1500	33	400	5.0	15
MILITARY SUB-TOTALS		152.42		43.02	28.2		706		160	23
GRAND TOTALS		268.27		69.47	25.9		1298—1323		324—356	25—27

Notes: 1 Bln (1 Billion) = 1000 Millions
1 ECU = US $1.2 (1987 economic conditions)
n.a. = data not available

Fig.7 Analysis of aircraft markets — past and future

Turning first to the *civil sector* with its increasing customer demand, world passenger traffic has doubled in the last ten years and is forecast to double again in the next ten, as shown in Figure 7. The EAI has built up an impressive increase in world market share, from 5% in the early 1970s to nearly 23% in recent years. Over the past seven years the cumulative value of this 23% share amounts to ECU 26,450 million (an average of 3,778 million per year). There is clear potential for a 32% market share over the next 24 years with a cumulative value approaching ECU 200,000 million (an average of 8,200 million per year). Some of the new projects involved will have a commercial life far beyond the year 2010, with a continuing market potential. Furthermore, the potential of China with its large and growing market has still to be exploited. In

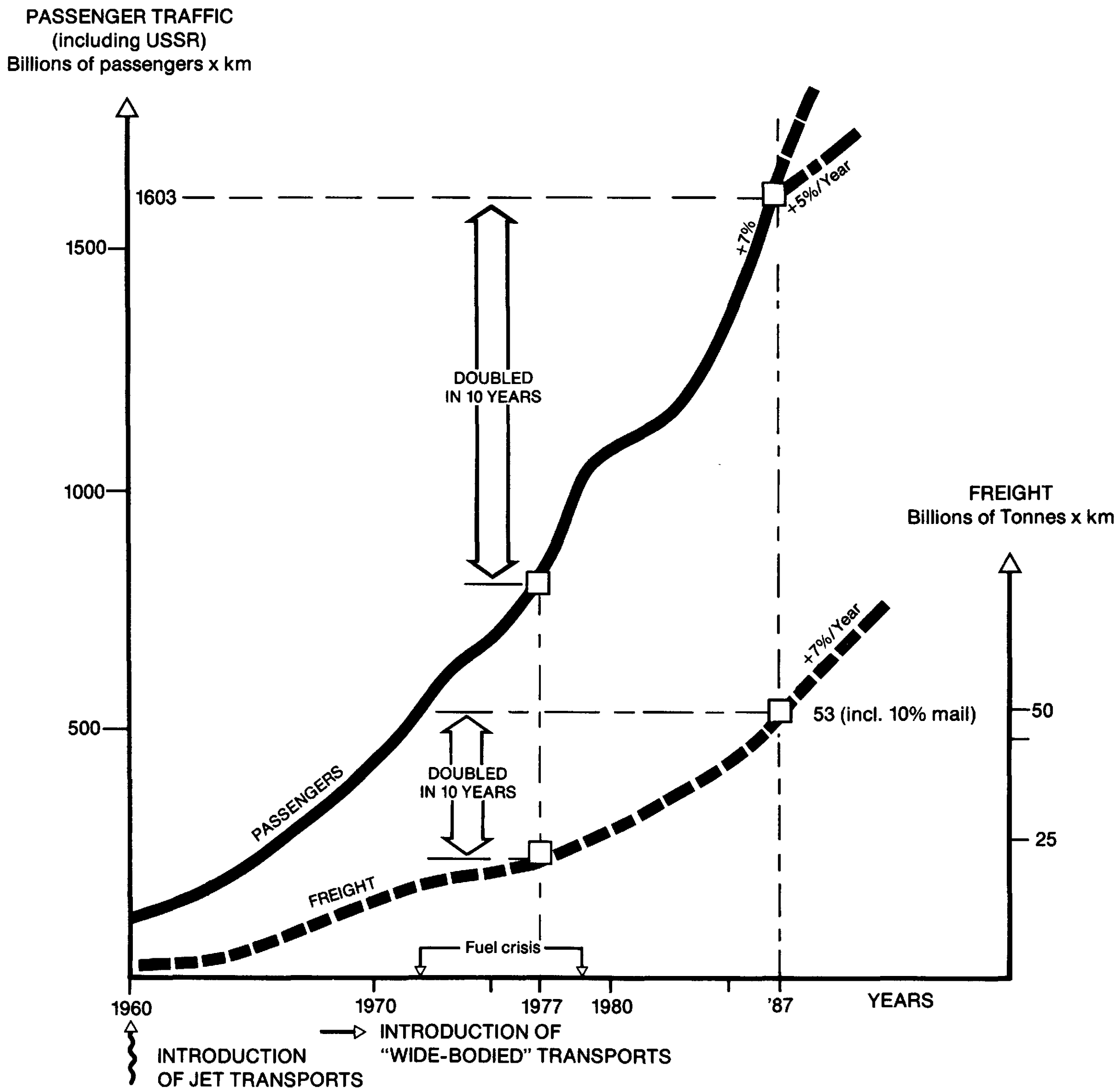


Fig.8 World scheduled airlines traffic

fact, the whole area of the Pacific Basin is expected to be a major growth region over the period of the forecast.

In the *military sector* the EAI has improved its market position as a result of embarking on collaborative programmes. Over the past seven years it has obtained 28.2% of the world market, valued at ECU 43,000 million (an average of 6,100 million per year). It is expected that the share of Gross National Product dedicated to defence spending will fall in future years. Nevertheless, a 23% market share over the next 24 years is projected, with a cumulative value of ECU 16,000 million (an average of 6,600 million per year).

Overall, it emerged from the study that, using plausible assumptions for economic factors (rate of growth of the world product, the price of oil, etc.), the EAI can substantially increase its level of sales by maintaining or improving its current percentage share of an expanding world market, provided its competitiveness can be maintained. As indicated in Figure 9, this global result, which envisages a significant shift from military to civil aircraft sales, can be summarised in terms of market performance and potential (at 1987 prices) as follows:

EC MANUFACTURERS ONLY

1980—1986		1987—2010	
Average annual delivery value	ECU 9,900 million	Average annual delivery value	ECU 14,800 million
Total delivery value over period	ECU 69,470 million	Total delivery value over period	ECU 356,000 million
Market share over period (by value)	25.9%	Market share over period (by value)	26.9%

2.3 Role of Technology in Future Competitiveness

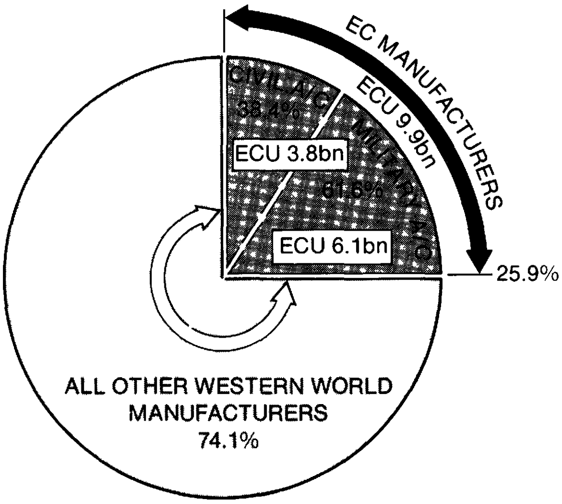
It results from the above considerations that to maintain or increase its share of the market, whether through direct competition with non-European industries or by co-operation on an equal footing with non-European partners, the EAI must increase its competitiveness in support of the range of future project categories which it aims to cover. This competitiveness will depend on many factors. Some of these are internal company factors (quality of management, commercial skill, cost of labour, specialist expertise, etc.). Others are special external factors, some of the most important of which have already been mentioned.

The aeronautics industry differs from most other industries in that technology in all its aspects is one of the most, if not the most important factor affecting competitiveness; Figure 10 gives some indication of this. Aeronautics products have a high level of technological dependence and complexity; technological advances have an exceptionally high gearing effect on product competence, product appeal, and hence break-even time-scales. Scientific advances offer continuously increasing opportunities for their innovative application to products. Competition will therefore be led by those who are in a position to exploit new technological opportunities at the earliest stage. Hence, the political, economic and industrial options for the future of the EAI are formulated to a substantial extent in successful research and technology efforts of today.

This technological environment demands from the EAI a consistently high level of competence across a very wide range of advanced design and manufacturing techniques. This range extends from sophisticated analysis techniques used for aerodynamic and structural design through the evaluation and use of advanced materials, the integration of electronic technologies into complex operational systems, to new types of manufacturing methods.

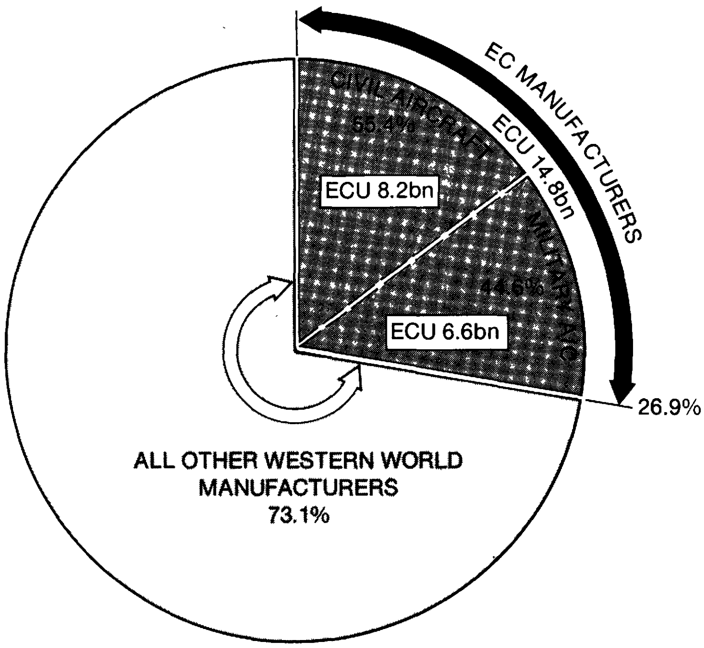
ALL-AIRCRAFT MARKET ANALYSIS, PAST AND FUTURE

Charts show average annual value (at 1987 prices) of aircraft deliveries over the periods indicated



PERIOD 1980-1986

Average annual value of total market = ECU 38.3bn



PERIOD 1987-2010

Average annual value of total market = ECU 55bn

Figure 9

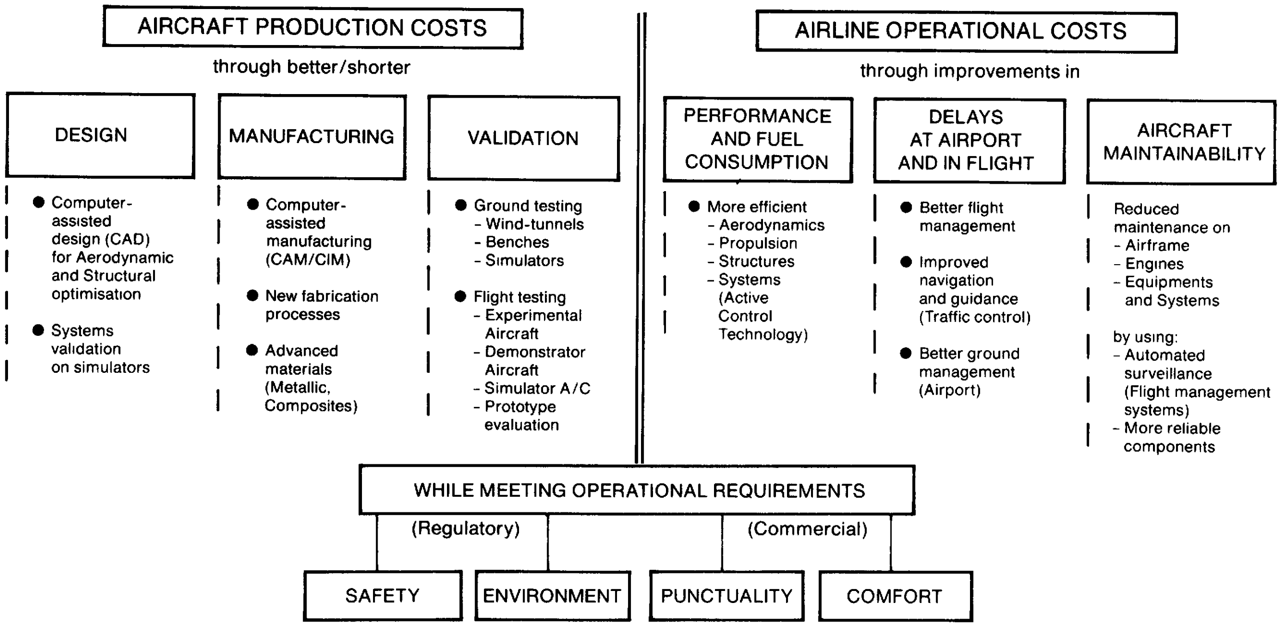


Fig.10 Competitive air transport demands continuous improvement in.....

The required level of technological competence can only be achieved by persistent and consistent efforts in research and technology which, in turn, implies that EAI strategy has to span long periods of time. As standard orders of magnitude, five to ten years are required to develop a new technology; an additional five years are required to incorporate it in a new developed product; and this product would in turn have to be manufactured for more than a decade in order to give a proper return on investment. For example, the development of a full-authority autoland capability for civil transport aircraft, which offers virtually unlimited operation in all weather conditions, took about 12 years from research to first production flight. This development was based on previous basic technology work and generic research, conducted in close cooperation between the aircraft manufacturers and the equipment industry.

The acquisition of the required technological capabilities must rest largely on development work conducted within Europe. The EAI cannot buy or otherwise obtain this upgraded technological skill from its US competitors without giving up the independence it wishes to maintain. Furthermore, in seeking this upgraded technological skill within Europe industry cannot rely solely on research institutions, for they are not in the best position to link the technological goals with operational and industrial constraints, or long-term industrial strategy. Although these institutions are, and will continue to be, major contributors to the extension of EAI capabilities, it is clear that such an extension must rest largely on autonomous efforts within, or under the guidance of, industry itself.

While emphasizing the European aspect of EAI technology, it must not be forgotten that some future projects, particularly high-speed (supersonic, hypersonic) transports, will almost certainly need to involve partners outside Europe (e.g. USA, Japan) to cope with the enormous technical and financial challenges. In these cases, early and adequate European research and technology in the relevant areas is still essential if fair and proper partnership conditions are to be negotiated for the European aeronautics industry in such international programmes. In most areas this means striving for a level of knowledge and expertise comparable with; or even exceeding, that of potential partners.

In short, to achieve future technological competitiveness, industry must make continuous efforts to maintain a "leading edge" position in a very wide range of advanced techniques across the spectrum of basic technology, enabling technology, and applications technology. Major opportunities across this technology spectrum over the next two decades are perceived.

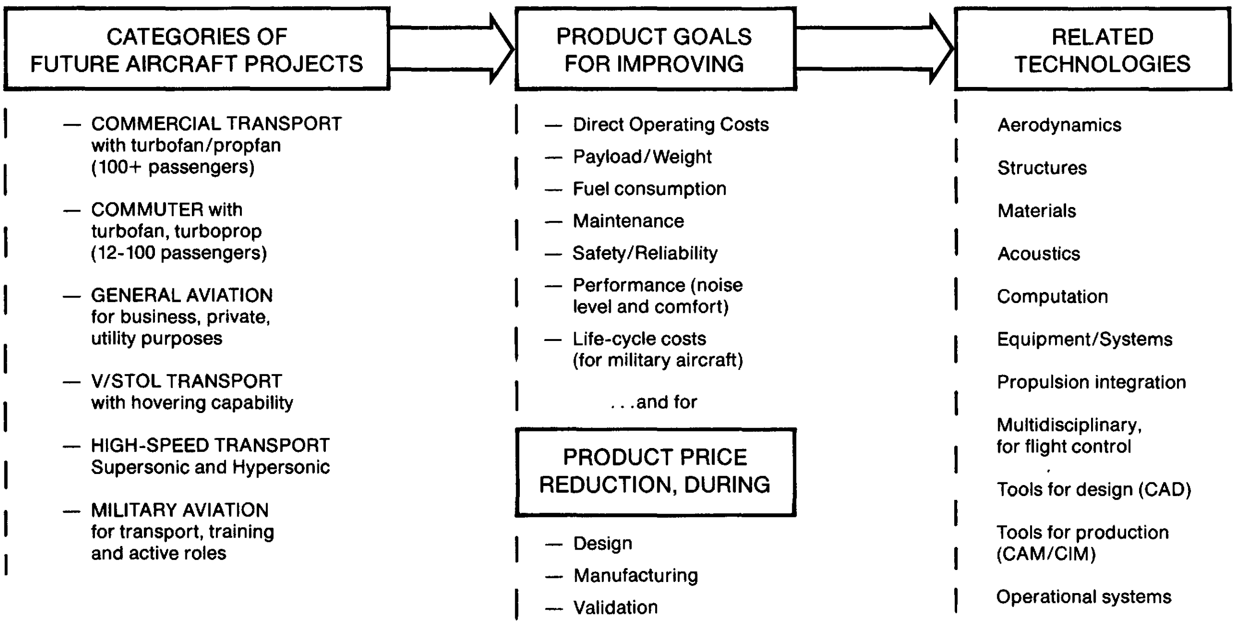


Fig.11 Common technology requirements plan for future products

2.4 Common Technology Requirements Plan

The content and level of the technological endeavours needed either to resist outside competitors or to co-operate with them under mutally beneficial conditions, must be judged on the balance between technological opportunities on the one hand and product options on the other. This judgement must be related to the range of possible future aircraft projects, the availability of resources, the commercial strategies of the individual companies, and the necessary consistency with national policies.

With this philosophy in mind the Study Group set about preparing a commonly-agreed technology requirements plan identifying and listing under a standard set of headings all the possible aircraft projects of concern to the EAI likely to arise over the next 20—30 years. These headings, or categories, cover all the major types and sizes of civil and military aircraft (Figure 11).

For each of these future 'project categories' realistic 'product goals' were then identified, in terms of influences and dependencies (operational systems, infrastructure, etc.), qualitative improvements (capacities, new features, etc.), and parameter improvements (performance, payload, weight, fuel consumption, noise level, etc.). Next, related 'technology goals' which can be achieved by a continuing and expanded effort on research and technology were identified, in terms of opportunities, targets, and priorities. Figures 11 to 13 illustrate these relationships.

Then followed an assessment process to determine the general level of effort required to support the technological endeavours needed for competitiveness. This assessment was based

TECHNOLOGY \ AIRCRAFT CATEGORY	COMMERCIAL TRANSPORT		COMMUTER		GENERAL AVIATION		VTOL/STOL		HIGH-SPEED TRANSPORT		MILITARY AVIATION	
	1.1 Narrow body >100 pax	1.2 Wide body >200 pax	2.1 12 to 40 pax	2.2 40 to 100 pax	3.1 Business	3.2 Private, Utility	4.1 Conv Heli-copters	4.2 Adv V/STOL, Conver-tiplanes	5.1 SST	5.2 HST	6.1 Subs Transp and Trainers	6.2 Super-sonic Active role A/C
1 AERODYNAMICS	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●
2 STRUCTURES	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●
3 MATERIALS	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●
4 ACOUSTICS	●●	●●	●	●●	●	●	●●	●●	●●●	●●	●	●
5 COMPUTATION	●●●	●●●	●	●	●●	●	●●●	●●●	●●●	●●●	●●	●●●
6.1 AIRBORNE COMPUTING	●●	●●	●	●	●	■	●	●	●●	●●●	●●	●●●
6.2 AIRBORNE OPTO-ELECTRONICS	●●	●●	●	●	●	■	●●	●	●●	●●	●●	●●●
6.3 EQUIPMENT and SYSTEM - GENERAL	●●	●●	●	●	●	■	●●	●	●●	●●	●●	●●●
7.1 ENGINE/AIRFRAME INTEGRATION	●●	●●	●●	●●●	●●	●	●	●●	●●●	●●●	●●	●●
7.2 PROPULSION - GENERAL	●●	●●	●●	●●	●●	●	●	●●	●●●	●●●	●●	●●
8.1 SYSTEMS INTEGRATION	●●	●●	●●	●●	●●	●	●●	●●●	●●●	●●●	●●	●●●
8.2 MULTIDISCIPLINARY - GENERAL	●●	●●	●●	●●	●●	●	●●	●●●	●●●	●●●	●●	●●●
9 DESIGN TOOLS (CAD)	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●
10 PRODUCTION TOOLS (CAM/CIM)	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●
11 OPERATIONAL SYSTEMS	●●	●●	●●	●●	●●	●	●	●●	●●●	●●●	▲	▲

■ MANDATORY FOR SPECIAL-PURPOSE/UTILITY AIRCRAFT (ENVIRONMENTAL CONTROL, FIRE-FIGHTING, COASTAL SURVEILLANCE, ETC.)

▲ INDEPENDENT SOPHISTICATED MILITARY EQUIPMENT FOR AIR FORCES

Fig.12 Relative importance of the various technologies to the identified future aircraft project categories. (Highest importance is signified by •••, lowest by •)

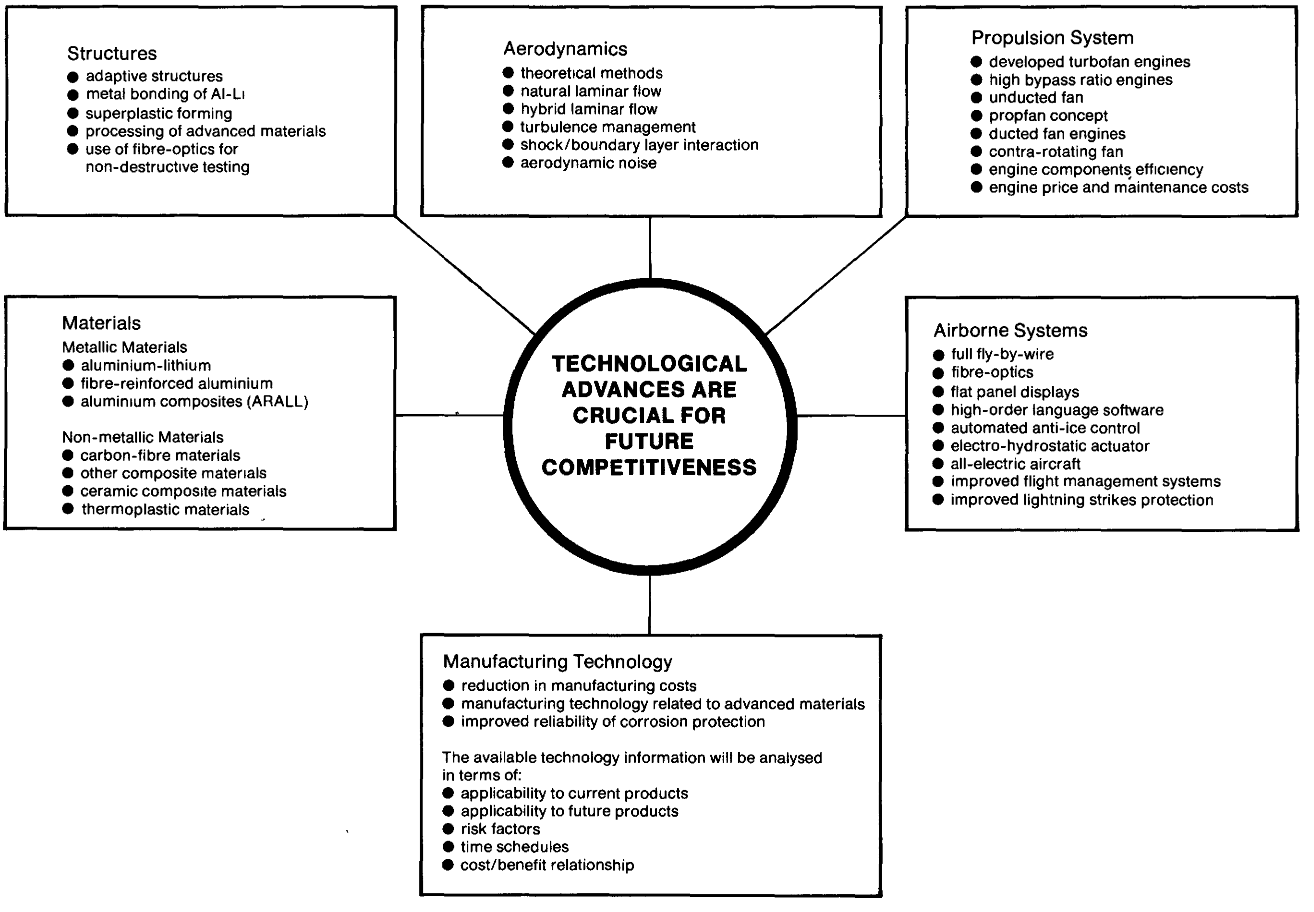


Figure 13

on the market analysis of the perceived range of future projects, an analysis of the identified product goals and technology goals, and the judged relationship with other factors such as lead times, resource distributions, and business priorities. The results of this assessment (Figure 14), clearly show that a substantial increase in the current level of research and technology effort over the next two decades is necessary.

While the accuracy of the level-of-effort estimate in Figure 14 must clearly diminish for years in the next century, there is no reasonable doubt that an urgent drive for the increasing effort indicated over the next ten years is essential.

Under the present conditions prevailing in Europe the available resources are well below those needed to secure this required increase in level of effort on research and technology. If measures can be taken to overcome this problem then the identified common technology requirements plan for the EAI will form a sound basis for the progressive planning and implementation of a co-operative work programme to meet the industry's technological objectives over the next two to three decades.

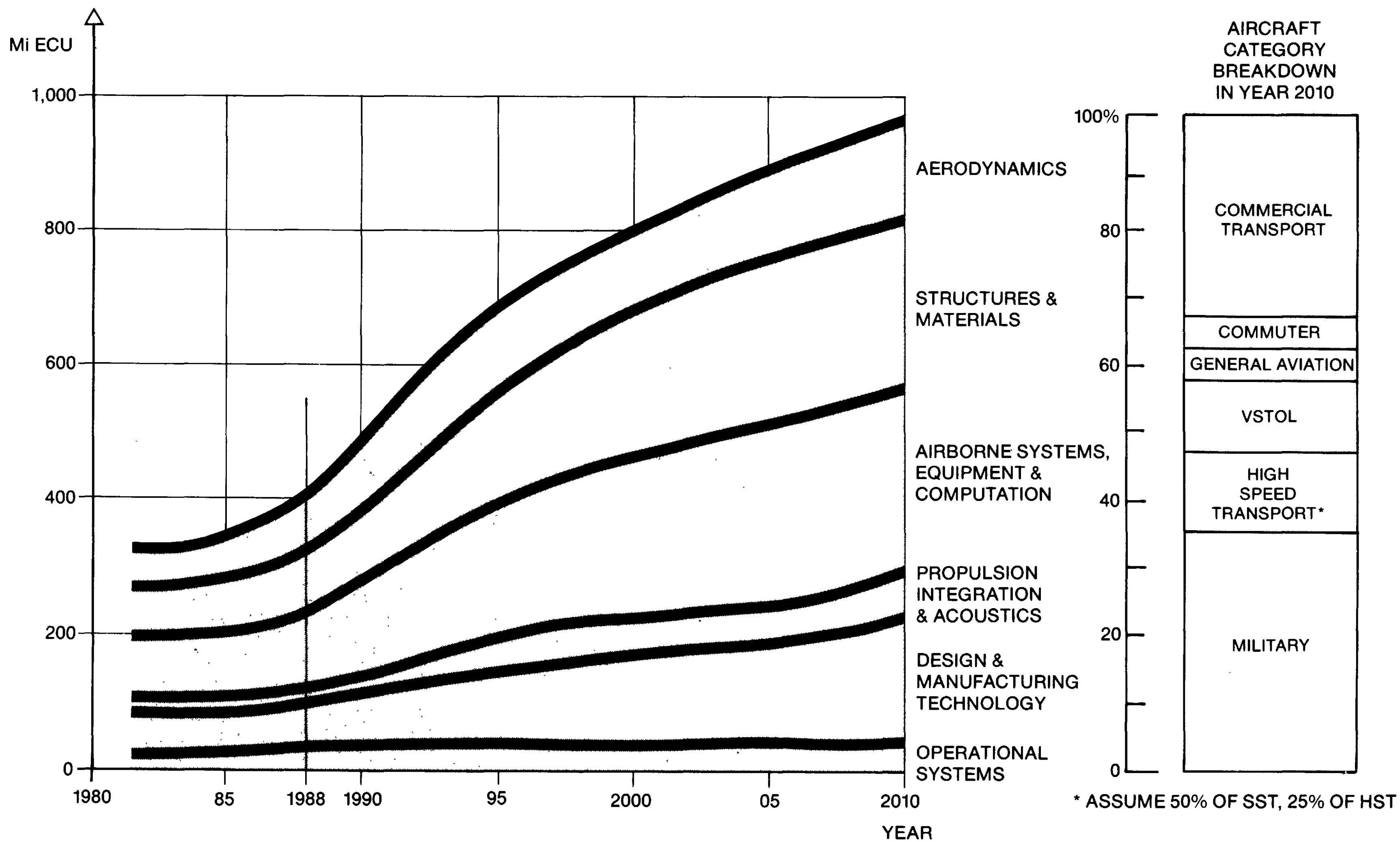


Fig.14 Future research and technology funding scenario

2.5 Key Technology Areas

Following completion of the requirements investigation described in Section 2.4, further analysis was undertaken to derive key technology areas in relation to the identified technology and product goals. The analysis covered the totality of the EAI requirements, leading to identification of key technology areas under the following established categories:

- AERODYNAMICS
- STRUCTURES
- MATERIALS
- ACOUSTICS
- COMPUTATION
- AIRBORNE SYSTEMS AND EQUIPMENT
- PROPULSION
- MULTI-DISCIPLINARY
- DESIGN TECHNOLOGY
- MANUFACTURING TECHNOLOGY
- OPERATIONAL SYSTEMS

More information concerning these areas appears in Appendix C.

An essential feature of aeronautics research and technology must be emphasised at this point. There will always be the rare occasion on which a major breakthrough in technology occurs. Also, at any point in time there will be important 'thrust areas' within the above categories — for example, computational fluid dynamics under Aerodynamics; advanced composites and the use of new alloys under Structures; open rotors and advanced propellers under Propulsion; advanced cockpits and active controls under Airborne Systems. But the crucial progress being sought to maintain technological competitiveness will in the main stem from the aggregate of developments and improvements across the whole range of key areas indicated above. Such improvements will be incorporated in projects on a cumulative basis, with major benefit; this is illustrated in Figure 15 where the cumulative benefit on a large transport aircraft can be equivalent to the total price of four aircraft from a fleet of ten operating over a period of 15 years, which is a typical lifetime for a 'first operator'. This "broad front" approach must be central to any framework for EAI technological progress; however, within this framework there must also exist the capability to fully exploit any single technological breakthrough if and when it occurs.

As a general point to note, there appear to be no reasons which preclude a substantial level of research co-operation in any of the technology areas listed above. Difficulties in co-operation should arise only on specific detailed technical issues, either for government policy reasons, or industrial strategy reasons.

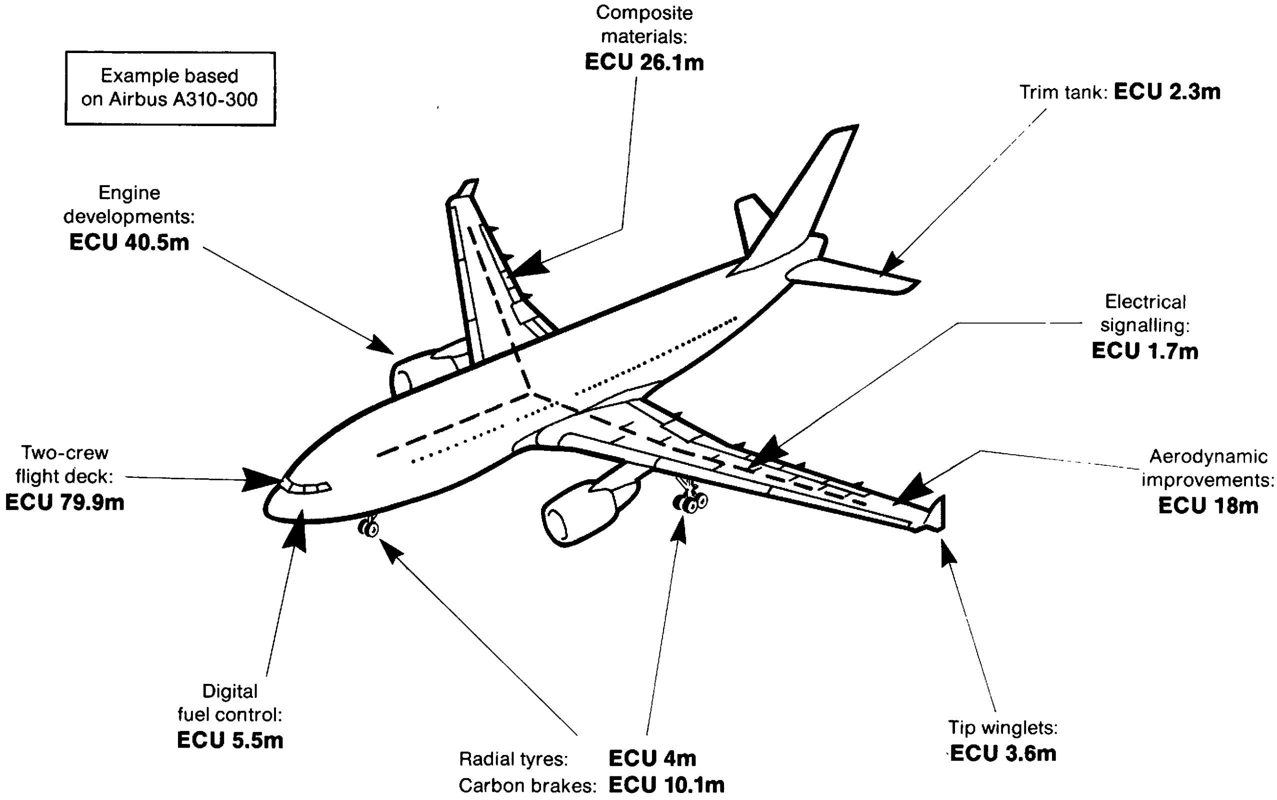


Fig.15 Cumulative benefit of technology improvements on a large transport aircraft. (The total savings shown (which exclude the development cost of the improvements) amount to ECU 192 million for a fleet of ten Airbus 310-300 aircraft over an operating period of 15 years, which is a typical lifetime for a 'first operator'. This saving is roughly equivalent to the price of four aircraft.)

2.6 Candidate Projects

Consideration of specific topics for the envisaged joint programmes have so far resulted in the establishment of:

- A comprehensive topics list covering as completely as possible all important aeronautical technology areas.
- Over 100 potential joint research projects in the various key technology areas.
- Over 60 outline projects identified as candidates for a new co-operation programme. (These have been assigned first, second, and third priority grading following evaluation against agreed criteria.)
- Relevance of these selected outline projects to the envisaged main categories of activity, that is, basic research; applied research; demonstrators; support facilities; standardisation.

The 60 outline projects constitute the basis for development of detailed candidate projects for additional co-operation. Indeed, a number of these projects have already been so developed as 'lead projects' for increased collaboration (see Appendix E).

2.7 New Overall Approach to Cooperation

There already exist various schemes for cooperative working within the Community which deal with research and technology and involve to varying degrees the EAI. Although these offer considerable benefits, are appreciated by the EAI, and must be continued, the fact is that none of them exhibits simultaneously all the features which the industry would wish to see, namely:

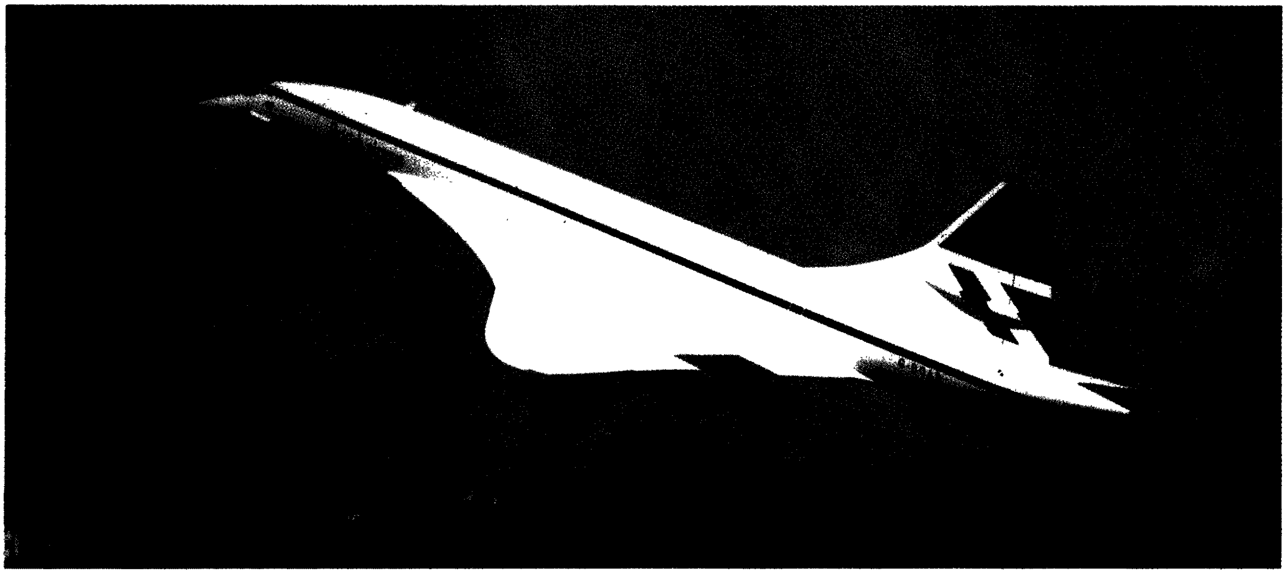
- To be dedicated to aeronautical research and technology
- To indicate the interests of all EC member states with aeronautics industries
- To give the EAI a leading role in defining and carrying out the programme
- To improve the co-ordination between the EAI and aeronautical research establishments on a Community-wide basis
- To provide funding resources additional to those currently available from governments and companies.
- To establish a single common budget in order to promote enhanced co-ordination of research within the EAI.

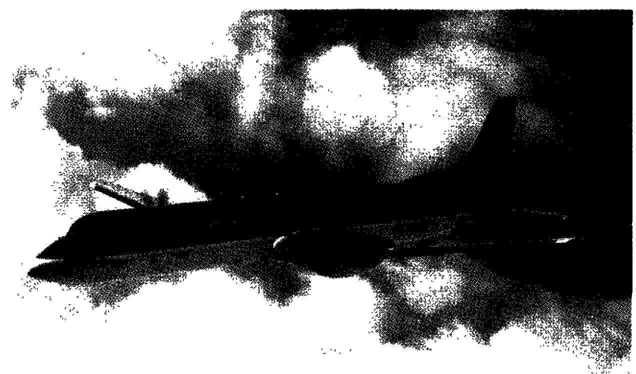
It is therefore considered that there is a need to develop a new form of co-operation, a scheme taking into account these six points. Because of its Community scope, the Commission could play an important role in the development of such a scheme.

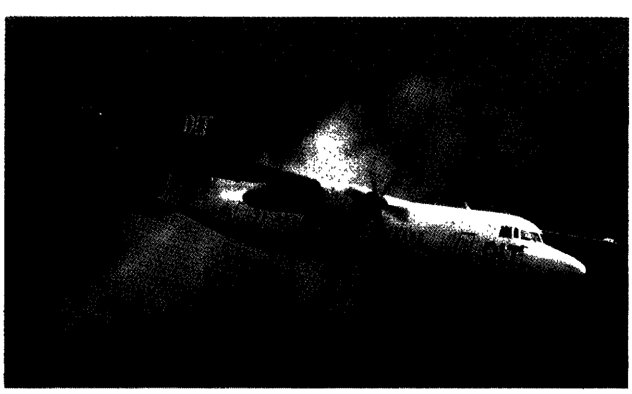
It would be neither necessary nor appropriate for the proposed new scheme of co-operation to compete with or displace existing national and co-operative research activities. It should be seen, rather, as a major reinforcement of, and complementary to, existing co-operative arrangements. It would nevertheless be necessary to take measures to ensure a close and harmonious relationship between the new and the established activities.

This proposed new scheme of research cooperation, established in a Community framework and under management arrangements taking full account of the interests of governments and of the EAI, is seen as an important and necessary means for providing the infrastructure for the common research and technology measures proposed in the report. (In such a structure EAI interests could be represented by a body similar to the existing EUROMART group.)

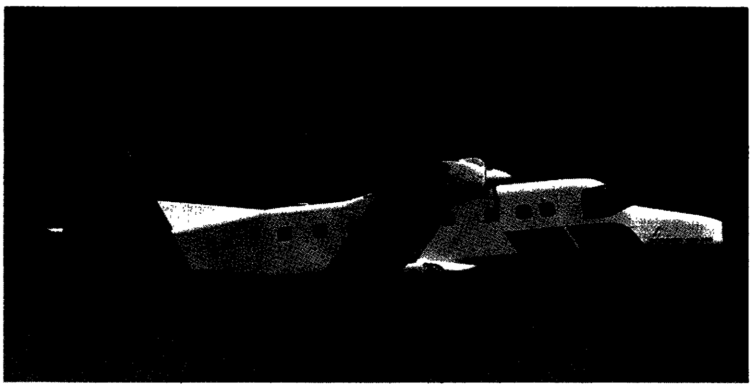
THE AIRBUS FAMILY



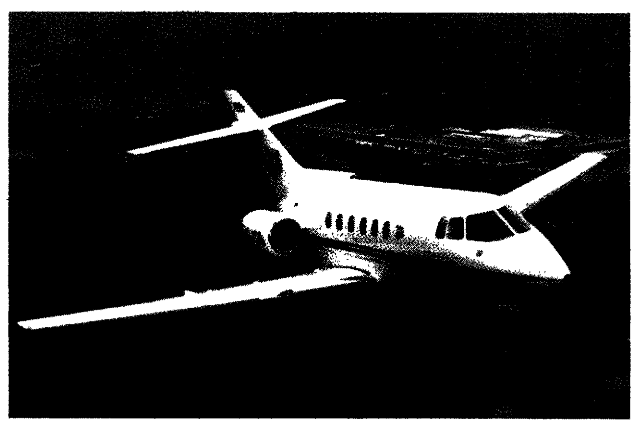


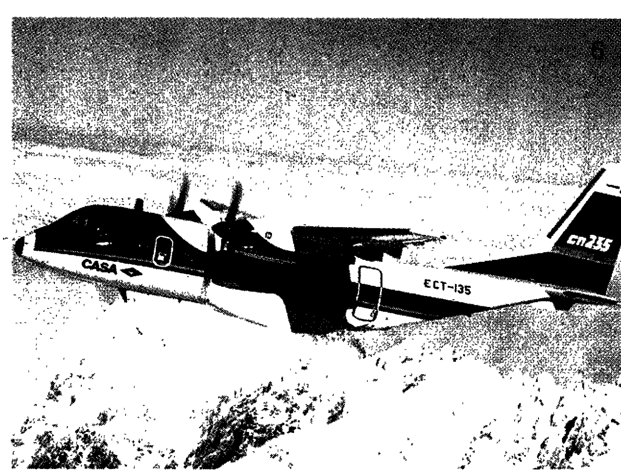


1 CONCORDE
2 BAe 146-100
3 Fo-100
4 Fo-50
5 BAe ATP
6 ATR-42
7 F-27-SAR



1 AEROSPATIALE HELICOPTER FAMILY
2 DO 228-200
3 FALCON 900 (top), F.50 F.20, F.10
4 BAe JETSTREAM
5 BAe 125-800
6 CASA CN-235





3. THE INDUSTRY'S VALUE AND VULNERABILITY

3.1 Value of the Industry to Europe

The cooperative ventures pursued by the EAI (Airbus, Concorde, Tornado, F.28/Fo-100, ATR42, etc.) over recent years are well ahead of those achieved in other industrial sectors, and have done much to promote faith in Europe and belief in its ability to succeed. A strong aeronautics industry should be recognized at the highest levels as an essential element in the promotion of a European identity. Moreover, it offers the smaller member states of the Community the opportunity to contribute to and participate in highly advanced technological programmes, and this is a further powerful factor in promoting European unity.

Air transport systems are essential to the well-being and economic efficiency of advanced nations. It is therefore desirable, wherever possible, to turn to a home-produced product which can contribute to maintaining the national level of civilisation.

Modern aircraft, being 'high-valued-added' products involving advanced technology, attract intense competition on world markets. With Europe able to provide such products, it has an invaluable asset in terms of international trade. The industry has a positive effect on the balance of trade for Europe and directly creates nearly half a million jobs. Europe's capacity for self-reliance in defence procurement is also highly dependent on the maintenance of a healthy aeronautics industry.

Apart from the direct commercial benefits, the existence of a European aeronautics industry in world markets confers substantial advantages in other areas, and helps to spread the economic and cultural influence of Europe.

Industry as a whole has been strongly influenced by the aeronautics industry, where the levels of skills and expertise needed have set high standards. The educational system, notably in France and The Netherlands, has benefited from this situation.

Also important are the spin-offs from the aeronautics industry, both by direct transfer or encouragement of innovations elsewhere, and by the movement of highly skilled personnel trained in the industry. A high level of subcontracting from the EAI has contributed substantially to the upgrading of technological skills in small and medium-sized enterprises by dissemination of technology and information. Figure 16 gives some indication of the spin-off range.

AERONAUTICS TECHNOLOGIES	SPIN-OFFS for OTHER INDUSTRIES
AERODYNAMICS	
Pipe and duct flows	Ventilation
Fan designs	
Wind tunnels	Cars, trains etc
Streamlining	
Wind effects	Afforestation, building, chimney design
Knowledge of aeroelastic problems	Chimney stack oscillation, stability of suspension bridges and conductor cables
STRUCTURES	
Structural theory for beams, struts, torsion and thin-walled structures, space-frames, and vibration	Bridges, motor cars, large buildings and general engineering Vehicles and general engineering
Strain-gauging and other test techniques	Building
Stressed skin and sandwich engineering	
MATERIALS	
High-duty aluminium alloys	Industrial turbines and diesels
Magnesium alloys	Heavy vehicle crank-cases and gear-boxes, textile machinery, cameras, office equipment
Nickel-based alloys	High-temperature furnaces Power generation
Titanium alloys	Chemical and metal-finishing industries
Vacuum melted steel	Ball bearings
Synthetic resin adhesives	Furniture and marine industries
Metal structural adhesives	Commercial engineering
Glass-reinforced epoxides and polyester resins	Building industry
Bonded and fired castings	
Polyetheline and Polyolefins	Building and agriculture
SYSTEMS, ELECTRONICS	
Airborne radar	Marine navigation
Digital computers	General industry and commerce
Fire control equipment	High rate servo-mechanism
Automatic test equipment	General engineering
Transistorised circuits	Clocks, watches, domestic appliances
Analogue computers	Water distribution, gas industry, mine ventilation, chemical and petroleum industries
Micro-miniaturised relay	Industrial control systems
Data-handling equipment	Industry, testing, research
Data link	Data transmission
Scanner control	Electric/hydraulic speed control of large turbine installations
Plugs and sockets	General
Simulators	Railways, car driving instruction, marine and nuclear power station training
Navigation systems	On-line computers for process control industry
Control rigs	Electro-manometric pressure controllers
Rapid photographic processors	Marine radar
Multiplex telemetry systems	Coal mining
Sealed-beam headlamps	Motor industry
Batteries	High-capacity light batteries
Actuators (and screw threads for them)	
PRODUCTION METHODS	
Aluminium production equipment (plate mills extrusion presses, forging hammers, stretchers)	Shipbuilding, building and commercial vehicle industry
Electro-chemical machining	General engineering
Welding control methods	Steel, motor, and atomic energy industries
Vacuum metallurgy	'New' metals and 'traditional' metals with higher properties, steel-nickel alloys
Explosive electro-hydraulic forming	Steel dental plates, artificial limbs, large tubes
Electron beam welding	Atomic energy industry and general engineering
Ultrasonic and radiographic inspection	Metallurgical industry
Spark-machining	Die manufacture
Investment (lost-wax) casting	General engineering
Large, high-quality forgings	Railway bogey beams and general engineering
......Etc....	

Fig.16 Some examples of how advances in aeronautical technology provide benefit to other industries

3.2 Market Demands and Effects of Technology

The general case for the importance of setting technological goals in relation to product goals which in turn meet anticipated market demands has already been presented.

To take some examples, advanced cockpit technology and active control technology played a very important role in advancing sales of the Airbus A-320 (Fig.17) and Fo-100 aircraft. In fact, A-320 sales and purchase options before first flight were an historical record at above 400. These technologies must be progressively updated, however, if sales impact is to be maintained. Another case was the boost to helicopter sales resulting from the development of composite rotor blades, which improved performance and dramatically increased both service life and safety, with attendant reduction in operational costs. In contrast, technological efforts were not maintained in respect of the Caravelle and BAe One-Eleven and this was a prime reason why sales fell away.

Fig.17 The application of advanced cockpit technology played an important role in establishing record pre-first-flight sales for the Airbus A-320

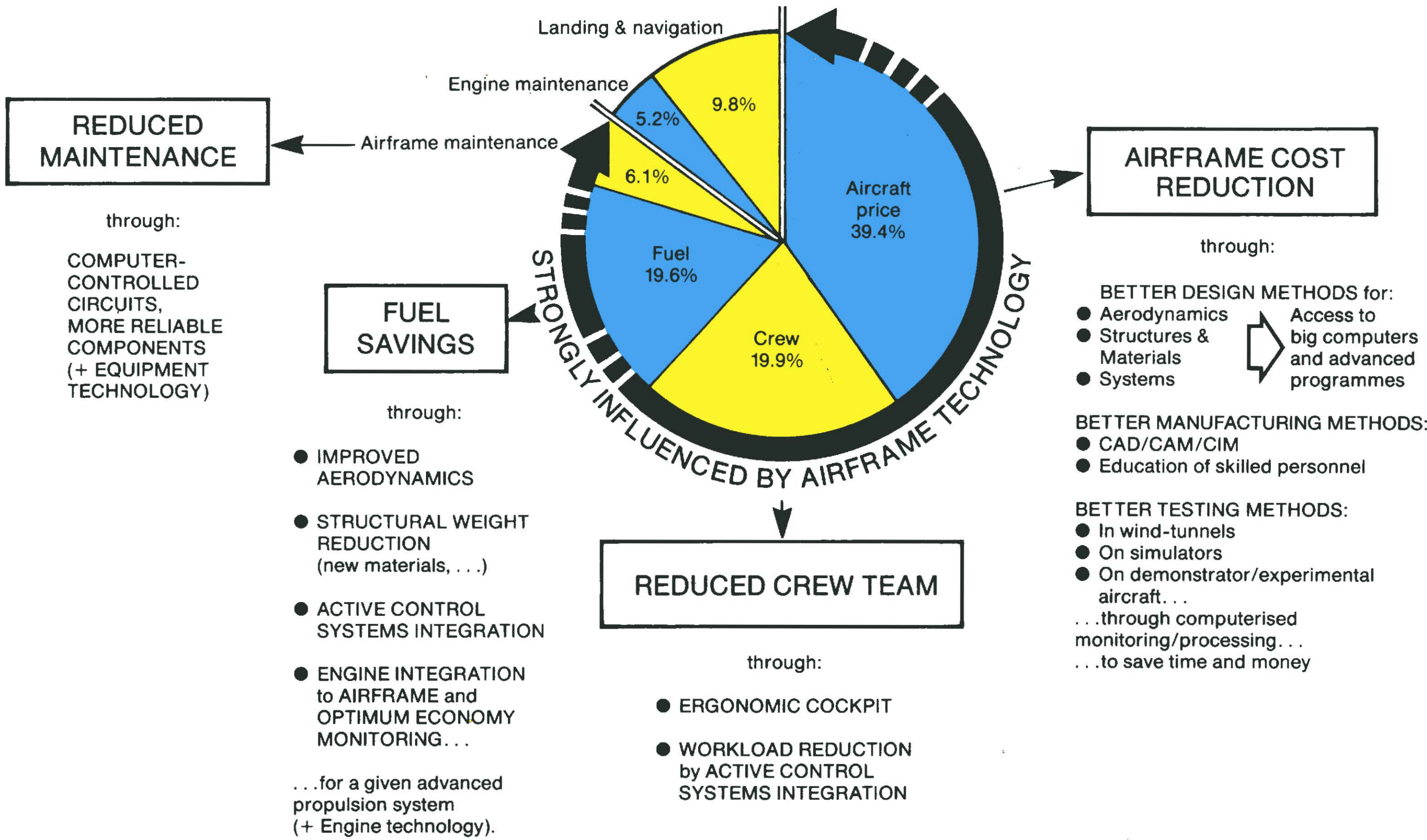


Fig.18 How improved technology can reduce the direct operating cost (DOC) of a commercial aircraft. (Chart shows a typical DOC breakdown (using 1987 costs) for an Airbus A-320 on a 500 n mi trip.) Source: Airbus Industrie

The key criteria in the competitive purchase and operation of civil aircraft are the Direct Operating Costs (DOC), and the Life Cycle Costs (LCC) for military systems. The major components of DOC (Fig.18) are the costs related to the aircraft selling price, and fuel costs. Other components, such as maintenance and crew costs, make up the balance. In this respect, advances in technology may be generally categorized under:

- Advances aimed at increasing the efficiency of the aircraft during service (such as fuel economy and lower maintenance costs), and
- advances aimed at reducing the design, development and manufacturing costs of the aircraft (leading to a lower aircraft selling price).

The EAI believes there is a clear potential to reduce DOC over the next two decades by 20 to 30 percent. This means that:

- The overall benefits over 20 years (i.e., the typical lifetime of a major civil aircraft project) will be large and of critical commercial/competitive significance.
- Advancing technology will contribute the greater part of the gain, expressed in DOC terms.
- The DOC of products can be drastically reduced through the right combination of efforts in each main area of technology.

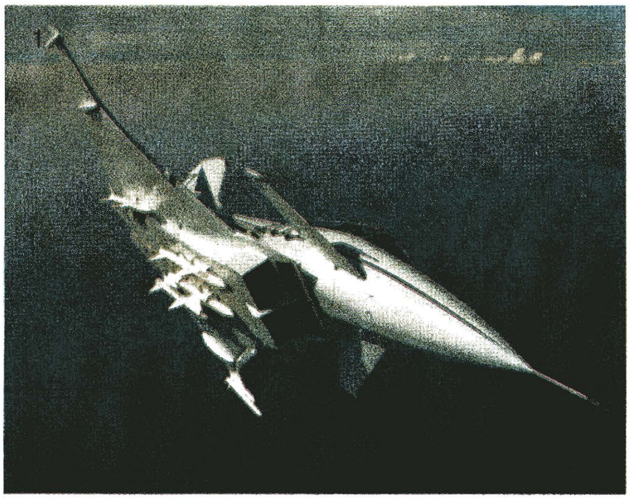
For the future to be assured, it is not merely a question of protecting present capabilities. It is essential to advance to assume a leading position in the competition. In addition, the mastery of specific advanced technologies is a prerequisite for the development of new types of aerotransportation. The potential market for supersonic and hypersonic flight vehicles is a case in point: this will be open only to those industries capable of mastering particular relevant technologies such as aerothermodynamics and high-temperature structures.

So there are solid reasons for the view that the EAI will have to increase its technological capabilities in order to maintain its competitiveness and market standing. The development of these capabilities is imperative, both to keep abreast of the advances which will surely result from the resurgence of US effort, and to counter the advantages enjoyed by competitors as a result of low monetary exchange rates or low labour costs.

3.3 Strategies and Threats

While comparable in scale and technical competence to the US aeronautics industry in its earlier days, the EAI after the second World War had difficulty in re-establishing itself and adjusting to the changed conditions. As a fragmented force it was overshadowed by the American industry which benefited greatly from its extensive home market and from large-scale US government purchases.

The US industry also built up a unique product development relationship, long-term and special, with the US Government. This relationship recognised that, in aeronautics, commercial and financial strategy cannot be the exclusive concern of industry, and that interplay,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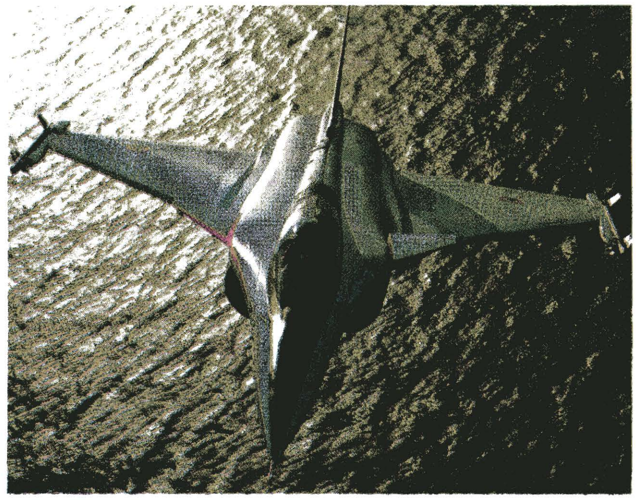


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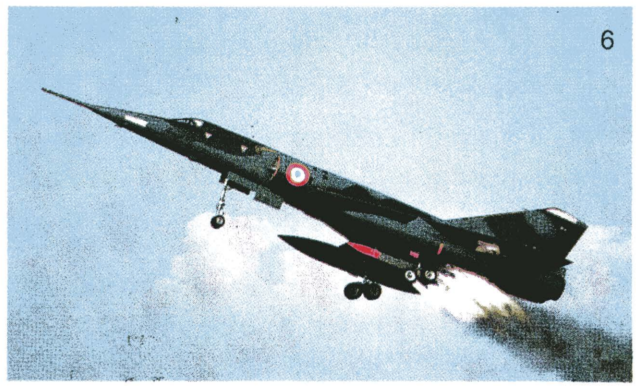
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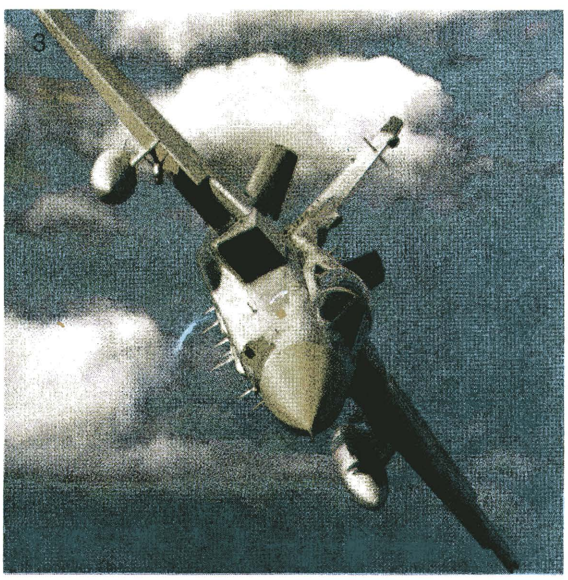
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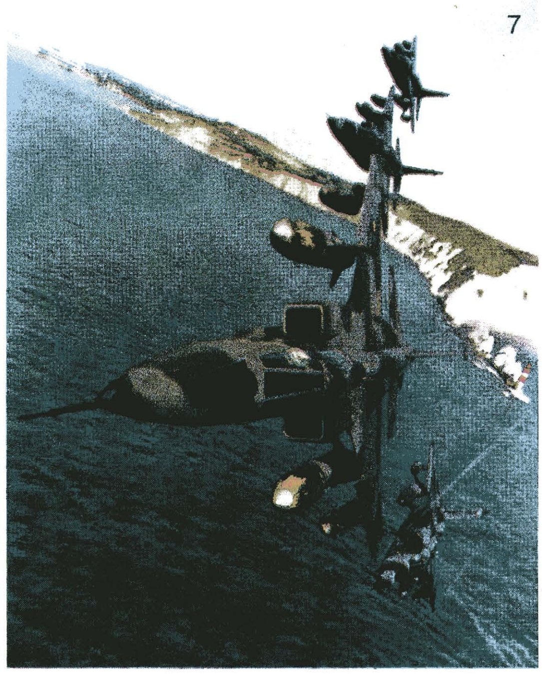
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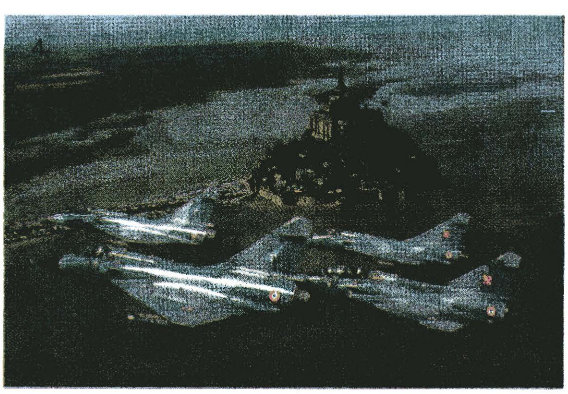
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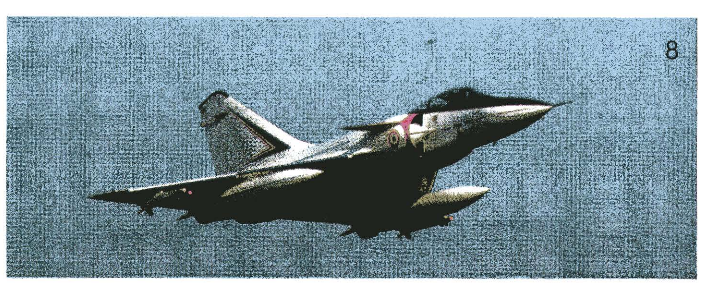
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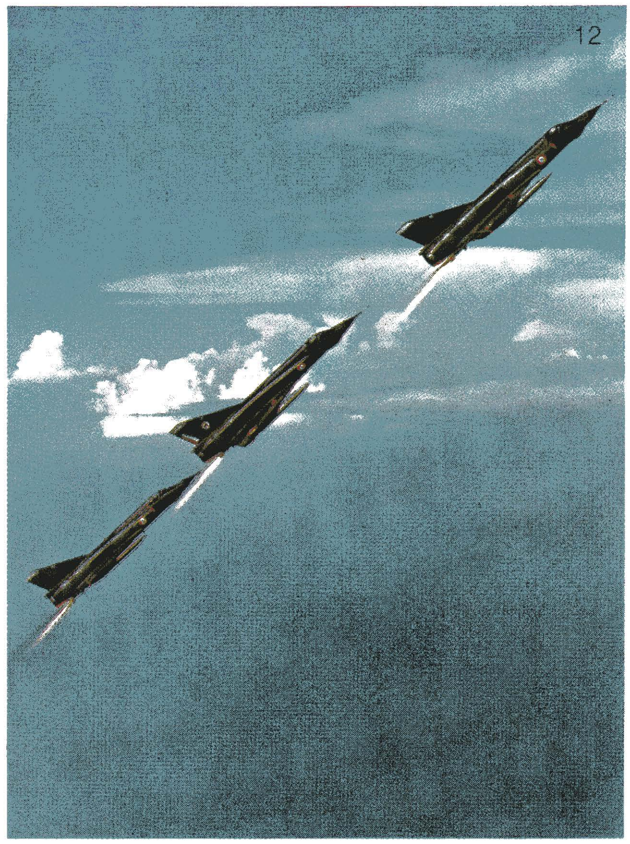
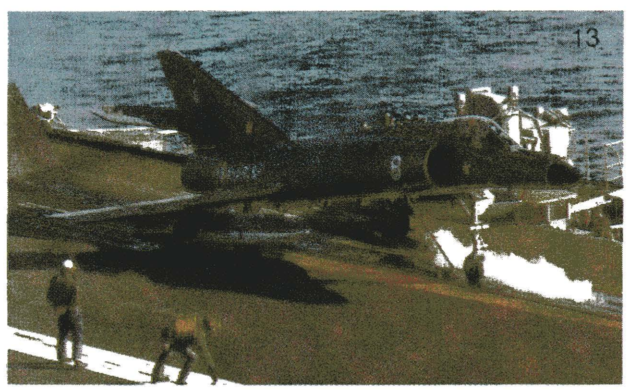


1 EAP
2 HARRIER GR3
3 TORNADO
4 MIRAGE 2000
5 RAFALE
6 MIRAGE 4
7 JAGUAR
8 MIRAGE 4000
9 ALPHA JET 2
10 ATLANTIC II
11 HAWK T1
12 MIRAGE 3
13 SUPER-ENTENDARD



cooperation, and coordination with government are essential to the industry's strength and development.

European industry did, however, develop the infrastructure of learning, research and testing, design, manufacture and marketing, necessary to support its ambition to become a world supplier. It had notable high-points of technical achievement but, while attaining a reasonable level of parity in key areas of research and technology, it still failed to deal with other competitive factors which sustained the US dominance.

Recognising this deficiency, individual aircraft companies regrouped and reorganised into major units at national level. The industry turned also to multinational cooperation to undertake major product development and build up its capabilities in the main shortfall areas — product planning, manufacturing productivity, aggressive marketing tailored to the customer, financing terms, and product support.

This strategy has proved successful for Europe, with the industry producing technically proficient aircraft and achieving effective market penetration. But this success, posing as it does a major challenge to the American aeronautics industry has triggered a determined US attempt to try to regain and sustain its historical dominance. This US response involves the establishment of clear pertinent national technological goals and the strategy and plans to pursue them, with positive support at the highest national and industrial levels.

The new US approach mirrors the carefully planned industrial strategy on which Japan's success in world trade is based, and which is available to underpin Japan's expected development of its own aeronautics industry. A similar pattern is evident in the national and industrial strategies of technologically emerging countries (Brazil, Indonesia, India, China, etc.) in support of their increasing strength in aeronautical products, which has a good foundation in their low labour rates. Furthermore, the state-supported aeronautics industry of the Soviet Union is a direct competitor in certain major markets.

The EAI is obliged to operate in a market which is US dollar-based. With a low-value dollar, the value of which has halved in the last two years relative to all major European currencies, the EAI market opportunities deteriorate in favour of US products — not only in the US — but world-wide. The EAI's yields shrink, production break-even points are pushed out in time and, as a result, the resources to support research and technology inevitably become more difficult to obtain.

In summary, the principal threats presently facing the EAI are:

- The technological thrust in aeronautics in the US, and
- The emergence of new nationally-subsidised competitor industries.

Additionally, the commercial effects of a low-value dollar is a substantial new burden.

3.4 The Need for Common Measures

There is a clear need to take special and urgent action in Europe to counter the threats in the technological field which the EAI now faces and which have been described in the preceding Sections of this Summary. For such action to be successful it must be in the form of common measures to tackle commonly-recognised issues, namely:

- The importance of maintaining a 'leading-edge' position in all technologies which impact on the performance of the product in the market.
- The increasing complexity of aeronautics technology, which continues to add many new areas (systems, electronics, software, opto-electronics, etc.) to the still rapidly developing 'classic' areas (aerodynamics, structures, materials, etc.).
- The increasingly crucial development of advanced design and manufacturing technologies to reduce the cost of the whole range of aeronautics products, which may incorporate varying levels of 'on-board' technology. (It should be noted that high technology in manufacture is increasingly necessary to produce a product apparently having relatively low technology 'on-board'.)
- The ongoing necessity to match developing technology with developments in other major competitive areas such as product planning, productivity, marketing, product support and product financing.
- The developing necessity to maintain technological competence for the most innovative types of future aircraft projects, as a prerequisite for negotiating a fair and substantial role for the EAI with potential partners outside Europe.
- The increasing discrepancy between the demands of maintaining technological competitiveness and the limitations in national and company specialist manpower resources, research facilities, and finance.

The cumulative effect of these issues on the EAI's activities and resources (specialist manpower and facilities, as well as funding) leads to the conclusion that key technological capabilities must in major part be acquired on a joint basis.

A good basis for this joint action already exists in the collaborative programmes which have been built up progressively by the European companies and which necesarily have to take account of differences in scale, independent capability, accountability to owners, strategic and commercial objectives, and government policies. The level of success achieved in these collaborations, despite the problems involved, is almost unique to the aeronautics industry and provides the essential foundation for even wider collaboration.

The envisaged joint actions will need to place particular emphasis on harmonised means to meet medium and long-term research and technology requirements. There is also a clear need for these measures to be set against carefully defined goals, in concert with respective government administrations and the EC Commission.

4. THE WAY AHEAD

4.1 Overall

As stated earlier, the commercial success of the EAI is crucially dependent on its ability to maintain an acceptable level of technological competitiveness. However, it is impossible to do so with the funding resources available under current arrangements. Because of this limitation, and for reasons of economy, efficiency and resources (including specialist manpower and special facilities), new cooperations in aeronautical research and technology are essential. The proposed joint programmes which are to form a major part of this increased cooperation must be concentrated on key technology areas identified in new jointly-agreed technology goals and product goals covering the next 20 years and beyond.

In short, an improvement, enhancement, and expansion of the technological capabilities of the EAI is necessary if the industry is to continue to thrive. This can be achieved by adopting a consistent and interdependent set of commonly-agreed measures, the first two separately and jointly ensuring the cost-effectiveness of the third measure, namely:

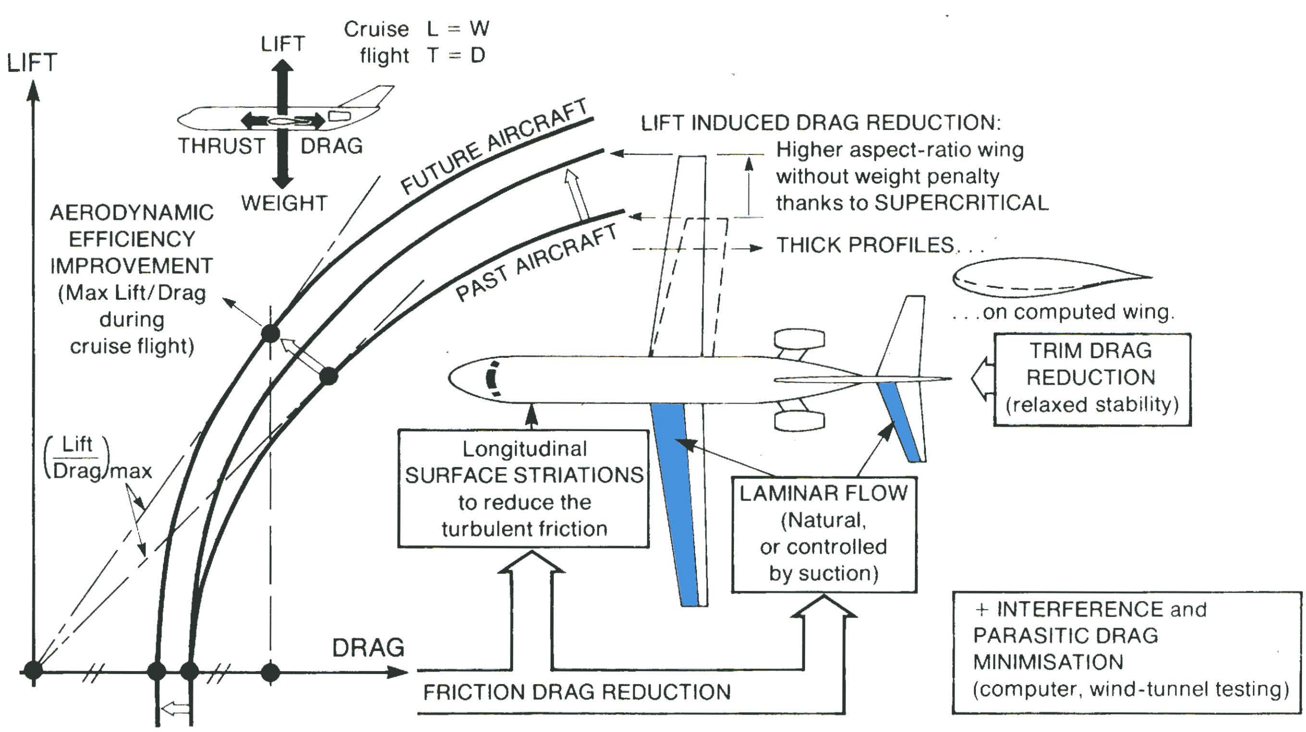
- Increase cooperation in research and technology activities
- Concentrate on key technology areas identified in new joint requirements
- Provide additional funding resources to support this increased effort.

As a first step in implementing common measures based on this approach, a number of essential joint actions will be required. These are indicated in the following Sections.

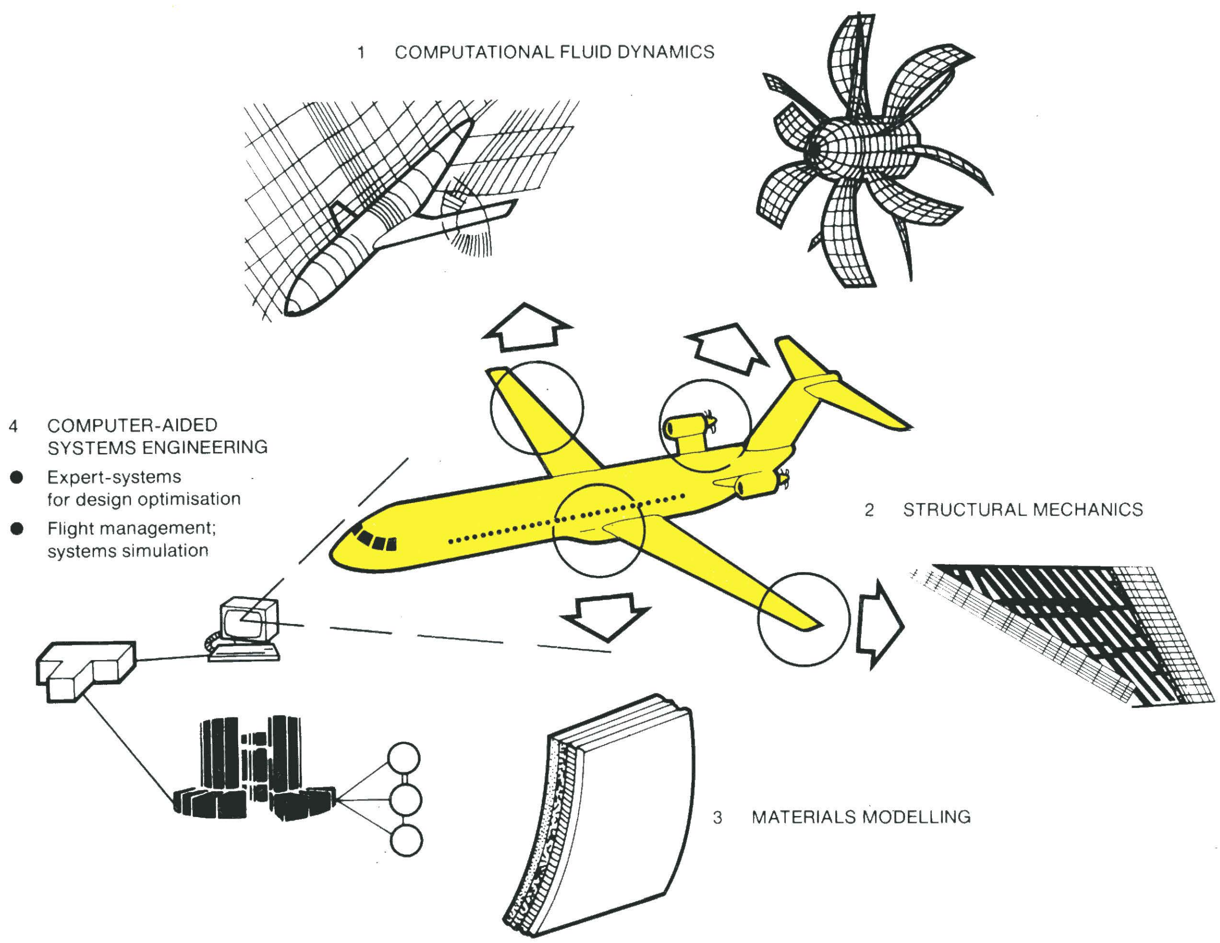
4.2 Increased Cooperation in Research and Technology

The proposals for a new cooperation scheme under the aegis of the Commission require early consideration if a suitable infrastructure to support the proposed common measures is to be established in good time. It is recommended that joint actions to initiate such a scheme should be undertaken by the Commission, in consultation where necessary with national government agencies and the EAI. The current EUROMART group could form a starting point for EAI involvement.

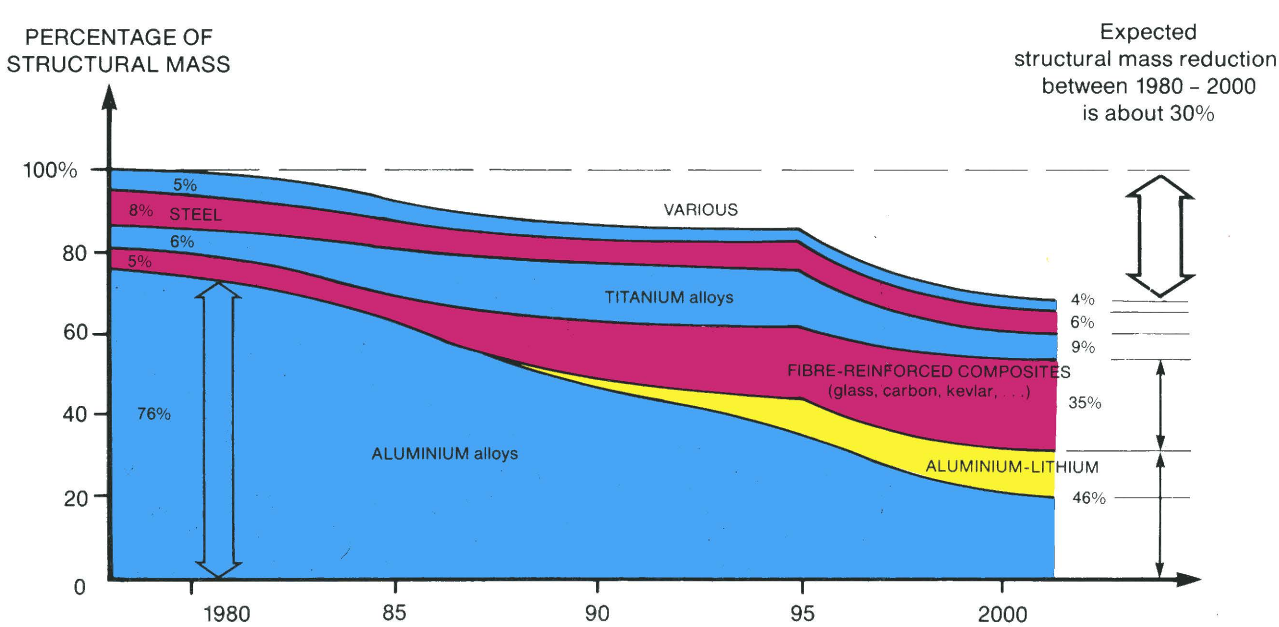
PROGRESS ON AERODYNAMICS

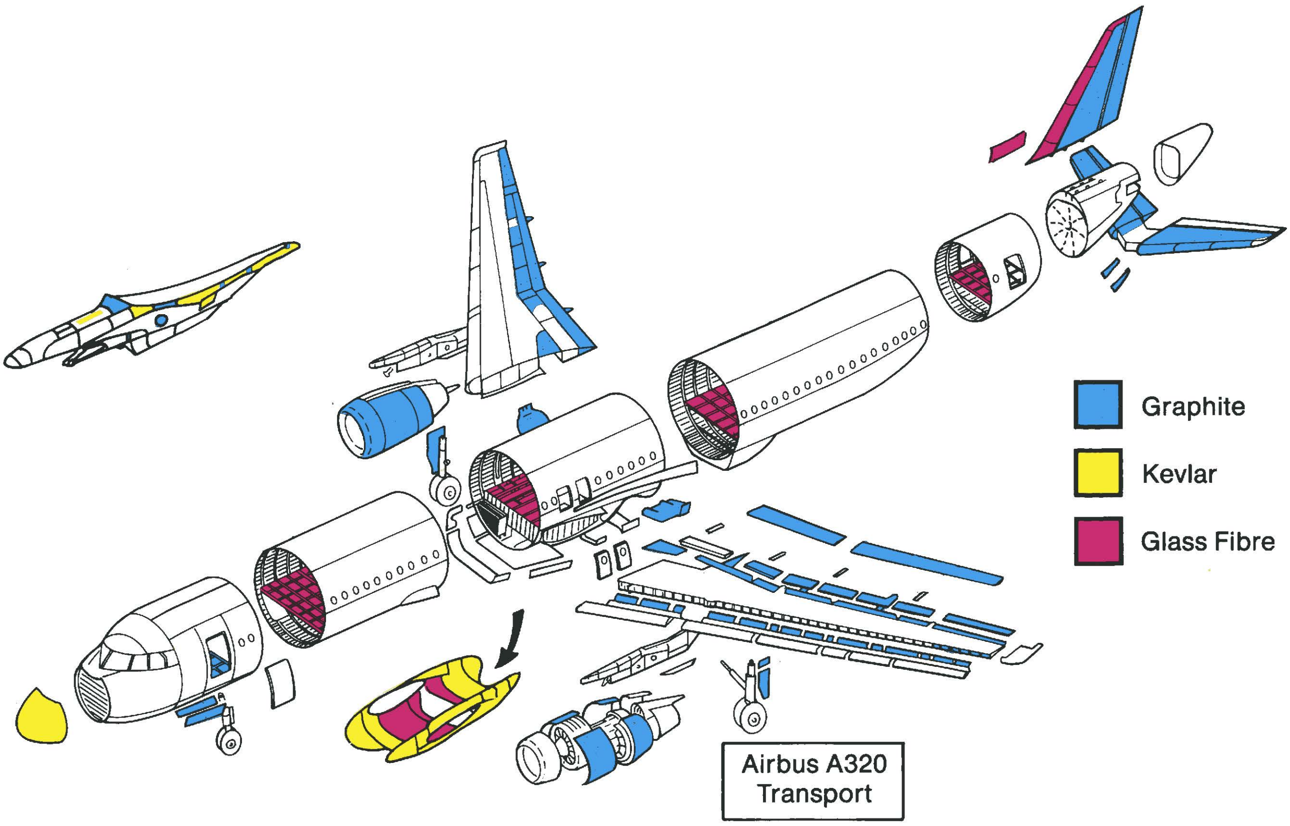


FUTURE USE OF SUPER COMPUTERS

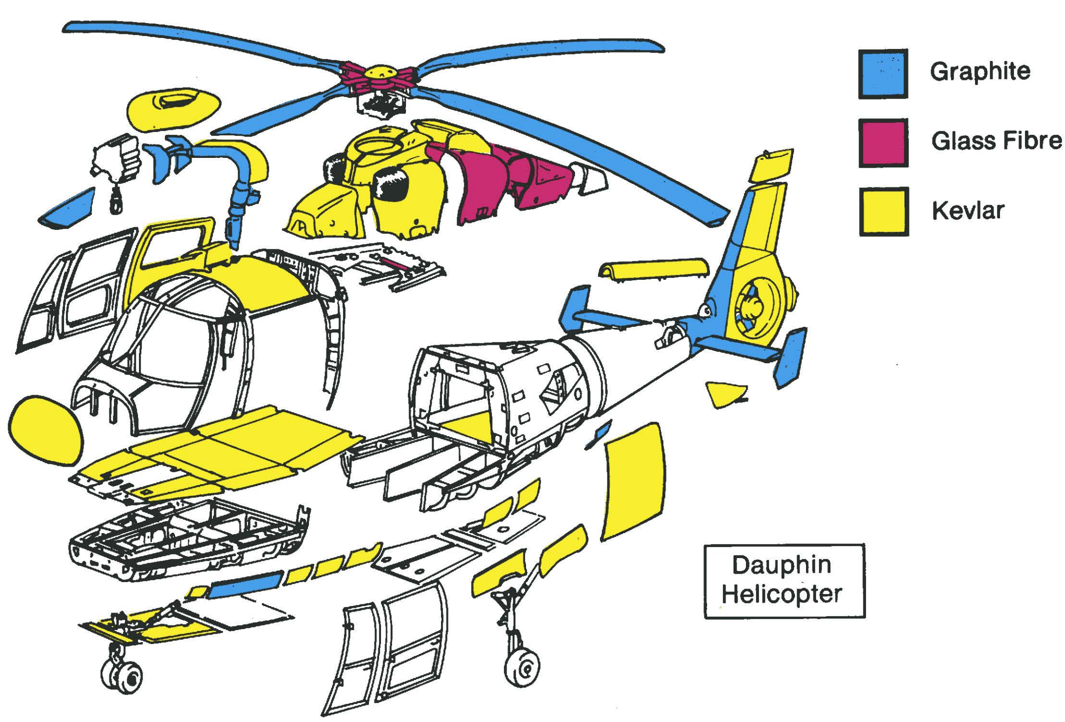


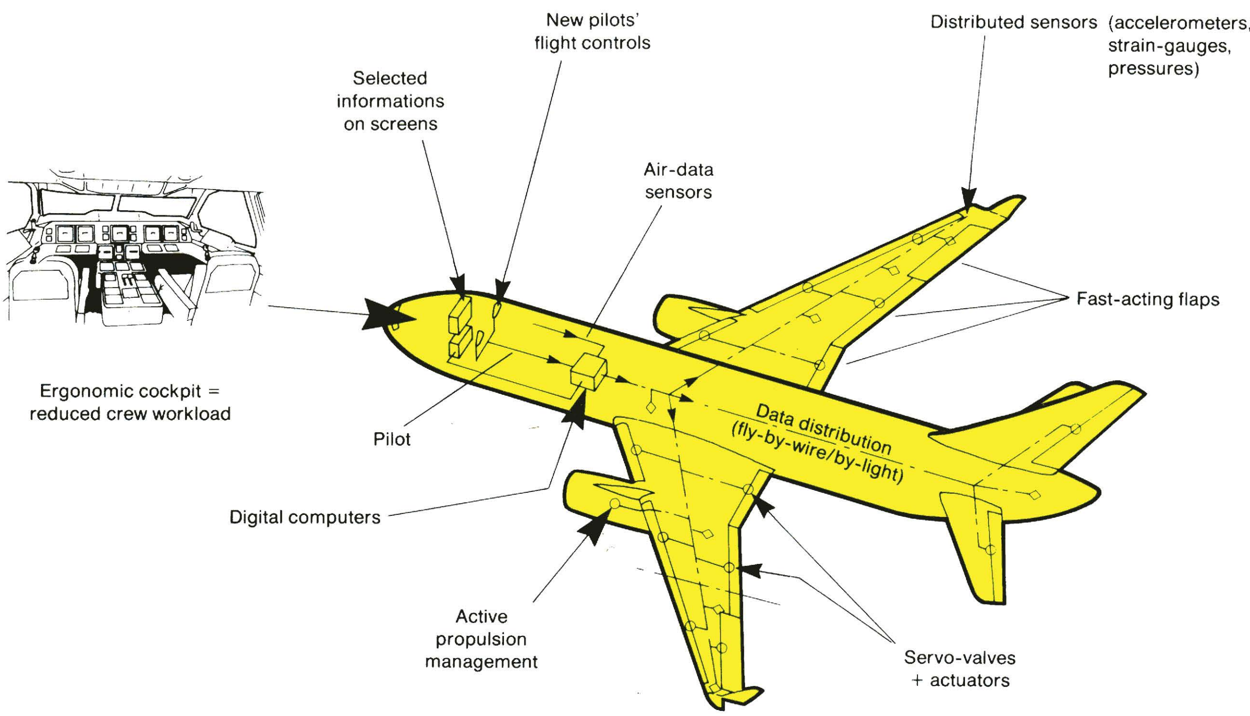
PROGRESS ON AIRCRAFT STRUCTURES AND MATERIALS



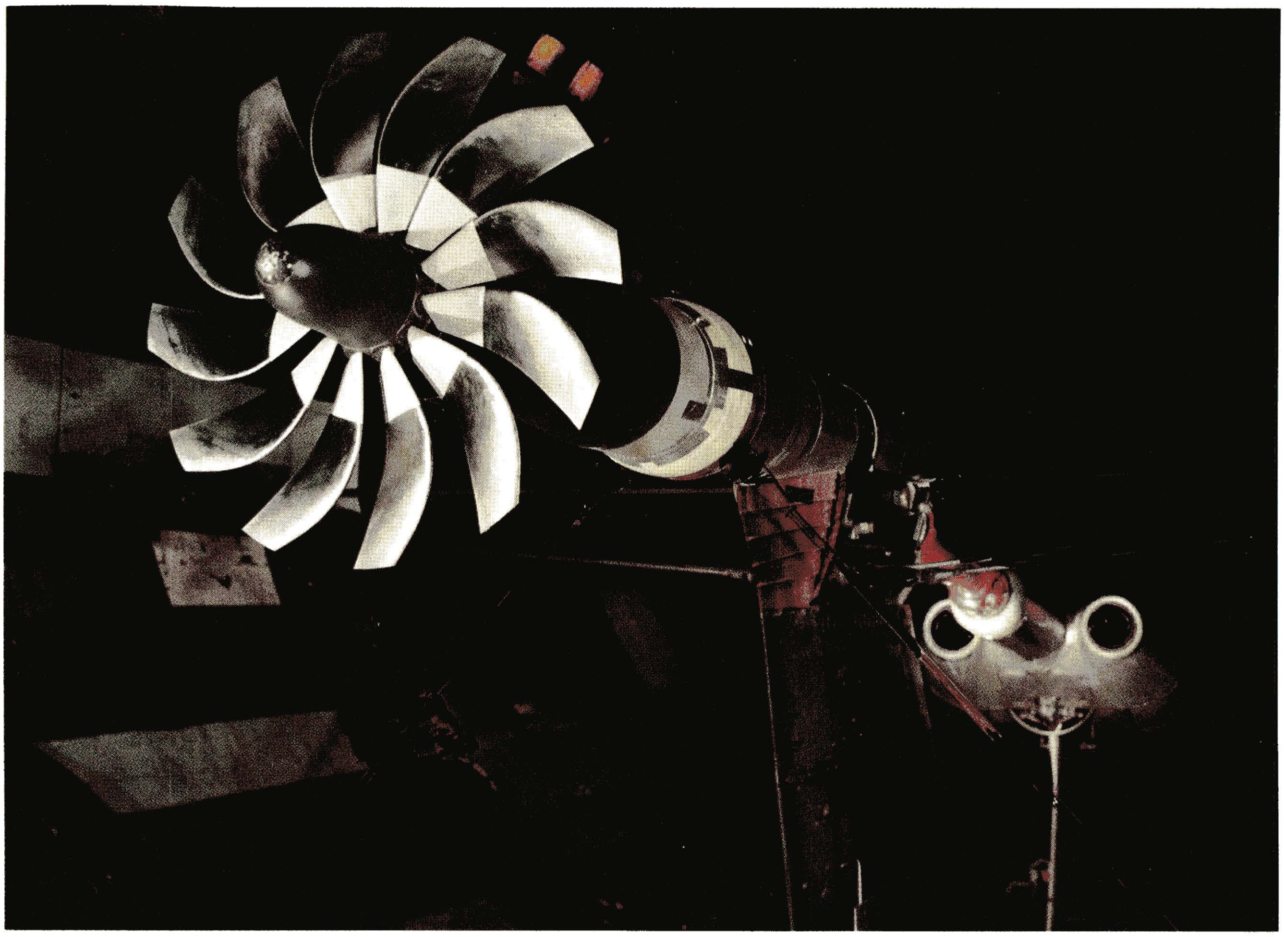


INCREASING APPLICATION OF COMPOSITES

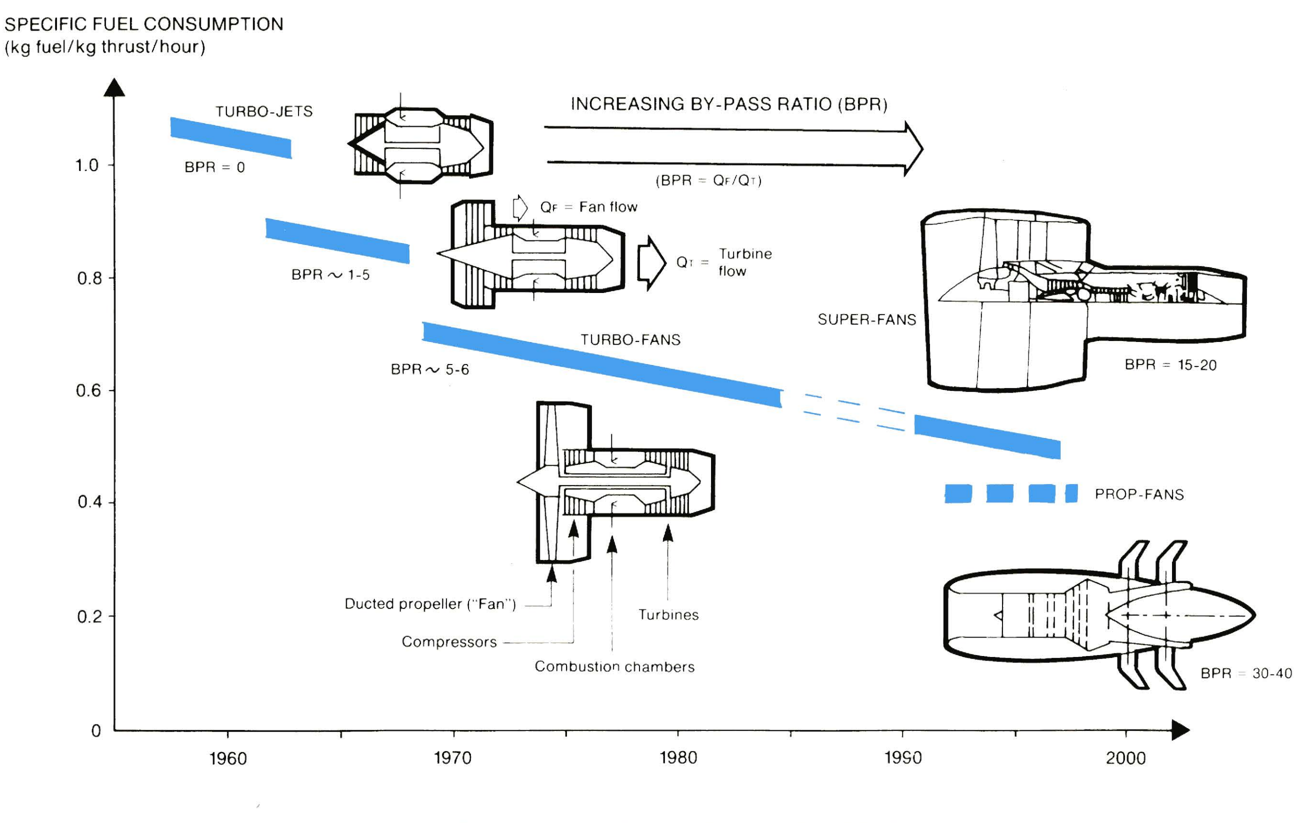




PROGRESS ON AIRBORNE SYSTEMS



PROGRESS ON PROPULSION



In considering the infrastructure required, proper account must be taken of the fundamental requirements for successful aeronautics research and technology, namely, sustained levels of effort over many years, long-term financial resources, and high levels of commitment from all parties concerned.

It is the EAI's judgement, based on its extensive experience of project collaboration, that the overall cost-effectiveness of its research and technology effort could, in due course, be raised by about 10—20% by the proposed increase in cooperation, assuming the effort to be concentrated on the key technology areas identified in the study. However, such an increase is crucially dependent on an efficient infrastructure.

4.3 Concentration on Key Technology Areas

The key technology areas derived from the common technology requirements plan were established by an extensive joint analysis undertaken in the course of the study; this was in turn based on separate work done previously by the individual companies. The results of this analysis should be ratified by industry, and company research plans and programmes adjusted, if necessary, to suit. Actions to ensure compatibility with appropriate national research programmes should also be put in hand. The task definitions and priorities identified in the analysis should then be used as the authoritative framework for the detailed development and implementation of the proposed cooperative programmes.

4.4 Provision of Additional Funding

The overall judgement that a substantial increase in the current level of EAI research and technology effort is required has already been discussed, and the level-of-effort analysis (Figure 14) clearly illustrates the point.

A staged approach in increasing the current level of expenditure of ECU 370 million per year to match the requirement indicated in Figure 14 is clearly necessary. It is judged that this should be based on:

- A need now to increase the annual expenditure by 25%
- Over the next five years a need to continue the increase to reach 50—60% above current annual expenditure.
- A longer-term aim to double the current annual expenditure over the next decade.

Consideration of measures aimed at the provision of these additional funding resources should be undertaken on an urgent basis by the EAI and the Commission, in consultation with national government administrations.

That the EAI itself has already recognised the need to make available more resources for research and technology activities is evidenced by the fact that, since 1985, the amount spent on

R&T has gone up by about ECU 50 million per year. Strong efforts must be made by industry to sustain or improve this increase over the coming years.

4.5 Candidate Projects

Over 60 outline projects on aeronautical research and technology have been identified as candidates for new near-term and medium-term cooperative programmes, varying from Aerodynamics to Operational Systems under the categories listed in Appendix C and based on the criteria set out in Appendix D. From these outline projects nine 'lead' projects have been developed to a sufficiently detailed form to allow work to start within the framework of an envisaged two-year pilot programme. This pilot programme is intended to be followed by a main programme spanning a five-year period and encompassing the full range of candidate projects. The proposals for the nine 'lead' projects are outlined in Appendix E.

As a first step, there should be urgent joint action to launch these 'lead' projects within a pilot programme. For this programme, and for a succeeding main programme, some important stipulations should be observed:

- The programmes should be developed and implemented to meet the objectives of industry
- The programmes should be closely coordinated with the plans and funding arrangements of national Ministries resposible for aeronautical research and technology
- The programmes should take full account of the research and technology interfaces between the aeronautics industry and the engine, equipment and systems, and materials industries.

4.6 Complementary and Additional Joint Actions

4.6.1 Related Collaborations

To complement the approach described in Section 4.5, increased coordination should be sought between existing arrangements for research and technology collaboration to seek improved benefits from integrated working, planning, financing and implementation. In so doing, it must be recognised that these related collaborations normally have good and continuing reasons for their particular form of structure and methods of operation, and these must be respected.

4.6.2 Facilities

Experience in Europe has shown that arrangements for developing and operating common major aeronautical facilities need to be developed on a case-by-case basis. (Examples are the European Transonic Windtunnel and the joint German-Dutch Windtunnel.) At present, the main subject of interest, which should be jointly investigated, is the possible establishment of a parallel computing centre.

4.6.3 Regulations and Standards

Regulations and standards can have profound effects on aeronautics industry products, in terms of cost, timescale, operation and marketability:

- Continued joint efforts to work towards common European approaches and standards for airworthiness certification regulations should be encouraged by industry and official bodies
- Further joint work should be undertaken to seek a higher level of standardisation for aeronautics industry purposes of materials, components, equipment, and methodologies.

4.6.4 Training and Education

- Close alignment of training arrangements for selected key scientific and technology fields should be established or extended. Major areas involved are computation, software engineering, software management, CAD/CAM, artificial intelligence.
- Investigations into improved coordination of post-graduate education in aeronautics, should be considered, including possible new or developed establishments, links between existing schools/universities, scholarships, student exchanges, and industrial experience programmes.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A strong, prosperous aeronautics industry is a major asset to Europe, its economy, strength, the welfare of its people, and its culture.

In recent years, the industry has organised itself to compete strongly in world markets. Over the period 1980—1986 it obtained 23% and 27% of the world markets in civil and military aircraft, respectively. This represents an average annual delivery value of ECU 9,900 million, and a total value of ECU 69,500 million (1987 prices).

The industry aims to increase its overall share of the markets, which have been analyzed for the period 1987—2010. This aim, if realised, would represent a major increase in business with an average annual delivery value during the period of ECU 14,800 million and a total value over the 24 years of ECU 356,000 million (1987 prices). There will be a shift in emphasis to the civil market (32% share) from the military market (23% share).

Exports will continue to play a vital role in the future of the industry since the European home-market as a proportion of world demand is unlikely to increase greatly over the next twenty years. The United States industry will continue to have the substantial benefit of a very large home market.

The study confirms that there *is* substantial cause for concern about the future. In particular, the competitiveness of the European Aeronautics Industry in world markets is threatened by the intensification of technological competition resulting from the powerful drive underway in the United States, particularly in research and technology, which expresses a positive national determination to try to sustain its historical pre-eminence into the next century. A further factor adversely affecting European competitiveness is the decline in the value of the dollar.

There is a crucial relationship between technological competitiveness and commercial success in the aeronautics business and it is now clear that the EAI will be unable to maintain a state-of-the-art competitiveness under present conditions for the conduct of research and technology activities (funding, organisation, etc.). More and improved cooperation is essential. Furthermore, these joint efforts must be concentrated on those areas which analysis of future technological opportunities and product options has shown to be of key importance. The work of the study has yielded an inventory of such key areas. It remains now to find ways and means of securing and deploying the resources necessary to make such cooperative work effective.

In short, an improvement, enhancement and expansion of the technological capabilities of the European Aeronautics Industry is necessary if the industry is to continue to thrive. This can be achieved by adopting a consistent and interdependent set of common measures, the first two separately and jointly ensuring the cost-effectiveness of the third measure, namely:

- Increase co-operation in research and technology activities
- Concentrate on key technology areas identified in new joint requirements
- Provide additional funding resources to support this increased effort.

Specific proposals for cooperative work are contained in this report. Some sixty outline projects have been identified as candidates for new near-term and medium-term cooperative programmes, nine of these being in a sufficiently detailed programme proposal form for work to start. The experience and expertise built up within the industry during successful collaboration in the past should provide a firm basis for the extension of cooperation in research and technology now being proposed.

To give a reasonable prospect of success, the present level of expenditure on research and technology (excluding development) within the European Aeronautics Industry, excluding engine and equipment companies, needs to be built up well above the current ECU 370 million per year. This is best done in stages:

- Immediately, there is an urgent need to raise yearly expenditure by 25%
- Over the next five years there is a clear need for the build-up to continue such that by the end of this period expenditure will be 50—60% higher than it is at present
- By the end of the next decade it is foreseen that a doubling of expenditure will be necessary and this should be prepared by further studies.

Industry cannot meet this level of funding from available resources.

The proposed changes must be coordinated with the plans and funding arrangements of the national government administrations concerned and with those of the European Community.

5.2 Recommendations

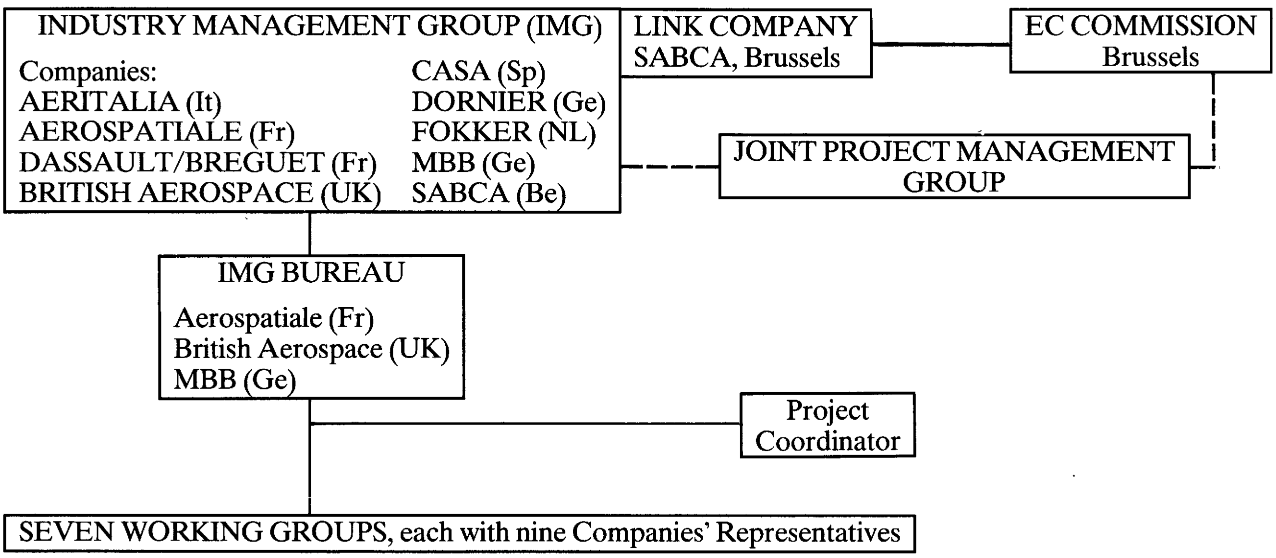
The companies who have conducted the EUROMART study submit this report to the EC Commission for its consideration. They invite the Commission:

- To take note of the report and its conclusions
- To take these conclusions into account in the formulation of its future programmes to encourage the competitiveness of Community industry and strengthen the Community science and technology base
- To take the initiatives necessary to secure implementation of the needed actions.

* * *

APPENDIX A

EUROMART STUDY GROUP ORGANISATION



Companies involved in the Study	Representative on Industry Management Group
AERITALIA Rome	Vittorio Maracci
AEROSPATIALE Paris	Jacques Balazard*
AVIONS MARCEL DASSAULT-BREGUET AVIATION Paris	Roger Guenod
BRITISH AEROSPACE London/Weybridge	Ronald Cole*
CASA Madrid	Angel Perez-Vidal
DORNIER Friedrichshafen	Johannes Spintzyk
FOKKER Amsterdam	Menno van der Veen
MESSERSCHMITT-BÖLKOW-BLOHM Munich	Jürgen Wild*
SABCA Brussels	Marc Duray
Project Co-ordinator	Philippe Poisson-Quinton

*IMG Bureau Members

COMMERCIAL – IN – CONFIDENCE

EUROMART STUDY: MEMBERSHIP OF WORKING GROUPS

Working Group No.	1.1	1.2	1.3	2.1	2.2	3.1	3.2
	STATUS AND PROSPECTS OF EUROPEAN AERONAUTICS INDUSTRY Phase One			FUTURE REQUIREMENTS OF R & D Phase Two		CONSIDERATION OF JOINT ACTION Phase Three	
Companies:							
AERITALIA (It)	G. M. MARCHISELLA	C. LATELLA*	D. FERRERI	D. FERRERI	C. VOTO	G. ARIDON	A. FELICI†
AMD-BA (Fr)	A. KATANY	V. PETIT	D. DUVAL	D. DUVAL	J. CZINCZENHEIM*	A. KATANY	D. DUVAL J. CZINCZENHEIM
AEROSPATIALE (Fr)	J. M. d'AUTUME	J. HUBER/D. KAHAN	J. M. d'AUTUME†	J. CORON	M.MARQUEZE-POUEY M.PACULL	F. MARY	F. MARY*
BAe (UK)	A. J. TURNER†	M. C. HUGHES	P. SMITH P. LIDDEL	D. P. HOWLETT†	I. C. TAIG	D. P. HOWLETT* R. COLE	B. SCHOFIELD
CASA (Sp)	C. GRANDAL	J. RUIZ de OJEDA	E. GOMEZ LEAL	J. J. MOLINA*	E. GOMEZ LEAL	J. J. MOLINA	J. J. MOLINA
DORNIER (Ge)	G. BEHRENDT*	M. KREHBIEHL	B. HUININK	B. HUININK	D. JACOB†	G. BEHRENDT	G. BEHRENDT
FOKKER (NL)	L. J. SCHUNSELAAR	G. PRONK†	J. CORNELIS	H. VAN GROUW	A. W. NIEUWENHUIJSE	P. KEEGSTRA	P. H. SURINK
MBB (Ge)	H. TAYSI	H. TAYSI	H. H. VENGHAUS*	H. H. VENGHAUS	H. JOHN	J. WILD†	H. H. VENGHAUS
SABCA (Be)	—	—	M. KNEIP	R. S. BHATTI	E. STENNE	DE WILDE	M. KNEIP
EEC	D.BE† (+ GTS)						

*Chairman
†Deputy Chairman

APPENDIX B

AIRCRAFT CATEGORIES

The types of aircraft of interest to the European Aeronautics Industry are encompassed by the following categories.

1 COMMERCIAL TRANSPORT AIRCRAFT (Turbojet and advanced propfan) about 100 passengers minimum
1.1 Narrow-bodied (single-aisle)
1.2 Wide-bodied (twin-aisle)

2 COMMUTER AIRCRAFT (Turboprop and turbojet) 12 to about 100 passengers
2.1 12 to about 40 passengers
2.2 40 to about 100 passengers

3 GENERAL AVIATION AIRCRAFT
3.1 Business aviation
3.2 Private, utility and others (special-purpose)

4 V/STOL AIRCRAFT
4.1 Advanced conventional helicopters
4.2 Advanced V/STOL Aircraft (including convertiplanes)

5 HIGH-SPEED TRANSPORT AIRCRAFT
5.1 Supersonic transports
5.2 Hypersonic transports

6 MILITARY AIRCRAFT
6.1 Subsonic: transports and trainers
6.2 Supersonic: active roles

APPENDIX C

KEY TECHNOLOGY AREAS

Key technology areas related to technology and product goals have been identified in the following categories:

AERODYNAMICS (including Flight Mechanics) — covering:
computational fluid dynamics, shape integration, high lift, drag reduction, air intakes, flight dynamics.

STRUCTURES — covering:
new concepts, new computational methods and tools, high-temperature structures, new experimental methods (verification and testing).

MATERIALS — covering:
new metal alloys, composites, metal matrix, thermoplastics, high-temperature materials, related processing, etc.

ACOUSTICS — covering:
external noise fields, cockpit and cabin noise, active noise control, measurement techniques, prediction methods, structure fatigue effects, noise shielding.

COMPUTATION — covering:
large-scale software, modelling, simulation, vectorial supercomputing.

AIRBORNE SYSTEMS AND EQUIPMENT — covering:
system architectures, new system concepts (all-electric aircraft) man/machine interface, advanced optoelectronic concepts, detection and recognition, software engineering, lightning protection, flight control, sensors, actuators.

PROPULSION — covering:
engine/airframe integration, incorporation of new propulsion concepts (propfans, high bypass ratio turbofans, ramjets), fuel systems.

MULTIDISCIPLINARY — covering:
cockpit integration, active control technology, structural mode control.

DESIGN TECHNOLOGY — covering:
computer-aided design, methodologies and means leading to an increase of design productivity and integration with manufacturing processes.

MANUFACTURING TECHNOLOGY — covering:
computer-aided manufacturing, computer integrated manufacturing, flexible manufacturing systems, advanced manufacturing and inspection systems (robotics, non-destructive testing).

OPERATIONAL SYSTEMS — covering:
air traffic control, operational research, overall fleet management, advanced navigation concepts.

APPENDIX D

CANDIDATE PROJECTS: SELECTION/PRIORITIZATION CRITERIA

The following criteria, which are explained in the text that follows, were used by the Study Group in selecting, and subsequently assigning a priority rating to, the most suitable of the technology topics proposed for the new cooperation programme.

1. TOPICS SPECIALLY CONCERNING AIRFRAME MANUFACTURERS (AS OPPOSED TO ENGINE OR EQUIPMENT MANUFACTURERS

2. SUBJECTS NOT YET ADEQUATELY ADDRESSED WHICH INVOLVE HIGH RISK

3. SUBJECTS ON WHICH EUROPEAN INDUSTRY IS LAGGING FAR BEHIND FOREIGN COMPETITION

4. TOPICS OF COMMON INTEREST FOR THE EUROPEAN AIRFRAME INDUSTRY

5. SUBJECTS CRITICAL FOR FUTURE MARKET COMPETITIVENESS

6. BASIC RESEARCH WITH CLEAR POTENTIAL FOR FUTURE INDUSTRIAL APPLICATION

7. SUBJECTS DIRECTED TOWARDS SPECIFIC AIRCRAFT TECHNOLOGY GOALS

8. COST-EFFECTIVENESS IN RELATION TO THE SCALE OF EFFORT REQUIRED

9. LARGE PROGRAMMES EXCEEDING THE FINANCIAL CAPACITY OF INDIVIDUAL NATIONS

10. LEVEL OF POTENTIAL CONFLICTS OF INTEREST AND OF PROPRIETARY PROBLEMS (IPR — INDUSTRIAL PROPERTY RIGHTS)

11. LONG-TERM RESEARCH SUBJECTS IMPROVING EUROPEAN PREPAREDNESS IN VERY ADVANCED TECHNOLOGIES, EVEN IF NOT IMMEDIATELY COST-EFFECTIVE

Adoption of these criteria was based on the following considerations:

1. **TOPICS SPECIALLY CONCERNING AIRFRAME MANUFACTURERS (AS OPPOSED TO ENGINE OR EQUIPMENT MANUFACTURERS)**

   In the aircraft development process, the airframe industry maintains a close cooperation with engine and equipment manufacturers, with material development and supply industries, with electronics manufacturers, etc.

   In many circumstances, the aircraft industry appears as a powerful driver for those industries with which it has many common interests, in particular in the advanced technology fields. However, in the EUROMART Study, the Research Proposals are limited to topics of direct concern to the airframe manufacturers, assuming that subjects more directly concerning other industries are or can be dealt with in the framework of other actions/supports.

2. **SUBJECTS NOT YET ADEQUATELY ADDRESSED WHICH INVOLVE HIGH RISK**

   For various reasons (new technologies, new or renewed interest, past economic limitations, etc.) there are subjects not yet adequately covered, identified as advanced technologies and many of them involving high technical and/or financial risk. It is felt that these topics are primary candidates for cooperative action, which will allow shared investment and reduce the risk involved by each individual participant.

3. **SUBJECTS ON WHICH EUROPEAN INDUSTRY IS LAGGING FAR BEHIND FOREIGN COMPETITION**

   The main objective of the EUROMART study being the improvement of the European Aeronautics Industry's competitiveness, this criterion is fundamental. However, the question was raised as to what should be done about technology fields in which this industry is <u>more</u> advanced than its competitors. In this situation it is necessary to maintain investment at an appropriate level for retaining a competitive advantage.

4. **TOPICS OF COMMON INTEREST FOR THE EUROPEAN AIRFRAME INDUSTRY**

   This is a prerequisite for cooperative action; if many companies are interested in a given subject, there will be strong motivation for cooperation and the probability of a successful outcome will be high.

5. **SUBJECTS CRITICAL FOR FUTURE MARKET COMPETITIVENESS**

   Market analysis documented in the course of the study and the requirements for future competitiveness which were identified constitute a solid basis for the evaluation of criticality levels of the various topics.

   In some cases (e.g., super/hypersonic transports) where the conclusions are less clear, other considerations will have to be taken into account (see below).

6. **BASIC RESEARCH WITH CLEAR POTENTIAL FOR FUTURE INDUSTRIAL APPLICATION**

   Applicability of basic research is sometimes questionable. In the EUROMART research proposals a clear application potential is postulated in the timescale contemplated for the various product goal developments (example: applicability of basic research results on laminar flow control on a wing can be expected in the next 5 to 10 years).

7. **SUBJECT DIRECTED TOWARDS SPECIFIC AIRCRAFT TECHNOLOGY GOALS**

   When a subject has limited general application but is particularly important for a specific aircraft type, it is considered eligible for cooperative action (example: thermal protection system for hypersonic aircraft) and can have a high priority level.

8. **COST-EFFECTIVENESS IN RELATION TO THE SCALE OF EFFORT REQUIRED**

   Competitiveness of the industry is tightly related to the cost of products. Therefore, all industrial activity, including research, must be affordable, compatible with available budgets and has to insure a reasonable return on investment, at least on a long-term basis. Evaluation of the cost-effectiveness of research is generally difficult, but is a definite need for the purpose of good planning.

9. **LARGE PROGRAMMES EXCEEDING THE FINANCIAL CAPACITY OF INDIVIDUAL NATIONS**

   Historically, such programmes were the first examples of large-scale cooperation in aeronautical programmes between European nations. The choice was cooperation at development and/or production level or acquisition of aeronautical products off-the-shelf. The last solution would inevitably produce a deterioration of the technological capabilities of the buyer, a possible decrease in industrial activities, and social problems. On the contrary, there are numerous examples of successful cooperation where the technology assets of the participating nations were significantly enhanced. It is felt that an additional benefit can be provided if the cooperative activity is extended to the early and long-term research level (basic and applied).

10. **LEVEL OF POTENTIAL CONFLICTS OF INTREST AND OF PROPRIETARY PROBLEMS (IPR – INDUSTRIAL PROPERTY RIGHTS)**

    Such difficulties can arise between cooperating companies, customers, individuals, etc. They can be entirely absent in particular technology areas, and the corresponding topics are certainly favourable for cooperation. However, it is considered that, when appropriately treated from the outset, with well-defined and agreed working rules, most of the problems can be solved in a manner acceptable to all the participants. This criterion should therefore be an obstacle to cooperative actions only in exceptional cases.

11. LONG-TERM RESEARCH SUBJECTS IMPROVING EUROPEAN PREPAREDNESS IN VERY ADVANCED TECHNOLOGIES, EVEN IF NOT IMMEDIATELY COST-EFFECTIVE

By scientific tradition, the European aeronautics research and industrial community has the willingness and capability to participate in very ambitious future projects. The second-generation supersonic transport and the hypersonic/transatmospheric vehicle programmes are examples for which the huge investments required can be obtained only through world-wide cooperation between many industrialized nations. In order to be prepared for a well-balanced role and equal partnership in such programmes, several actions must be initiated at the basic and applied research levels in a number of technology fields. European-wide cooperation will be the best basis for carrying out the actions efficiently.

APPENDIX E

PROPOSED 'LEAD PROJECTS' FOR COOPERATION

As indicated in the main text of this Executive Summary (Section 2.6), during the course of the EUROMART study some sixty outline projects, out of a total of over 100 potential joint research projects, were identified as being suitable for inclusion in a new cooperation programme. It is proposed that these sixty outline projects be further developed into detailed candidate project form so as to constitute the basis of the new programme.

With this object in view, nine 'lead projects' were selected from the sixty already mentioned. These have been the subject of a more detailed study, with regard to work content, timing, cost, etc. The Project Definition Statements for the nine lead projects are summarized below.

LEAD PROJECT NO.1 Category: AERODYNAMICS

Title: **AEROTHERMODYNAMICS**

Background

A hypersonic vehicle probably will be developed in the first quarter of the next century. Because of the very large investment required it is possible that there will be only one such project and that it will be a world-wide cooperative venture. Europe cannot afford to be left out. Its aeronautics industry must be ready to make a substantial contribution from the outset, that is from the pre-design stage onwards. Aerothermodynamics is a subject fundamental to hypersonic flight, one which will involve the accumulation of basic knowledge over a lengthy period of time. This project, which will focus mainly on the Mach 5 to 7 range, commences such a process, its purpose being to establish over the two-years pilot phase a very detailed, comprehensive programme of research to be conducted during the five-years main phase of the project.

Work statement

The project will embrace general optimization concepts as well as theoretical and experimental research, including techniques to elaborate computation models on very large computers, novel experimental techniques, and means of measurement. The nine topics of principal interest are as follows: topics 1 to 5 inclusive, the objectives of which are indicated in parentheses, will constitute the pilot phase of the project.

1) Framework integration (definition of optimization objectives: investigation of design concepts: integration of work in chapters)
2) Optimization strategy and method (formulation of optimization problem: formulation of constraints: basic method work)
3) Approximate methods, loads and coefficients (aerodynamic coefficient methods: list of tasks for main phase)
4) Transport and thermodynamic phenomena and models (basic definition work (choice of models): identification of special efforts in main phase)
5) Numerical methods (basic approaches and codes in two dimensions)
6) Grid generation
7) Shock/vortex boundary-layer interactions
8) Experimental techniques, measurements, and data-base (adaptation of basic measurement techniques: definition and setting up of windtunnel tests: first measurements)
9) Low-speed performance (identification of relevant low-speed effects: analysis of stability properties)

The object of the *pilot phase* is to establish and define a work programme for the main phase of the project. Essentially, it comprises

- the conduct of a detailed feasibility study,
- the preparation of a detailed research programme covering the whole subject, and
- the development of computation models, and means of testing and measurement.

The purpose of the *main phase* of the project is to conduct the research programme established during the pilot phase. It will involve work on all the topics listed above.

Timescale and cost estimates

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 15 million
MAIN PHASE (5 years) — ECU 45 million

(It is expected that the research project on aerothermodynamics will have to extend beyond the seven years covered by this project, probably for a full duration of approximately 15 years, at a preliminary estimated total cost of ECU 110 million.)

LEAD PROJECT NO.2 Category: AERODYNAMICS

Title: **LAMINAR FLOW TECHNOLOGY**

Background

It is a well-established fact, resulting from the considerable volume of research already done on this subject, that flow laminarity around the fuselage and wings of an aircraft is a decisive factor in reducing drag. This improvement in aerodynamic performance in turn reduces the Direct Operating Costs of the aircraft. The laminar flow can be extended downstream by theoretical surface shaping and/or suction at critical areas (spanwise on wing and tail, section-wise on fuselage and nacelles). Validation must be carried out in flight in the transonic and supersonic regimes. The purpose of this project is to extend the research in this field by developing successful work already done and exploring new, potentially valuable concepts and possibilities.

Work statement

The topics of principal interest are as follows:

1) Windtunnel testing to acquire experimental data
2) Development of measuring and testing techniques
3) Numerical flow-field calculation (2-D and 3-D)
4) Effects of profile roughness and contamination
5) Flight testing on a demonstrator aircraft
5) Cost-benefit analysis

The proposed two-years *pilot phase* will be devoted to

- basic preparatory work, both theoretical and experimental
- detailed analysis, organization and planning of the work to be done in the main phase of the project
- cost evaluation.

The purpose of the *main phase* of the project is to conduct the research programme established during the pilot phase. It will involve work on all the topics listed above.

Timescale and cost estimates

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 26 million

MAIN PHASE (5 years) — ECU 65.8 million

LEAD PROJECT NO.3 Category: MATERIALS

Title: **APPLICATION AND DEVELOPMENT OF ADVANCED MATERIALS**

Background

The search for new and improved materials to be used in aircraft construction continues to gain momentum. In some aircraft as much as 25% of the fuselage structure is now fabricated from composite materials. The trend will accelerate for weight is a decisive element in the competitiveness of aircraft of all kinds. Experience indicates that a weight difference of only a few percent between competing aircraft can exert a decisive influence on Direct Operating Costs and hence on sales. Since this is a subject of concern to all the companies in the European Aeronautics Industry it is an obvious choice for any cooperative research programme. Large overall savings in time, money, and specialist research staff are to be expected.

Work statement

New composite materials are made up of basic elements (fibres and matrices) which commonly require special fabrication techniques when they are made up into aircraft parts. It follows, therefore, that, in addition to the materials themselves, structural concepts and manufacturing technologies have to be considered at the same time. Hence, this project is directed at exploring the most promising of all three of these elements, as follows:

Common objectives are analysis, specifications, characterization, and qualification criteria

- Aluminium-lithium alloys (material production capacity)
- Metal matrix composites (target definition and material characterization, for existing material: process techniques and material characterization, for new material)
- Powder metals (bibliography: test specifications)
- Testing and qualification methodology (definition of common criteria, methods, and test techniques under operational conditions (temperature, humidity, cracks, etc.)
- High-temperature organic composites (bibliography, test specifications)
- Fibre-reinforced carbon and ceramics (selection of components: improvement of materials: process optimization: mechanical properties and degradation laws)
- Surface technology (bibliography: establishment of working groups)
- Adhesives (feasibility study: selection of candidate materials, processes and manufacturing techniques: preparation of composite surfaces: demonstration tests)
- Composites with organic matrices (optimization, evaluation, and quality control of present-generation thermosetting materials: optimization of parameters for composite/metal combinations)

Timescale and cost estimates

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 25 million
MAIN PHASE (5 years) — ECU 120 million

LEAD PROJECT NO.4 Category: ACOUSTICS

Title: **AIRCRAFT NOISE: PHYSICS AND EFFECTS**

Background

The volume of air traffic (it has doubled in the last ten years) is now such that the reduction of noise disturbance caused by aircraft flying in the neighbourhood of busy airports has become not only a sensitive political issue but also the subject of increasing control and regulation. This is one aspect of the problem — namely, exterior noise and how to minimize it.

There is also interior noise. For modern commercial transport aircraft to be attractive to airlines and their customers, on-board noise must be reduced to the lowest possible level, so achieving better working conditions for the crew and improved comfort for passengers.

There are also important technical considerations. For example, acoustic fatigue can cause premature structural deterioration: this is a matter which has to be investigated when any new material is to be introduced into an aircraft structure.

Past research has achieved spectacular results in regard to the quiet operation of subsonic jet transports powered by high-bypass-ratio turbofans. However, much remains to be achieved with respect to propeller-driven aircraft either in the classical or in propfan configuration. Helicopters and V/STOL aircraft are also still noisy, in spite of the considerable improvements so far achieved.

Aircraft noise is, of course, a subject of concern to all aircraft manufacturers, which is why it is a prime candidate for inclusion in the new cooperation research programme.

Work statement

The topics of principal interest are as follows:

- aircraft noise source identification, prediction, and reduction
- interior noise prediction and reduction techniques
- exterior noise reduction by active noise control
- acoustic fatigue and related problems in regard to advanced composite materials.

The *pilot phase* has as its main objectives:

1) Development of prediction methods
2) Active noise control theory
3) Identification and definition of facilities and testing techniques
4) Refine objectives and review cost estimate for main phase.

Timescale and cost estimates

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 23 million
Main Phase (5 years) — ECU 62 million

LEAD PROJECT NO.5 Category: COMPUTATION

Title: **FUTURE COMPUTING CAPABILITIES**

Background

Many technology areas in the aeronautical industry involve very complex phenomena which, even when the basic theories involved are well-known, require very sophisticated equation sets to be treated completely.

Some of the main application fields are: aerodynamics and aerothermodynamics, structural strength, aeroelastics, flight controls, acoustics, heat transfer, and electromagnetism.

Until recently, the study of these techniques relied mainly on tests (wind tunnel tests, structural tests, etc.). But the emergence of very powerful computers made it possible to solve full equation sets in more and more sophisticated cases. The present supercomputers (like Cray II) seem to be only a step on the way towards still more powerful units.

The development, orientation, and use of these computers need to be coordinated, since they are of major importance in the development of the future products and because of the large facilities needed to solve the problems encountered.

Work statement

The prime objectives of the project are to:

- develop the models and software to make best use of the present supercomputers
- define future needs and the architectures that will best suit these needs
- train the engineers and researchers who will have to use the computers and software
- establish a network of computer centres, capable of handling the problems concerned.

The *pilot phase* of the project will be concerned with the preparation and subsequent conduct of a detailed feasibility study, the drafting of the relevant system definition and equipment performance specifications, and a first analysis and definition of work to be done in the *main phase* of the project.

Timescale and cost estimates

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 20 million
MAIN PHASE (5 years) — ECU 100 million

LEAD PROJECT NO.6 Category: AIRBORNE SYSTEMS AND EQUIPMENT

Title: **OVERALL INTEGRATION OF AIRCRAFT SYSTEMS & EQUIPMENT**

Background

An aircraft contains very many systems and items of equipment all of which have to operate correctly if the aircraft is to perform properly and safely. Until the early 1970's, although all the systems, etc., were monitored and controlled from the cockpit, most of them operated quite independently. The advent of numerical technologies permitted close interconnection of many of these systems and their functional integration within the cockpit, thus affording enhanced and safer operation of the aircraft, and even allowing completely new means of operating the systems to be introduced. However, this development requires that the softwares controlling the systems have to be consistent and compatible with one another and has led to the necessity to programme hundreds of thousands of instructions.

Work statement

In order to cope with this situation and maximise the advantages arising from it this project will address the following subjects:

1) avionics design and digital data-bus concepts
2) future cockpits for fixed-wing aircraft
3) future cockpits for rotary-wing aircraft (helicopters and V/STOL aircraft)
4) systems development and evaluation tools
5) intelligent knowledge-based-software (IKBS) development to bring about improved maintenance techniques.

The initial *pilot phase* of the project has the following goals:

- create a common aircraft equipment data-base
- establish harmonized design requirements
- carry out demonstration and simulation experiments
- achieve a measure of harmonization between the interests of manufacturers, suppliers, and operators.

Timescale and cost estimate

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 23 million
MAIN PILOT (5 years) — ECU 68 million

LEAD PROJECT NO.7 Category: AIRBORNE SYSTEMS AND EQUIPMENT

Title: **ALL-ELECTRIC AIRCRAFT SYSTEMS**

Background

Today's aircraft systems are powered by a variety of means — hydraulic, pneumatic, mechanical, and electrical.

The inherent complexity of such an arrangement creates a very large maintenance burden. Moreover, the power taken from the engines in order to operate these systems degrades engine performance and increases fuel consumption. This project will pursue the examination of ways in which all systems can in future be operated exclusively by high-efficiency electrical power sources.

Work statement

The main topics of interest are as follows:

1) Protection against icing	Deletion of engine bleed air Reduction of energy consumption Weight reduction Application to non-metallic structures and prop-fan blades
2) Flight controls actuation	Deletion of centralized hydraulic system Electrical powered flight controls Deletion of mechanical inputs to flight controls Increased reliability by extensive application of health monitoring (built-in-test techniques)
3) Secondary power generation	Elimination of engine air bleed for cabin and avionics cooling Mass and volume reduction by elimination of pneumatic ducts in the wing and the pylon areas.

The objectives of the *pilot phase* are:

— World survey of the state of the art
— Feasibility study to identify the problems to be solved
— Define the basic research areas to be investigated in relevant laboratories on research establishments
— Conduct trade-off studies for every change in power supply type
— Establish a complete programme for the main phase.

Timetable and cost estimates

Budgetary cost estimates for project are:

PILOT PHASE (2 years) — ECU 10.8 million
MAIN PHASE (5 years) — ECU 20.7 million
FOLLOW-ON PHASE (—) — ECU 17.5 million

LEAD PROJECT NO.8 Category: PROPULSION

Title: **AERODYNAMIC ASPECTS OF ADVANCED PROPELLERS**

Background

Advanced propeller propulsion systems (so-called propfans) are now being developed and tested. Due to the use of new blade profiles and multi-blade discs these new systems can operate at M.7—M.8 with a predicted fuel consumption 30—50 per cent lower than that of current turbofan engines.

However, the slipstream from such propellers can interfere greatly with the air flow pattern around the rest of the aircraft. If this interference cannot be counteracted it could cancel out most of the expected saving in fuel. Hence, the need exists for a generic test model with which to investigate these systems and their effects, in particular:

1) Single-rotating and counter-rotating propfans
2) Wing-mounted and aft-mounted engines
3) Tractor and pusher configurations
4) High-wing and low-wing configurations
5) Distance between propeller disc and wing or fuselage
6) Wing sweep angle.

The model (say, of 4.5 m wing-span and with a propfan diameter of 0.6 m) must be operated in windtunnels to measure behaviour at both low speeds (including ground effects) and high speeds (including transonic effects). Later, the experiment will be used to verify flow patterns calculated with the help of Euler and Navier Stokes codes and to provide acoustics measurement data in support of Lead Project No.4.

Work statement

The workplan has three phases:

— *Pilot phase*, in which the experimental windtunnel test programme will be fully defined:
  - Adaptation of theoretical equation sets and first results to orientate the experimental programme
  - Definition of the model and its elements
  - Selection of turbine-powered simulators
  - Definition of model propfans in cooperation with engine/propeller manufacturers
  - Identification of equipment requirements (for measurements, data acquisition, results analysis, etc.)

— *Main phase*, in which the wind-tunnel programmes will be executed and the resulting data analysed. Further more specific investigations probably will be needed in order to complete the desired technology data-base.

— *Follow-on phase*, in which the applicability of selected propulsion/configuration combinations to different aircraft categories (that is, large commercial transports, regional/commuter aircraft, etc.) will be further investigated experimentally, possibly in combination with an in-flight technology demonstrator.

Timescale and cost estimates

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 10.5 million
MAIN PHASE (5 years) — ECU 25 million
FOLLOW-ON PHASE (to be decided later)

LEAD PROJECT NO.9

Catetories: DESIGN TECHNOLOGY and MANUFACTURING TECHNOLOGY

Title: **HIGHLY INTEGRATED CAD/CAM/CIM SYSTEMS**

Background

With the increasing sophistication of aerospace products, the development, manipulation and management of the huge amounts of data generated (design, engineering, and other data) require a high level of computer-based information.

The main tools of the automation effort result from the integration of computers with alphanumeric and graphic displays, supported by very large-scale Computer-Aided Design (CAD) and Computer Integrated Engineering (CIE) software. Numerous CAD/CIE systems have been developed in the aerospace and other industries during the last decade and their generalized use has produced profound changes in the design and engineering office environment.

A similar evolution has taken place at the manufacturing level with the application of the Computer-Aided Manufacturing (CAM) and Computer Integrated Manufacturing (CIM) technologies. Despite the very significant improvements and economies which have resulted from all these changes it must be pointed out that, during the development and installation of these systems, many difficulties were encountered. In large part these were due to the heterogeneous systems used within any particular company and to the serious communication problems between companies participating in cooperative projects.

In the CAD/CAM/CIM area, one major objective will be to achieve an all-digital product and manufacturing definition for all aerospace projects. This implies a change in the philosophy from an analogue drawing documentation system to a digital one in which computer files become master documents.

This all-digital definition must be constructed within the following framewok:

- all multinational, multicompany collaborative projects
- varying customer requirements even for the same product
- projects are subject to frequent, quick changes and small production runs
- very large amounts of data very different in nature (e.g., CAD/CAM models, BOMs, wire and components lists, ECO, configaration control information, NC-programs)
- multi-system (CAD/CAM/CIM) environment.

The overall purpose of this Lead Project is to devise means whereby the efficiency of the European aeronautics industry can be increased by extending the use of computerised tools and applying them in a coordinated and consistent manner. The aim is to:

1) reduce unit costs

2) reduce development and lead times, capital employed, and time to react
3) increase the reliability of products and processes
4) adapt more quickly to customer demands
5) apply technical innovations and changes more quickly.

Work statement

The workplan has two phases:

- *Pilot phase*, in which a complete analysis will be made of the present CAD/CAM/CIM status in the European Aeronautics Industry, all the preliminary planning work for the project will be completed, and the techniques and procedures defined such that there is industry-wide agreement on the objectives to be sought. This phase will also:
  1) Identify those research themes which are already dealt with in other programmes (e.g., ESPRIT)
  2) Set up a comprehensive programme of research actions to be taken in cooperation with specialised software companies
  3) Set up common specifications for systems, data-bases and development tools
  4) Devise a common integration process.
- *Main phase*, during which research activities will be addressed to the following principal topics:
  1) Integration of systems applied within the product-generation activities and processes through intelligent interfaces
  2) Reliable and complete data exchange and communication between partner companies, customers, subcontractors and suppliers (e.g., by using a common data-base)
  3) 3D Solid-modelling techniques, for example, in the
     - design of product and tools
     - simulation of product design
     - simulation of manufacturing processes
     - programming of nc-machines
     - programming of coordinate measurement machines
  4) Man-machine interfaces and human factors including education systems.

Timescale and cost estimates

Budgetary cost estimates for the project are:

PILOT PHASE (2 years)— ECU 15 million
MAIN PHASE (5 years) — ECU 100 million

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