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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARD REPORT No.782

Seminar on the Structure of Aeronautical R&D

(La Structure de la Recherche et Développement en Aéronautique)

NORTH ATLANTIC TREATY ORGANIZATION

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(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

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Seminar on the Structure of Aeronautical R&D

(La Structure de la Recherche
et Développement en Aéronautique)

The material in this publication was used as the basis for a Seminar organized by AGARD Headquarters, held on 31st May—1st June 1990 at Lisbon, Portugal, on 4th—5th June 1990 at Patras, Greece and on 7th—8th June 1990 at Ankara, Turkey.

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- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Exchange of scientific and technical information;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

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Preface

In recent years, AGARD has implemented a Support Programme for Greece, Portugal and Turkey. This support generally consists of advice from organizations in supporting Nations to supported Nations. This advice is conveyed by means of visits by consultant specialists from the supporting Nations to the supported Nations and equally by visits of scientists and engineers from the supported Nations to R&D facilities in the supporting Nations.

The Support Programme was reviewed by AGARD in 1988. During this review the need was expressed for Long-Term National Aeronautical R&D Planning, based on short and long-term national goals. The objective of the present Seminar, organized along the lines of the AGARD Lecture Series, is to present and discuss those elements needed to develop a Long-Term Aeronautical R&D Plan. The lecturers will share their experience with representatives from government, industry and research in Greece, Portugal and Turkey, responsible for the organization of aeronautical R&D.

The written contributions to this Seminar, given here, present the basis for the discussions. The papers show that aeronautical R&D is a complicated process, that long periods of engagement of dedicated and competent groups are essential and that there has developed an intricate network of exchange of information and of collaborative research and development, both nationally and internationally. The papers are contributions to the development of a better understanding of the aeronautical R&D process but they certainly do not give a complete picture nor do they cover all aspects involved. The present views and experiences are from North America and Europe. The lecturers obtained their experience in research laboratories and industry. In several cases the same topics are treated by different authors but from a different vantage point.

The participants in the Seminar must ultimately decide whether or not the information is useful to them. The most important aspect of this Seminar may be that those responsible for planning aeronautical research and development in each country will be stimulated in their difficult task.

* * *

Ces dernières années, l'AGARD a mis en oeuvre un programme d'aide à la Grèce, au Portugal et à la Turquie. En général, cette aide est apportée sous la forme de conseils donnés par des organismes de pays procurant l'aide aux pays recevant l'aide. Ces conseils sont communiqués à l'occasion de visites faites par des spécialistes des pays "aidants" aux pays "aidés", ainsi que par l'intermédiaire de visites effectuées par des scientifiques et des ingénieurs de pays "aidés" à des installations de recherche et développement dans les pays "aidants".

Le programme d'aide a été revu par AGARD en 1989. Cet examen a révélé le besoin, pour le long terme, à l'échelon national d'une planification de la Recherche et Développement (R&D) aéronautique fondée sur les objectifs nationaux à court et à long terme. L'objet de ce séminaire, qui est organise de la même facon qu'un Cycle de conférences AGARD, est de présenter et de discuter des éléments nécessaires à l'élaboration d'un plan de R&D aéronautique à long terme. Les conférenciers partageront l'expérience qu'ils ont acquise dans ce domaine avec des représentants du gouvernement, de l'industrie et des établissements de recherche, de la Grèce, du Portugal et de la Turquie responsables de l'organisation de la R&D aéronautique.

Les contributions écrites à ce séminaire, qui sont reproduites ci-après, présentent une base pour les discussions. Il ressort des communications en question que la R&D aéronautique est un processus compliqué, qu'elle exige de longues périodes d'engagement de la part d'équipes compétentes et dévouées et que par conséquent, au fil des ans, il s'est développé un réseau complexe d'échanges d'information et d'activités de R&D poursuivies en collaboration, tant dans les pays qu'au plan international. Les communications devraient permettre une meilleure compréhension du processus de la R&D aéronautique, mais elles sont loin d'être exhaustives. Les opinions et les expériences présentées émanent de l'Amérique du Nord et de l'Europe. Les conférenciers ont travaillé dans des laboratoires de recherche et dans l'industrie. Dans certains cas, le même sujet est traité par des auteurs differents, mais chaque fois d'un point de vue différent.

En dernière analyse, il incombe à chacun des participants à ce séminaire d'évaluer l'intérêt des informations communiquées pour son cas particulier.

Peut-être que la conséquence la plus importante de ce séminaire sera d'encourager dans leur tâche difficile, ceux qui sont responsables de la planification de la R&D aéronautique dans chacun des pays visités.

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THE PROSPECTS OF AERONAUTICS

by

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Introduction

(by J A van der Bliek)

When considering aeronautical research and development it is useful to begin by reviewing the prospects of aeronautics for the next decades. As is clear from the other papers, the participation in any major development in aeronautics requires a sustained effort of many years and so we are really considering major contributions, nationally or internationally, which will come to fruition in the next century.

The 20th century saw the development of aeronautics on a global scale. One may ask the question if this development now has levelled off and if from now on only marginal improvements and utilization will take place. This paper indicates that there will be tremendous challenges and opportunities in the coming decades.

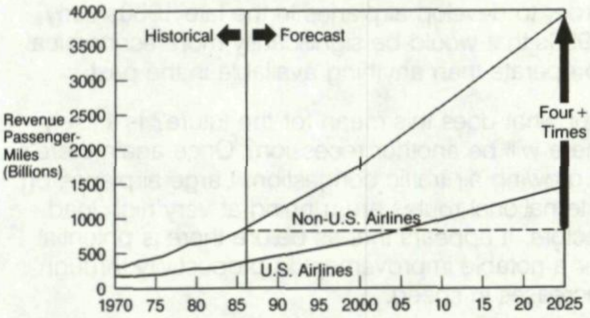
The paper contains the essence of the 50th Wright Brothers Lecture, first given in St Louis, Missouri, USA on 14 September, 1987. Mr Swihart was then Corporate Vice-President - International Affairs, The Boeing Company. The lecture concentrated on civil aeronautics, but of course many identical technical developments apply equally to military and civil aviation. In fact the history of aeronautical development shows that there is an intimate relationship beween civil and military aeronautical developments. During several periods the military provided the driving force. We may now be entering a period where civil requirements will dominate.

The developments since 1987, when the paper was written, make us expect that the outlook for technical aeronautical developments has not become less and, in fact, the developments may far exceed the expectations of a few years ago.

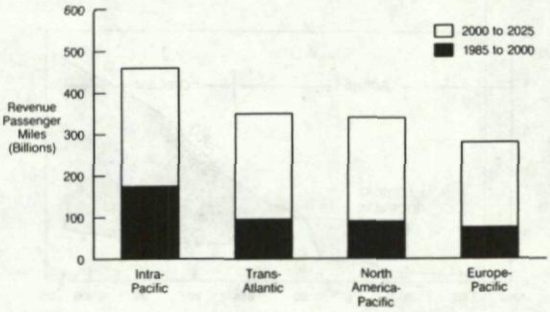
The Market

There are about 7000 commercial transports in the world today flying about 870 billion revenue passenger miles per year. By the year 2025, it is expected that passenger travel will increase by more than a factor of four and 16,000 transports will produce close to 4000 billion passenger miles. There will be extensive expansion of commercial airplane travel on a worldwide basis. When we look closely at various areas of the world where traffic is going to increase, we find that in the transatlantic, North America-Pacific, intrapacific, and Europe-Pacific regions, traffic is going to swell from three to six times beyond what we have today. Growth in the next 12 years will be larger than all the traffic we have generated from the start of commercial service until the present time. This magnitude of increase is potentially the driving force for the development of higher speed transports.

World Revenue Passenger-Miles

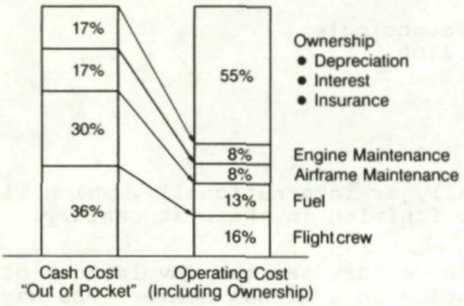


Potential High-Speed Markets



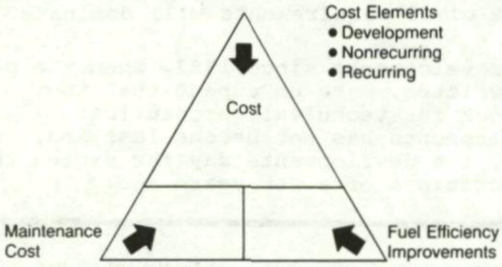
Economic Environment

Elements of Direct Operating Cost



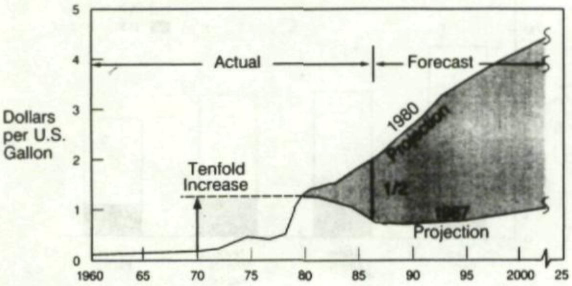
In this day of rapidly changing technology, it is important to realize that operating costs are particularly important from the airline point of view. Airlines cannot afford to purchase technology for technology's sake. It must contribute to reducing cash operating costs such as the flightcrew, fuel, airframe maintenance, and engine maintenance. With improved fuel efficiency, these elements assume a greater importance than they did in the past. In addition, we can not ignore the fact that the costs of ownership—depreciation, interest, and insurance—have become more vital considerations.

Manufacturer's Cost Objectives



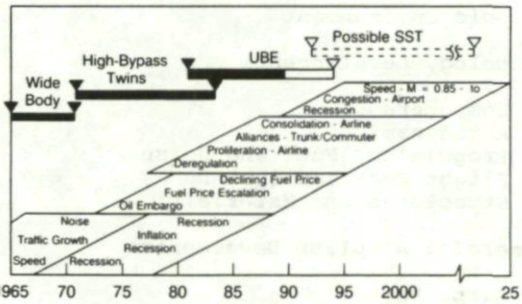
Pressure is ever on manufacturers to reduce development costs through high technology, reduce nonrecurring costs through the application of computers, and reduce recurring costs through the application of robots, etc. The objectives are lower maintenance costs and reduced fuel consumption, which next to flightcrew pay is an airline's biggest single out of pocket expense each day.

Unpredictable World Jet Fuel Prices



It is important to note that the yardsticks for predicting airplane performance and cost are constantly changing. For example, in 1970, who would have thought that by 1980 there would be a tenfold increase in the price of Jet A fuel? In 1980 it was commonly believed that by 1990 there would be another increase of at least a factor of two; however, in 1987, fuel cost is about one-half what it was in 1980. Consequently, predicting the economic elements of the commercial transport business is extremely difficult.

Changing Market Influences



To illustrate, it is only necessary to go back about 20 years and look at the changing market influences and what they have meant to airframe manufacturers and airline operators. In 1965-66, traffic was increasing at about 15% per year. All major airports in the United States had long lines of airplanes waiting to take off. Wide-body transports were the solution to that problem.

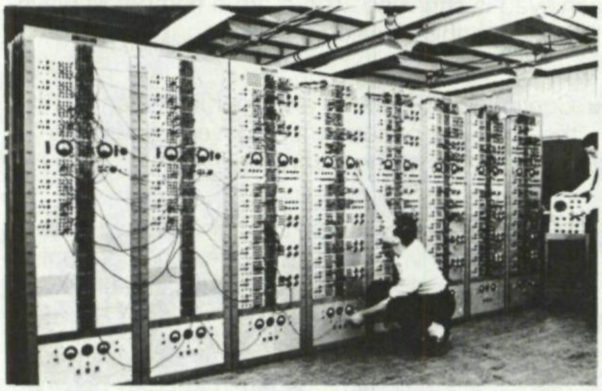
By 1970, noise had become a significant factor. The economy suffered a major recession. Shortly thereafter came the oil embargoes, which led to a great emphasis on fuel efficiency.

Under an important NASA program—the ACEE—each manufacturer was striving to build the most fuel-efficient airplane possible. This was the genesis of the 757 and 767 airplanes at The Boeing Company. Before the decade was over, deregulation had occurred. Fuel price rose again very substantially and there was another deep recession through 1983. The number of airlines operating in the United States went from less than 30 to nearly 150. All of a sudden, fuel price turned around and started to decline. Manufacturers began looking at very-high-bypass-ratio turbofan engines and cost effective advanced technology in order to develop airplanes in the late 1980s/early 1990s that would be significantly more economical to operate than anything available in the past.

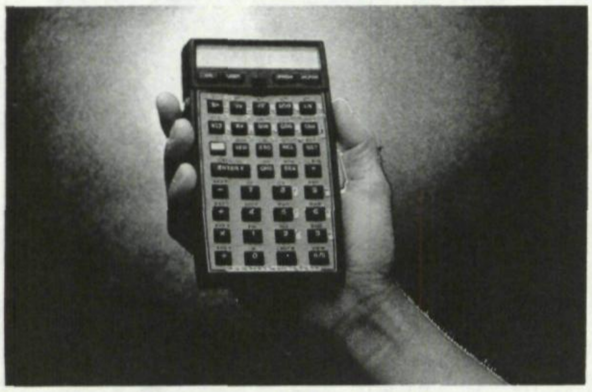
But what does this mean for the future? Is it likely there will be another recession? Once again there's a growing air traffic congestion. Large airplanes on international routes are running at very high load factors. It appears that as before there is potential for a notable improvement in productivity through increases in speed.

Technology Developments

Computers



No projection of the future in 1987 would be complete without recognizing the tremendous influence the modern computer has had upon our design, business, and manufacturing systems. A first-generation scientific computer in the 1958-1960 time period occupied an entire room. Today a very small hand-held computer has more memory and faster computation capability than that room full of equipment had. Today we are able to generate computations at the rate of nearly a billion per second; soon the capability will be 10 times that, done by a machine the size of a large coffee can.



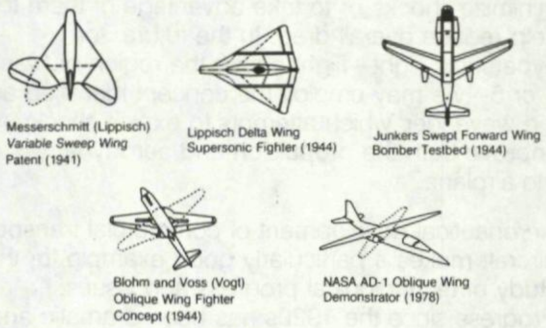
There is also the potential for an optical computer that may be 10 times faster still. With each improvement, the cost per computation goes down. Application of these computers to all elements of the manufacturing, design, and actual operation of airplanes is going to continue.

We now have the capability to do computations that in the past were impossible, and we can optimize the airplane in many areas where we formerly had to make do with the cut and try process.

With that as background we can now address several technology elements.

Aerodynamics

Aerodynamic Configurations Development

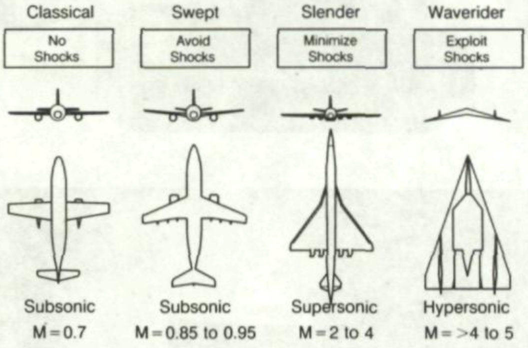


It is aerodynamics in concert with structural and manufacturing considerations that largely define an airplane's exterior contours. To the public at large, the shape and size of the aircraft is what one sees and tends to associate with technological progress in aeronautics.

It·can be argued with some validity that the vast majority of existing aircraft configurations were established (at least on paper) 40 to 50 years ago. The swept wing, conceived by Busemann (1935) and later R.T. Jones, and the development of the delta wing planform by Lippisch are the basis for almost every modern high-speed airplane configuration.

During the decade between 1935 and 1945, visionaries foresaw a range of configurations that even today can be considered very modern. These include the swept forward wing embodied in the current X-29 and pioneered at Junkers in the early 1940s, the oblique wing originally conceived by Vogt at Blohm and Voss in 1943, and variable sweep wings, a patent for which was issued to Messerschmitt in 1941 for the concept by Lippisch.

High-Speed Wing Trends



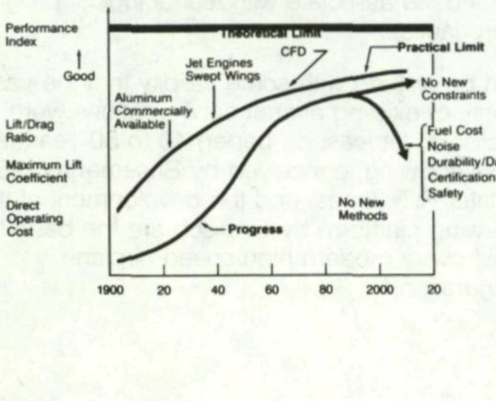
It is interesting to note that before the advent of the turbojet engine and the modern transport airplane, we built airplanes that had no shocks. In other words, there were no regions of supersonic flow. As speed increased due to use of swept wings and jet engines, we tried to avoid shocks as much as possible, designing the airfoil to minimize the effect of shock on the wing and around the nacelles.

The designs of the Concorde and the initial United States supersonic transport attempted either to minimize shocks or to take advantage of them to help reduce overall drag. In the future, for hypersonic flight—flight above the region of Mach 4 or 5—we may employ the concept identified as the waverider, which attempts to exploit shocks to improve both the propulsion and aerodynamics of the airplane.

Aeronautical development of commercial transport aircraft makes a particularly good example for the study of technological progress and issues. Progress since the 1920s has been dramatic and has continued as a result of many advances in a broad range of technologies.

Aeronautical Technology Development

Subsonic

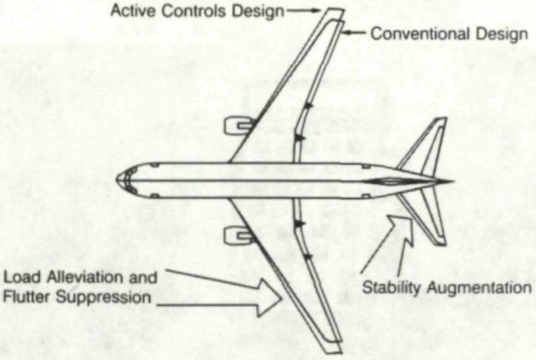


However, subsonic aeronautics is a maturing technology. When progress is compared to what is practical and what is theoretically possible, we see a convergence. The gap between the practical limit and the level of performance we have currently achieved is shrinking. There are a number of ways to deal with this situation:

- Continue work in finer and finer increments until the achieved performance converges with the practical limit of the technology
- Plan technological breakthroughs that will raise the practical limit boundary, or exploit dormant technologies that would have the same effect, e.g., laminar flow control
- Start a new ball game, wherein the gap between the limit and present achievement allows more competitive leeway (e.g., supersonic and hypersonic transports)

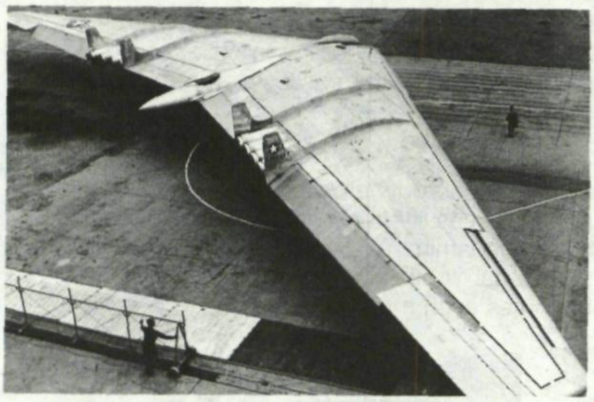
All of these approaches are in the cards, but three have been selected for brief extrapolations into the future: active controls, laminar flow control, and computational fluid dynamics.

Active Controls Concept



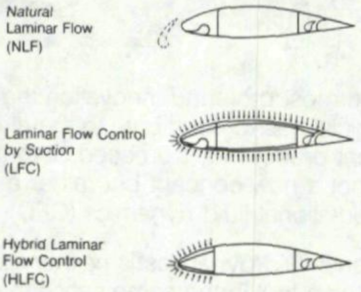
Until recently, all commercial transport aircraft had to be inherently stable. The advent of electronic flight control technology and potential reliability as great as that of fail-safe structure may allow significant changes.

The proportions of even a conventional airplane configuration may be altered (and improved) through the use of emerging active controls technology. In this case, the sum of a number of small but significant advantages, properly merged in a system sense, can result in a substantial payoff. More span for the same weight and hence greater aerodynamic efficiency can be obtained.

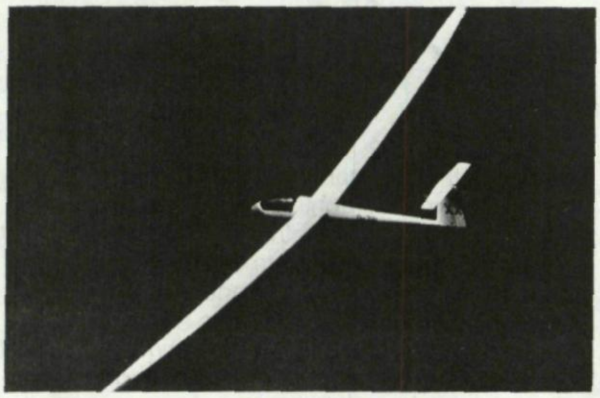


Perhaps complete dependence on electronics for stability, control, load, and flutter suppression will allow the true flying wing as conceived by Jack Northrop over 50 years ago to become a practical alternative to the transport aircraft we know today.

Types of Laminar Flow Control

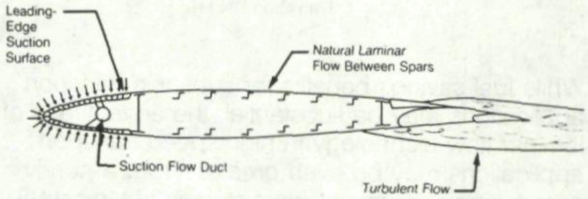


Laminar flow control offers a singularly significant opportunity for further improvement in aerodynamic efficiency. It is now possible to build transport aircraft on a routine production basis whose surfaces are very nearly hydraulically smooth with respect to turbulent boundary-layer flow. As a measure of this progress, excrescence drag accounts for a mere 5% of total airplane drag during cruise on a well-maintained modern aircraft. Reducing viscous drag by very much more than that achieved in current practice requires a major change in the character of the boundary-layer flow. One must attempt to create attached laminar as opposed to turbulent boundary layers wherever feasible and practical.



Passive boundary-layer control (shaping the pressure distributions) aimed at drag reduction is referred to as natural laminar flow control. Sailplanes offer a good example with an aerodynamic efficiency of nearly 60.

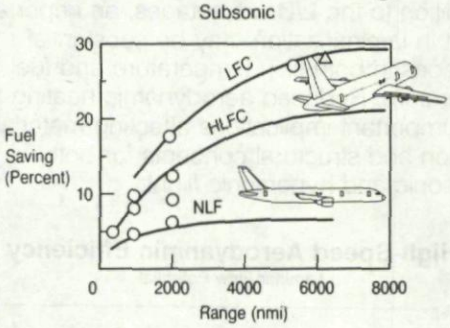
Hybrid Laminar Flow Control



In practice, producing a full laminar flow control wing for a transport airplane has always been a formidable mechanical engineering challenge (operational considerations aside). Recently attention has turned to a more practical alternative labeled hybrid laminar flow control (HLFC).

In an HLFC control scheme, active boundary-layer control (usually suction through a slotted or porous skin) is applied only to the portion of the wing ahead of the front spar. In addition, by proper shaping and smoothing of the airfoil, the greatest run of natural (passive) laminar flow is sought. This scheme produces a good balance between drag (skin friction) reduction, mechanical system complexity, and minimum disruption of the spar box/fuel tank structure.

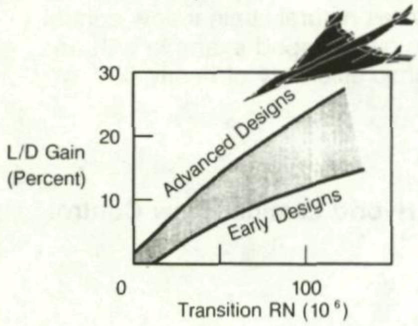
Laminar Flow Fuel Savings



Fuel savings anticipated from full and partial laminarization of transport aircraft are significant. The conclusion one draws from the available data is that, for long-range subsonic transports, the potential fuel saving from laminar flow control can no longer be ignored.

Laminar Flow L/D Improvement

Supersonic

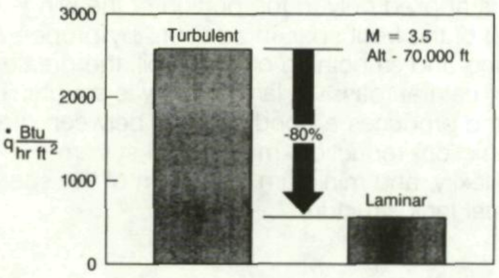


While fuel savings benefits for subsonic transport applications may be substantial, the advantages of laminar flow technology in high-speed transport applications may be even greater. From a purely aerodynamic viewpoint, past studies of typical SST configurations have illustrated the potential increases in cruise lift/drag (L/D) ratio obtainable as a function of the extent of laminar flow achieved.

Experimental data upon which present performance improvement estimates can be based is limited and suggests the need for improved supersonic wind tunnels with quiet test sections to supplement flight experiments.

Aerodynamic Heating

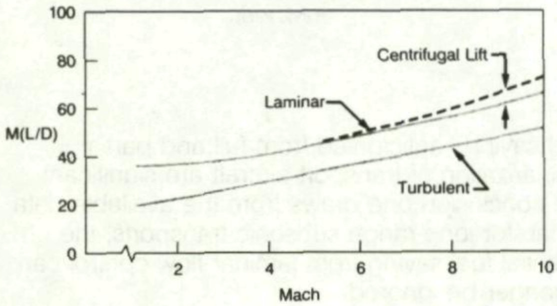
Laminar vs Turbulent



In addition to the L/D advantages, an important benefit in laminarization may be substantial reductions in both skin temperature and fuel temperature. Reduced aerodynamic heating has many important implications affecting materials selection and structural concepts for both supersonic and hypersonic flight.

High-Speed Aerodyanmic Efficiency

Laminar Flow Potential



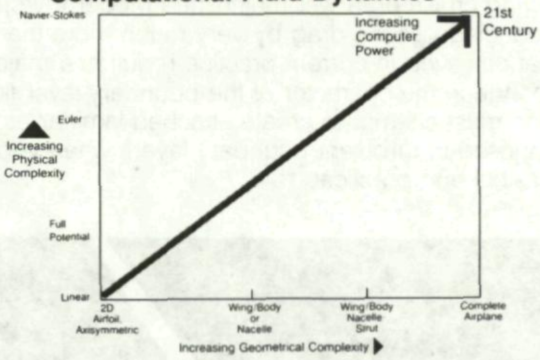
If the aerodynamic gains anticipated from laminarization of a significant portion of the airframe can be achieved, then associated reductions in airplane gross weight and sonic boom intensity can be expected.

Looking at aerodynamic efficiency as Mach number times lift/drag ratio, the importance of achieving laminar flow can be readily seen. When centrifugal lift effects are added, the efficiency becomes even more attractive.

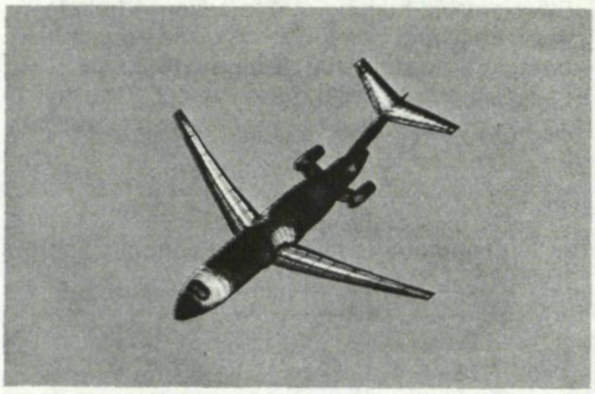
Perhaps the most profound innovation the aerodynamicist has to contribute to the airplane development process as it proceeds into the next century is not a new concept but rather a tool—computational fluid dynamics (CFD).

Computational fluid dynamics is neither fad nor panacea. It is a tool in the same sense that the wind tunnel or any other test facility is a tool. It produces data that, like any other data, must be carefully interpreted by someone with experience, physical insight, and healthy skepticism. As far as can be foreseen at present, CFD is a powerful complement rather than substitute for intelligently conducted wind tunnel and flight test experimentation.

Computational Fluid Dynamics

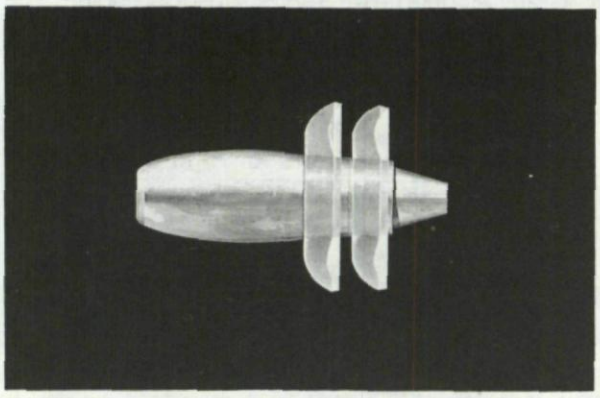


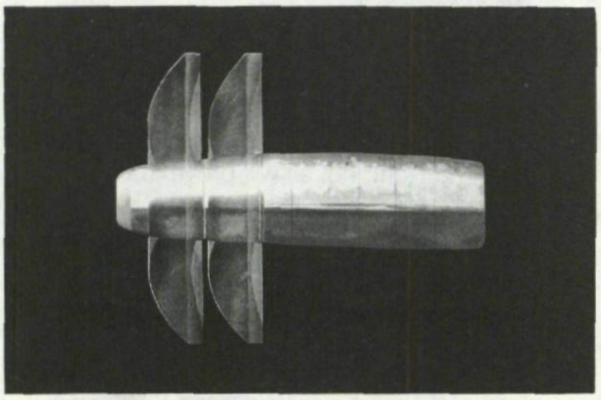
It is now within our hardware/software capability to analyze full airplane configurations and to simulate conditions of significance that are extremely difficult and sometimes impossible to test in wind tunnels available to us. A hypersonic analysis using Reynolds averaged Navier-Stokes equations produced results within 3% of experimental data at Mach 20. Real gas effects were included.



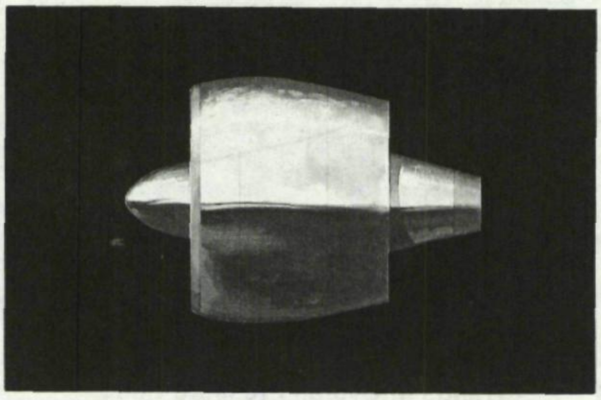
We have every expectation that computational fluid dynamics will become the irreplaceable third partner with the wind tunnel and flight testing in the airplane development process. At present we can rely on CFD to show local pressure, temperature, Mach number, and flow directions quite clearly. The illustration above shows the local pressure distributions for a complete airplane as it is subjected to different angles of attack.

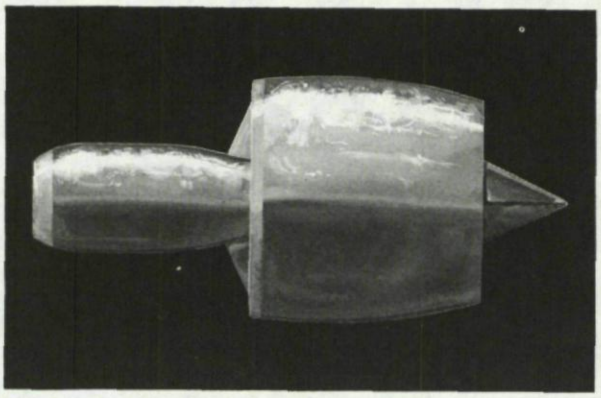
Propulsion, Fuel, and Noise

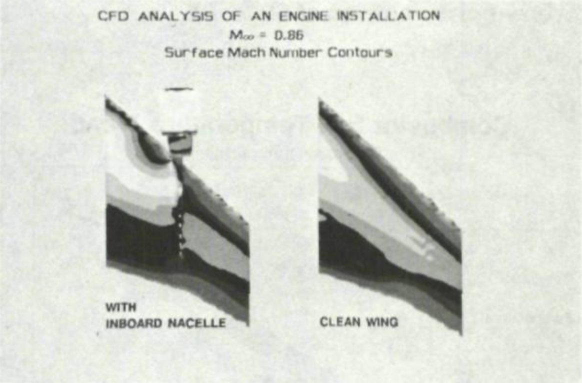




Turning now to propulsion technology, we see that for subsonic engines there are many different concepts. There are pushers and tractors, ultra-bypass engines and counterrotating advanced propellers. There are geared fans and ultra-bypass-ratio fans with cowls.



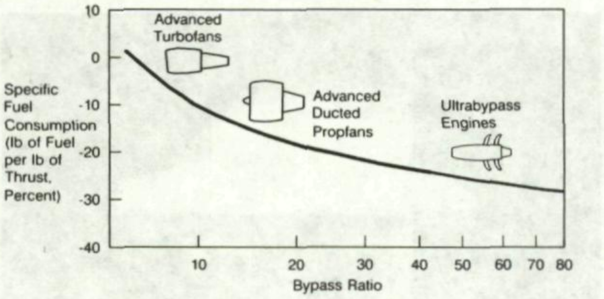




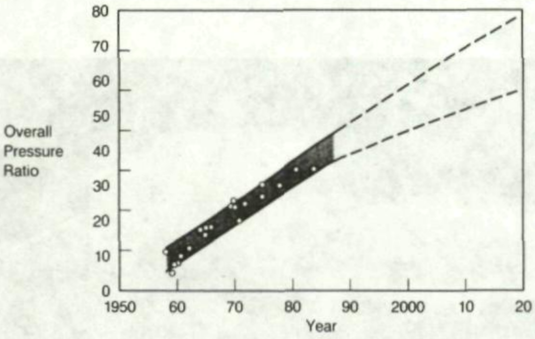
Computational fluid dynamics can aid substantially in determining the choice of powerplant as well as its location on the airplane. Data with and without the wing can be rapidly generated to help make those decisions.

Bypass Ratio Trends
Subsonic Transports

It's interesting to look at history and see that the engines we are talking about for the early 1990s will probably have specific fuel consumptions as much as 30% to 35% lower than the advanced turbofans of only 10 years or so ago.



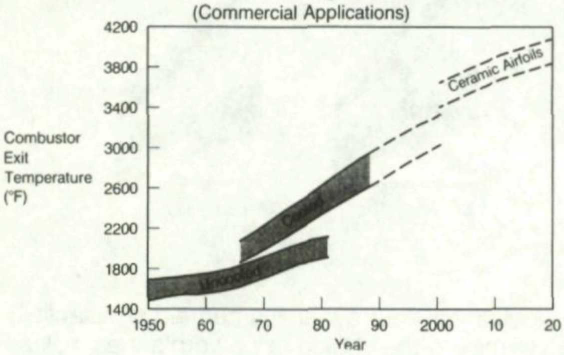
Trends in Overall Pressure Ratio



Substantial basic technological improvements can be made to both subsonic and supersonic engines. For example, fans and perhaps compressors could operate at supersonic forward speeds, perhaps with a higher pressure rise per stage, yielding overall pressure ratios of 60 to 70.

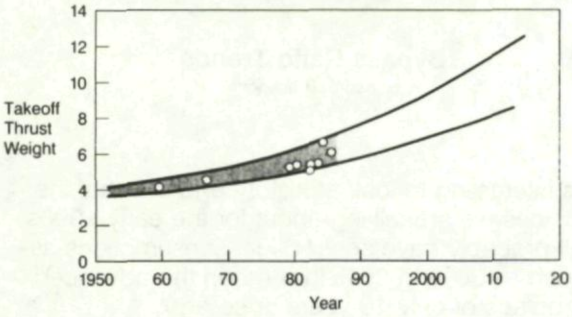
Combustor Exit Temperature Trends

(Commercial Applications)



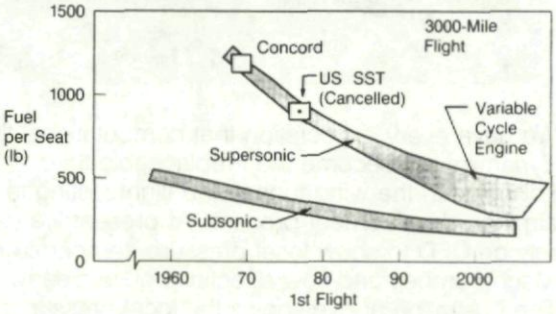
Engine Thrust-to-Weight Trends

Commercial Applications



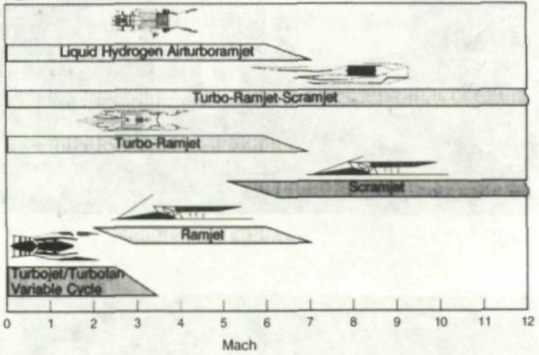
Stochiometric burning due to advanced blade technology and better cooling could reduce fuel burn. Improved turbine materials and case materials coupled with these internal advances could produce thrust to weight ratios of over 10 to 1.

Technology Is Improving Economic Factors



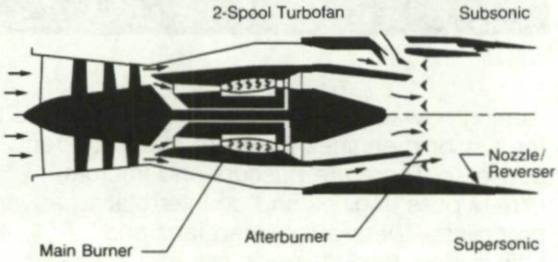
Application of all these technologies will lower the fuel burn per seat dramatically. Because of the weight effect, the rate of improvement in a supersonic engine should result in an installation nearly as good as a 1980s subsonic engine. The pitfall here could be the effect on noise level.

Engine Configurations for High-Speed Flight



Several powerplant types have been proposed for high-speed flight; not all will prove to be practical.

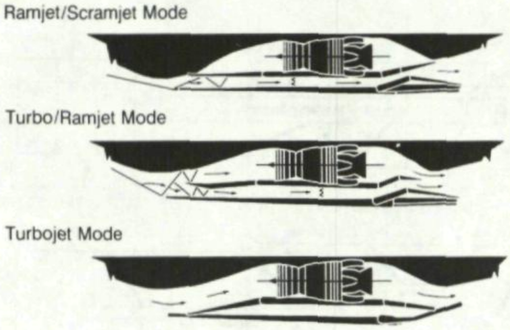
Variable Stream Control Engine (VSCE)



One that might be applicable to supersonic flight in the region of Mach 3 to Mach 4 is the variable stream control or variable cycle engine. In subsonic flight the engine acts as a conventional turbofan. As it accelerates into supersonic flight it becomes strictly a high-pressure-ratio turbojet, bypassing part of the air around the burner and into the exhaust nozzle, possibly with some low level of afterburning during the acceleration phase.

Advanced engine technology—improvements in materials, improvements in the capability of the fans to operate at supersonic speeds, and higher pressure ratios—gives us the capability of having an engine that would operate at supersonic speeds with nonafterburning power.

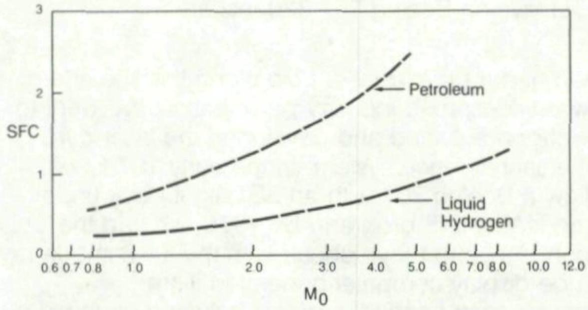
Turbojet/Ramjet/Scramjet Engine



For speeds beyond the region of Mach 4 we must consider using a combination turbojet-ramjet. At these speeds we will shut off the turbo machinery and start to rely almost exclusively on the ramjet until reaching such a velocity that the subsonic-burning ramjet can no longer stand the temperature. To go still faster we will probably need supersonic combustion ramjet (scramjet) engines in which the fuel is burned at supersonic speeds.

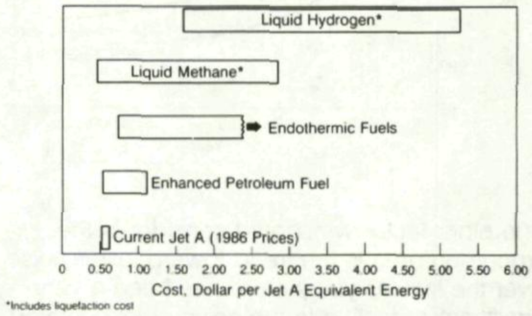
Fuel Selection

Speed and SFC Trends



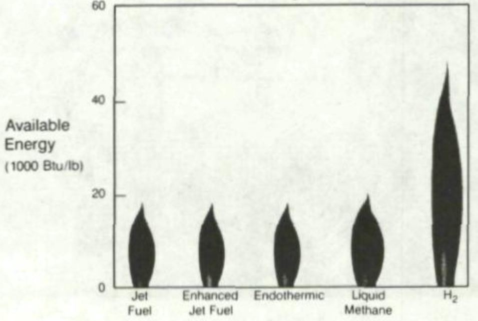
Looking at specific fuel consumption as a function of speed, we find that petroleum fuels will be effective to the vicinity of Mach 3. Beyond that the use of liquid hydrogen provides substantial reductions in specific fuel consumption (SFC). In the Mach 6, 8, 10, or 12 regions, a liquid hydrogen-fueled supersonic combustion ramjet is probably the powerplant of choice. At Mach 8, this engine has approximately the same SFC as a petroleum-fueled turbojet flying in the vicinity of Mach 2.

Fuel Costs



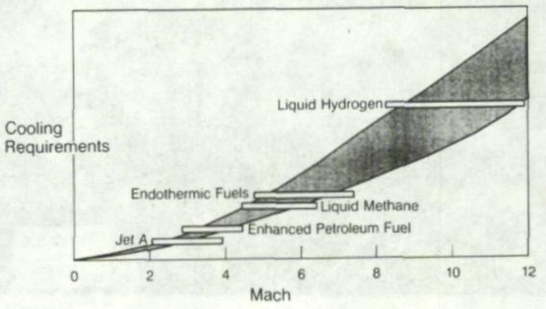
Hydrogen fuel, with its high available energy and great cooling capability, might cost as little as $1.50/gal. On the other hand, if it is made by electrolysis, its price undoubtedly will run in the vicinity of $4.00 to 5.00/gal and will be highly dependent on the cost of energy.

Fuel Properties

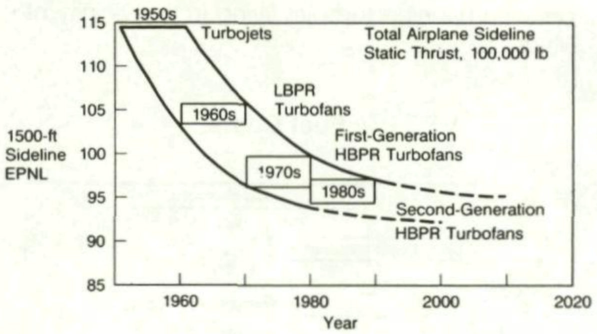


The price of methane fuel, on the other hand, might be roughly equal to kerosene-type fuels, such as Jet A; or it might cost as much as four times that amount. Using methane does not avoid the difficulties associated with cryogenic fuel—its temperature is roughly -165°F. It has liquid hydrogen's characteristics of boil-off and the need to have a regeneration plant at the airport.

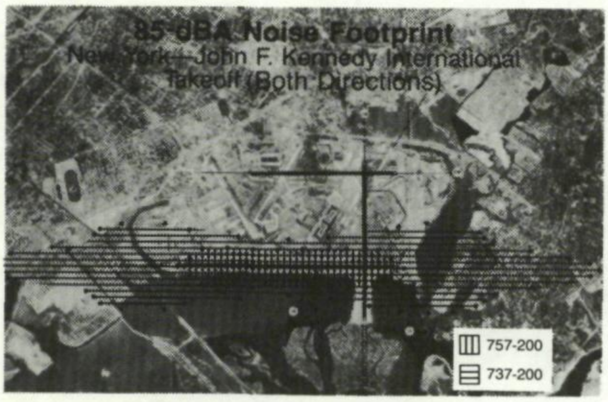
Fuel Heat Sink Limits



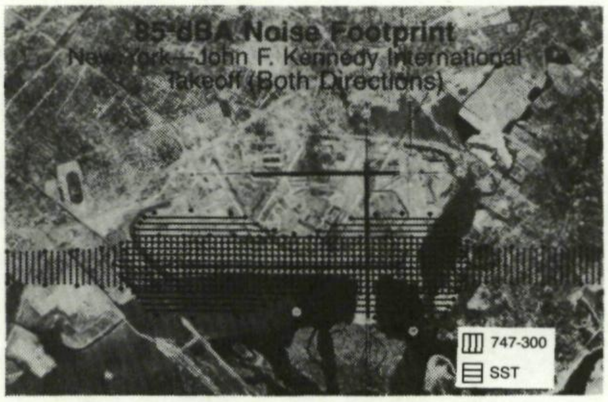
Noise Reduction Progress



One other factor we should consider in the propulsion area is the trend toward lower noise. Over the last 20 years there has been a very significant reduction in the noise of jet-powered aircraft, coming down by nearly 20 dB. For every 3-dB reduction, noise power is halved. Consequently, there has been a noticeable improvement in the overall community noise level of aircraft.



Let's make a comparison of takeoff noise by looking at what we call a "footprint" with an 85-dBA contour. Comparing an older medium-range, two-engine airplane, the 737-200, against the 757, which meets FAR 36 stage 3 noise requirements, it is clear that we can reduce the noise level in the community by a very large amount and largely confine the 85-dBA contour to the airport property itself.

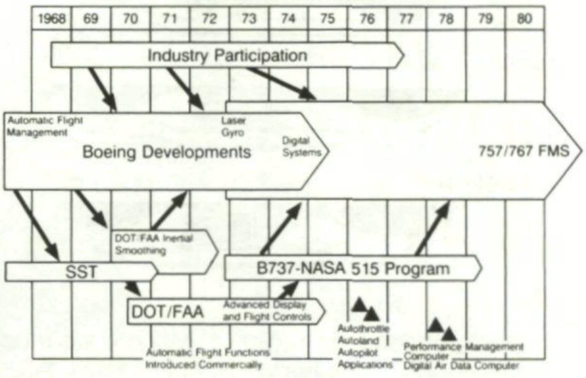


Comparing an advanced supersonic transport (SST) with today's largest four-engine transport—the 747—we see that while the SST may generate slightly more noise to the side of the runway, the actual closure of the 85-dBA contour line is shorter because of the SST's high climb rate.

Presumably, with the variable stream control engine, we could get an advanced design supersonic transport with a noise level that is very close to the best of the four-engine airplanes we have today. This will take a tremendous amount of work, but it is well worth doing.

Flight Deck and Systems

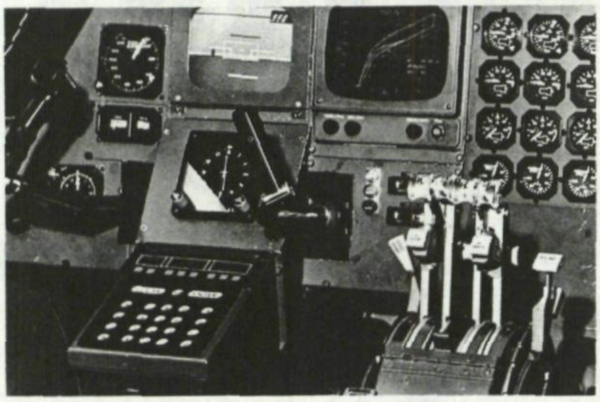
FMS Evolution



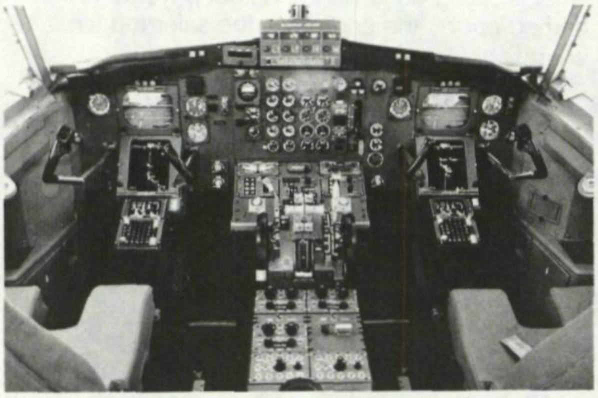
On the subject of avionics and systems, let us consider the evolution of the flight management system. Many people take the 757, 767, and the advanced developments in those airplanes almost for granted, but it is important to look back in history. Work actually started on this system in the early 1960s, and by 1966 had progressed to the point where we were flying cathode ray tube displays on Boeing 707-320 test article.

We had a great deal of help along this line; there was widespread industry participation. We went to work on autoland and developed the laser gyro inertial reference system. In the early 1970s we flew a Boeing 737 with an SST flight deck under the NASA 515 program. By 1975, we had the confidence to move ahead with the full cathode ray tube display computer-generated flight management control system, including coupling of the engines, autopilot, and navigation system. This grew to the point where we had a completely automatic system ready for development on the 757 and 767 programs. They were certificated in 1982.

The accompanying photographs depict the evolution of cathode ray tube (CRT) displays. The



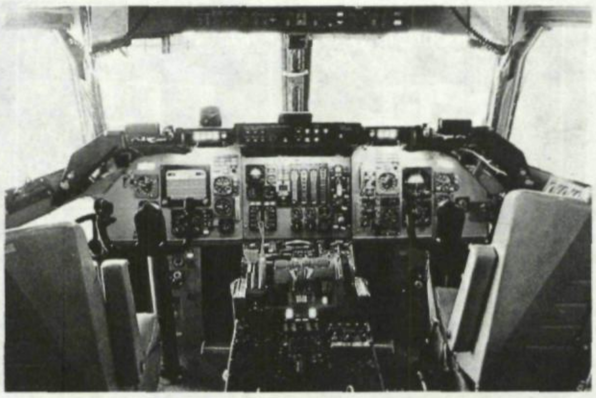
1966 photo shows a CRT in use in a 707-320 flight test. In 1969, CRTs were part of the initial United States SST flight deck designs. The complete SST flight deck was installed midship in a 737 for flight testing under the NASA 737 TCV program.

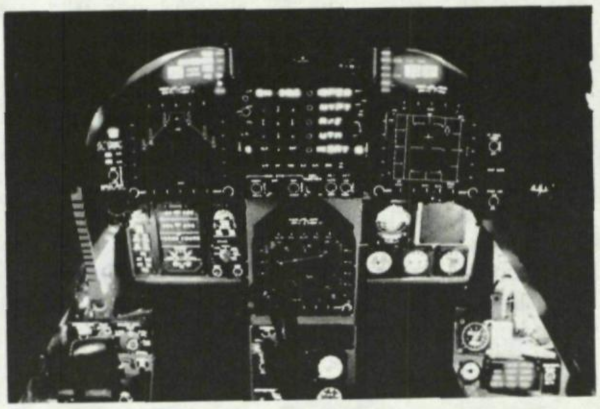


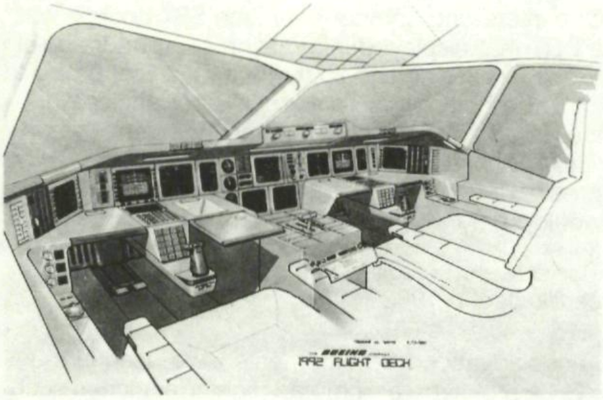
One interesting component in the SST cockpit was a CRT that displayed information showing the pilot exactly where he should fly on the vertical profile to minimize both engine and sonic boom noise on the ground and to follow the most efficient flightpath possible. It also contained the first predictive information to show the pilot where he would be 30, 60, and 90 sec ahead.

This research resulted in the 757/767 flight decks certificated in 1982.

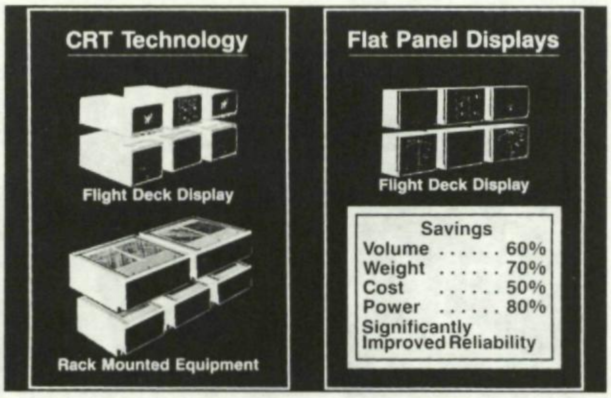
These advanced developments were used in the YC-14 prototype and military fighter airplanes such as the F-18. Advanced flight deck development will continue in parallel with the reduction in size and weight of computers. As mentioned earlier, the diminished size and increased speed of computers gives us the capability of doing things that were impossible only a few years ago.



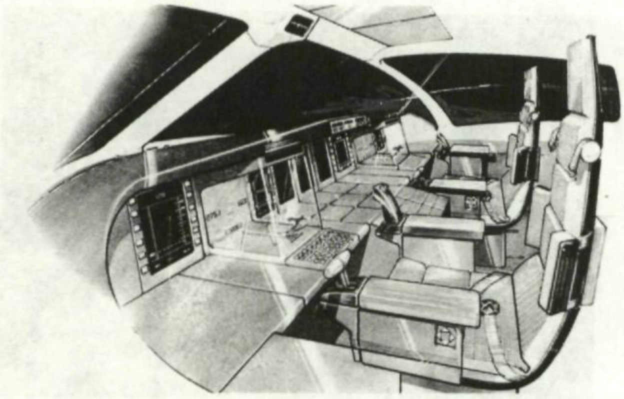




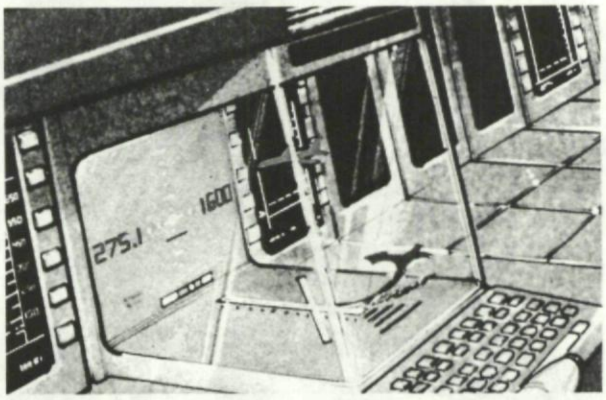
When it flies in 1988, the 747-400 will have the most advanced cathode ray tube displays of any current airplane. Beyond that will be an even more automated flight deck, as shown in this rendering of a 1990 cockpit.



The next generation of subsonic airplanes will have flat panel displays generated by powerful computers, resulting in substantial savings in volume, weight, and cost. One of the more significant savings is the reduction in power required. Early CRTs averaged about 5W per tube in heat generation; flat panel displays put out only about 0.5W per panel. This is a very important improvement. It reduces the airplane's air-conditioning requirements and leads to significantly better reliability of the device. Our goal is to achieve reliability equal to the lifetime of the airplane.



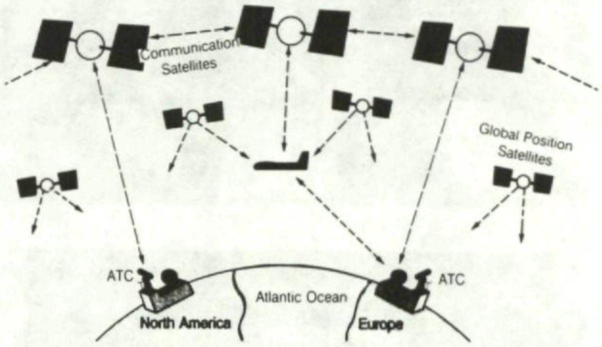
Beyond these flat panel displays are further developments such as the application of artificial intelligence or expert systems in the cockpits of the future. It is possible that we will have the capability of putting together a three-dimensional holographic electronic attitude display for the pilot, who will not only have the type of computation that we have today, but also a voice-activated control and response system.



We know that most pilots do very well when flying visually. If we could generate a small airplane and show it to him in relation to a field or waystation and give him predictive information, we believe we could enhance safety.

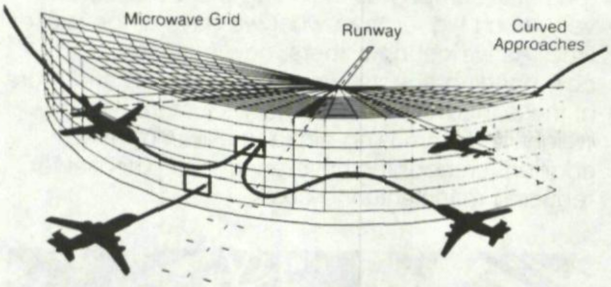
The objective will remain the same as it has always been: to improve the safety of the airplane by reducing pilot workload, giving him more command information and taking him out of the role of doer. The more the pilot acts as commander, overseeing what is going on while the actual physical tasks are carried out by the computer, the safer the airplane will be.

Global Positioning System/ Communication Satellites



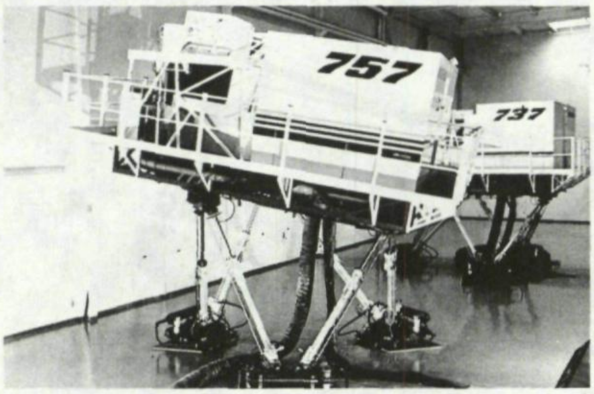
Combining a data link with the inertial reference system would help air traffic control reduce spacing by precisely locating every airplane, even over the ocean. This system could be in use even before we get global positioning satellites up and working during the 1990s and early in the next century. Global positioning satellites will allow much greater densities on long overwater flights than we have currently.

Microwave Landing System (MLS)



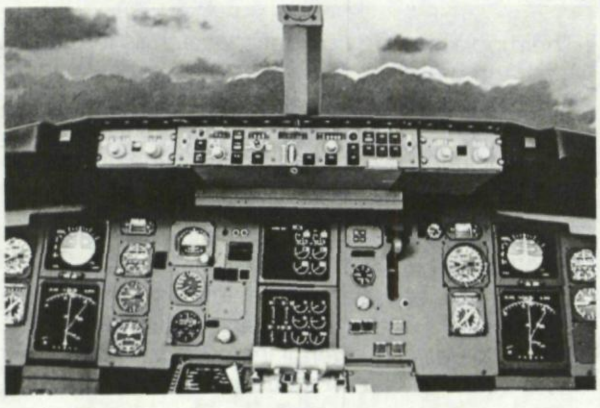
MLS-equipped aircraft receive precision guidance to the runway from many different directions and glideslopes.

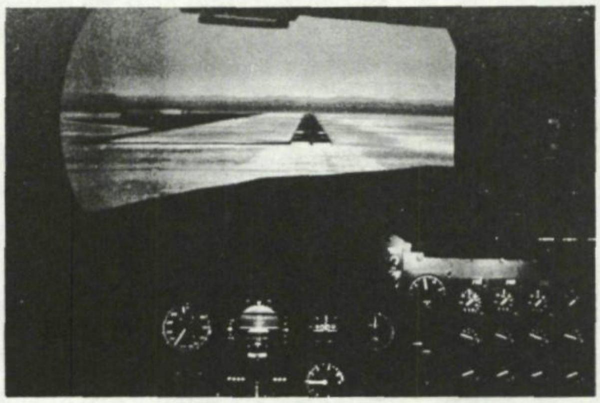
Also, by the turn of the century we should have a microwave landing system that, when coupled with a true four-dimensional navigation system, will handle many more airplanes in the terminal area. These systems will all help relieve pilot workload and improve safety.



Future simulators, with their computer-generated imagery and ability to accurately portray all characteristics of an airplane, will also enhance safety. The simulator will also be a member of the design team almost from concept to completion.

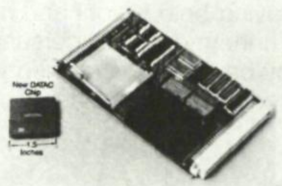
Another significant application in the airplane of the future will be what is known as digital autonomous terminal access communications (DATAC); in other words, a two-way data bus. We have made a good deal of progress in this area in the last few years and have reduced the electronic components to one very small chip. We can have major reductions in wires, connectors, bundles, and segments, cutting the weight of those items by 50%, decreasing maintenance—perhaps even to zero for the airplane's lifetime—and improving overall reliability.





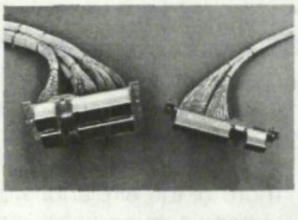
DATAC Data Bus

- Digital autonomous terminal access communcations (DATAC)
- For a 150-passenger airplane, eliminates
  - 46 miles of wire
  - 250 lb of connectors
  - 360 wire bundles
  - 17,200 wire segments
- Benefits
  - 50% reduction in wire bundles weight, and connectors
  - Decreased maintenance
  - Increased reliability

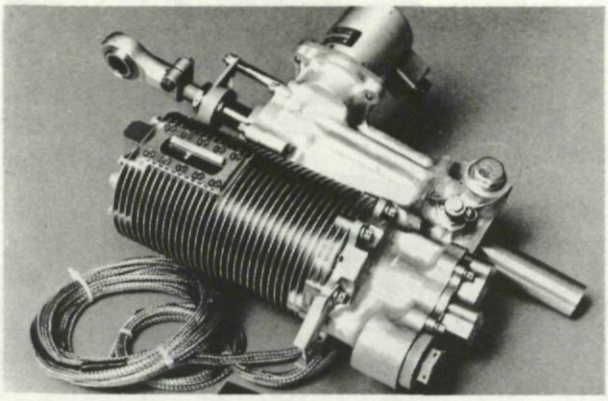


Fiber Optics

- Current signal systems
  - Wire based
  - 45 to 90 miles per airplane
- Future technology
  - Fiber-optic based
  - Significant size and weight reductions
  - Increased safety and security
- Use of fiber optics may be essential to a composite structure design



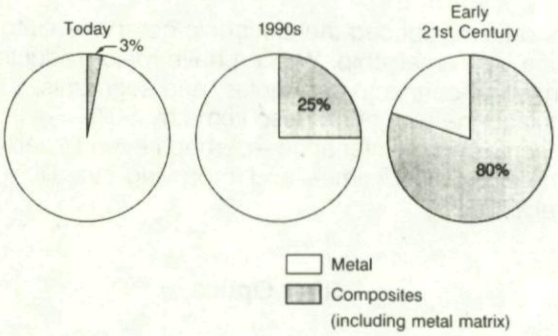
As is advertised so often by telephone companies, tens of millions of fiber-optic tubes can be packed in a very small space. Fiber optics may eliminate most airplane wiring. They are immune from electromagnetic interference, can reduce weight significantly, and increase safety and security. Indeed, fiber optics may be essential to an all-composite structural design. In the areas of fuel gaging, electrohydrostatic actuator signaling, and engine control, we may very well see a much-expanded use of fiber optics.



A possible new system that would be greatly enhanced by superconducting materials would be a self-contained control system actuator—the electrohydrostatic actuator. Such a system could eliminate engine-driven hydraulic systems, thereby saving both weight and maintenance costs. Furthermore, in supersonic flight it could save drag by being fully contained within the aerodynamic contours of the surface.

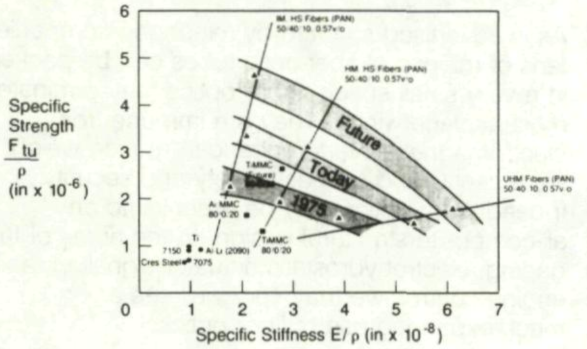
Structures and Materials

Material Distribution Trend

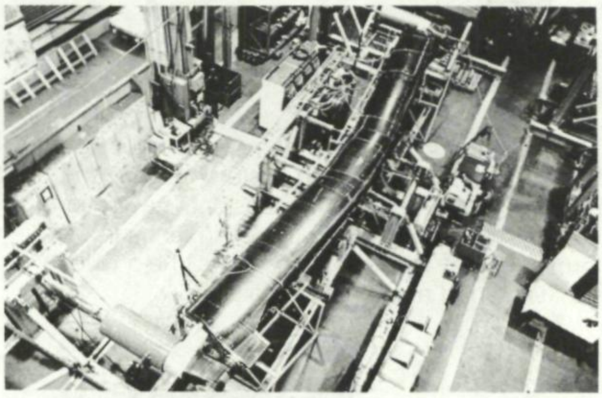


Today approximately 97% of airplane structure is metallic. By the 1990s, that will be reduced to about 75% because of increases in the use of composites. Early in the 21st century, it is possible that composite structures will account for 80% or more of the airplane, whether the design is for subsonic, supersonic, or hypersonic flight.

Strength Properties of New Materials



Strength-to-density ratios of the new materials (primarily composites including metal-matrix) are very much higher than what we have at the present time. As we get new fibers, new materials, and new bonding agents, we will adapt more and more of these innovations to primary structure, saving weight and increasing airplane efficiency. In addition, composites have enormous potential for reducing manufacturing costs.

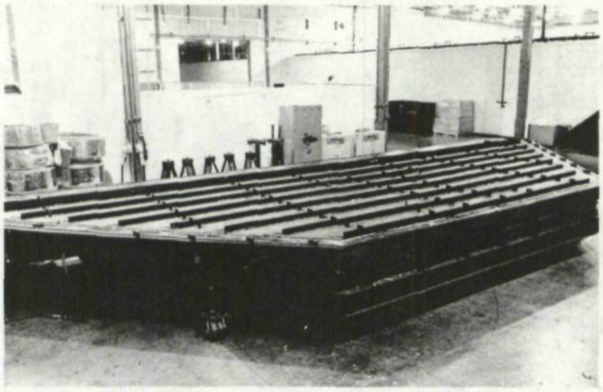


The wing and the fuselage for the new tiltrotor V-22 airplane are constructed entirely of composite materials. We have recently flown a Boeing Model 360 helicopter that has more than 80% composite structure, including the fuselage, rotor, rotor hubs, transmission housing, landing gears, and drive shafts.

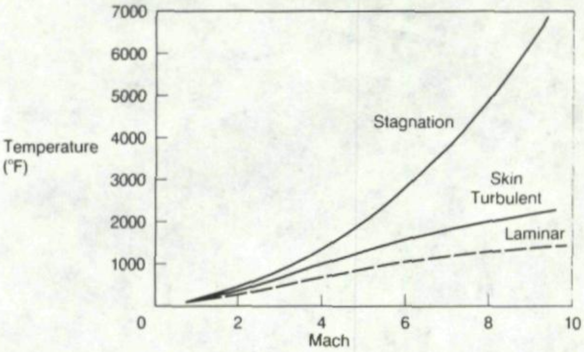
The Model 360 is an aircraft the size of a CH-46 that will carry the payload of a CH-47 at about 200 knots—a very significant improvement in helicopter technology.

Thermoplastics are composite materials formed by heat and pressure. They offer great promise for advanced supersonic aircraft such as the advanced tactical fighter. They might also substantially reduce manufacturing costs because large integral structures can be made in a single press.

The potential 30% weight reduction offered by composites compared to previous metallic structures is especially valuable for supersonic and hypersonic aircraft, where each pound saved is several times as powerful in improving performance as a pound saved on a subsonic airplane.

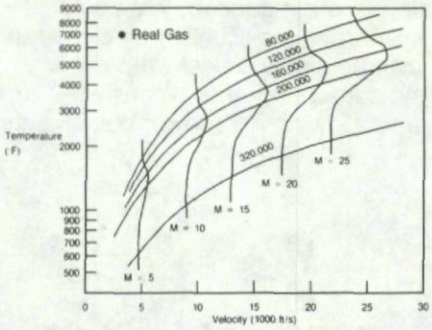


Typical Flight Temperatures



Stagnation Point Equilibrium Temperatures

1-ft-Radius Nose

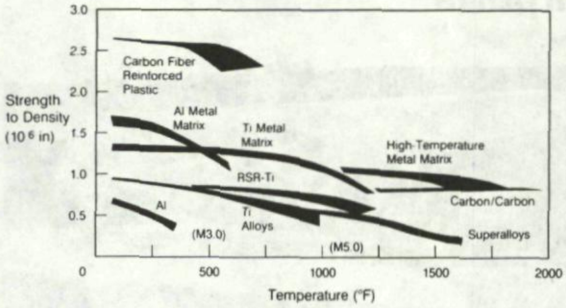


Of course, we can not ignore the fact that supersonic and hypersonic airplanes are going to be operating in a very hostile thermal environment. Look at the stagnation temperature, for example, as a function of Mach number. Near Mach 10, stagnation temperatures approach nearly 9000°F for ideal gas; real gas effects on practical hypersonic vehicles show stagnation temperatures much lower. Obviously, advanced cooling methods such as heat pipes will be required.

However, at lower Mach numbers actual skin temperatures are much lower; for example, if we could achieve laminar flow on an airplane at Mach 6, skin temperature would be less than 1000°F. A number of materials could survive in that temperature range. At Mach 3 to 3.5, skin temperature would be in the vicinity of 500°F.

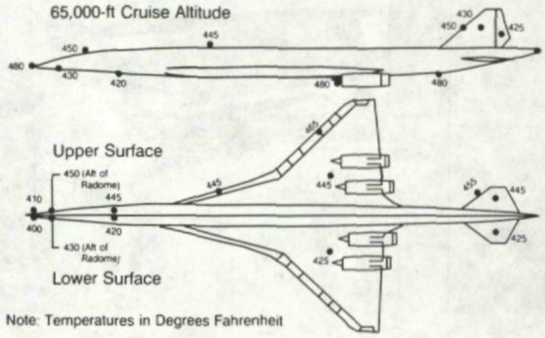
Advanced High-Temperature Materials

Strength/Density Ratios



Equilibrium Skin Temperatures

Mach = 2.7

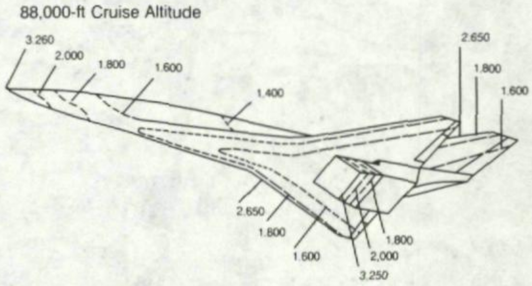


Note: Temperatures in Degrees Fahrenheit

At Mach 2.7, equilibrium skin temperatures at 65,000-ft cruise are in the vicinity of 425°F for the lower surface, while the upper surface of the wing is about 445°F due to thermal heating. If we could achieve laminar flow, we would be able to maintain those temperatures at speeds 300 to 400 mi/h faster than Mach 2.7.

Equilibrium Skin Temperatures

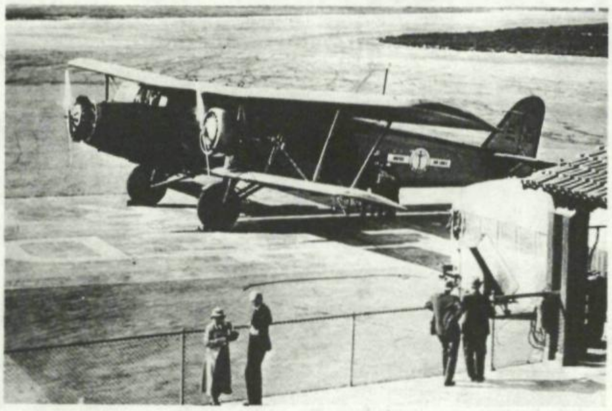
Mach = 8.0



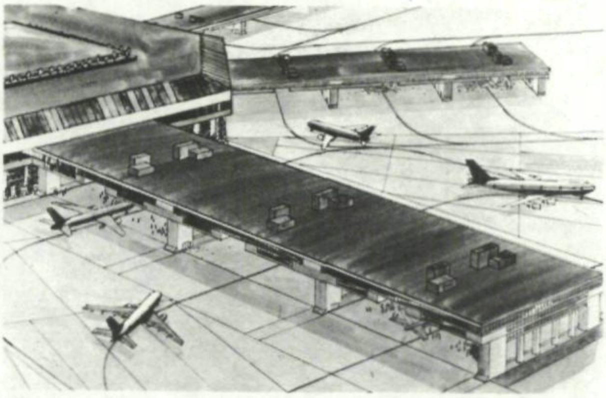
Note: Temperatures in Degrees Fahrenheit

On a large airplane at Mach 8 at 88,000-ft cruise altitude, substantial areas reach 1600°F to 2000°F. We do not have composite materials that would survive in those temperatures without positive cooling.

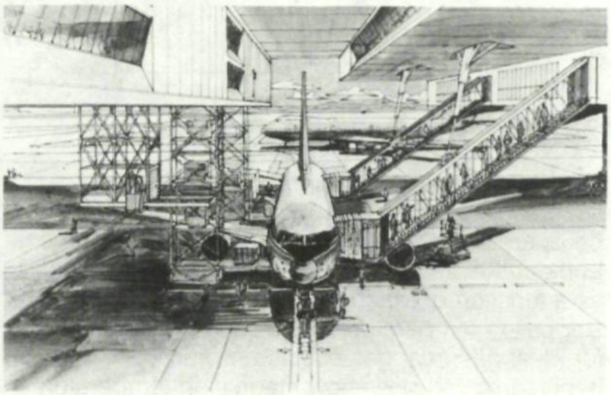
Airports



It's also important from the commercial standpoint to take a look at the airport environment. Airports have not changed much overall since the early days of commercial service. Although there are many containers, much luggage is still hand-loaded, and very little baggage handling is automated. Passengers still enter and exit the airplane one at a time through a single door. It's time to improve airport design.



Pressure from increasing congestion, traffic growth, and a demand for faster airplane turnarounds may result in future airports that are considerably different from the ones we know today. Depicted here is a drivethrough concept that could significantly improve the situation by eliminating the need to push the airplane backward out of a gate—a time-consuming and expensive process—and allowing it to power out, straight ahead.

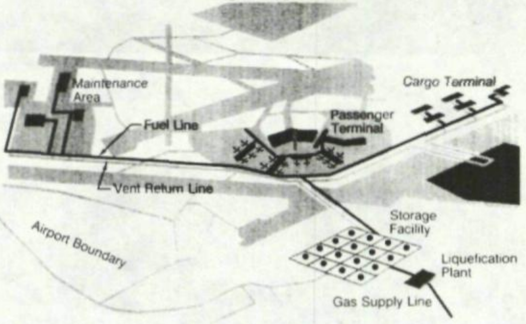


Inside this airport, passengers, baggage, and cargo could be moved quickly and effectively. Passengers would use multiple boarding ramps, as many as four, each with moving stairs. Baggage and cargo would be conveyed by elevators and sophisticated handling equipment, possibly including security scanners for reading computer generated tags, an automatic sorter-distribution system, and automatic loading and unloading.

Instead of exchanging a number of individual modules in a galley, the entire galley might be removed and quickly replaced by a fully serviced unit. This concept could also be employed with tiltrotor-type feeder aircraft.

All of this would combine to make a very big improvement in airports.

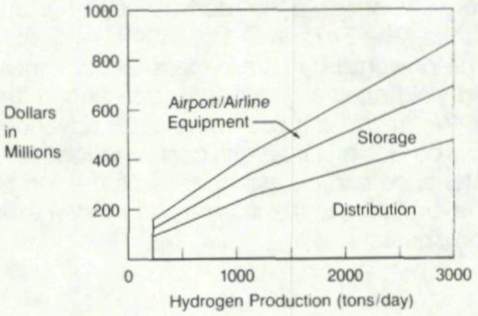
Cryogenic Fuel Distribution and Storage System



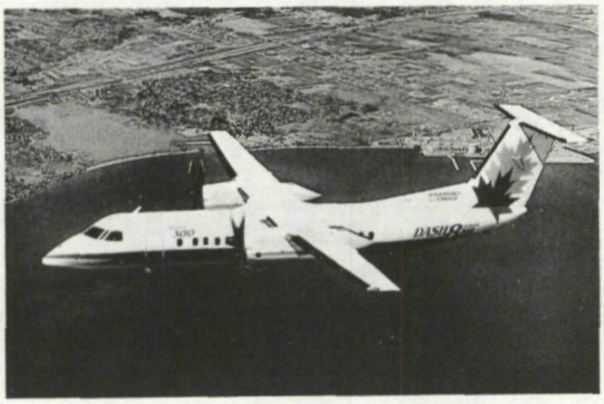
We cannot ignore the possibility that economics could dictate a cryogenic-fueled airplane, which would greatly affect airports. A whole new *infrastructure with vent return lines, initial* liquefication, and reliquefication facilities would be necessary on airport property, posing a substantial cost burden. Conversion to a cryogenic airport, which would serve as an international hub, would entail an expense of about $1 billion.

Cost of Airport Conversion

Liquid Hydrogen



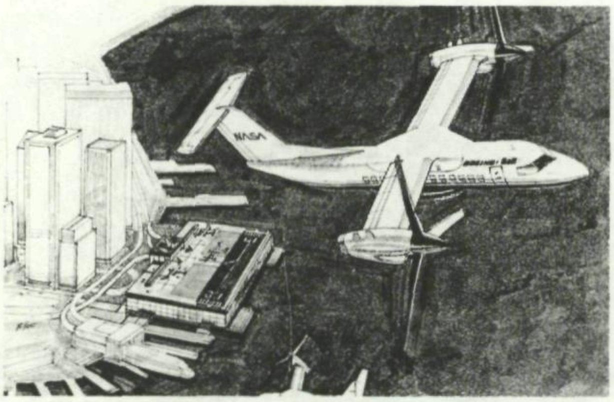
Subsonic

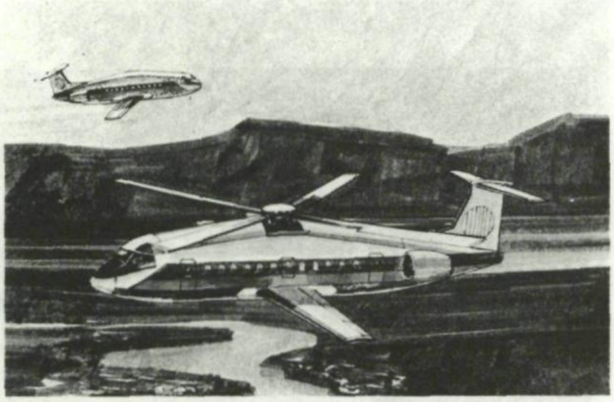


We have made great advances in turboprop commuter airplanes in recent times, but we still have a long way to go before they are as efficient as their larger brothers. Here are a few things that might happen before the 21st century in terms of *commuter and VSTOL* airplanes.

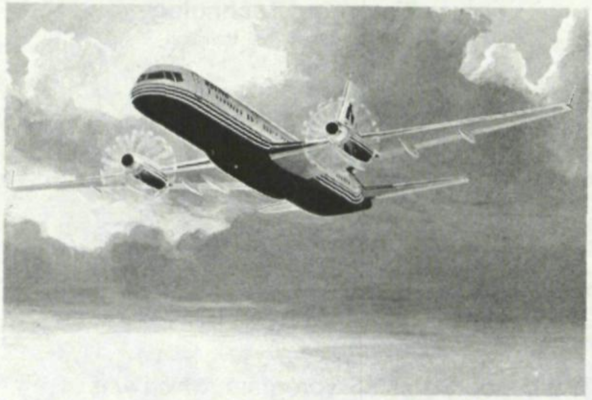
To begin with, the federal government and the FAA will have to do a tremendous amount of work before these vehicles can be integrated into the overall air transport system and make a real improvement in passenger travel time. We will need separate air traffic controls so commuter airplanes can operate in major airports without interfering with the large airliners.

Application of all-composite structures as in the Boeing Model 360 helicopter, potential tiltrotor configurations with pressurized fuselages up to 50 or 60 seats, and beyond that, the possibility of having rotors that fold back so the airplane can fly at the speeds of today's conventional subsonic transports might make very attractive commuter operations. Another idea being pioneered at this time by NASA is the tandem-rotor X-wing airplane. *It might carry 50 to 60 passengers at 300-400 kn,* yet be able to land vertically and have a low noise level.



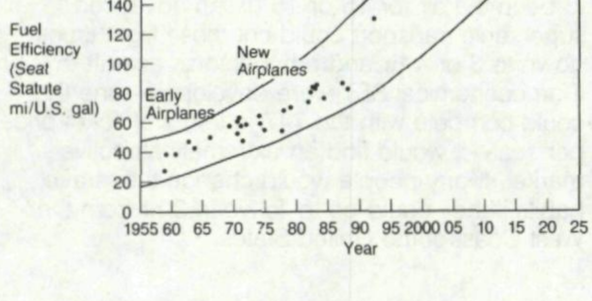


Moving on to large transports, after the turn of the century it is possible that derivatives of our current airplanes—the 747s, MD-11s, A340s—might very well be powered by ultra-bypass-ratio engines that would yield another significant reduction in fuel burn. We might also see some other advanced turboprop designs if safety, cost, and low maintenance can be assured. (Note the winglets on the airplanes in the illustration, an idea to save airport space.)

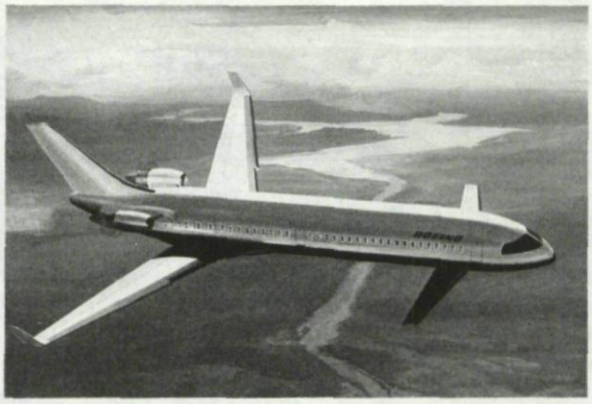


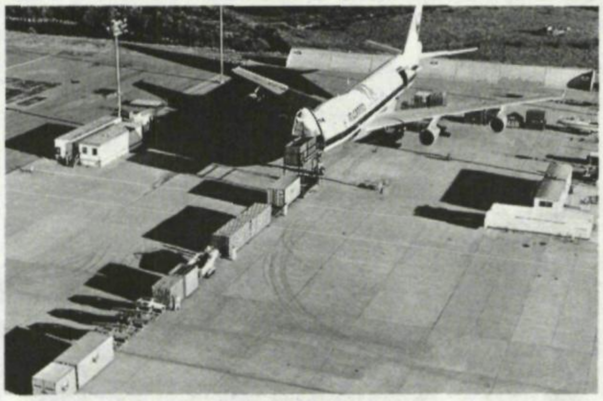
In the 21st century, airplanes are going to be operating at higher speeds. Speed has always been a marketable commodity. Perhaps by the turn of the century subsonic airplanes will be flying close to Mach 0.95, significantly reducing travel time.

Fuel Efficiency Trends



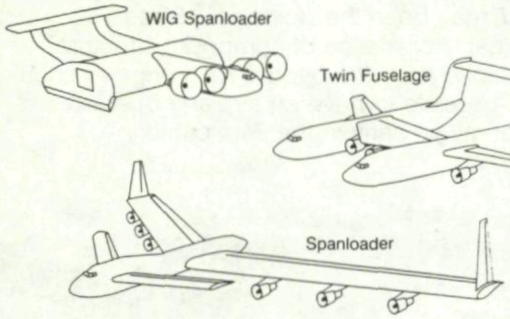
Current airplanes such as the 757 and 767 have a fuel efficiency of approximately 70 seat-mi/U.S. gal. The 7J7 may be in the vicinity of 130 to 150 seat-mi/gal. Application of composite structure, laminar flow, and ultra-bypass ratio engines should make it possible to have an airplane operating at 200 seat-mi/gal early in the 21st century.



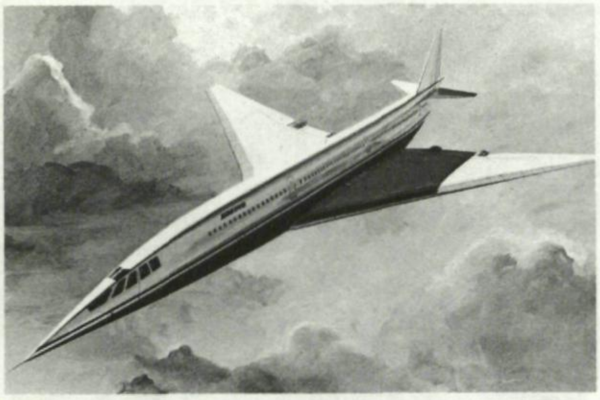


The large, wide-bodied transports existing today or in development have ample cargo capacity. Even though the cargo market is expanding at a rate faster than the passenger market, the lower and upper deck capacity of these airplanes probably precludes the need for a separate cargo development. However, if cargo volume continues to increase and high-value cargo grows in overall size, we will want to move it in the most fuel-efficient manner.

Innovative Designs - Cargo Aircraft

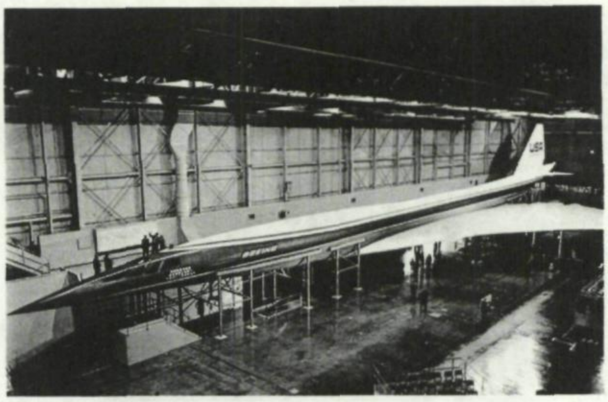


In that case, there will probably be some very special developments for cargo airplanes. Roy Lange of Lockheed-Georgia contributed the designs illustrated here.



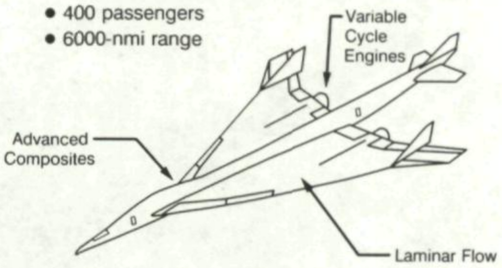
Overnight package express has grown at such a rapid rate in recent times that there might very well be a need to move those packages at supersonic speeds. If the business expands to overseas delivery, it is possible that this might be one of the driving forces behind the creation of a supersonic transport.

The Concorde has been in operation for over 10 years. It has been a great technological accomplishment although the economics of the airplane have left a lot to be desired. The Concorde with its 100 seats was probably never large enough to make the program a success.



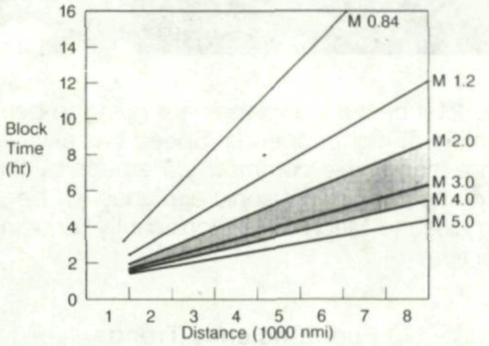
Emerging Technology

High-Speed Civil Transport



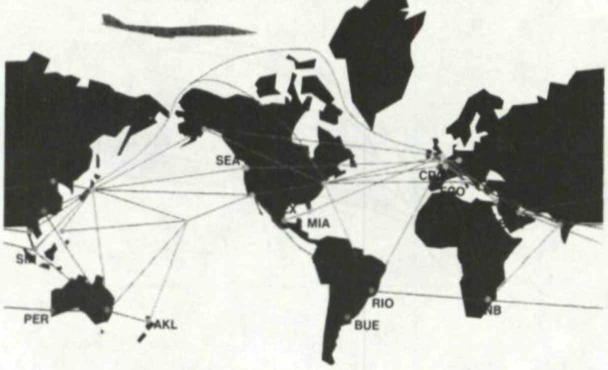
The United States SST program, which was terminated in 1971, was targeted at producing an airplane that in commercial use would have carried approximately 300 passengers, probably large enough to be competitive at that particular time. Today as we apply advanced technology to give us lightweight airplanes, variable cycle engines, active controls, and new flight management systems, airlines will probably want an SST that carries about 400 passengers and flies ranges of 6000 nmi and beyond.

Trip Time



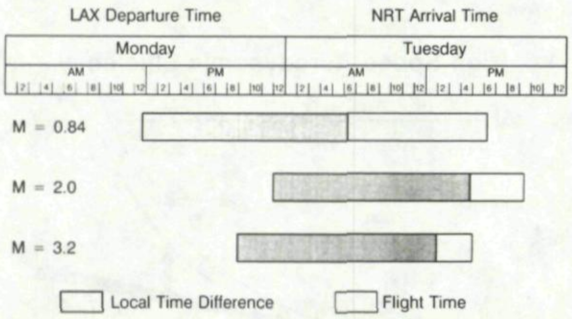
Today's aircraft are able to fly very long routes. The 747-400 with its 7000-nmi range capability is going to be in the air for 15 or 16 hr. An advanced supersonic transport could cut those flight times down to 3 or 4 hr and a hypersonic aircraft to 2 hr. If an economical SST were developed—one that could compete with the 747 in terms of ticket price per seat—it would find an extremely attractive market. Many people would change their travel habits if they could go to Tokyo in 3 hr from the West Coast of the United States.

Advanced Supersonic Transport Study Routes

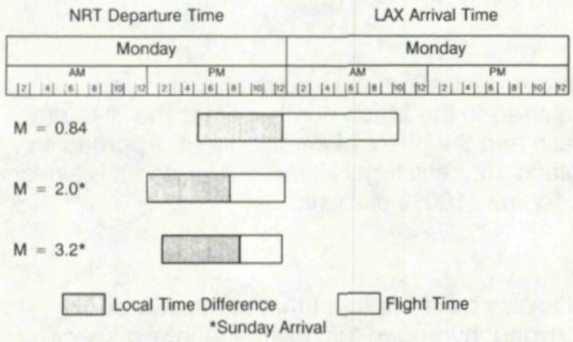


With such a vehicle, operators might give serious consideration to a different kind of airline consortium than we have today. A typical itinerary for a 400-passenger Mach 3.2 airplane might be London-Anchorage-Tokyo-Sydney-Honolulu-Los Angeles-New York-London, all in one day. The airplane would travel through many different sovereign territories. Perhaps airlines would develop a leasing arrangement similar to the way banks now lease aircraft—an airline would pay only for the part of the flight in which the airplane traversed that airline's traditional routes. This might be a way of efficiently operating a supersonic airplane.

Los Angeles - Tokyo Schedule

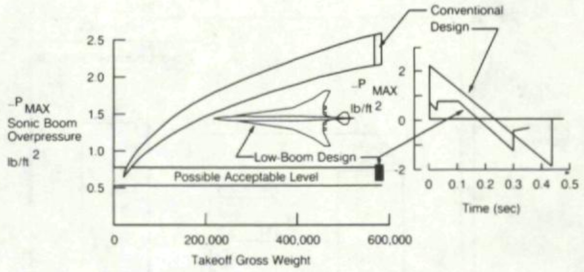


Tokyo - Los Angeles Schedule



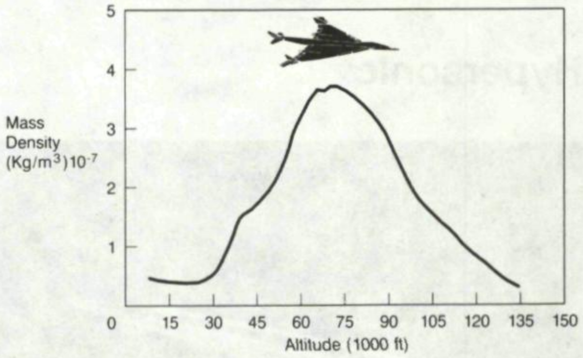
Airlines will need the productivity of speed, but flights will have to fit time windows, airport curfews, and reasonable arrival and departure times. Interestingly, on the Los Angeles-Tokyo-Los Angeles route a Mach 3.2 airplane would present the possibility of two arrivals and departures per day, making better scheduling possible for ongoing connect banks.

Cruise Sonic Boom Levels



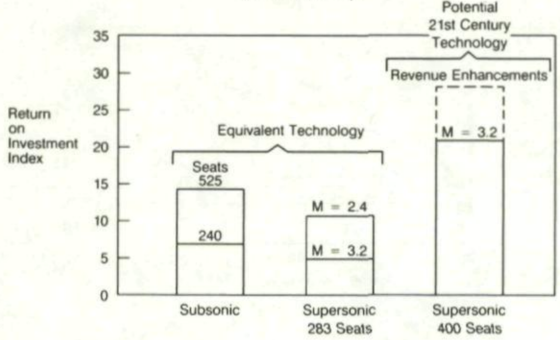
Environmental considerations might affect the supersonic airplane. The fear of sonic boom is still with us even after 10 years of Concorde operation and more than 20 years of SR-71 operation. However, sonic boom overpressures generated by the SR-71 are less than 1 lb/ft^2. There is probably no provable case of significant damage from such a sonic boom. Ambient noise levels have certainly gone up in this time period. It might very well be that if an airplane could be designed to make a sonic boom of less than 1 lb/ft^2, overland operation would be tolerated by the public.

Ozone Model Atmosphere



One of the major environmental effects of the airplane passage might be on atmospheric ozone. Ideally, a supersonic transport would fly at the altitude of maximum ozone concentration. There has been a lot of discussion as to whether the water vapor combined with sunlight, nitric oxides, and particulates generated by the engine would reduce the ozone. There is absolutely no proof at this time that anything is happening to the ozone due to this particular source. There are no experimental data from Concorde to show it either increases or decreases the ozone as it flies in the high ozone concentration at 55,000 or 60,000 ft. A hypersonic airplane might be immune to both these environmental concerns.

Extensive research involving many airplanes will be required before we fully understand the situation. At this moment, it appears there will be nothing that will have a significant effect on the ozone as a result of the airplane itself.

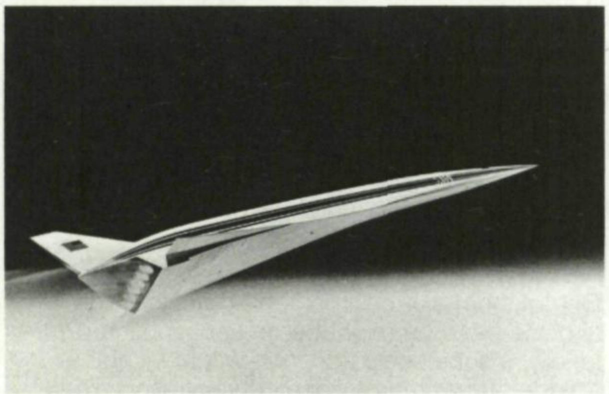


SST Economic Viability

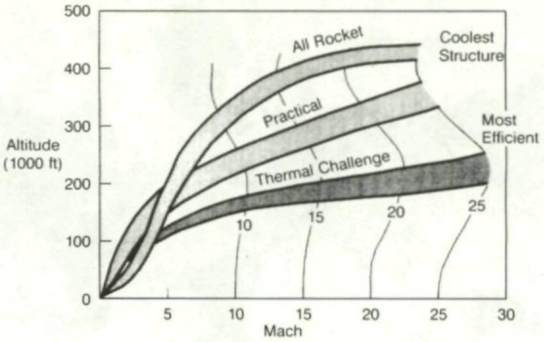
3000-nmi Trip

The economics of an advanced supersonic transport will be the key to its development. If costs can be controlled through CAD/CAM, improved factory methods, computational fluid dynamics, and other new developments, it appears that a large SST may be competitive with the 747. It does hold the prospect for the increased productivity of speed.

Hypersonic

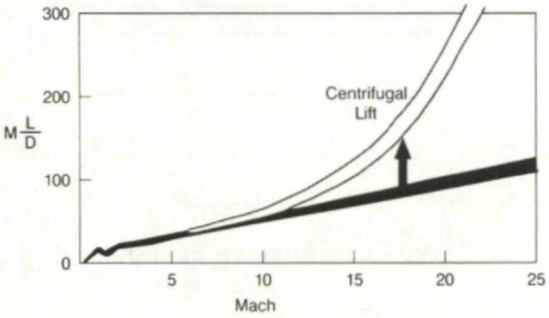


Turning now to hypersonic flight, the X-30—the National Aerospace Plane—is the rallying point in the United States today for hypersonic flight. The potential for its air-breathing engine to generate efficiencies much beyond those of rocket power is very attractive. The idea of being able to combine improvements in aerodynamic technology with space technology is obviously quite appealing. The X-30 could reduce the cost of placing payloads in orbit and help move people and things from point to point on earth at a very rapid rate compared to today. The research results of the X-30 program could provide a wealth of technical data over the entire hypersonic speed range.



Flight Envelope Challenges

But there are some significant challenges to be addressed. For instance, a look at a flight envelope, altitude versus speed, shows that the most efficient flightpaths for getting from takeoff to orbital speed are also the most difficult from the temperature standpoint. Flying at lower altitudes would be the most efficient for an air-breathing engine, but temperatures would be extremely high. An all-rocket ascent, on the other hand, has the potential of having the lowest heating, but it also would starve the air-breathing engine at a very early time. The X-30 program includes the development of high heat flux thermal protection systems and materials with very high temperature capability to address the ascent and descent issues of flight.

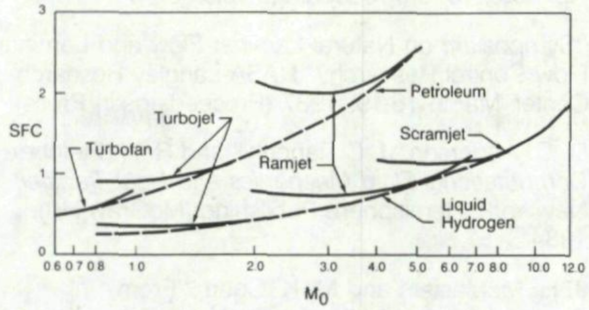


High-Speed Aerodynamic Efficiency

In our discussion of aerodynamic efficiency we referred to the Mach number times the lift-to-drag ratio and the effect of centrifugal lift. Approaching Mach 25, centrifugal lift takes over and the airplane becomes 100% efficient.

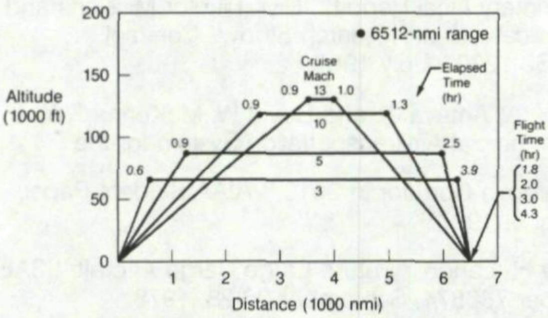
It is also quite apparent that at Mach 4 and beyond, hydrogen fuel offers the lowest specific fuel consumption of any of the powerplant options. Or stated another way, hydrogen offers the highest specific impulse. At the same time, it is necessary to cool the structure at higher temperatures, and hydrogen is the best fuel for doing that. When hypersonic transports are built, they will need hydrogen fuel, which must be manufactured cheaply at the airport site.

SFC Cycle Characteristics



Mission Profile

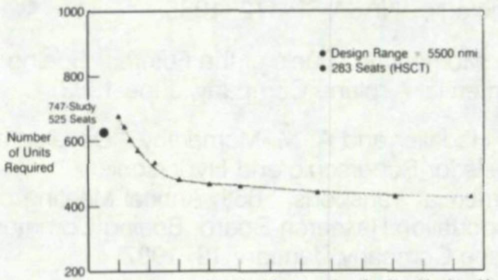
Los Angeles - Sydney



It's interesting to look at the flight times for various speeds for a particular airline route. For example, one of the longest nonstop routes in the world today is Los Angeles to Sydney, Australia, a distance of 6512 nmi. In a Mach 3 airplane, total flight time would be about 4.3 hr. A Mach 5 airplane would fly the route in approximately 3 hr. A Mach 10 airplane would take 2 hr. At Mach 13, the flight would take a total time of about 1.8 hr—almost 0.9 hr in climb and 0.9 hr in descent.

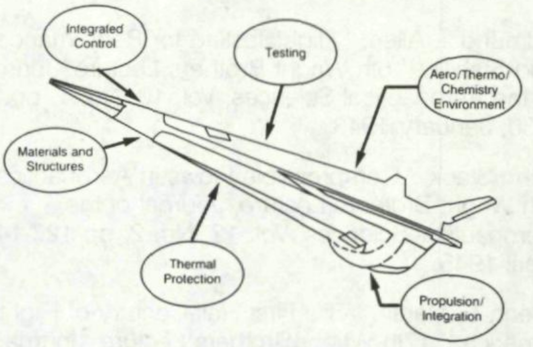
Potential Market

High Speed Civil Transport



Many people are concerned about whether a market for supersonic aircraft exists. Using very conservative elements such as 2-hr turn and through times, it appears that a Mach 3 or Mach 4 aircraft would have a market for 500 to 600 units. Demand would decrease with increasing speeds; for a Mach 10 aircraft the market would be about 400 units. In times past that has been a large enough market to be attractive. As always, economics will dictate market size.

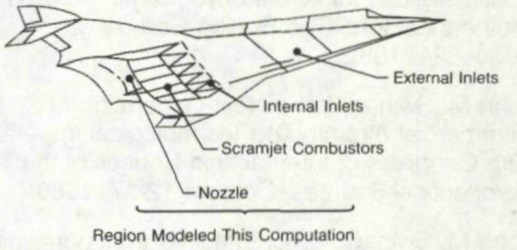
Critical Technologies

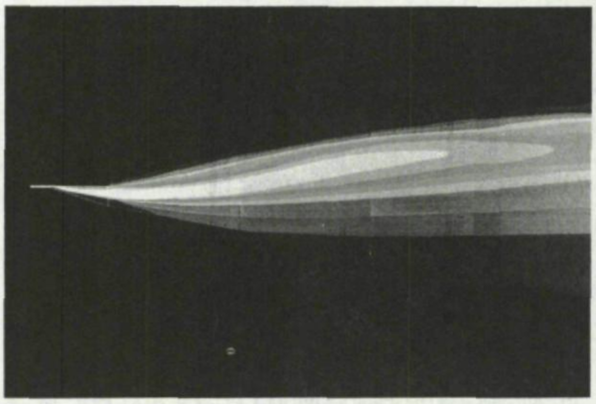


Our technology is advancing at such a rate that if we make a vigorous effort to develop the critical technologies—integrated controls, aerodynamics, thermal and chemistry environment, overall integration of propulsion and aerodynamics, and thermal protection and materials—it is very possible that we could solve the problems of designing a hypersonic airplane by the early part of the 21st century. Much of this work will depend on our computational fluid dynamic capability; the X-30 program is driving that capability at an increasing rate.

Hypersonic Vehicle Analysis

Computational Fluid Dynamics





The advent of very-high-speed large capacity computers will enable us to completely define an airplane and calculate its performance, stability and control characteristics, heating load, local Mach numbers, pressures, and temperatures. We will have a new combination of analysis, wind tunnel test, and flight test.

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THE PROBLEM OF RESEARCH IN LDDI (LESS DEVELOPED DEFENCE INDUSTRY) COUNTRIES

by

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CONTENTS

1. Applied Research - Why?

Most of us can drive a car. At night we use headlights. What is the use of headlights? They allow us to see the road ahead and to choose the right way. But we choose the way. Headlights are neutral, they don't decide. And in order to decide we must know where we intend to go.

Applied research can be compared to the headlamps of a car.

When you have an industrial project to carry out you want to complete it as soon as possible. On the way you encounter a lot of difficulties. You must detect them in advance.

But to be efficient you must have chosen a good project. Applied research supposes that you know what you intend to do.

Fundamental research is different. It can be compared to a search light used by a man to explore the whole landscape. You may be acting out of mere curiosity, not knowing what will be done with the knowledge acquired in this way. But this kind of knowledge can be transmitted to other people, so that they can see the terrain ahead. We are talking about government-funded education and information because well-educated and well-informed people are necessary for research and industry.

So, in order to undertake applied research you must have well-educated and well-informed scientists and you must know where you intend to go. But it is not enough, you must have money. Therefore the direction in which you are going must be interesting to your sponsors. Your sponsor can only be industry (to earn money) or the Government (for economic and political reasons). In most cases, you will have to convince them.

This is valid for all applied research and, in particular, for military or aeronautical research. For bigger countries which already have an aeronautical industry, the problem is relatively simple. If the national industry is prosperous this is proof that the system works. The planning and programming process must be well organized but continuity is the rule. You will find in another paper a description of the way research programmes are established in France by way of example. But what about countries where the aeronautical industry is young and weak and sometimes even non-existant? Should such countries launch industrial projects and aeronautical research?

2. Existing baseline resources

Every country in our civilized world has airplanes and weapons and experts to use them. One cannot use such complicated instruments without having a sound knowledge of them. There are invariably pilot schools and training schools for the use of weapons. The teachers involved are always specialists. Moreover, even if you buy an armament item off the shelf you have to choose between different types and contractors. You cannot do that without having experts who know the market and understand performances. Once purchased, the materiel must be tested and again you need specialists. Finally, when the materiel is in service in a country, skilled personnel must be found for maintenance, overhaul and repair.

So any modern country must have a certain amount of well-trained and well-informed specialists. And these people need some infrastructure. Any country will have, as a minimum:

- a flight centre equipped with measuring instruments
- maintenance and repair workshops, etc.

It is clear that these people with their infrastructures can be used to do some research if they are given the right task and the right sponsor with funds.

3. Cooperation with other countries

If you consider an Alliance like NATO consisting of a lot of countries of different sizes, it may be a disadvantage for the whole Alliance if each country pursues its own policy. If, for instance, each individual state of the USA was considered as independent, a lot of them would not be big enough to have an aeronautical industry and do applied research, and the USA would be much weaker than it is as a whole. This lesson was learned early on. Europe has already reached some degree of integration. More and more active cooperative projects are being organized within NATO or outside. One can say that the aeronautics and space industry is well ahead of political integration in Europe.

Great Britain, Germany, Spain and France are associated in Airbus Industry. The national industry of any one of these countries could not compete with Boeing. But associated together they form a valuable competitor. Ariane is another good example. Who would have thought that such a complicated organization of 10 or 11 European nations could win 50% of the satellite launching market? In both these cases - Ariane and Airbus - Europe is completely independent (except for certain engines), and applied research for both projects was carried out in Europe.

There are many other good examples of European cooperation such as ATR (France and Italy), TORNADO (United Kingdom, Germany, Italy) Jaguar, Concorde (UK, France) for airplanes and Milan-Roland (France and Germany) for missiles and so on. There are cooperative projects between European and non-European states, for instance, the CFM 56 engine (General Electric(USA) + SNECMA(France)) and the CN 235 airplane (CASA(Spain) + IPTN(Indonesia)). But in most of these examples the size of the cooperating industries is of the same order of magnitude. So the technical and scientific return would be more or less the same for each country. If the size or expertise of the countries is too dissimilar then cooperation tends to be dominated by one of the partners; the other being a subcontractor with less scientific and technical return.

This is, for instance, the case when subcontracting some small Airbus parts to the People's Republic of China. Although it is perhaps not so interesting for the country, it is nevertheless a good introduction to an industrial activity.

Small countries fully appreciate this difficulty. Increasingly when buying expensive equipment, the customer asks to construct a major part of the item himself. Very often, technology transfer is required. Other agreements are based on a complete license transfer after a transition period, during which only the assembly of mainly imported parts, is performed in the country.

The interest of such agreements depends very much on two considerations:

- complexity of the materiel
- expertise and capacity of the local industry.

It happened recently that less-developed countries having bought rather simple materiels were able to produce them at a much lower price because of their less expensive manpower. In this way they could conquer important parts of the market.

But if the complexity of the materiel is such that a rather long period is necessary to produce it industrially, it may be obsolete before being built. (*)

(*) This is the reason why developed countries should concentrate on the development of sophisticated materiel that cannot be easily imitated. This is also why they need a good applied research organization.

The global capacity of the industry and of the related applied research must be sufficient to enable rapid assimilation of the transmitted know how (*). The smaller the country the more difficult it is. Each country must decide what type of effort and for how long, before engaging in such a process.

(*) the cooperation between Spain and Indonesia is interesting in this respect. Indonesia is bigger than Spain but less expert. Indonesia began assembling the small Spanish aircraft CASA 212 before cooperating on the design of CN 235, but an applied research capacity was developed at the same time.

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4. Some characteristics of the Aeronautical and Armament Industries

In the Western World there are only a few companies able to design big commercial airplanes:

- Boeing, McDonnell-Douglas, Lockheed in the USA
- British Aerospace, MBB, Aerospatiale and Fokker in Europe.

That is about all.

Only four companies are able to design big engines:

- General Electric, Pratt & Whitney, Rolls Royce and SNECMA.

Only four or five companies in the USA and about as many in Europe can build military airplanes.

A Boeing 747 costs more than 100 M dollars and a fighter about a quarter of it.

It is clear that there is not much room for young and weak companies in these big sectors. They can only be sub-contractors for the manufacture of some sub-systems or for maintenance and repair. There are, however, sectors in which these countries could be active, such as light aviation and third-level transport aviation. Some countries of moderate size have had success in this field.

As yet we have mostly spoken of the civilian side. The same applies on the military side. The general trend is towards sophistication if not hypersophistication. Military airplanes are full of very complicated electronic equipment. Far-reaching IR and electromagnetic detection facilities are evolving very rapidly. Sophistication calls for more sophistication.

The more expensive the weapon the more expensive the detection and destruction capability. It is therefore necessary to develop more efficient anti-weapon systems. Because of the high velocity of modern systems the reaction time must be shortened. It is in many cases too short for the human operator to react, so man must be helped, if not replaced, by electronic systems.

Another possibility of coping with the enemy threat is to deceive the sensors in the attacking weapons. Measures call for countermeasures and counter-countermeasures. The system becomes so complicated that human intelligence cannot master it in real time. Decision-preparing or decision-making devices must be designed using artificial intelligence. The thinking has culminated in the well-known SDI or star-wars system.

There are consequences on the financial side. Extrapolating the increasing cost of one airplane and the total amount of the USA defense budget leads to the conclusion that by the year 2000 the US Government would be able to buy only one airplane every year. The cost of a stealth bomber could already approach one billion dollars. Even a major country's economy can be (or has been) endangered by such expenses.

The question is whether this is the right way. Simplicity is smart (and unfortunately difficult). Could not those countries which cannot afford very expensive weapons militate for simplification? The search for other solutions is very important.

In the civilian sector too, sophistication is perhaps not the only solution. Recently there was a discussion about supersonic and hypersonic transport. The main advantage would be time saving. But it was stressed that at least two other solutions exist:

- better telecommunications, making travel unneccessary;
- slow planes for comfortable passenger travel in bed, during the hours of darkness.

Sophistication can be dangerous if not fully controlled. Recently a civilian plane was mistakenly shot down by a ship which had a very elaborate detection and destruction system. Maybe under combat conditions, the relationship between man and the whole system was not good enough. Simplified representation of the situation is very important. New cockpit designs take this point into account.

On the other hand, developed countries sometimes introduce rather simple and efficient new weapons. One of the best examples is the "Stinger". With such a light weapon a single man can destroy a large airplane. It has become a nightmare for the mighty and a blackmail possibility for the weak. But this example shows that these simple weapons result, nevertheless, from the use of modern technology: I.R. sensors, electronics, etc.

5. Some characteristics of modern technology

In order to look for new solutions we must make use of the new possibilities offered by modern science and technology. The military field has in the past been an area for very brilliant innovation. For example, radar was developed for military use and then found very beneficial applications in the civilian sector. More recently, composite materials have been studied with the main aim of reducing the weight of aeronautical structures, but are now widely used in other sectors, as for instance, the automobile industry. The spin-off can occur in the reverse direction as with the advent of solid state components and micro-electronics. Thanks to these new technologies we can build compact, rugged low-cost logic systems. They can be used in several ways, for instance for scientific and on-board computers, but also for decision-making systems when combined with appropriate sensors. They happen to have a feature particularly important in the military field: they resist acceleration very well (for instance, they are used in shell proximity fuses). Compared to the traditional mechanical industries, they require more brainpower but less plant and investment.

Far East countries have become expert in this field in a relatively short time, but more for civilian applications. In fact this discipline covers several different activities:

- fabrication of micro-chips: obtaining very pure material, thin or thick layer deposit methods, mechanical work for the creation of the different functions, etc. It is high-tech limited to a few nations if the aim is to achieve optimum performance;

- design of logic functions as integrated as possible but practically feasible;

- use of a combination of logic functions for the practical control of devices. This application field is very large extending from toys to very complicated space robots. It is a challenging domain for applying ingenuity and all the possibilities have not yet been explored by far.

A combination of such devices with large data banks can lead to complex functions such as form reconnaissance of computer-aided design, computer-aided machining, etc. These new methods have an immediate impact on industrial activities, considerably increasing their efficiency. In any event, progress is so rapid and so spectacular that it is impossible to ignore it, if one wants to survive.

There are, (and there will be more in the future) other highly promising technologies. Laser, for instance. We must follow up any new ideas and try to take advantage of them so as to improve on the solutions we offer. As we have said, new ideas which can be used in the military sector sometimes come from the civilian side. It follows that their development can be useful for both sectors. This is a big advantage because the bigger the field of application the bigger the number of interested industries and possible sponsors. Clearly good information is a prime requirement. Documentation is essential. In this field AGARD can help a great deal. The scientists can learn about the state of the art by attending Specialists' Meetings and know-how can be transmitted more directly by consultants. A further step is the Support Programme. I can understand the wish expressed by some nations of the Southern Flank not to concentrate on a few subjects. The scientific landscape must be complete. But the means are limited on the AGARD side, as with the Nations, so there should not be too much dispersion in the Support Programme.

6. What is to be done

It is up to you to decide. It is very easy to give advice, it is much more difficult to succeed.

The choice of the possible developments (objectives)

- R and D in the modern world is a highly integrated activity. For this reason the three partners: Government, Research and Industry must inform one another continuously of the evolution of their wishes and capabilities (technical, industrial, financial). Clear objectives must be fixed and accepted by all. The choice is essential, it may be based on a political decision (for instance, the necessity to build for oneself a weapon which other countries are reluctant to sell), it may be based on careful market and cost studies if one intends to sell the material. But in all cases it must be realistic taking into account the capacity of the country. Aiming too high is dangerous.

- You know better than anyone else the strong and weak points of your national capabilities and the particular national features. To give an example, in your countries the terrain is often mountainous and rough. This may be important for some weapons such as RPVs or small planes. You have a big coastal domain with strategic islands or communication routes. Some special detection, communication, or defence material may need to be designed for special purposes related to this feature. This is perhaps an opportunity to look for simple solutions. It may be an original development or a modification of a system existing in other countries. The life of equipment being relatively long in peace time a refurbishment is sometimes necessary. Modernisation may be required but also a better adaptation to the local conditions.

- For political or economical reasons cooperation with other countries may take place. The partners may be reluctant to cooperate because of the possible competition with their own industry, but within the European community of NATO there exists an increasing tendancy to involve all countries in the general development process. This has been embodied in an IEPG communique creating the programme EUCLID in 1989 (see Annex 1).

It may be interesting for you to know the three reasons for which France decided to participate (following a speech given by the Assistant Director of DRET, IGA Cremieux).

1. In recent years R and D and production expenses have increased. The R and D costs represent about one third. EUCLID should allow a better utilisation of available funds.

2. Some connections have already been established between European national companies working for defence. But even after 30 years of cooperation these connections are considered not strong enough. EUCLID should foster cooperation in the field of R and D, that is before industrialisation, and thus contribute to the creation of an European defence industry.

3. European cooperation has been developed in various fields such as coal and steel, agriculture, etc. More recently, something has been done in the field of high-tech for civilian use with ESPRIT and EUREKA. Defence should not stay behind and launch some big common research projects in order to maintain its former advance.

It is sometimes wiser to accept a lesser role in a cooperative study than overestimate one's capacity and fail.

It should also be remembered that since 1979 a "Science for Stability Programme" exists within the NATO Science Programme. Annex 2 gives some details.

Planning Research

Once the objectives have been clearly identified, the second phase is the planning of the research work in close connection with industry.

Planning means drawing up a research programme compatible with the available
- human resources
- facilities
- money
- time.

If the human resources or the required facilities are not available they must be created and it takes a certain amount of time to recruit people and to build installations.

As far as the human resources are concerned there must be experts in schools, procurement services and in industry. It may be very useful to organize a flow between these different organizations. The exchange of knowledge provides cross fertilization and personal contacts make for understanding between services.

As for the facilities, these may be very expensive. (*) Do not forget they are only the means not the end. Everybody is proud of a magnificent wind tunnel or a powerful computer. But first they must be built or purchased and second they must be operated and maintained. In this case too, cooperation is a good solution. You can perhaps use a facility existing in an allied country. In this way you can reduce cost and implementation times. If not, you can decide to build the facility together with another country. So you can share the costs both for construction and use and you have more funds for the research itself (see Estoril communique in Annex 1).

(*) The cost of the European Transonic Wind Tunnel will be two billion French Francs, about 300 million US Dollars.

ANNEX 1

ESTORIL COMMUNIQUE 28 June 1989

The Defence Ministers of the thirteen IEPG nations met in Estoril on 28 June 1989. Following the November 1988 Ministerial meeting at which far-reaching decisions were taken on the implementation of an Action Plan on the step-by-step development of a European defence equipment market, Ministers took stock of the progress made. They reaffirmed their support for the IEPG as the main European forum for cooperation in the research, development and production of defence equpment, and they emphasised the important contribution made by the IEPG to strengthening the European component of the North Atlantic Alliance. Ministers restated their resolve to establish such a market in order to ensure the most effective use of resources and maintain, and wherever possible, strengthen the industrial and technological base of all IEPG countries, while at the same time encouraging transatlantic cooperation.

Opening the European Armaments Market

Ministers noted the first step towards opening the European defence equipment market and towards enhancing the competitiveness of the European defence industry. Each IEPG nation has already nominated one or more focal points to which companies in other IEPG countries could register an interest in bidding for defence contracts. Ministers examined progress towards the publication by all IEPG countries of regular bulletins setting out defence contract opportunities for companies; they noted with satisfaction that some countries would do so by the turn of the year. Moreover, Ministers directed that work should continue on formulating proposals for the criteria for contract award, technology transfer, and for concrete transitional measures for "juste retour". Ministers also directed that the consequences for the European defence equipment market of developments in other European forum should be studied.

Developing Defence Industries (DDI)

Ministers reaffirmed their commitment to the support of countries with Developing Defence Industries (DDI) and to the implementation of practical measures designed to help to develop the defence industrial and technological bases of these countries.

They confirmed their view that an open European defence equipment market would assist DDI countries by providing them with increased opportunities and also agreed to consider transition periods before these nations fully open their borders.

Research and Technology

Ministers agreed to launch a joint programme of research and technology in the defence field. This programme will be called "EUCLID". It is based on the work done by the IEPG's Research Panel on an European Technology Plan, which specifies priority technical areas. Ministers tasked the Research Panel with producing proposals to the National Armaments Directors to implement this initiative, including firm plans for future funding; this could amount to approximately 120 million ECU in 1990. Proposals will be submitted for agreement at the next Ministerial meeting. They also tasked it with informing European industry, through the European Defence Industrial Group (EDIG), of the details of the joint programme and with inviting joint proposals, including appropriate financial participation. This initiative, together with the continuing work on Cooperative Technology Projects (CTPs) should also facilitate the technological development of the DDI countries.

Harmonisation of Requirements

Ministers noted the value of the IEPG's annual review of equipment replacement schedules aimed at harmonising requirements and timescales, and welcomed the *consideration being given to improving* identification of long-term cooperative programmes.

Equipment Projects

In the light of their common objective of making the most effective use of defence resources by enhancing industrial and technological cooperation, Ministers stressed the importance of collaborative equipment projects.

European Defence Industrial Group (EDIG)

Ministers expressed satisfaction at the prospect of the European Defence Industrial Group (EDIG) playing a fuller role in IEPG activities, and noted that IEPG officials meet EDIG representatives regularly to establish closer ties.

IEPG Secretariat

Ministers noted with satisfaction that the IEPG secretariat had been established in Lisbon and had already taken a range of practical (initiatives?)activities, including the distribution of information about each nations' focal points.

Transatlantic Dialogue

Ministers stressed the importance of defence cooperation among all members of the North Atlantic Alliance. They expressed concern at any measures which might be construed as protectionist on either side of the Atlantic, believing that this was likely to have an adverse impact on the cohesion and capabilities of the Alliance.

European Session for Armaments Managers

Ministers noted with approval that the first European session for armaments managers, bringing together national experts at both official and industrial levels, had been held in France and the UK, and that this would be a regular event, to be held next year in France and Spain.

Next Meeting

In view of the importance of the work in process and in prospect, Ministers decided to maintain the frequency of their meetings; they will meet twice during 1990.

ANNEX 2

A. The NATO Science Programme

The NATO Science Committee is an important element of what is known as the "third dimension" of the North Atlantic Alliance - the dimension concerned with the enhancement of contacts and cooperation between Member nations in the areas of science and technology, culture and the problems of modern society.

The Science Programme was established in 1958 in recognition of the crucial role of science and technology in maintaining the economic, political and military strength of the Atlantic community. Broad policy and direction are provided by the NATO Science Committee, whose membership is drawn from amongst the most eminent scientists of each nation and chaired by the Assistant Secretary General for Scientific and Environmental Affairs of NATO.

The Committee's main objective is to enhance the scientific and technological capability of the Alliance by supporting progress and exchange and cooperation among scientists of Member nations and by catalysing remedial action to help close gaps in scientific capability and knowledge.

Under the Programme's auspices more than 1,000 scientists have benefited from the chance to conduct research in another country - an opportunity which not only enriches the host organization and the scientist concerned but additionally leads to the establishment of valuable contacts for future exchanges of ideas and expertise. This dissemination of scientific expertise throughout the Alliance is further enhanced by other sub-programmes, such as the many Advanced Study Institutes and Advanced Research Workshops held each year. Since the beginning of the Programme approximately 200,000 scientists and technologists have been involved in one or more elements of the NATO Science Programme.

B. The Science for Stability Programme

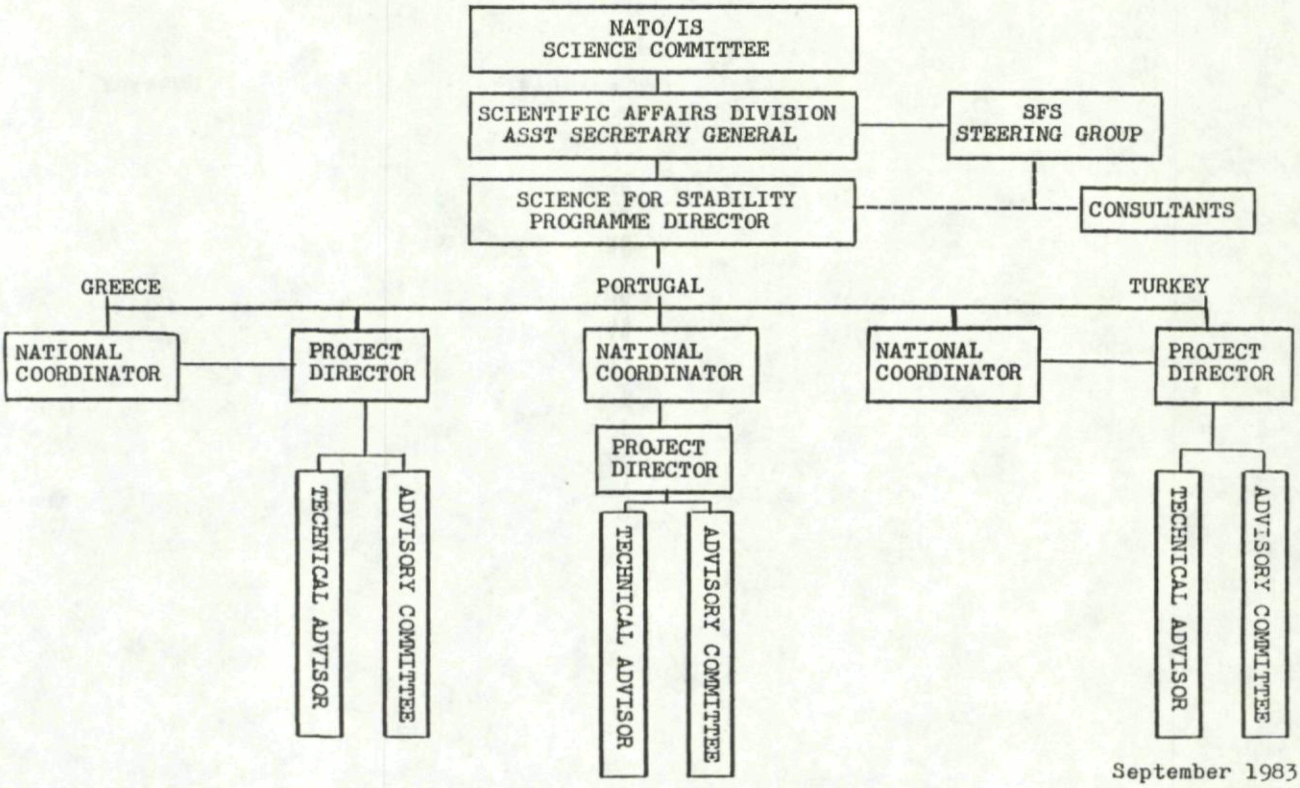
Objective: Science for Stability is a special fixed-term programme of the NATO Science Committee, created in 1979 and approved by the NATO Permanent Council in 1980. The overall goal is to strengthen the NATO Alliance by enhancing the scientific, technical and managerial skills of certain member countries and the contribution these skills can make to economic progress and political stability. Specially, the Programme was established to strengthen the R&D management infrastructures in Greece, Portugal and Turkey and thus make better use of the existing academic, industrial and government R&D capabilities in their application to economic development. This means that, in effect, the Programme is a practical experiment in the transfer of the technology of the management of research and development. Its focus is an applied research, conducted by collaboration among experts in universities, industrial and government laboratories. It is not a typical aid or assistance programme: in terms of its explicit objectives, it is probably unique among international development programmes. Finally, and perhaps most important, each project is a joint undertaking, the NATO funding being matched or exceeded by the national contributions.

Organisation: The Assistant Secretary General for Scientific and Environmental Affairs, head of the Scientific Affairs Division, also serves as Chairman of both the Science Committee and the Science for Stability Steering Group. Day-to-day management of the Programme is the responsibility of the Programme Director, who acts as Staff (and Executive Secretary) to the Steering Group.

The organizations of the Programme within the three countries differ from country to country in keeping with the intended flexibility in the overall conduct of it. Figure 1 shows the organisation of the Programme. The relationships between the Programme Director and the individual National Coordinators and the Project Directors are under active consideration with the objective of shifting the responsibility for the management and administration of the national programmes and of the individual projects in each country to the national authorities to better insure that the projects (or similar ones) will continue beyond the period of NATO funding.

In the organization of the individual projects, the Project Director normally has two advisory activities - an Advisory Committee broadly representing university, government laboratory and industry involved or interested in the project, and a Technical Advisor who is a senior foreign expert appointed by the Project Director with the concurrence of the National Coordinator and the Programme Director.

ORGANISATION OF PROGRAMME



September 1983

Figure 1

AERONAUTICAL R&D IN SMALLER COUNTRIES

by

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CONTENTS

1. Introduction

Aeronautics fulfills an important function in education (engineering sciences), industry, traffic and trade. It is quite often considered as a major factor in the economic future of a country, together with electronic computers, atomic energy (recently with more emphasis). This, combined with the necessity to maintain an effective air defence, makes it mandatory for industrially developing countries to evaluate carefully to what extent they want to invest in aeronautics and, more generally, in aerospace.

This Seminar is concerned with aeronautics and not specifically with space technology. In industrialised countries the aeronautical industry is also heavily involved in space technology. In fact space technology is by-and-large developed by the same industries and institutions which are involved in aeronautical technology.

Many of the smaller European countries have very limited, or no, national space programmes but they can participate in the ESA programmes. ESA pays particular attention to the fair return principle in high quality technological work and thus the ESA programmes contribute to the technological development of these countries.

This paper discusses the planning and organization of aeronautical R&D and its role in aeronautics in general. Special attention is given to the situation of smaller countries. The paper is to a large extent based on experiences gained in Canada, the USA and especially in the Netherlands. Although this experience may be only of limited direct use to industrially developing countries, it may assist in charting the course of those countries.

2. The aerospace industry

The aerospace industry is a major industry in the world as indicated by the following estimates of the European Community (EC) for the year 1988:

Turn-over aerospace industry

USA	78.6×10^9 ECU *)
Canada	4×10^9 ECU
EC (7 countries)	45.9×10^9 ECU
	128.5×10^9 ECU

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*) 1 ECU (European Accounting Unit) = approx US $ 1.17 (end 1989)

It is also a major employer

USA	971,000 personnel
Canada	49,000
EC	460,000
	1,480,000

These figures are all related to direct employment in the aerospace manufacturing industry. The total number of people employed in aerospace, when taking into account the airlines, the government agencies, the Air Forces, the laboratories and the educational institutions, etc. is several times this number.

It is to be expected that in the 1990s employment will be more or less the same. Although it is now expected that several military aircraft programmes will be changed or stretched in time, the prospects for civil aviation are very good.

The growth of air transport has been spectacular over the last several decades. Forecasts by the ICAO, IATA and others indicate that this growth will continue well into the next century. One market forecast indicates that the present number of 7,400 commercial jet transporters will increase to 11,000 by the year 2000. Together with the retirement of 2,600 airliners in the 1990s this means that a total of 6,300 airliners will be put into operation in the 1990s, almost as many as there are now in operation. Including space parts, engines, etc. this represents sales of the order of US $ 10^{12} (one trillion dollars).

The military needs are, at least in the near future, qualitatively at the same level as before and although the quantitative needs may decrease there will be many technological subjects requiring increased attention, such as service life extension, modifications and further improvements in communications, command, control and sensor technology.

Every industrially-developed and developing nation has aeronautical activities, civil and military, and given the size of the industry on a world scale, every nation needs to answer the question to what extent does it want to be an intelligent buyer, manufacturer and supervisor of the goods and services. In all cases a national investment needs to be made. Of course the smaller industrial and industrially developing nations are very much influenced by what takes place in the large industrial nations.

Smaller industrial nations cannot stay abreast in all fields. Highly developed smaller nations such as Sweden, the Netherlands and Switzerland rely on often complicated networks in the public and private sector to arrive at the proper investments. Increasing their R&D spending is only useful if the industrially-oriented research is related to a network of producers and users.

3. Characteristics of aerospace research

Aeronautical research, as carried out by the various institutions mentioned in Section 4, is characterised by a number of factors which are important for organization and management.

The main characteristics are:

- It takes a relatively long period to build up the knowledge and equipment required to make significant contributions. The examples given in Section 6, illustrate this point in more detail. Although these are historical examples there are no indications that such periods will be much shorter in the future, particularly since the market requirements (the application period) are difficult to predict in time so that a more or less constant "readiness" (at least over several years), is required.

The consequence of this characteristic is that continuity (finance, personnel) is very essential. Skills and experience built up over a period of ten years can be lost in one or two years if a discontinuity occurs.

- To carry out aeronautical research which is ultimately useful for the aircraft designer, the operator (air force or civil operator), the traffic control authority or the governmental certifying and supervising authorities, require relatively highly trained and experienced personnel.

- Much of aeronautical research, particularly that directly related to aircraft development, is characterised by the use of advanced installations of significant size (wind tunnels, flight simulators, laboratory aircraft, computers, structures and materials test equipment).

- There exists a long tradition of extensive exchange of ideas and of cooperation in the aeronautical sciences. In this respect the aeronautical sciences are somewhat comparable to the more fundamental sciences to which the aeronautical sciences are closely linked. The exchange of information and ideas is, of course, limited once commercial applications become a reality.

- In aeronautical research it is often necessary to operate with multi-disciplinary teams (aerodynamics, flight mechanics, structures, avionics, etc.). Although, on the one hand the organization must be sufficiently in-depth discipline oriented, it must also be capable, on the other hand, of organizing the work in a multi-disciplinary-project-team mode to deal with complicated aeronautical problems.

- Finally, many aeronautical research organizations are characterised by the fact that they carry out research in support of aerospace vehicle development and also in support of operations in aerospace. In many cases the ultimate users are both civil and military organizations.

While several of the above characteristics can also be found in other research organizations, the combination of these factors is unique to aerospace research laboratories.

4. Aerospace laboratories

From the beginning of flight, early this century, theoretical and experimental research has been an essential part of the development and operation of civil and military aircraft.

Aeronautical*) research is carried out in universities, industry and in special aerospace research institutes. Most countries with a substantial aeronautical activity have specialised institutes supported or owned by their governments. Some examples in the Western World are (in alphabetical order):

DLR	Deutsche Forschungsanstalt fur Luft und Raumfahrt, FRG
FFA	Flygtekniska Forsokanstalten, Sweden
NAE	National Aeronautical Establishment, Canada
NASA	National Aeronautics and Space Establishment, USA

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*) Aeronautics and space technology are closely related and most of the organizations considered here are concerned with both. The terms "aeronautics" and "aerospace" are used indiscriminately in this paper.

NLR	Nationaal Lucht en Ruimtevaartlaboratorium, The Netherlands
ONERA	Office National d'Etudes et de Recherches Aerospatiales, France
RAE	Royal Aerospace Establishment, UK

Most of these institutions, or their predecessors such as NACA, the forerunner of NASA, were formed at the early development of aeronautics. The development of aeronautics is closely associated with the development of the engineering sciences of aerodynamics, flight mechanics, structures and materials and laboratories, such as mentioned above, and the research carried out at universities played an integral role in the development of aeronautics. This leads towards the statement that the aeronautical industry is a <u>science-based</u> industry as compared to a <u>craft-based</u> industry. Obviously this distinction becomes less meaningful as the influence of scientific development affects more industries. Nevertheless the statement is important in considering the implementation or even implantation of an aeronautical industry in an industrially developing country.

This Seminar is concerned with the R&D structure in aeronautics or at least some of the important elements of the structure. The Seminar does not concentrate especially on management of laboratories. It is clear, however, that management is a very important aspect of implementing an R&D structure and a few remarks are in order here.

There are several management aspects. Undoubtedly the most important is personnel management. It is really the management of change; the management of changes in personnel and organization. Ideally: once a person has been given the responsibility of a department, division or group, or a certain personal task, the management layers above him should only monitor this performance and feed him with the information which the organization as a whole considers as important. The leaders of the organization should analyse and evaluate in particular:

- the economic developments
- the overall technical development
- the social and cultural development
- the political scene, including regulation and law-making by governmental authorities
- the development and plans of the competition.

The personnel of an aerospace research institute typically consists of one third university graduates, one third graduates of advanced technical colleges and one third technicians, administrative personnel and others. The actual ratios obviously depend on the degree of subcontracting of services (machine shops, guards, etc.) and the local circumstances.

An analysis at NLR (Ref. 1) showed that the specific know-how of the personnel could be divided up as follows:

- Specific aerospace knowledge	55%
- Technical and scientific services	20%
- General services, incl. administration, library, etc.	15%
- Management	10%

This means that more than half of the personnel had the specific experience and knowledge which distinguishes the laboratory from other institutions. To a lesser extent this also applies to those working in technical and scientific services such as instrumentation, model design and manufacture, central computer services including programming, etc. However, what is important is that more than half of the personnel must have knowledge and experience of aerospace allowing them to perform tasks that are more or less unique in the market for which the laboratory performs its services.

The means of acquiring and maintaining this knowlege and experience are, among others:

- to carry out in-house research directed towards the (national) long-term needs;
- to cooperate and exchange information with foreign institutions;
- to participate in congresses, symposia, etc;
- to take specific courses;
- to cooperate with universities and stimulate universities to carry out aerospace research in the applied sciences and engineering departments;
- to engage personnel with the desired know-how and experience;
- to study the literature;
- to carry out contracts in the relevant areas.

The necessity of the above-mentioned activities is demonstrated by an analysis of the changes in engineering curricula of some universities in the USA, Ref. 2. Numerical data over the period 1935 to 1965 indicate that in aeronautical engineering changes of 50% occured over a period of 10 years and that over a period of 30 years the changes were over 90%.

The paper (Ref. 2) uses the changes in the engineering curricula as a measure of obselence of engineers during the period after graduation.

It is possible that since that period the rate of change has decreased through the fact that in many universities, certainly in the USA, the character of engineering courses has become more fundamental. Nevertheless, the point is that at any research and development organization "education permanente" or in-service training is extremely important, and may become even more important in the future.

5. <u>The position of R&D in the total process</u>

Aeronautical research is carried out for several different purposes: aircraft development, aircraft operation, air traffic management, aircraft certification, etc. In this Section the position of research and development is sketched out for the process of aircraft development, after which some more details are introduced for other applications.

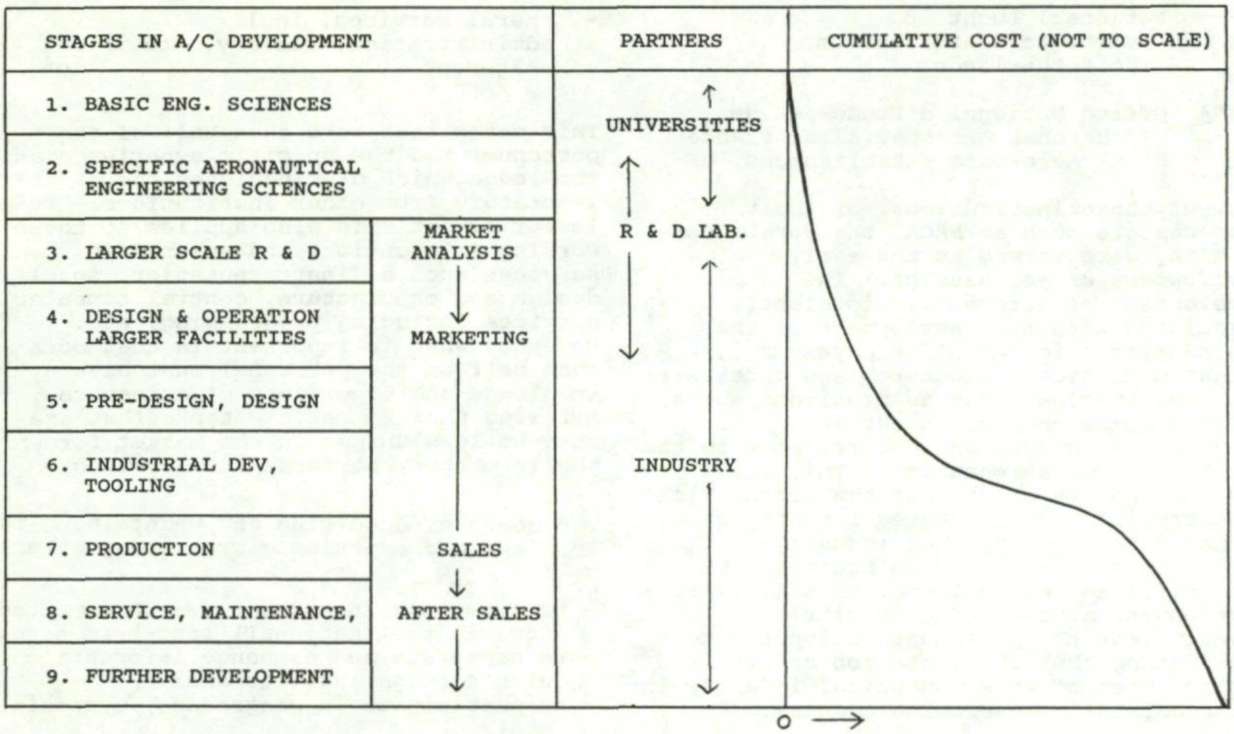

Fig.1 - STAGES IN AIRCRAFT DEVELOPMENT

The aircraft development process is summarised in Fig. 1. The nine stages chosen are somewhat arbitrary and, in reality, these stages are overlapping. Based on the collective knowledge and experience available to the aircraft company, including Stages 1, 2 and 3, marketing is all important to come to a decision of detailed design and development. The role indicated here for the R&D laboratory may well extend to further phases and, depending on the company, may be done more or less in-house.

Before a decision for full-scale production can be made, substantial investments must be made as indicated in Fig. 2. This figure indicates schematically the various phases in the realization of an aircraft series production and the net income per year for such a project. Ideally, the decision for full-scale production is taken at the time when a sufficient number of firm orders and options have been obtained. In many cases this decision has to be postponed because the market development and the competition may not (yet) warrant the even greater investments needed to start series production and to place orders for long lead items.

Ideally an aircraft factory would have to start a new aircraft project every 4-6 years so that an even cash flow occurs. In reality, this is only possible for one or two of the world's largest aircraft manufacturers.

The Figure is meant to indicate the long periods of investments required to develop and manufacture an aircraft. The Figure gives a time scale approximately valid for modern civil transport aircraft and military combat aircraft. For small transport and general aviation aircraft the times are considerably shorter, although here also substantial delays can take place influenced by competition and the market demands.

In some cases laboratories carry out important tasks in the actual aircraft development. For instance, NLR developed a large part of the flight test equipment used in the flight test programmes of Fokker aircraft. Other laboratories are even involved in the design and management of exploratory programmes (National Aerospace Laboratory, Tokyo). Fig. 3 from a NASA presentation in 1984, indicates NASA's role as an agency carrying out research and exploratory development during the stage of high technical risk.

The R&D establishments such as listed in Section 4, are engaged in several other applications besides support for aircraft development. Obviously in each country there are differences in the division of tasks, often due to historical reasons, and the availability of expertise elsewhere. The following list, adopted from Ref. 3, gives a fairly complete picture:

Main roles and functions of R&D establishments

Basic and applied research
Monitoring government-supported industrial research
Formulating systems concepts
Advice to the services
Operational assessment
"Fire brigade" action
Provision and maintenance of test facilities
Acceptance, evaluation and certification
Statutory and safety roles
Design requirements
Advice and consultation available to industry
Training
International collaboration on research - TTCP (The Technical Cooperation Programme), AGARD, GARTEUR (Group for Aeronautical Research and Technology in Europe), etc.

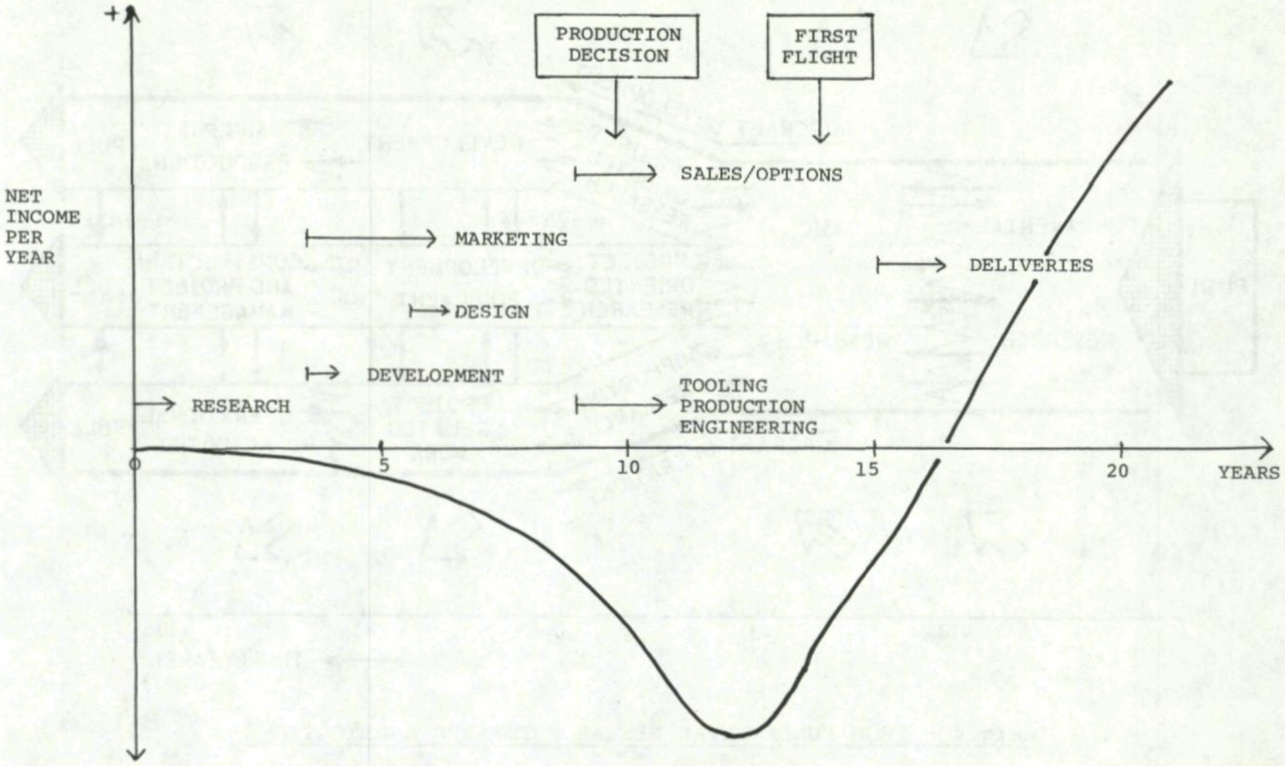

Fig.2 - TYPICAL ANNUAL NET INCOME FOR A NEW A/C DEVELOPMENT

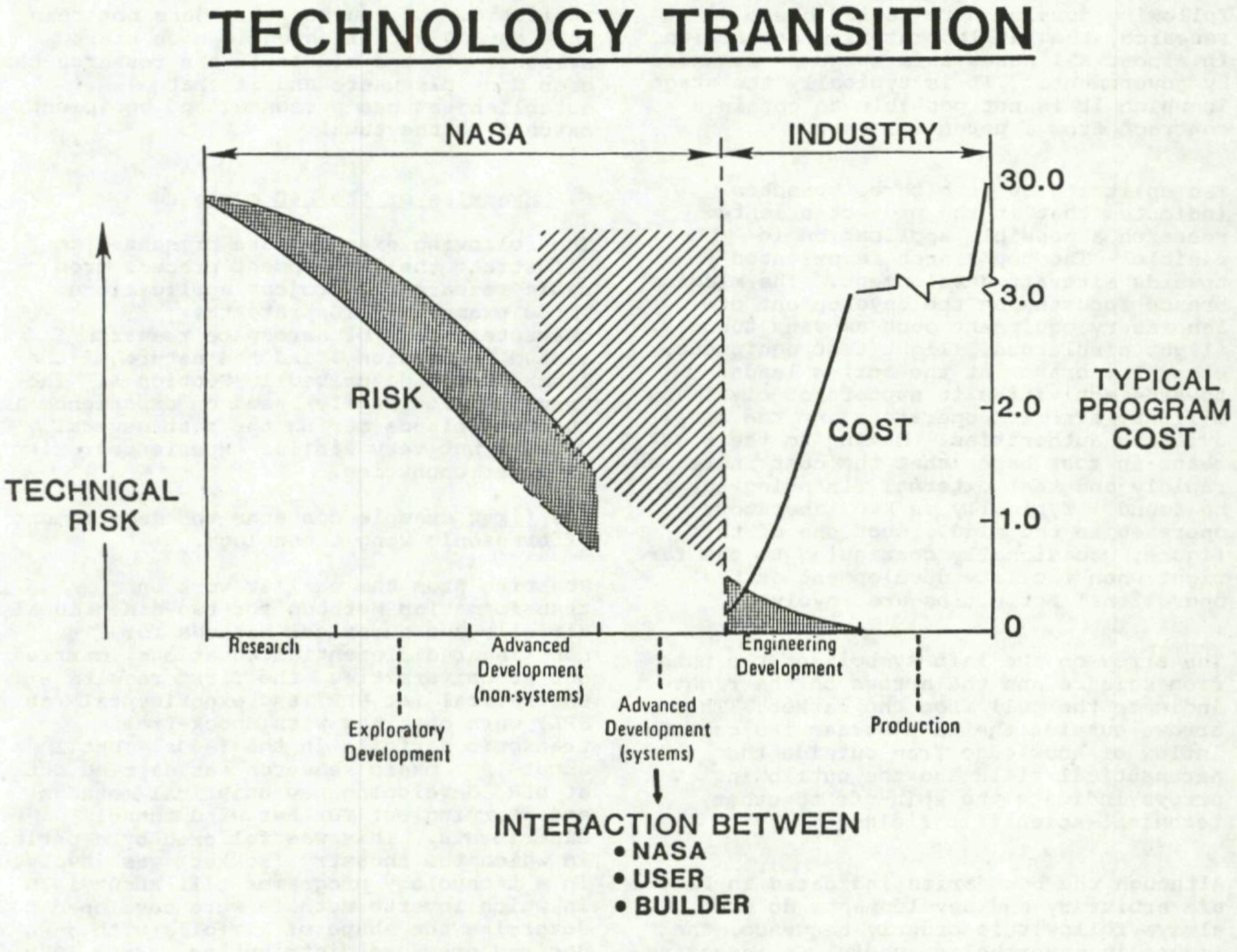

Fig.3 - THE ROLE OF NASA IN AEROSPACE DEVELOPMENT

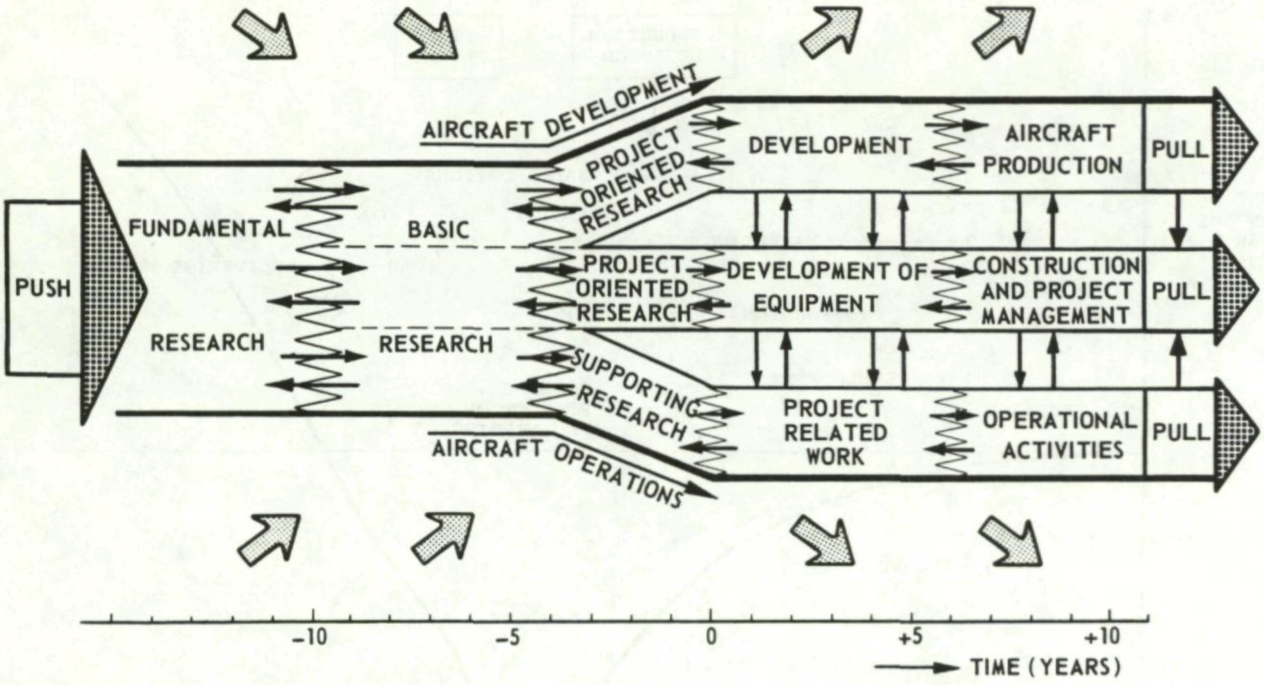

Fig.4 - FROM FUNDAMENTAL RESEARCH TOWARDS APPLICATIONS

Finally Fig. 4, from Ref. 4, is a model in which various activities can be viewed in a time frame. The area to the left, fundamental research, is typically the domain of the universities. In the following domain, here called basic research, the R&D laboratories are active. In almost all cases this stage is financed by governments. It is typically the stage in which it is not possible to obtain a contract from a potential user.

The splitting up into three branches indicates that in the project-oriented research a possible application is visible. The top branch is oriented towards aircraft development. The middle branch focusses on the development of laboratory equipment such as wind tunnels, flight simulators, flight test equipment, etc. The branch at the bottom leads towards activities in support of civil and military aircraft operators and the civil aviation authorities. Moving to the right means in most cases that the cost increases rapidly and that external financing has to be found. Typically an R&D laboratory operates in the middle sections of this figure, occasionally continuing to the far right when facility development or operational activities are involved.

The arrow on the left symbolises the push from science and the arrows on the right indicate the pull from the market. The arrows outside the main stream indicate the inflow of knowledge from outside the aeronautical field and the outflowing arrows indicate the spin-off to other technical-scientific fields.

Although the boundaries indicated in Fig. 4 are arbitrary and developments do not always follow this orderly sequence, the figure is nevertheless useful in assessing the status of research.

The time scale at the bottom shows the relatively long time period involved in developing new technologies from inception to application. The examples in Section 6 all show that this time scale is realistic. Of course, this does not mean that an R&D establishment cannot start somewhere in the middle if the research has been done elsewhere and if that establishment has personnel and equipment matched to the task.

6. Examples of the R&D cycle

The following examples are presented to illustrate the development process from basic research to project applications. These examples illustrate the characteristics of aerospace research listed in Section 3 and the nature of the laboratories described in Section 4. The examples are largely based on experience in the Netherlands during the past several decades but very similar experiences exist in other countries.

The first example concerns the development of transonic wing technology.

Starting from the earlier work on transformation methods for two-dimensional airfoils and numerical methods for non-linear differential equations, carried out at universities, the first results - theoretical (at NLR) and experimental (at NPL) were obtained with shock-free transonic airfoils in the 1960s. Until about 1973 basic research was carried out at NLR, developing new numerical methods and carrying out further wind tunnel experiments. This was followed by a period in which the industry (Fokker) was involved in a technology programme till about 1979 in which inverse methods were developed to determine the shape of airfoils with a desired pressure distribution. From 1975 till 1979 numerous wind tunnel tests were carried out resulting in a state of readiness of this technology. This technology was introduced in various project studies: the Fokker F-29 (1979-1980), the MDF 100 (1980-1982), a joint project study with MacDonnell-Douglas and finally, fully applied in the Fokker 100 (1983-1985). This technology could have been applied earlier if the market prospects had been suitable to launch a new civil airliner but, of course, the intermediate period was used to gain more theoretical and experimental experience so as to reduce the risk of a new wing design. It is also clear that parallel supercritical wing developments were being carried out in other countries but it was mandatory to keep the national development alive since the application to projects was too near for a free interchange of information.

The <u>second</u> example is the development of a method to extract from a single aircraft manoeuvre a complete set of performance parameters and stability derivatives: the instationary measurement method. This method was conceived in the early 1960s at the Technical University at Delft and experiments were carried out with the university laboratory aircraft using a very sensitive inertial platform and gyroscopes. By using this method the number of flight hours required to measure the performance of a new aircraft is greatly reduced compared to the older methods whereby for each data point a stationary flight situation has to be achieved. Besides that the method yields stability derivatives not otherwise obtainable experimentally on a full scale aircraft. Such data are needed more and more as automatic flight control systems and training flight simulators are further refined.

In the late 1960s and in the 1970s the method was further developed and prepared for aircraft prototype testing using, i.a., NLR laboratory aircraft and an F28 transport aircraft. Finally, during the period 1985 - 1987 the method was applied in the flight test programme of the Fokker 50 and the Fokker 100.

As a <u>third</u> example, illustrating in particular the long gestation period, the introduction of new aircraft structural materials can be noted. Carbon fiber reinforced plastics (CFRP) and Aluminium-Lithium alloys. Here several more players are involved: the material manufacturers, the industry providing the process tools and equipment and the certifying government organizations. Nevertheless, the fundamental work at universities and more basic laboratories started decades ago and the aeronautical R&D laboratories have been active for a long time to determine the material properties including, in particular, delamination, fracture mechanics and crack growth. The certifying authorities can only fully accept a new construction material when it can be shown that at least the safety level attained with well-known older materials has been achieved. This, combined with the fact that manufacturers have an enormous experience in designing and manufactuirng with more conventional alluminium alloys, makes it a difficult process to introduce a new construction material.

Finally, as a <u>fourth</u> example, illustrating the various stages of the conception, design and construction of major aeronautical test facilities needs to be mentioned. The most recent example in Europe is the cryogenic ETW (European Transonic Wind Tunnel), now under construction at Porz, near Cologne (FRG). The tunnel is scheduled to be fully operational in 1992. This is a four nation project now run by a separate organization, ETW GmbH, owned by DLR, ONERA, RAE and NLR. This project, starting with the selection of the drive system, followed by design studies, a pilot wind tunnel and a joint cryogenic technique programme covered a period of 15 years until the actual construction started. Apart from the technical problems encountered, this project was complicated by the fact that four nations participated and the national decision and budgetary processes do not follow the same time schedule. Nevertheless even in the USA where such facilities can be realised on a national scale, the time periods are not much shorter.

It is, of course, possible to shorten the R&D cycle considerably, given enough priority and the resources. But even in such cases a closer look reveals that much of the technology was already available and could be absorbed by those charged with the project.

7. <u>Planning and marketing of R&D programmes</u>

Having discussed some of the characteristics of aerospace research and the role it plays in the development of aircraft and, more generally, in aeronautics, it is logical to consider how the goals of a research programme can best be established.

A major consideration is that in engineering research, far more so than in scientific research, the activities ought to fit into the total strategic planning of a country, region or organization. This does not mean that success of the research has to be guaranteed in a technical or economic sense, but if public (or, for that matter, company) funds are involved at least the subject should fit into a strategy.

Before actually planning the activities of an engineering research organization it is necessary to consider the activities which may benefit from the research to be undertaken. In aeronautics the following list gives most of the activities which can be carried out in a country:

1. evaluation and acquisition of aircraft and helicopters
2. acceptance and certification
3. operation, training
4. accident/incident investigation
5. regulatory activities
6. air traffic control
7. participation in international organizations (ICAO, IATA, NATO, IEPG .....)
8. repair of aircraft, helicopters and engines
9. maintenance
10. assembly
11. sub-contracting

12. partner in development
13. major (sub)system supplier
14. aircraft and helicopter design and manufacture

An inventory of all aeronautical activities in a country may show that there is a common need for technical-scientific support. For example, under repair there may be a need for a better welding technique and material evaluation for turbine blades while, if a successful research programme were undertaken to improve the welding process, this might be of interest to those responsible for activities mentioned under item 5 (regulatory activities) and 9 through 14. A material science laboratory may be stimulated by these activities.

Flight mechanics experts may be in a position to support the activities under items 1 through 7 and, of course, 14.

This is really technical-scientific marketing. Each of the organizations responsible for a particular activity may want to consider the advantages and disadvantages, including the financial consequences, of wholly relying on foreign resources for support as contrasted with a national combined effort to build up a technical-scientific capability. Ideally such a national effort should lead towards a capability which is internationally recognized and as such could attract contract support from other countries. It is also clear that military and civil aviation have so much in common that, at least for the smaller nations, the ever-scarce national talent must be accessible to both branches of aviation.

Having carried out a market analysis for aeronautical research, the required expertise, skills and equipment needed can be outlined and viewed against the existing situation.

Starting with the existing situation and the projected need a work plan can be drawn up.

The research plan must fit into the higher national or company goals if they have been formulated. Then it is necessary to identify the required knowledge and experience in the disciplines that have been identified by the market analysis.

A good starting point is to use the AGARD Terms of Reference and Topics Lists for the AGARD Panels, Ref. 5, supplemented by design and manufacturing disciplines. It can be used as an aid to determine which disciplines need reinforcement and what is lacking. It is advantageous to focus on certain areas and rely on purchasing support from abroad in other areas.

Such an exercise should also cover the national need for facilities, short-term and long-term. Many major facilities (wind tunnels, flight test aircraft and equipment, flight simulation equipment, major structural test installations, large scale computer facilities, engine test facilities, lightning test facilities, ditching facilities, etc.) are only required in very special cases and it is therefore economic to rely on such facilities available within the Alliance.

At this point it may be interesting to consider the planning process of a medium-sized (750 personnel) laboratory - NLR, Fig. 5 (from Ref. 6).

The column at the left lists the input for the annual planning process. The first input is the multi-year plan for the financial contribution or subsidies. With several of the major customers (the Air Force, the Civil Aviation Authority, the Agency for Aerospace Development and the industry) the laboratory has established medium-term plans forecasting their plans for up to five years. There is also a long-term plan for the in-house research. Needless to say that during each review cycle adjustments have to be made. The long-term investment plan is not only important for its financial implications but also for the capacity that has to be planned to realise the investment.

The results of the current year, in terms of achievements and use of the financial resources are a determining factor for the planning of the coming year as are the national and international developments affecting aerospace.

Starting from these inputs the Department heads begin to draw up (or adjust) their plans for the coming year. With at least six of the major customers meetings are organized to obtain their view of current and future developments and their projected need of the services of the laboratory.

With this information a work plan for the coming years is drafted by the laboratory staff. Based on this, adjustments are made to the investment plan. This work plan is submitted to the scientific committee (see also Section 9) for review and discussion.

After these steps the laboratory staff drafts the documents listed below for the following year:

- the operating budget (1 year)
- the investment plan (1 year)
- the long-term investment plan (10 years)
- the work plan (1 year) and
  the longer term plan (5 years or more)
- the personnel plan (capacity needed)

The package is then submitted to the Board in which government, including defence, industry and universities participate. After approval, these plans form the basis for the year's activities. It goes without saying that there must be sufficient possibility to deviate from the plans for technical or financial reasons.

This example gives the impression that the planning of aerospace research is a relatively straight-forward process. This is indeed the case during periods where the long-term goals are clear and well defined, which is not always so. On the other hand carrying out this exercise to its full extent every year reduces the chances of sudden discontinuities. It also helps to make users aware of the need for long-term planning of their own needs. It must be noted here that in aerospace the situation at NLR is somewhat unusual in that 70% of the financing is through contracts from users and only 30% of the income is derived from a direct government subsidy for the basic, in-house, research programme.

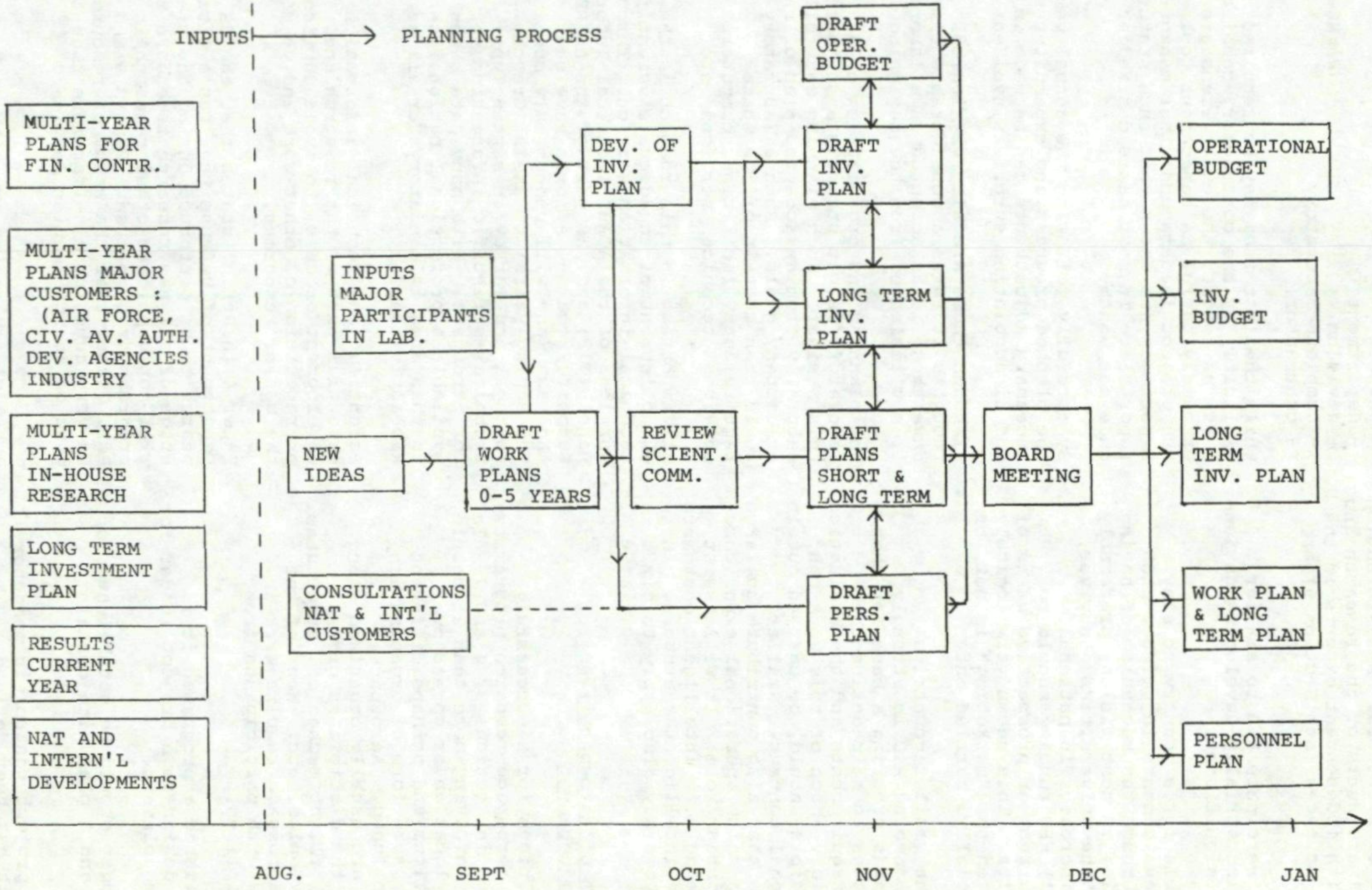

Fig.5 - EXAMPLE OF A LABORATORY PLANNING PROCESS (ADAPTED FROM REF.6)

The planning process becomes more difficult when aeronautical research is carried out by several separate institutions, but it is clear that the necessity of careful planning is then even more important. Simply centralizing the planning in a bureaucratic manner does not guarantee the effective use of resources. An interaction with the ultimate users of the research and a dialogue with independent experts in the aeronautical sciences (see Section 9) are needed.

The value of aerospace R&D to smaller nations and industrially-developing nations can be quite significant.

It is desirable for a country to stay abreast of developments in science and technology through the mechanism of having some activities in most fields, preferably primarily at the universities. However, substantial increases in national (governmental) R&D funding should be related to current or prospective users of the R&D results. This seems very logical but quite often the "marketing" is not, or only superficially, carried out.

In some of the smaller countries government-sponsored R&D is strongly directed towards creating a base for the defence agencies to help define the operational requirements and the evaluation of the materiel. Much of this work can, and when possible should, be carried out in an international context. Smaller countries can then also contribute to large programmes in which operational experience plays an important role. It will assist them in becoming more intelligent customers and also more intelligent operators. In aeronautics this may also apply to civil aviation.

8. Execution of aerospace research programmes, management

Several conditions for a successful execution of aerospace research programmes were mentioned in Sections 3, 4 and 7. In any activity involving more than 20 people, be it at one location or spread over several locations and perhaps different institutions, some form of organization must be established. Aerospace laboratories are usually organized along the lines of the disciplines of aerodynamics, flight mechanics, structures, materials, avionics, etc. Many of the subjects in aerospace require work in project teams with participants from various disciplines.

Having established a programme it is advisable to designate a project leader for each programme element.

Ideally a budget should be established for each project and a plan with certain milestones.

Some form of project control is mandatory once a project has been defined.

Basically, the same accounting system can used in a research laboratory as in industry.

This means that the account must contain:

- direct man hours (project and direct services)
- internal costs
- external costs.

Using a computerized system it is relatively easy to periodically produce a review of the financial status per

- project
- department
- division
- complete laboratory
- contractor.

While the last item may be required explicitly by the contractor, combined with a status report, the other items are extremely useful as management tools for the project leaders and other managers. Experience has shown that such status reports are in most cases desired at least once per month.

By carefully following the actual versus the planned progress and expenditures the necessary adjustments can be made in time and disappointing surprises avoided.

Although these are all very logical thoughts it takes a considerable time to have these ideas accepted in a laboratory if not implanted from the beginning.

The planning and organization of a laboratory is not strictly a subject of this Seminar. Such planning may follow naturally from an accepted plan of national or company goals. Such a laboratory plan would then contain office space requirements, facilities, computer services, technical services, etc.

All important in this respect is the establishment of an adequate scientific and technical information service. Through the services of the AGARD Technical Information Panel (TIP) and, as part of the AGARD Support Progamme, efforts have been made in the past (and will undoubtedly continue in the coming years) to assist Greece, Portugal and Turkey in setting up technical-scientific information services for aerospace. With many data bases now available a professional national service in this area is mandatory for all aerospace R&D activities.

Scientific and technical information is an essential part of the research and development process, to avoid duplication or repetition of other work and to maximise the use of resources.

Paper 4 in Ref. 7 states that the US Department of Defense requires a literature search to be performed during the planning stage of all new research to ensure that it will not duplicate other research in progress or completed. Papers 5 and 6 of Ref. 7 show that the waste of resources can be very substantial - far more than the cost of an information service.

9. Advisory bodies, quality control

For the financiers, the management and the investigators of a laboratory it is very useful to have their programmes, progress and results discussed and judged by independent scientists.

In the Netherlands there is a Scientific Committee, consisting of five members, and five sub-committees covering Aerodynamics, Space Technology, Structures and Materials, Applied Mathematics and Informatics, Flight Mechanics and Applications. The total membership consists of 40 experts from the aerospace community and the universities, selected on the basis of their expertise. Each sub-committee meets two or three times per year to review the proposed programme, to monitor progress and to critically review the publications with the authors present, except for material subject to national or commercial security restrictions. The Committee advises the Board and Management of the NLR laboratory and the Netherlands Agency for Aerospace Development. The Committee also occasionally reviews aerospace research programmes carried out by others and provides advice on aerospace matters in general.

Of a somewhat different nature was the Aeronautical Research Council, ARC, in the UK. The ARC was established in 1909 but had a wider task, in principle, providing advice directly to the government on desirable developments to be undertaken. The ARC also reviewed a great number of scientific publications. For various reasons, mainly since the membership changes over the years had resulted in a less independent body according to Ref. 8, the ARC was closed in 1980. Be that as it may, the discussion in Ref. 9 indicated that there was a desire in the UK to couple university engineering research to that of industry and government establishments. The reference also outlines briefly the arrangements in other countries.

Recently it has been observed that research, development, design and manufacturing in the US are far more compartimentalized than in Japan where these processes are carried out concurrently so that knowledge from one area can readily influence decisions made in other areas, Ref. 10. The Japanese method would thus speed up the transformation of new discoveries into new commercial products.

This is an important observation although it is somewhat doubtful that, for instance, the development of critical wing technology mentioned in Section 6 would have been much accelerated since the validation process was rather lengthy and occured in a period where computational fluid dynamics was only beginning to become useful.

Nevertheless, the point made by Reich in Ref. 10 supports the idea that a well-balanced scientific advisory committee with representatives from the aircraft industry (the producers), the airlines and the Air Force (the users) and the government aviation agency (the supervisors and regulators) and, of course, the universities (the scientific background) is extremely useful for an efficient aeronautical research programme. Of course the members of such a committee must be really prepared to study the research proposals, the intermediate results and the reports and freely comment on them from their professional background and experience.

On their part, the management of the research laboratory must seriously consider the advice obtained from such a committee. Even if the overall opinion of such a committee on the start or continuation of a particular research activity is not positive the management of the laboratory must have the opportunity to continue the research if, in spite of the advice, they are convinced of the ultimate success and usefulness.

A point not to be overlooked is the reporting, at least annually, to the national experts, or scientific advisory committee, of the results, and the analysis with them of the differences compared to the original plans. It is some kind of a scientific accountability.

From the above it is concluded that an independent advisory committee, consisting of technical-scientific experts is desirable to assure a well-coordinated, high-level and effective research programme. The task and the composition of the committee will depend on the local needs and the availability of the experts.

10. Motivation for aerospace in smaller countries

Several smaller countries have managed to develop and maintain an aircraft industry with a full design capability. This is the case in i.a. Sweden, the Netherlands, Israel and now Taiwan. Others, such as Belgium and Switzerland, maintain aircraft industries with limited design capabilities for smaller aircraft and participate in larger international programmes. Countries such as Spain and Brasil, although they cannot be classified as small countries, maintain an in-between position and are quite successful in the design of small transport and training aircraft.

In Ref. 11 Gullstrand argues that although the aerospace business is technically very difficult and risky, and financially very demanding, small countries still may want to have an aerospace industry of their own for one or more of the following reasons :

- Prestige, because of the belief that a domestic aerospace industry is a sign of the standard of the country.

- Independent supply of defence products. Although for a neutral nation like Sweden this may be an argument, in the context of NATO, this argument may not be very important.

- Spin-off effects. Aerospace is often the leader in technology. Knowledge is transferred to other industries through people, through universities, etc.

- Employment. Apart from the fact that a truly domestic aerospace industry creates a certain level of high-technology employment, there are the various means of negotiating compensation in defence and even in civil aerospace purchases.

However, Gullstrand states that in very few cases is a good economic return on investment quoted as the reason for having a domestic aeronautical industry. The

Netherlands and Sweden are an exception, although the return on investment is probably low compared with other industrial branches, mainly since the periods needed to recover investment are so long.

There are, of course, various levels of involvement of an aircraft industry. Starting with maintenance, overhaul of civil and military aircraft, followed by assembly, sub-contracting, co-production or production under license if the series is large enough. The final level of full development and production requires a much broader, and long-term investment and the following quotation from Gullstrand's paper summarizes the situation.

"It is not only a question of sufficient technical knowledge of the products and how to define and develop them. The marketing aspect is also extremely important and so is economic strength. There is a saying that it is impossible to be a competent developing organisation if the organisation has not already achieved at least two successful projects. The necessary experience canot be learned at school, it has to be passed from one generation of engineers to another. It is therefore extremely difficult for a country without a complete aircraft industry to start building one, and this is especially true of the developing countries.

One difficulty which is worth mentioning is to define a new product in such a way that it will be competitive, say 20 years later. This is a typical time period from the start of a programme to full utilisation of the aircraft by operators.

A group of highly skilled people with vision and reliable knowledge of what is going to happen in the future has to work with project and market analysis for many years. Their knowledge has to be based on scientific research and worldwide information. We are now talking of really long-term planning. It takes decades to build up the general level of knowledge and the industrial infrastructure required."

In spite of this statement there are at least two notable exceptions in recent years, namely Taiwan which has, for defence reasons, decided to develop their own fighter, albeit with much assistance from foreign companies, and Indonesia.

In the latter case we are dealing with a very large developing nation with a "controlled" market and a government that is very determined to support this industrial development (see also Section 11). Strong personal motivation often plays an important role. Prof. H.J. van der Maas, heading the aeronautical engineering education, research and development activities in the Netherlands during the post-World War 2 period, was quoted*) as having answered "No" to the question: "Can we as a small nation afford to be without our aircraft industry?" And to the question: "Do you see it as a hazardous project?" he is reported to have answered: "The whole of Holland is a hazardous project". This humourous remark contrasts with the long and serious preparations preceeding the launching of the Fokker F27 in 1951, the F28 in 1961 and the Fokker 50 and Fokker 100 in 1983 but it illustrates that some risk has to be accepted.

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*) Quotation from Prof. J. Singer, President Technion, Israel, while lecturing in Delft, October 1983.

Governments of many nations <u>support R & D for defence purposes</u> for different reasons. Some of the arguments for a strong defence R & D are:

- national independence;
- stimulation of the industry to export defence systems;
- increased preparedness for purchases on the international market;
- stimulation of the industry in general, defence and civil;
- satisfaction of the ambitions of industry, groups or individual;
- perhaps most important of all, the sheer economic necessity of participation in the research, development and finally production.

Particularly the latter argument can be very important, <u>if</u> participation in R&D activities holds the key to production sharing. Richer nations and nations with a large positive balance of trade can better afford to buy complete systems rather than to invest in uncertain R&D efforts.

The opinion that support of R&D for defence also stimulates the civilian industry is not shared universally. In some of the papers given at a Defence Economics Workshop, Ref. 12, representatives of some countries expressed the opinion that expenditures on defence are poor instruments for improving international competiveness. It was however recognized that in aerospace, in certain aircraft technologies and certainly in aircraft engine development dual use of technology takes place.

These statements are contrasted by the opinion of Staal, Ref. 13, who after a life long career at HSA, Signaal, particularly in the area of radar, stated that the defence requirements for its materiel are an important stimulus for the development of a high technology industry. There is not only a direct spin-off, but also an indirect one. Defence requirements force the industry to produce high quality products. That re-inforces its position in the civil market place.

This example of an industry developing products based on radar certainly proves that civilian products (air traffic control, harbour wall radar, etc.) are sometimes a direct application of military developments (navy radar, systems for gun and missile control).

Cyert and Movery, Ref. 14, note that the funding for civilian research and development in the US has in recent years represented a smaller share of national economic output than in West Germany or Japan. The US however, spends more money on military R&D than the other two countries. Although the technological "spillover" from military R&D did assist the early development of the civilian semi-conductor, jet engine and computer industry. These authors argue that it <u>now</u> has a less important role in stimulating industry than in the past.

Some of the above statements may be true for investments in the defence industry in general but they do not necessarily apply to the aeronautical part of the defence industry and as illustrated in Sections 5 and 6, the more basic research has civil and military applications and that is the research which usually is funded from government sources.

Also, the conclusions to be drawn from these experiences are not the same for all countries. There is, for instance, a substantial difference between countries such as the UK and Germany on the one hand and Greece, Portugal and Turkey on the other hand. While countries in the first group have a well-established infrastructure of engineering research, in the second group any contribution to such a research structure, be it from defence or civil sources, is useful for the industrial development of the country if the subjects are well chosen, the goals are achievable with the resources and manpower available and sufficient continuity can be expected.

11. Aerospace and research in industrially developing countries

Having discussed the nature and role of aerospace research for the design, development and operation of aircraft and the way it is organised and planned in industrially developed countries, the question arises as to how industrially developing countries can benefit from that experience.

This Seminar is specifically planned for Greece, Portugal and Turkey. In early 1989 a review of the AGARD Support programme was carried out by the AGARD Staff, Ref. 15. The programme is concerned with assisting aeronautical research engineers and scientists in these three countries by organising advice from an individual or organisation of a supporting nation in a specialised area. A maximum transfer of know-how and assistance is given with a limited number of contacts. In several cases joint research projects are carried out. Since the review report is not generally available it is practical to note here some of the remarks and conclusions made in that report, mixed with further observations.

There are considerable differences between Greece, Portugal and Turkey in history, culture, educational traditions, population, etc. It is therefore to be expected that the national aeronautical goals, as they are being developed, will not be the same. During the Seminar the discussions will focus on the specific national situation.

A common aspect of the three countries is that major efforts started recently (in the last 10 years) to build or rebuild an aeronautical activity (research, development, production). With the time scale involved in such a process, perhaps ten to twenty years, as indicated in the previous sections, a further discussion of this subject is still very timely.

In all three countries several thousands of people are directly involved in maintenance, repair, and fabrication of parts or the assembly of aircraft. They all have air forces and civil airline operators. The educational facilities specifically related to aerospace are different, probably because of differences in the educational systems and their history.

Truly national aerospace research establishments serving all of the aeronautical activities do not (yet) exist in Greece, Portugal and Turkey. Undoubtedly a point of debate is whether or not such institutions should be built up or whether a more dispersed research and development effort is desired, considering the national circumstances. In any case, the need for national coordination in aerospace and related subjects will become more of a necessity in the 1990's. Even if the military demands do not increase then civilian aeronautical development will certainly dictate some close coordination of the available talent.

Aerospace is one of the few spearhead activities in engineering which can assist materially in upgrading the national technical-scientific capability. Examples of elements of the engineering sciences which are greatly stimulated by aerospace research are:

- material sciences (high strength steel, advanced aluminium alloys, composite materials, etc.)
- applied mechanics (finite element analysis, dynamics, fracture mechanics, load analysis, fatigue, etc.)
- fluid dynamics (stimulation of applied mathematics, computational fluid dynamics, advanced measurement techniques, etc.)
- flight mechanics (control theory, handling qualities, human engineering, ergonomics, etc.)
- avionics (instrumentation, communication, navigation, surveillance, etc.)
- propulsion (combustion, energy management, etc.)
- systems engineering, project management.

These disciplines, developed and maintained for specific aeronautical goals can, through people, via universities, laboratories and industry, become national assets.

The annual defence expenditure in the three countries is considerable. Most of the more sophisticated systems are bought from other NATO countries. In many cases elaborate compensation and off-set agreements have to be negotiated. These off-set agreements are often not only for gaining additional employment opportunities but, in general, they are a sheer necessity to meet trade balance requirements. Co-production or where possible co-development can have long-lasting positive effects on the economy. However participation in high-technology development programmes requires a strong commitment of government and industry to engage in long-term investments as is clear from this Seminar. On the positive side the long-term benefits can be very substantial in terms of education, the upgrading of the industry, quality control, etc.

Similar arguments, but under quite different circumstances, led to the Indonesian aircraft development activities. In Ref. 16, a keynote address at a Symposium, held ten years after the initiation of an aircraft industry in Indonesia, the Minister gave a rationale for investing in aeronautics. That country is large in size (larger than North America) and population (180 million) and consists of well over 13,000 islands. It is clear that there is an important aeronautical market. The market in Indonesia is domestically "controlled". There is clearly a limit to the production of gas and oil and to the agricultural output. The standard of living and employment can be increased by developing the industrial sector. Because of the large internal aeronautical market, there is the opportunity to develop an aircraft industry. This was done by a "progressive" manufacturing process. Starting with the assembly of a small transport aircraft, the CASA-212 in Indonesia, gradually parts of the airframe were manufactured at the ITPN plant in Bandung until, at the end of the ten-year period practically all of the airframe was manufactured in Indonesia.

A similar process was started with the BO-105 helicopter, followed by the Aerospatiale Super Puma.

The next step was participation in design of the CN-235, together with CASA, in which the production of components between the two companies, CASA and IPTN, is shared.

Other projects are following and ITPN is now studying their own design, albeit with the assistance of others. The major point is that in a period of ten years it has been possible to build up an aircraft industry, including the start of a design capability, with the assistance of others, but with a large internal market potential. Also a structures and materials laboratory, an Aerodynamics Laboratory and a Flight Test facility were started with the assistance of institutions in Germany and the Netherlands. On the educational side aeronautical engineering at the technical university is being upgraded with assistance from the same countries.

The circumstances in Indonesia are far more difficult than in Greece, Portugal and Turkey, mostly because the economic infrastructure is less developed.

Nevertheless, it is felt that in the long run an industry like IPTN will have a very beneficial effect on the economic development of the country. Obviously, the national need to operate aircraft internally is a major factor. But if there is a national need there are opportunities to develop one's own capabilities.

One observation with respect to Indonesia is that to some extent the reverse order of the R&D cycle is being followed. After having gone through the phase of assembly and progressive manufacture of more airframe parts, the Indonesian industry started to participate in the design of an aircraft, the CN 235, with CASA. At that time there was certainly not a broad R & D base in Indonesia to draw from. CASA, on the other hand, had the experience of developing, designing, manufacturing and marketing the C-212 and other aircraft. Indonesian aeronautics moves ahead in leaps and bounds it seems, filling in the gaps as they occur.

It is difficult to draw a general conclusion as to the best path to arrive at the desired aerospace capability. Obviously, much depends on the available talent, the political will and the drive of the people concerned together with the ability and willingness to invest in the future.

12. The role of the AGARD Support Programme and NATO-CAPS

CAPS (Conventional Armament Planning System), is a recent NATO initiative to be used by the CNAD, the Conference of National Armament Directors. Nations are invited to state their requirements for defence systems in the short, medium and long term. At NATO Headquarters these requirements are collected and edited into a volume organised by function.

After a trial period, 1987-1989, CAPS is being launched as a full plan starting 1990. It is intended to review the CAPS volumes every two years.

It is to be noted that the military requirements of the Alliance are expressed in the context of force planning in the form of Force Goals. CAPS however lists the armament goals issued by each nation, so not on an international basis. This allows all nations, including France, to participate in CAPS.

The importance of CAPS to AGARD is that the volumes will list the nations' intentions to develop systems autonomously, to develop them in cooperation with partners, or to buy systems from abroad.

The NATO International Staff will analyse the national requirements and suggest possible cooperation when the requirements appear to be similar.

Since CAPS is concerned with long- term planning it will stimulate international cooperation in research and development at an early stage.

Special provisions are being made for Greece, Portugal and Turkey to participate in joint research and development stages, before actual commitments on participation in production and purchases are made, on a case-by-case basis.

The CAPS documents are confidential and available to the national authorities. This is not the place to discuss the use of CAPS but it should be noted here that in principle it will give the nations with developing defence industries in NATO a chance to become involved in the early stages of research and development, even though the ground work for this may have been laid in other nations.

The AGARD Support programme is intended to help strengthen the research base in Greece, Portugal and Turkey. The effectiveness of this programme would increase if the subjects chosen were, at least in some cases, related to the long-term requirements and, in particular, those for which there are opportunities to cooperate in the R&D phase with other NATO nations.

Appendix

Laboratory Management - checklist

Overall Management

Organization
Periodic meetings
Lines of reporting
Decision levels
Instructions
Operational procedures
Planning procedures

Personnel

Selection procedure, hiring procedures
Performance, merit review
Grading, classification
Manpower development and training
Management development
External courses and in-house training
Personnel files, statistics
Rules and regulations related to the facilities

Administration

Operations budget
Investment budget
Book keeping system
Cost calculation, direct and indirect
Cost registration
Contract administration
Project administration
Billing
Purchasing
Property registration
Stores, supplies control
Project management, files
Management information system
Correspondence, central files
Travel, allowances

Reporting

Reporting of activities
Financial reporting
Reporting per project, contract
Publications

Acquisition, Public Relations

Market analysis
Development of external relations
Publications
Coupling to long-range planning

Services Required

Maintenance
Cleaning
Security
Communications (telephone, telex, telefax, etc.)
Mail distribution
Typing, illustrations
Printing
Photocopy, film
Library, documentation
Computing services
Instrumentation services
Design office
Machine shop
Canteen services
Transportation

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Determining Technology Objectives

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Summary

Scientific research continues to offer an ever increasing number of technological possibilities capable of exploitation. Governments and Industrial concerns alike have to make decisions on which technologies to support. When broad defence needs or market objectives have been determined the study method, developed by AGARD and its Aerospace Applications Studies Committee, provides an effective means of focusing technology objectives. The application of the study method to Project 2000, a broad technology forecast undertaken for the NATO Military Committee is described. Guidance is provided on how to set up similar studies.

1. Introduction

Determining the right technologies to develop for the future is a matter of vital concern for Government and Industrial concerns alike. Over the last 50 years basic science has continued to offer an ever increasing number of technological possibilities which may be capable of exploitation. Some developments such as the silicon chip have gone on to revolutionise the world with its myriad application in digital processing. In some applications, such as Concorde, the technical innovation and development has been enormously successful but the market response was far smaller than the original proposers had imagined. In other cases such as civil VTOL airliners, nuclear power plants for merchant shipping and electro-magnetic levitation for railway trains, the original aspirations have been proved to be completely erroneous. Investment in technology is always expensive and is only worthwhile if it leads to exploitation - in the defence field by producing superior and cost effective systems and in the commercial world by producing products that are market leaders giving a major economic return for the original investment. Getting the right technology decisions requires more than enthusiasm on the part of the scientists and technologists putting forward their proposals. These proposals have to be assessed against a market need and cost effective product application. This paper will describe how AGARD has developed an approach to this technology decision making which is capable of wide application.

2. Project 2000

Back in 1975 AGARD was asked by the NATO Military Committee to describe hypothetically "with relation to the most probable technological trends/developments the state-of-the-art in the year 2000 and the conceivable military applications in terms of systems". The study was to be confined to aerospace applications. From 1975 to March 1977 Phase 1 of Project 2000 was carried out. This involved the AGARD Panels in completing, each in their particular discipline, technology forecasts of what might be available by the year 2000. Almost inevitably the list of technological possibilities was those technologies which were likely to be most valuable to the NATO Military Committee. To identify priority mission areas for study a user input was necessary and NATO convened an Ad Hoc Group of military experts. The military experts foresaw a need for technological advance to meet the threat, in the following areas:-

- Anti-Missile Systems
  - 0 Active air defence on land
  - 0 Self-defence of maritime areas
  - 0 Active air defence at sea
  - 0 Self-defence of strategic airlift
  - 0 Self-defence of tactical airlift

- Standoff Weapons
  - 0 Air Attack on fixed targets beyond the Forward edge of the battle area (FEBA)
  - 0 Air attack on mobile targets beyond the FEBA
  - 0 Air attack on targets at or near the FEBA
  - 0 Air attack on submarines
  - 0 Air attack on surface vessels

- Satellite target pinpointing
- Combined air-to-air and air-to-ground missile
- Ballistic missile with terminal guidance
- Cruise missile with KE warhead
- V/STOL
- Unmanned Aircraft
- Replacement and hardening of satellites
- Satellite attach system
- Future air base layouts
- Air base resilience
- NBC developments
- Command, Control and Communications

It was clearly an enormous task to tackle each of these problems independently, therefore the study effort was organised under three main topics derived from the previous list. These were:

- Attack of surface targets
- Defence against missiles
- Detection, location and recognition of ground targets

Taken together, these three areas were considered to cover the most important problems of tactical warfare directly or indirectly. The main work of Project 2000 was then undertaken by three Multi-National Study Groups following the study format that had earlier been developed successfully by the AGARD Aerospace Applications Study Committee.

A Project 2000 Review Board was established bringing together members of the Aerospace Applications Study Committee and members of the Ad Hoc Military Group who had determined the user needs. This Review Board first established the Terms of Reference for the studies. A typical set of Terms of Reference for the Study on "Detection, location and recognition of ground targets" is given below. for the Study on "Detection, location and recognition of ground targets", is given below.

Title of the Study

Project 2000 - "Detection, Location and Recognition of Ground Targets".

Description

Evaluation of the fundamental technological developments in aerospace up to the Year 2000 for ground target detection, location and recognition and their impact on possible military applications. The study should correlate appropriate existing technological forecasts with the military task of detection, location and recognition in order to arrive at an imaginative assessment of how prospective technological advances and potential operational military needs can be matched. The intended time frame is sufficiently in the future so that consideration should not be limited by current plans and policies.

Background

Phase 1 of P-2000 has provided a compendium of aerospace technology forecasts which, though not complete, provides a technology input for this effort. Subsequently, an initial, and again not necessarily complete, military input outlining priority future military tasks was provided which considered the available technology forecasts. These two reports, the Phase 1 study report and the initial military input, represents the first steps in an iterative dialogue between the military and the technologists of which the study on detection, location and recognition is a continuation.

Objective

To determine the most efficient means of target detection, location and recognition in the Year 2000 and to identify appropriate R & D avenues to pursue.

Scope

The study will examine all possible concepts for detecting, locating and recognising theatre ground targets, and targets on or near the forward edge of the battle area both mobile and fixed.

The study will:

(a) Identify the full set of parameters that define the relevant characteristics of ground targets and their defences.

(b) Suggest concepts appropriate for target detection, location and recognition for both the reconnaissance missions and also for target acquisition, battle management and for battle execution.

(c) List and project the relevant technology to support these concepts.

(d) Carry out a value analysis of these concepts against potential targets and their defences.

(e) Recommend areas of technology to be pursued.

(f) Concentrate on sensors and conceptual systems for data handling and transmission as opposed to developing vehicle design.

(g) Do not consider the command and control problem except as far as it interfaces proposed systems.

(h) Note those technologies which may be applicable to maritime, anti submarine warfare and airborne targets.

A Director for each Study Group was appointed together with a team of twenty or so members. The Study Group worked independently of the Review Board, but was required by the Review Board to give a day long briefing to them at the mid point of the study period, which in this case was after 6 months, and again at the completion of the study. The Study Group held nine one week meetings in the 16 months that the study lasted. Much work was undertaken by individual study members working at their home bases. The written report of the Study Group was edited by selected members of the Review Board acting on behalf of the Board as a whole.

The reports of the Project 2000 were greatly welcomed by the NATO Military Committee and AGARD took some pride in the fact that subsequently other NATO agencies have undertaken long term study work of a similar nature.

3. Other Applications

This type of two tier study work can be widely applied to other technology forecasting needs. AGARD 'Aerospace Applications Studies Committee' has now completed 30 studies of this type. Within British Aerospace we recently undertook a study " Air Transport 2010" using the same basic format. The Terms of Reference were:-

- Predict how the pattern of civil aviation will develop as a result of the probable change in the economic pattern worldwide.
- Develop outline aircraft specifications to serve the needs of the developing civil aviation field.
- Consider the technology that might be available in the timescale to be applied when meeting the outline specifications. The technology should embrace not only the traditional areas of aerodynamics, structures and systems but also manufacturing technology.
- Produce outline project aircraft to meet the specifications established.
- Determine the areas of technology in which we should be investing to meet the needs of the project aircraft.

The Study Group of about 20 was drawn from various functions within the Civil Aircraft Division, including the Marketing Department representing the user. The group was made up of people from different operating sites so that they were removed from their normal management line of authority and acted as a group. The group met when it could and it was not a full time task.

The reviews at mid term and at the end of the study were undertaken by the Directors of the Division, who had approved the original Terms of Reference.

The study report has been extremely valuable to the Company in determining the technologies of highest value in the commercial aircraft business, and as a result in shaping the priority research targets.

Two real but less tangible benefits have been that the young engineers from different sites who were involved in the study have established links which would otherwise not have existed, and the demonstration that the Company is considering its long-term future as well as its near term products and problems.

4. Study Methodology

All the studies take a similar general form, which is set out in the Terms of Reference. The sequence is:-

Market Need/User Problem

Possible Technologies

Conceptual solutions

Cost effectiveness analysis

Best solutions

Best technologies

It must be stressed that they start with a market need or a user problem. This is the study objective, set by "authority" before the study is set up. The study is about "problems looking for solutions" it is not about "solutions looking for problems". In the two examples quoted the problems have been broad. In Project 2000 the NATO Military Committee asked AGARD to question "How do we best counter the threat to NATO in the year 2000". In Air Transport 2010 the Company asked the question "How do we best meet the needs of the civil aircraft market in 2010". The study group may have to identify in more detail the "threat" or the "market", but the broad study objective is given.

The next stage of the study is creative. As wide as possible a range of alternative conceptual solutions or projects based on possible technologies should be thought up in an environment of unfettered lateral thinking. The activity should generally follow the principles defined by Osborn (Ref 1) as brainstorming. Brainstorming is a problem solving activity undertaken by a multi-disciplinary group. The group meet specifically to generate ideas aimed at solving the stated problems. They work within a framework of rules:

- criticism is banned;
- quantity of ideas is more important than quality;
- credit is shared by the group.

The principle of brainstorming is that the thought association process will be more effective in terms of generating original ideas when it is free to operate between individuals with differing backgrounds. The rules are intended to foster a creative climate.

With the range of alternative solutions identified the next critical task is decision making to determine the most cost-effective solutions. In some studies it is possible to make cost effectiveness analysis against some already established criterias. In Air Transport 2010 the direct operating costs of alternative project solutions could be assessed to give a value ranking. In Project 2000 one study group used the Delphi method of pairs comparison (Ref.2.) but the other groups used a simple value judgement matrix. A typical value judgement matrix is:

Tasks/Required Characteristics

		a	b	c	d	e	Total
	A	0	2	2	3	0	7
Conceptual	B	3	2	5	5	3	18
Solutions	C	5	0	0	2	0	7
	D	4	3	5	4	3	19
	E	1	3	2	1	3	10

Each member of the group fills in the matrix on a scale of 0 to 5 for effectiveness and the total for each solution is added up. It has been surprising how similar the scoring has been from different group members, and how readily the most cost effective solutions emerge. If major disagreements are found the reason for this can be debated by the group and hopefully resolved.

From this analysis best solutions are determined and their associated technologies listed for priority attention.

5. The Role Players

There are two separate groups of people involved in each study, the Review Board and the Study Group. Each group has a specific role to play, and the interaction between the groups is an important part in the study concept.

The Review Board

The role of the Review Board is authoritarian. They are responsible for the successful execution of the study, but not for the study work itself. The Review Board may be given the broad Market Need/User Problem by some higher authority, such as the NATO Military Committee in the case of Project 2000, or they may themselves be calling for the study as in the British Aerospace case. The Review Board is responsible for setting out the Terms of Reference along the lines given in the previous section. The Terms of Reference should also set out any limitations on the scope of the study and the timeframe for the solutions. They are responsible for ensuring the right calibre of people are made available for the Study Group, and that the group has the right mix of users, technical specialists and system or project designers. One member of the Study Group is to be appointed as Study Director. He should attend the Review Board meeting at which the Terms of Reference are finalised to make sure he is clear about what the Review Board are seeking. The Review Board must then leave the Director and the Study Group members to undertake the study without interference.

At mid-term of the study programme the Review Board should be briefed by the Study Group on the progress being made, and should be free to make critical comment on the briefing received. This is perhaps the most important part of the study process. It provides authoritarian comment at a time when the study group can still modify its work, or at least give considerations to the points made by the Review Board. At the end of the mid-term review the Chairman of the Review Board should provide guidance to the Study Group.

The final review by the Review Board is in reality the presentation of the completed study. Only in an exceptional case should the Review Board reject a major part of the study. After the final review one or two members of the Review Board should be asked to edit and approve the final report presented by the Study Group.

The Review Board should be about eight in number. They should be senior people with very wide experience. If possible they should be drawn from different backgrounds or organisations to bring together a wide range of views.

Osborn in 1953 stated the "Our thinking mind is mainly twofold a) a judicial mind which analyses, compares and chooses, and b) a creative mind which visualises, foresees and generates ideas". The argument he develops is that while everyone throughout everyday life has to exercise judgement and decision making, the opportunities for creativity tend to dwindle as we grow older. So unless a conscious effort is maintained to sustain and stimulate creative facilities, they tend to atrophy as we age while our initial analytical facilities continue to develop with us.

It follows that while senior people are readily able to undertake the judgmental role of the Review Board, the Study Group which has a major creative role to play, must include younger creative minds able to visualise a wide range of conceptual solutions.

The Study Group

The Study Group are the key players. They have to be creative, able to construct conceptual solutions to the problem posed. They must operate in an environment that encourages creative thinking. Other than the Study Director, who has to be their leader, they are a group of equals, able to undertake the type of brainstorming activity described above. Alternatives are essential to this type of study. Without them no assessment of a best solution is possible. Creativity is inhibited by early criticism by preconceptions and prejudice, and by timidity. The study group must develop its ideas as a group away from early criticism. It must be made up of people who are not prejudicial and have a certain courage.

Only when the creative phase has been exhausted should the Study Group move on to the cost-effectiveness or value judgement type of decision making along the lines described above.

A typical Study Group should be about twenty people, if possible drawn from different organisations with different but relevant backgrounds - users, technical specialists and system designers. If possible bring into the group some of the younger people who show promise, even if they are relatively junior. They will benefit, and so will the study.

In both AGARD and in Company studies, the Study Group has not been a full time activity. The group has met for short periods while members continue with their normal jobs. This has the great advantage of enabling really high calibre people to take part, people who could never be spared full time. Experience has shown that study groups soon establish a group identity, which becomes particularly strong when faced with the adversarial environment of a mid-term review. It cannot be stressed too strongly that the group must be free from interference or outside 'direction' during the study. The Review Board is their only master, and the mid-term and final reviews are the only time the Study Group is challenged. The group members are there as individuals, not representing their parent organisations, or their bosses. Only with this freedom is a study of real value achievable.

Conclusions

The study method developed by AGARD is one that helps solve problems. It does not identify the broad problems or market areas that Governments and Industries should be concerned about. What it does is enable the creative minds of young engineers and scientists to be brought to bear on problems that need investigation. By presenting these ideas for review by senior members of the technical community, their wisdom and experience are also fed into the study. In this way technologies can be identified which are likely to have most impact on future products and systems, and hence the greatest economic return.

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AERONAUTICAL COMPONENT RESEARCH

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Summary

The development of NACA to the present NASA is discussed. Details of the research planning process are reviewed. The planning and execution of a major research program, the Aircraft Energy Efficiency program, is reviewed and the various degrees of success are discussed. New areas of emphasis in component research include the use of computational analysis techniques on a broad range of topics and the continued emphasis on the environmental impact of aircraft operations.

The historical role of NACA and NASA in aeronautics from the beginning in 1915 up to today has been and continues to be in component research. In aeronautics NASA does not apply technology to development or operation of its own systems as it does in space. Its only mission is to conduct research and develop technology for use by others.

NACA/NASA aeronautical research is generally viewed as quite successful. Some reasons for its success were the favorable work environment created by management and the quality and flexibility of its research staff.

Historical Background and Some Observations on Management

The NACA was the National Advisory Committee for Aeronautics. The NACA was, indeed, managed by a committee made up of representatives of industry, academia and military services. There was a small headquarters staff based in Washington, D.C. The staff was organized along disciplinary lines and were referred to as sub-committee secretaries. Thus, there was a sub-committee secretary for propulsion, another for fuels and combustion and so on. These "secretaries" were responsible for all administrative aspects of supporting the committee members. These were typically career personnel, formerly researchers, but now "bureaucrats" in the best sense of the word. The "secretaries" had no authority over the research program. They did, however, assume the administrative burden of supporting the committee members and insulated the staffs of the research centers from the demands of the Congress, the Office of Management and Budget (formerly the Bureau of the Budget) and other parts of the government.

Top level of management was the committee of eminent aviation authorities. The chairman and the committee were responsible for setting a policy direction and general program oversight. Detailed plans and responsibility for the day-to-day execution of policy and plans were the responsibility of the research center directors and their staffs. The directors of the research centers emerged as powerful figures and have remained so for seventy-five years up to the present day.

For the first twenty-five years of its existence, the Langley Research Center was the only NACA center. It was conveniently close to Washington but far enough removed geographically to make frequent oversight of management details of the research program unlikely. Being the only research facility it was necessary to perform research in all disciplines associated with aeronautics. There were essentially no research contracts or grants. All research was done in-house. NACA Langley enjoyed an outstanding reputation in the international aviation community.

As American involvement in World War II became more likely, there was a move to expand the research activity of NACA. Two major centers became operational in the early 1940's. The Ames Research Center was established on a Navy base, Moffett Field, near San Francisco, California. It has an excellent complement of aerodynamic research facilities.

One of the principal reasons for locating the new Ames Center on the west coast of the U.S. was the concern that the Langley Research Center might be subject to bombardment by unfriendly forces during World War II. West coast installations were judged to be substantially less vulnerable. This decision on the placement of the new center has caused much study and debate. Critics say that the U.S. needs only one aerodynamic research center and hence all or part of either Ames or Langley should be shut down. Persons more familiar with capabilities of the Langley and Ames facilities see the mothballing of any significant part of these facilities as a major mistake. So far those concerned with the preservation of the Ames and Langley capabilities have prevailed and currently that issue has subsided in importance and rancor. Furthermore, the early and aggressive thrust into computational fluid mechanics by the Ames researchers in this area has brought widespread recognition of the value of the overall program at Ames.

The other NACA research center that became operational in the early 1940's was the Lewis Research Center. Its primary focus was on all aspects of propulsion. It was located in Cleveland, Ohio, where plentiful electric power for large-scale test facilities and a skilled work force were available. Facilities included not only component research rigs but also major wind tunnels for the study of subsonic, transonic and supersonic propulsion-airframe interactions. Initially the center focused on reciprocating engines and was criticized later for being slow to contribute to the development of the jet engine. The Lewis effort in the area was out-paced by the Whittle engine in Britain and by the von Ohain thrust in Germany. None the less, Lewis started making major contributions in the late 40's. In the early 50's work on compressor aerodynamics resulted in the development of the multi-stage transonic compressor. This technology had such high payoff in reducing the number of stages while maintaining high efficiency that it was incorporated in the design of new engine models very quickly. The thrust to increase stage loading without loss of efficiency remains as a prime objective today.

The preceding discussion points out the utility of a politically adept headquarters staff that insulates the research staff from the political vagaries of Washington. The same philosophy of operation has been in place through-out the history of NACA and NASA.

Research Planning

An underlying need in any program is for a plan that knits together various activities and results in a whole that is greater than the sum of the parts. Bear in mind that research done on a topic that is of little or no interest is useless no matter how well the work is performed. Mentioning planning or worse still, strategic planning, makes many researchers recoil in horror. However, a plan with realistic, appropriate objectives that are well understood by all concerned can be of immense help in guiding allocation of resources. Realistic assessments of project costs and other resource requirements at the beginning of a project can result in a more effective use of researchers' time rather than repeatedly justifying new estimates of apparently spiraling project costs.

In NASA's strategic planning process the draft plan is formulated by managers in headquarters in concert with mid- to upper-level research managers in the centers. This draft plan is reviewed with various groups from the NASA advisory committees, from the National Research Council and from the military services. After input from these groups is received a revised plan is drafted for review by the NASA Administrator and his immediate staff. His review is not only for program content but also for program budget. When all issues have been resolved, the plan becomes part of the total NASA plan submitted to the President through the Office of Management and Budget. Ultimately the plan is submitted to the Congress for legislative action.

Relations with the Military Services

In the period just after World War II the United States Air Force moved to a position of self-sufficiency in aeronautical research and development. This was true from total systems down to research activities. Facilities were built up by the USAF and a strong aeronautical program has long been established. The Navy has backed away from its early research efforts. The apparent policy of the Navy is to develop only those aspects which are unique to Navy requirements. For work that is generic to aeronautics the Navy has deferred to the Air Force.

About fifteen years ago the Army initiated a move to build up an in-house capability. However, budget restraints were such that the Army chose instead to form a partnership with NASA. The Army has assigned personnel to be collocated at NASA aero research Centers. These Army personnel work side-by-side with NASA employees in areas of mutual interest. The Army is greatly concerned with rotor dynamics for example. However, NASA efforts to reduce the cabin noise of helicopters is of little interest to the Army. So the Army might participate in planning the program and assign personnel to work on rotor dynamics but would not actively engage in methods of sound reduction to make a more benign cabin interior.

The military services differ widely in their relationship to NASA. However, it is necessary for NASA to have close relations with all three services in order to assure that agreed upon roles are maintained and that the research programs of NASA and the services are not duplicative. The organization with oversight responsibility to assure proper roles and non-duplicative programs is the Aeronautics and Astronautics Coordinating Board (AACB). Only rather serious disagreements make their way to the top of the AACB. The real program issues are dealt with effectively by the Aeronautics Committee of the AACB. This committee is made up of a highly competent cadre of very experienced middle managers who typically have been involved in the AACB for some years.

In summary the relations with the military services and the mechanisms for maintaining them appear to be well-established and working well.

Program Formulation and Advocacy

Over the last fifteen years the Aircraft Energy Efficiency Program (ACEE) has been the most important program in aeronautical technology in NASA. It is interesting to examine in some detail the evolution and execution of a major NASA aeronautical program.

The Aircraft Energy Efficiency Program is an interesting example of the confluence of forces - political, economic and technological-that converge to result in major program approval and support. There is a very large potential for fuel conservation in civil transport aircraft. The estimates of fuel saved by more efficient operations and technology exploitation are enormous. The economic justification for the program based on improving fuel efficiency was very strong and the U.S. Congress was eager to do something about the vulnerability of the U.S. petroleum supply. The technologies were ready for increased research investment. The legs of the three-legged stool of political, economic and technological support were all in place. In late 1975 Congress funded the program and continued to do so through-out the planned ten-year life of the program.

The program consisted of six major sub-programs as listed on the slide:

- Engine Component Improvement/
  Performance Degradation
- Energy Efficient Engine
- Advanced Turboprop
- Composite Structures
- Energy Efficient Transport
- Laminar Flow Control

These six sub-programs were advocated as a coordinated, unified program and were the output of a NASA team that worked intensely on the program definition and advocacy for six months. The interest and support of the U.S. Congress was the political underpinning of the program. However, the support of the U.S. aviation industry was very significant also.

An analysis performed in 1975 of the potential savings by the incorporation of these technologies revealed the enormous demand for jet transport aircraft that would begin to occur in about 1985. This estimate proved to be qualitatively correct. The surge in orders for new transport aircraft was unprecedented. The technology generated by the Aircraft Energy Efficiency Program played a significant role in positioning the large transport aircraft industry for a fully competitive position in the world transport aircraft market. The successful advocacy of this program resulted in approximately 500 million dollars being added to the NASA aeronautics program over a period of 10 years representing about a 35% increase in aero nautical program funding each year for almost 10 years. Furthermore this build up of funding was new money not money reprogrammed from another part of the NASA Aero budget.

The NASA Aircraft Energy Efficiency (ACEE) program provides some good examples of focused technology development and technology validation effort. It also illustrates the high cost of such activity and the uncertainty associated with return on such investments.

The ACEE program with six sub-programs was initiated in 1975, following the OPEC oil embargo and the resulting fuel price increases. It soon became apparent that fuel saving was only one of the potential benefits of improving aircraft and engine efficiency, and that the new technologies could be of great competitive importance. In most of the ACEE technical areas the NASA programs triggered independent corporate investments over and above the contract cost-sharing provisions. In some instances, as the effort progressed and applications became more apparent, the industry expenditures greatly exceeded the NASA funding.

The Engine Component Improvement (ECI) program was the only one of the six programs aimed at near-term product improvement. Its objective was component technology for improved performance, and performance retention, both in retrofits of existing engines and in new production. Because of the likelihood of near-term applications, the ECI contracts contained recoupment provisions calling for a 1 percent return to the government on the sale of engines and parts derived from ECI-funded research, up to the $24 million NASA investment.

Engine and aircraft manufacturers and airline operators suggested more than 150 potential engine component improvements. On the basis of technical and economic assessment, 16 were selected for technology development. They included subjects such as fan blade improvement, turbine aerodynamics, blade cooling, seals, and active clearance control. Results of the program began appearing in engines starting in 1978 and have by now been incorporated in later versions of the P&W JT8D and JT9D engines and the GE CF6-50 engine, providing efficiency increases on the order of 6 percent. It is now estimated that the combined improvements will result in saving more that 5 billion gallons of fuel over the lives of the improved engines. Thus far, the government has received almost $10 million through the recoupment provision.

The Energy Efficient Engine (E^3) program was directed at the longer-term development of technology for a new generation of fuel-conservative turbofan engines for future commercial transports. The program, completed in 1983, was the costliest of the ACEE programs ($185 million). It also inspired the largest corporate investment, and has resulted in the most visible return in the form of commercial application and development.

The E^3 technologies included a number of compressor, fan, and turbine gas-path improvements, improved blading and clearance control, and structural advances, all directed at a significant increase in overall efficiency. A goal of 12 percent improvement in cruise specific fuel consumption relative to then existing engines was established, and the results in fact made possible a 15 percent reduction.

Although many of the advances were already being pursued in ongoing NASA and industry research efforts, the NASA focus and the associated increase in industry funding permitted the design, fabrication, and test validation of large-scale experimental engines, and are generally believed to have accelerated the readiness for application in U.S. products by as much as 8 to 10 years. Some of the advances have been incorporated by industry in the PW 2037, PW 4000, and CF-6-80 engines, and more will be apparent in new engines now under development.

Recently General Electric announced its intention to initiate development of a new family of engines for commercial transports. The first engine in this family will be rated at 90,000 lbs. thrust. The engine is scheduled for certification in 1994 and will be based in considerable part on the GE version of the Energy Efficient Engine. It is interesting to observe that a new engine will come into existence about 20 years after the advanced technology development was begun.

The Advanced Turboprop (ATP) program was aimed at still greater efficiency improvement for advanced turboprop-powered aircraft capable of cruising at or near jet transport speed. The program involved the development of technology and a fundamental performance data base for thin, swept-tip, multibladed high-speed single- and counter-rotating propellers through analysis, wind-tunnel, and large-scale flight tests. The original goal was to achieve 30-40 percent fuel savings relative to equally advanced turbofan engines at equivalent noise and vibration levels. Current results indicate that savings at least on the order of 25 percent can be achieved.

Again, the NASA focus encouraged increased further industry investment, by engine, propeller, and airframe manufacturers. The program was later broadened to include an independently conceived GE alternative counter-rotating concept which would eliminate the need for a gear-box. All in all, the industry investments significantly exceeded the NASA $65 million investment in this area.

The ATP program has been an impressive technical success. It was awarded the Collier Trophy, and both the geared and ungeared counter-rotating approaches have been flight-tested in realistic tail-mounted medium-range transport installations representative of proposed Boeing and Douglas applications. The airlines, however, probably as a result of the reversal in the fuel price downward trend, have not as yet included these applications in their purchase plans.

ATP remains a potentially important technology development, at least for the medium-range transports. For the larger aircraft, ultra-high-bypass ducted fans more suitable for wing-pylon installation are being studied. It still appears highly likely that the new turboprop technology will eventually be applied in transport aircraft development. However, it is too early to discern how and when this technology will be utilized.

The Energy Efficient Transport (EET) program was intended to expedite early application of aerodynamic and control technologies to derivative and future production transport aircraft. It involved cooperative effort with industry on high-aspect-ratio low-sweep supercritical wing technology, new high-lift devices, winglets, propulsion/airframe integration, digital avionics, and active controls including maneuver/gust-loads control. NASA's investment in EET was approximately $80 million.

The major visible EET results converted to industry applications were winglets, which have now appeared on the Boeing 747-400 and other aircraft, and the active-control Wing Load Alleviation (WLA) system which was developed for the Lockheed L-1011-500. The winglets resulted in drag reduction and the active controls application resulted in weight savings due to reduced structural loads in maneuvering and gust penetration.

The Composite Primary Aircraft Structures (CPAS) program was intended to provide technology readiness enabling manufacturers to commit to incorporation of composites in primary structures in future transport developments. Test results on full-scale composite components confirmed predicted weight savings of 20-25 percent, and manufacturers built and successfully flight-tested primary empennage structures.

U.S. transports now incorporate composite structures, and increased use is being made in newer designs presently under development. However, the European transports have progressed much more rapidly in this application. The CPAS program funding of $103 million did not permit the originally planned work on large wing and fuselage structures, and confined the smaller empennage primary structures to fabrication on soft tooling. The program provided flight confirmation of composite tail structure feasibility but did not resolve manufacturing technology or cost problems. To date, the retooling and structural design costs have not been deemed economically justifiable for the empennage structures, and the much larger primary structures technology remains a high-risk item for private development.

The Laminar Flow Control (LFC) program was to develop and demonstrate a practical, reliable, maintainable laminar flow control system to reduce transport skin friction drag and achieve fuel savings of 20-40 percent.

With almost half of the engine thrust in cruise required to overcome it, skin friction drag has long been an important but elusive aeronautical research target. Recent advances in active suction LFC provided a basis for optimism that practical operational systems could be developed. The $37 million LFC program furthered the research considerably, and uncovered the possibility of a more practical and economical "hybrid" approach utilizing natural laminar flow over much of the wing in combination with active suction only where absolutely necessary. However, the hybrid approach is yet to be validated.

In summary, all elements of the ACEE program were productive and provided significant advancement in aeronautical technology. From the standpoint of validation for near-term application in product development some of the technologies proved to have been not quite ripe for large-scale research. The efforts required to bring them to full maturity were beyond the reach of the ACEE funding. This could mean that the focused effort was not sufficiently aggressive or not adequately funded -- or it could mean that it was launched prematurely and should have been proceeded by more thorough fundamental research. Either way, the potential applications still appear important but the possibility of industrial development without the NASA activity seems highly unlikely.

New Directions in Components Research

Two component research areas are growing in NASA. Beginning in the mid-60's NASA began a vigorous program on the effects of aviation on the environment. The U.S. Supersonic Transport was in development and it became apparent that sonic boom and jet noise were major problems. NASA became involved in research in both topics. It also became apparent that near-airport communities were becoming increasingly less tolerant of the noise from take-off and landings of subsonic transport aircraft. Furthermore there was increasing concern about the depletion of the ozone layer at high altitudes. The process appears to be oxides of nitrogen catalyzing the destruction of the high altitude ozone layer. It is interesting to note the present status of these concerns. Sonic boom has been banned by prohibiting supersonic flights over the United States. Various engineering modifications have resulted in the capability to reduce subsonic engine noise to comply with the most stringent requirements promulgated by the Federal Aviation Administration in conjunction with the Environmental Protection Agency. However, little or no progress has been made in understanding the complex interactions which may result in ozone depletion.

There is increasing interest in a high-speed transport. However, it seems imprudent to launch such a major program without understanding the phenomena of ozone depletion. This phenomenon will continue to be an important area of research for NASA and the aviation community.

The second area of interest is the application of computational techniques or computational fluid dynamics (CFD) to a wide variety of design and analysis calculations. CFD techniques have been applied to a wide variety of problems. However, the application of CFD to ever more and more types of problems as well as more detailed description of phenomena where CFD methods are in use make it likely that the use of CFD techniques will continue to grow at a rapid rate.

The NASA staff and its associate contractors have demonstrated the flexibility and adaptability to move quickly into new areas of research and to utilize advanced tools such as CFD in a wide variety of situations.

Concluding Remarks

Two things are essential for successful component research. They are talented people and adequate facilities. NACA/NASA has been blessed with a highly motivated staff and an outstanding complement of research facilities.

The NACA/NASA management has understood the need for a stable and sympathetic environment for researchers to do their best work.

The NASA aeronautics staff is losing talent at a significant rate and is not replenishing at an adequate rate. Providing for high quality staff to continue to perform high quality work is a challenge facing NASA management.

PLANNING APPLIED RESEARCH IN FRANCE

by

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France

CONTENTS

CHARTS

1. Introduction

The development of a new weapon system is a very expensive operation. It may begin by fundamental research followed by applied research, then design of a prototype and operational testing of this prototype. The production launch of sophisticated materiel is so expensive that everything must be done to prepare the final decision in a rational manner. That is the aim of applied research. Once industrial development has been decided upon it becomes a short-term preoccupation which should not prevent thinking about the future, and about the developments which will follow.

A distinction therefore must be made between research connected with ratified developments and advanced research.

Furthermore, certain advanced research concepts, which seem particularly promising may lead to "exploratory development". This means the development of experimental materiel, which is far from being operational in all respects, but which enables demonstrations of the capabilities of this type of solution.

So R&D can be divided into 3 phases:

1. Advanced Research - basic or applied research.

- The planning of applied research results in a document called PPRE - Plan Pluriannuel de Recherches et Etudes - (Multi-year Research and Study Plan).

2. A small number of new concepts resulting from the research must be tested: the PPDE -Programme Pluriannuel de Developpments Exploratoires - (Multi-year Exploratory Developments Programme).

3. Development. The final decision to implement industrial development results from the previous research and exploratory developments. Some research is included in this phase.

2. Organisation in the Ministry of Defence

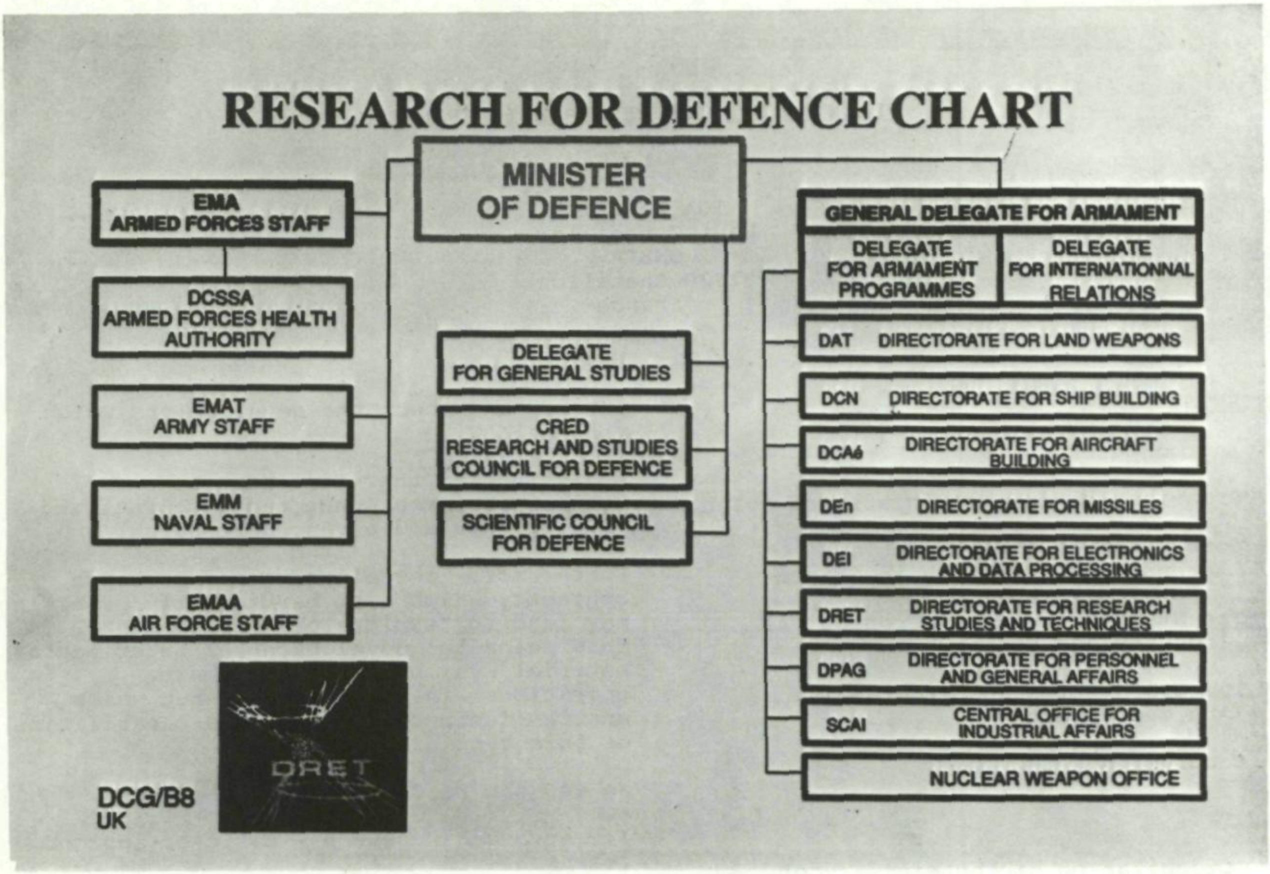
Chart 1 shows the organisation in the Ministry of Defence.

On the left-hand side are the various staffs: they define their needs for operational weapons. On the right-hand side is the General Delegation for Armament (DGA). It has to provide the concepts and specifications to industry. The DGA is in charge of the research and development programme on the one hand and of weapons procurement on the other.

In the middle of the chart are three organisations which have an important role as advisors to the Minister of Defence for research planning.

Chart 2 gives the total amount of the 1989 Defence Budget and the breakdown between Operating Costs, R&D and Procurement.

Chart 3 shows a comparison between the Defence Budgets of France and those of other countries.



RESEARCH FOR DEFENCE CHART

MINISTER OF DEFENCE

EMA ARMED FORCES STAFF

DCSSA ARMED FORCES HEALTH AUTHORITY

EMAT ARMY STAFF

EMM NAVAL STAFF

EMAA AIR FORCE STAFF

DELEGATE FOR GENERAL STUDIES

CRED RESEARCH AND STUDIES COUNCIL FOR DEFENCE

SCIENTIFIC COUNCIL FOR DEFENCE

GENERAL DELEGATE FOR ARMAMENT

DELEGATE FOR ARMAMENT PROGRAMMES

DELEGATE FOR INTERNATIONNAL RELATIONS

DAT DIRECTORATE FOR LAND WEAPONS

DCN DIRECTORATE FOR SHIP BUILDING

DCAé DIRECTORATE FOR AIRCRAFT BUILDING

DEn DIRECTORATE FOR MISSILES

DEI DIRECTORATE FOR ELECTRONICS AND DATA PROCESSING

DRET DIRECTORATE FOR RESEARCH STUDIES AND TECHNIQUES

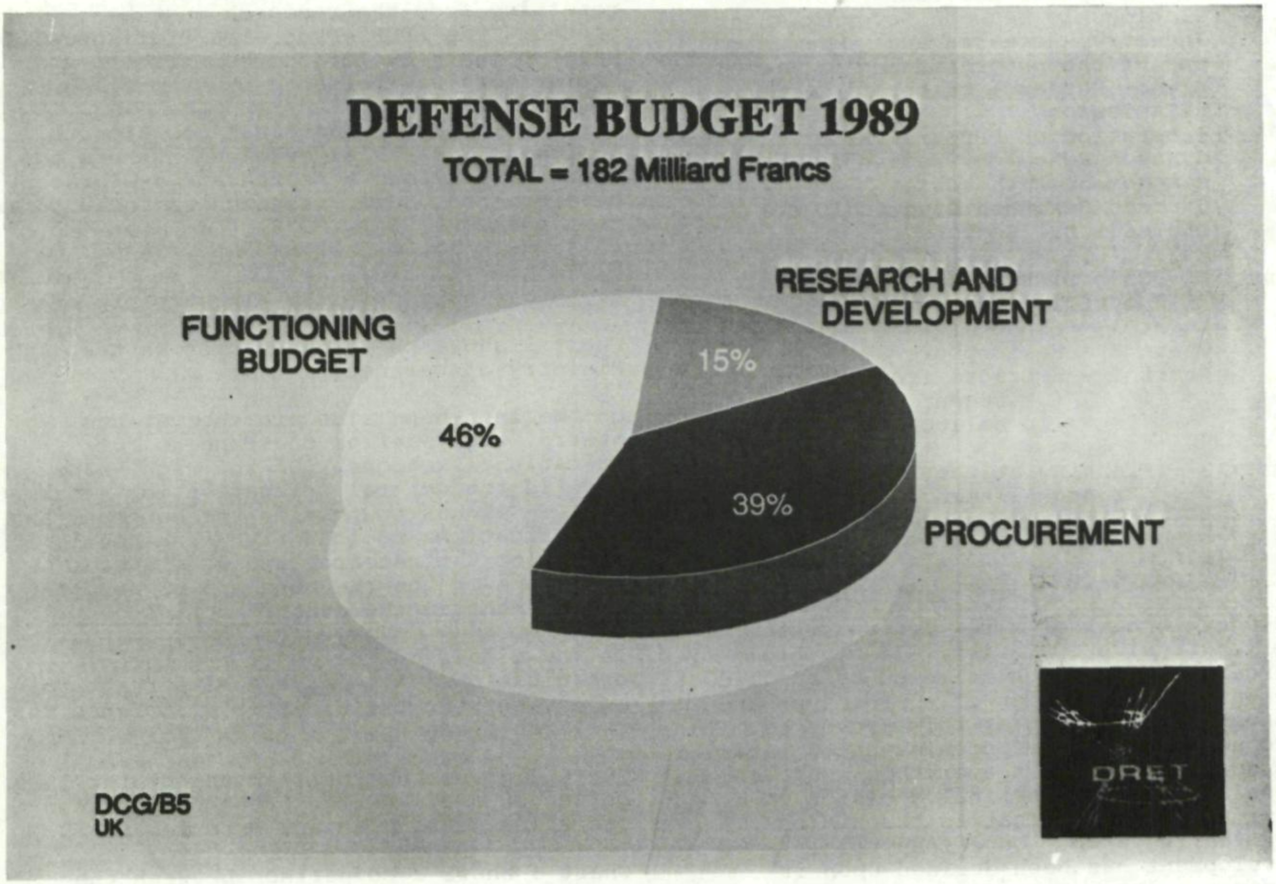
DPAG DIRECTORATE FOR PERSONNEL AND GENERAL AFFAIRS

SCAI CENTRAL OFFICE FOR INDUSTRIAL AFFAIRS

NUCLEAR WEAPON OFFICE

DCG/B8
UK

Chart 1



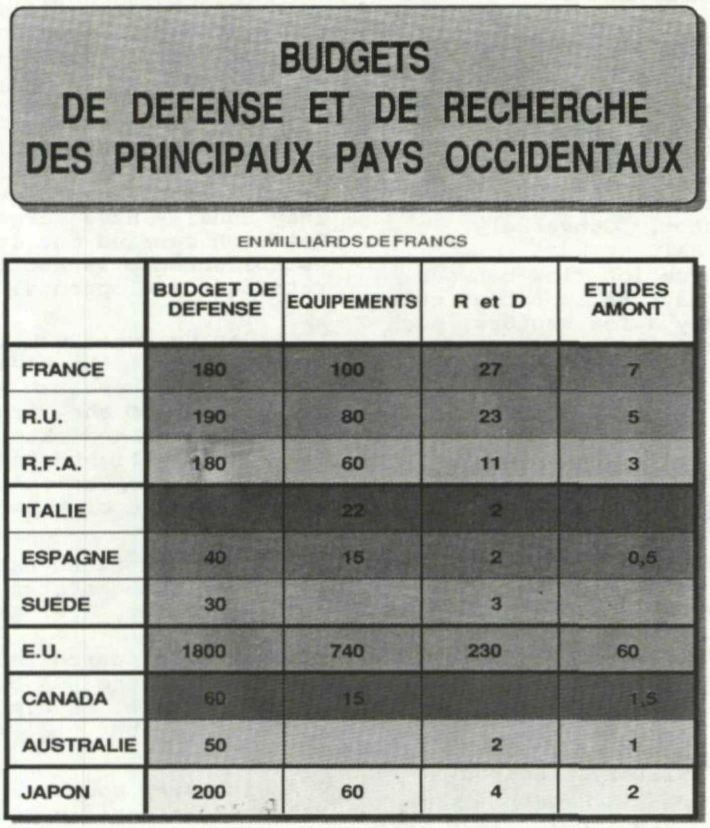
DEFENSE BUDGET 1989

TOTAL = 182 Milliard Francs

DCG/B5
UK

Chart 2

ANNEXE 1



BUDGETS DE DEFENSE ET DE RECHERCHE DES PRINCIPAUX PAYS OCCIDENTAUX

EN MILLIARDS DE FRANCS

	BUDGET DE DEFENSE	EQUIPEMENTS	R et D	ETUDES AMONT
FRANCE	180	100	27	7
R.U.	190	80	23	5
R.F.A.	180	60	11	3
ITALIE	[illegible]	22	2	[illegible]
ESPAGNE	40	15	2	0,5
SUEDE	30		3	
E.U.	1800	740	230	60
CANADA	60	15		1,5
AUSTRALIE	50		2	1
JAPON	200	60	4	2

Chart 3

QUALIFICATION and CERTIFICATION CENTERS in FRANCE

CEV : Centre d'Essais en Vol . BRETIGNY - ISTRES - CAZAUX .
Flight Testing and Flight Simulation .

CEAT : Centre d'Etudes Aéronautiques de TOULOUSE .
Structure and Material Testing . Air Conditioning Testing .
Effects of Lightning . Board Equipment and Calculator Testing .
Subsonic Wind - Tunnel .

CEPr : Centre d'Etudes de Propulsion . SACLAY .
Motor Test Benches at Ground and Altitude Conditions .
Anechoic Wind - Tunnel .

CELAR : Centre ELectronique d'ARmement . RENNES .
Measurement of IR and Electromagnetic Signature .
Antenna Test Facilities . Combat Simulators .
General Purpose Computer for DGA .

Chart 4

3. Some features of Armament and Aeronautical Research in France

Armament Research has certain special features:

- The most obvious of these is confidentiality, although industrial research today has such important consequences for the economic life of a country that confidentiality exists in every industrial sector. Conversely cooperation between NATO members necessitates an information flow between the Allies. AGARD plays an important role in this respect. Only a few sectors, such as atomic research and electronic warfare are almost totally covered by security restrictions.

- Another important feature is that the main customer is the French Government. Even though weapons may be sold to other countries, the French Government maintains control of this activity. The result is a high degree of integration within the Ministry of Defence. The Minister is responsible for weapons design and manufacture and at the same time Chief of the Armed Forces under the President. Such a situation does not exist in other industrial sectors (except perhaps telecommunications). There is, therefore a need for an original solution to the problem of planning military research.

- A third special feature results from the fact that in France responsibility for the whole aeronautical industry lies with the Ministry of Defence. It is clear that there is much in common between civilian and military aviation. Research and test facilities are common in most countries. In France the Ministry of Transport is responsible for civil aviation but makes use of the expertise of the technical services of the Ministry of Defence, in particular for qualification and certification. Aeronautics being a high technology field, in which most of the materiel must be ground tested before flying, a great number of facilities are used both for research and qualification and certification, e.g. structures and materials test facilities, engine test benches, wind tunnels, flight simulators, etc. Thus, when considering research and the necessary investment, the related field of government evaluation and certification must be included.

4. The Structure of the Aeronautical Industry and Research

There is a large aeronautical industry in France. Among the leading companies are Aerospatiale and Dassault for airplanes and helicopters, Aerospatiale, MATRA and Thomson-Brandt for missiles, SNECMA, TURBOMECA, MICROTURBO for engines, etc. But there are also many companies working on equipment which is connected with the aeronautical industry but has other applications. This is the case for AMD, THOMSON-CSF, SAGEM, etc. Some of these companies are totally or partially state-owned. Some of them are private companies. In addition some foreign companies have a manufacturing activity in France.

Most of these companies have a considerable research activity, financed either by private funds or by government contracts.

- In the research field itself there are a few private research companies e.g. BERTIN. Most of them are state-owned or state-controlled.

- Some of them belong to the DGA itself. Typically, these establishments have a dual activity partially in research and mostly in qualification and certification work. They usually have large installations. Research carried out in these establishments is mostly connected with ratified developments.

In order to avoid duplication of expensive installations, the Government allows industry and research laboratories to make use of some of the large installations such as structures and materials test facilities, flight simulators, wind tunnels, etc. Chart 4 shows the activities of the largest of them.

The status of these establishments can be compared to the status of USAF establishments, i.e. AEDC in Tullahoma.

Some other research laboratories are sponsored by the DGA but have looser ties with the State. A typical example is ONERA - Chart 5 - 5b

- As in every country, many University and National Scientific Research Centre laboratories occasionally work for defence.

- Mention should be made of French participation in two international organisations:

ISL - Franco-German Institute of St Louis (see Annex 2)
ETW - European Transonic Wind Tunnel.

Chart 6 gives a symbolic representation of the structure of aeronautical industry and research. It gives an idea of the complexity of the distribution of research resources. On the one hand, maximum efficiency must be achieved and on the other hand a balance must be struck between the various teams of scientists with different status.

5. The Orientation and Programming of Applied Research

In order to understand this process it is divided into phases, each of which is summarised below with the relevant documents underlined in the text.

Phase 1 - Every year the Minister issues an orientation letter following the meeting of the CRED (Conseil des Recherches et Etudes de Defense) (the Defence R&D Council). This is done after consultation with:

- The Scientific Council for Defence, made up of distinguished scientists working outside the Ministry of Defence. These personalities draw the attention of defence experts to relevant new scientific findings which could play a role in defence.

- The Delegation for General Studies. This organization prepares, together with the General Staffs and the DGA, an overall perspective document on defence and armament policy.

MISSION

Develop and guide aerospace research;

Design, build and implement the means required for conducting this research;

Circulate the results of the research;

Promote the use of the results by the aerospace industry;

Where applicable, facilitate the use of these results outside the field of aerospace.

Chart 5

MANPOWER AND FUNDINGS IN 1989

Manpower	2150
Operating funds	1138 MF
Investment funds	232 MF

Chart 5b

This document indicates the long-term aims of the Armed Forces, the most important areas for the future and the desired military capability, while leaving full latitude as to the means of achieving these goals.

- The amount of credit for R&D is fixed at the same time and an initial breakdown is agreed with the General Staffs.

Phase 2 - Acting on the instructions of the Minister, the various Divisions of the DGA make proposals concerning research objectives. These research objectives are discussed by different programming groups, a list of which is given in Chart 7. The programming groups are composed of experts from the DGA. Representatives of the Staffs and the DGA attend the meeting. The final result of the discussions within the programming groups is a "Programme Orientation Instruction" (DOP - Directive d'Orientation des Programmes d'etude). It does not include a breakdown of credits. It must be officially approved by a consultative board consisting of high level representatives of the General Staffs and the DGA. It is signed and implemented by the Delegue General pour l'Armement (see Chart 8).

One of the Divisions of the DGA (DRET) organizes discussions on the general research programme as indicated in phase 2 and the subsequent phase 3. In addition, this Division is responsible for the parts of the research programme not directly connected with other Divisions. Chart 9 shows DRET missions.

Phase 3 - This is the programming phase. Research objectives must be converted into research actions, each of them receiving a fixed amount of money. The different Divisions of the DGA prepare FRE - Fiches d'etude et recherche - (Individual Research Action Documents) and proposals for "Exploratory Developments".

The programming groups, as defined in the previous phase, work again on the subject and produce two different major documents:

- PPRE - Plan Pluriannuel des Recherches et Etudes

Multi-annual plan for R&D which includes the list of the research activities which will be carried out with the appropriate credits during the fiscal year. There is an indication concerning policy in future years but this cannot be binding as budgets are established year by year.

- PPDE - Plan Pluriannuel des Developpements Exploratoires

Multi-annual plan for exploratory developments (only binding for one year like the PPRE).

These two documents which must be approved by the CRED and the Delegue General pour l'Armement are published by the DRET (see Chart 10).

Chart 11 gives the breakdown of credits between the different managing authorities of the DGA. Two remarks can be made:

- In most cases research activities or exploratory development are not implemented by the managing authority. The DGA and its Divisions are customers which let research contracts to industry or research establishments. Chart 12 gives the breakdown of advanced research between the different professional sectors. As for ONERA the 8.2% mentioned in the chart represents only the basic subsidy of its budget. The rest is financed by contracts from other Divisions. These represent about 60% of the total resources.

- If we compare charts 2 and 11 we can see that out of a total amount of 27.3 billion FF for R&D, 6.7 billionFF goes to advanced research studies and exploratory developments. That is about 25%. So, advanced research receives an important part of the total Defence R&D Budget.

Phase 4 - This is the most important phase: i.e. execution of the programme by a research establishment. We will take the example of ONERA where there is a basic difficulty. The orientation and programming sequence extends over one year. The PPRE for the fiscal year (beginning on 1 January in France) is only published in February. Research establishment programmes must be ready in January. So, national and internal programming is being carried out at the same time despite the fact that internal programmes should be a consequence of national programming!

However it is still possible to plan ONERA research activity because:

- the main tendencies of the national programme are slow to change; continuity is a practical necessity;

- the people who discuss the programme of a large establishment like ONERA are the same as those who discuss the national programme during the same period;

- it is possible to introduce changes to the ONERA programme during the year, if necessary. The resulting plan should not therefore be considered as compulsory but rather as a provisional document.

One of the characteristics of research is that its planning depends very much on the results obtained. It is difficult to foresee the results which can be achieved during the following year (do not forget that scientists are very often very optimistic in this respect!). The only solution is to follow the progress in real time. This necessitates frequent personal contacts with the right persons. Very often the customer (i.e. the authority which signs the contract) is not the user. The user usually belongs to industry. Each scientist responsible for a research action must personally know the authority responsible for the contract and the potential user of the results. Constant interaction between these three persons is a must. In this way one can avoid the famous N.I.H. (Not Invented Here) and ensure that the results are communicated as quickly as possible to the user. It must not be forgotten that the novelty of today is the banality of tomorrow. Research and industry are racing against time. (*)

(*) To give some idea of the contacts taking place at the ONERA centre at Chatillon (1000 personnel of which about

500 are scientists), it should be noted that we receive about 300 technical and scientific visitors every day.

In the case of ONERA the detailed programme is prepared during the summer and discussed for three days with representatives of the DGA and Industry in November. As mentioned before, the national programme is being discussed at about the same time. The programme consists of:

- a general paper on each application sector: airplanes, helicopters, space, etc., summarising the work to be done;

- a short document of one or two pages for each research task. In addition to the provisional content of the task and the history of previous work this document contains:

- indications as to the link between the task and the DOP (Programme Orientation Instruction)
- name of the scientist in charge of the task
- names of the DGA and Industry liaison persons interested in the task
- amount of money allotted (typically 1 to 10 million Francs)
- breakdown of this money between direct costs and use of large-scale facilities (wind tunnels, computers, etc.).

At the end of the year a document of the same length is issued on the same task, giving the results achieved and the amount of money spent. In this way one can compare the forecasts with the results. Discrepancies often indicate a re-orientation of the task and it is interesting for the future to understand why this happened. In order to clarify how this process works, Appendix 1 gives a case history of a task. The execution of this task was succesful, it was carried out by an excellent team and the relations with the authorities and industry were well established. For comparison, Appendix 2 provides the planning of research in a bi-national establishment, ISL.

6. Conclusion

Describing the planning process of advanced research is rather tedious. Every country has its own solution depending on the structure of its civil service and industry. Nevertheless, there are some general principles which should be kept in mind.

1. An applied research operation must only be undertaken when there is a national need.

This national need must be recognized by the authorities or by industry which implies a readiness to provide funds for this research.

2. The research establishment must plan for its research programme:
   - manpower
   - direct costs
   - use of large-scale facilities.

An idea of the time-span required for completion of the initial phases of this task must be given. If one element is lacking: i.e. manpower, facilities, money, the task must not be undertaken in its present form. Be careful: scientists are always optimistic.

3. During execution of the task, contacts must be established with customers' representatives and potential users of the results. Any important finding or failure must be announced as soon as possible.

All this is necessary, of course, but success depends above all on the quality of the team. Nothing can replace good, dedicated scientists. The first phase of any sound planning operation is to recruit competent people.

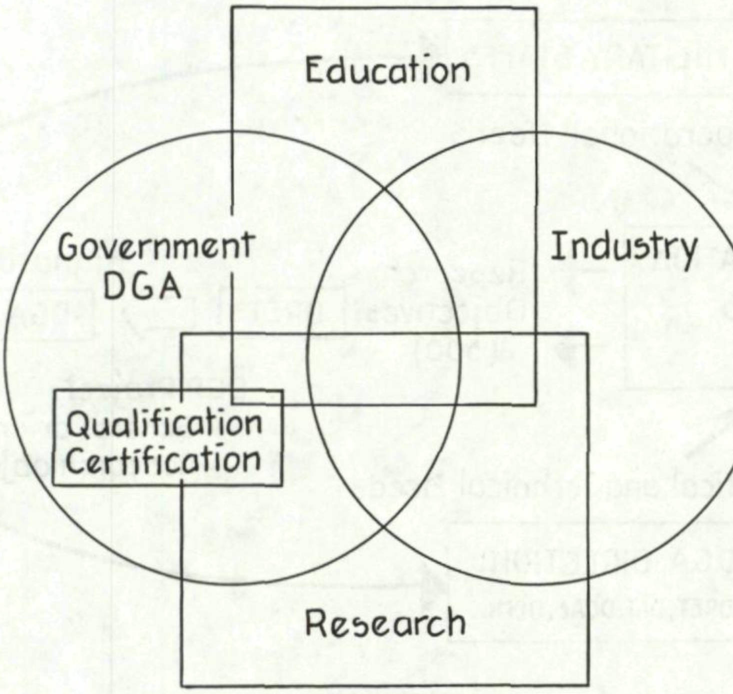


Chart 6

Some of the Programmation Groups

Electro magnetic detection

Computers and Robotics

Electronic components

Electronic measures and countermeasures

Lasers

Optronic

Missile terminal guidance

Inertial guidance

Anti aircraft/missile defence

Tactical missiles propulsion

Strategic missiles propulsion

Planes

Combat helicopters

Design, Production and Maintenance

Chart 7

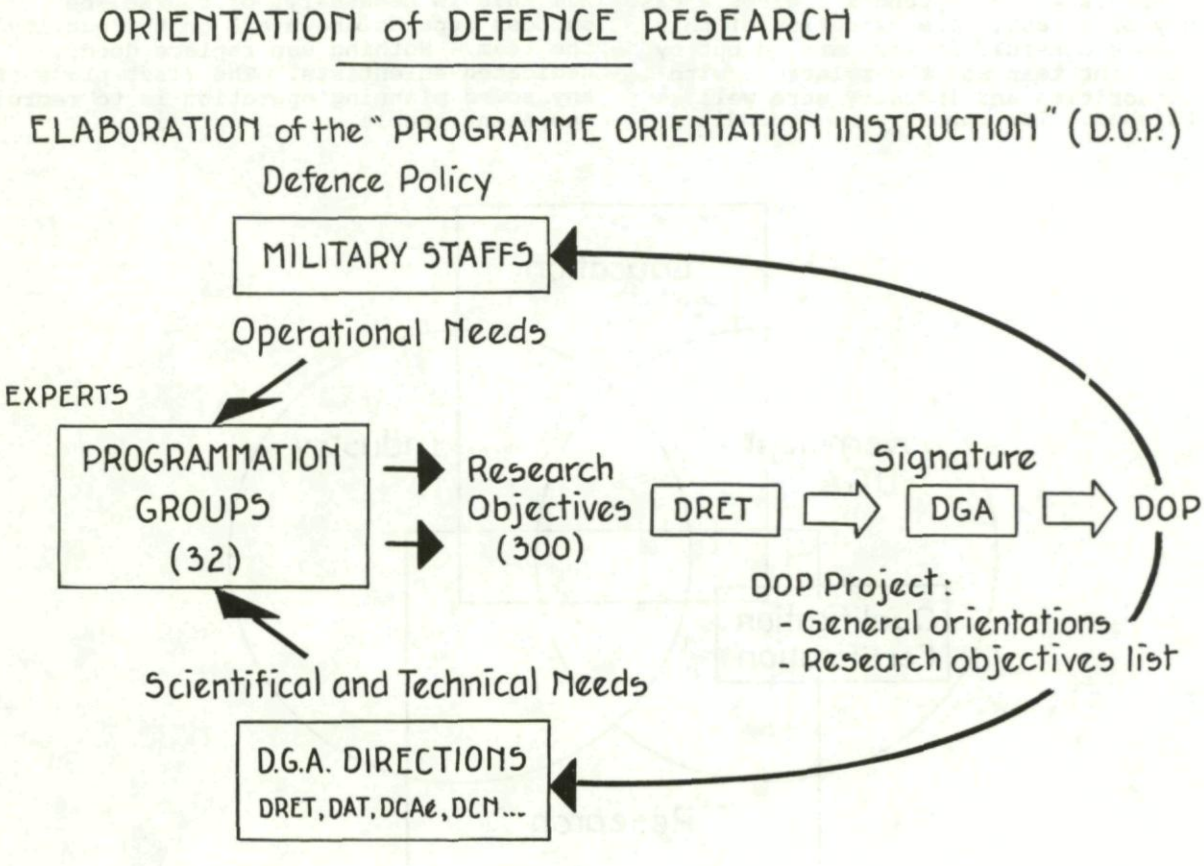
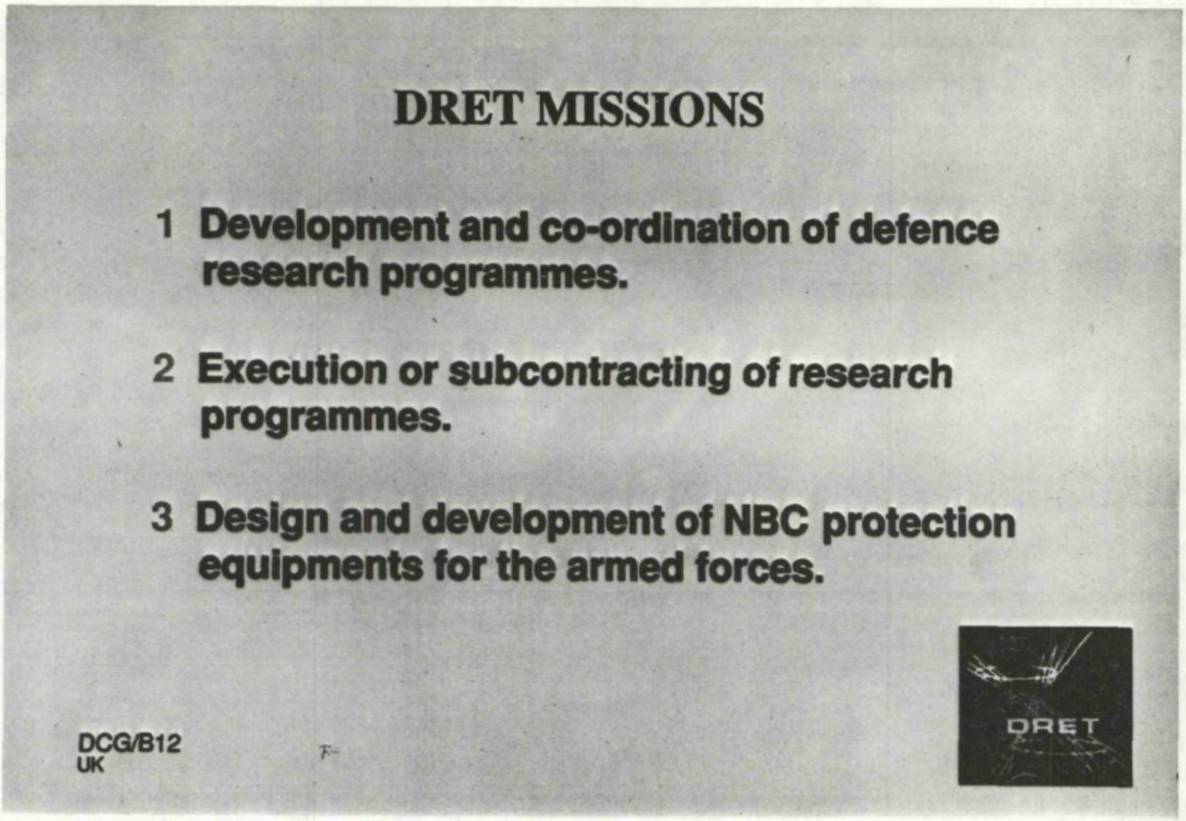


Chart 8



DRET MISSIONS

1 Development and co-ordination of defence research programmes.

2 Execution or subcontracting of research programmes.

3 Design and development of NBC protection equipments for the armed forces.

DCG/B12
UK

Chart 9

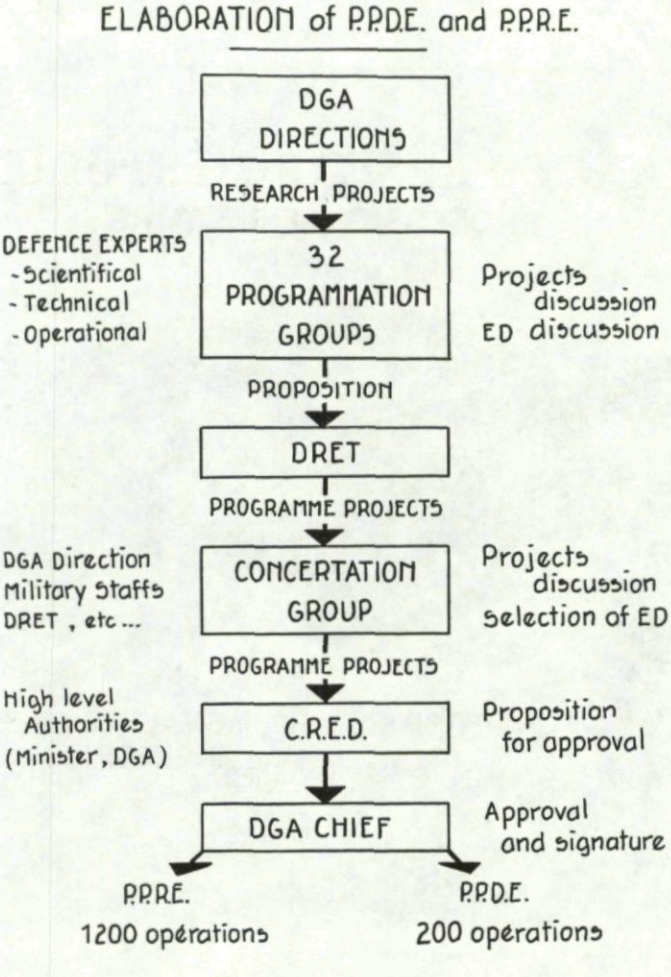
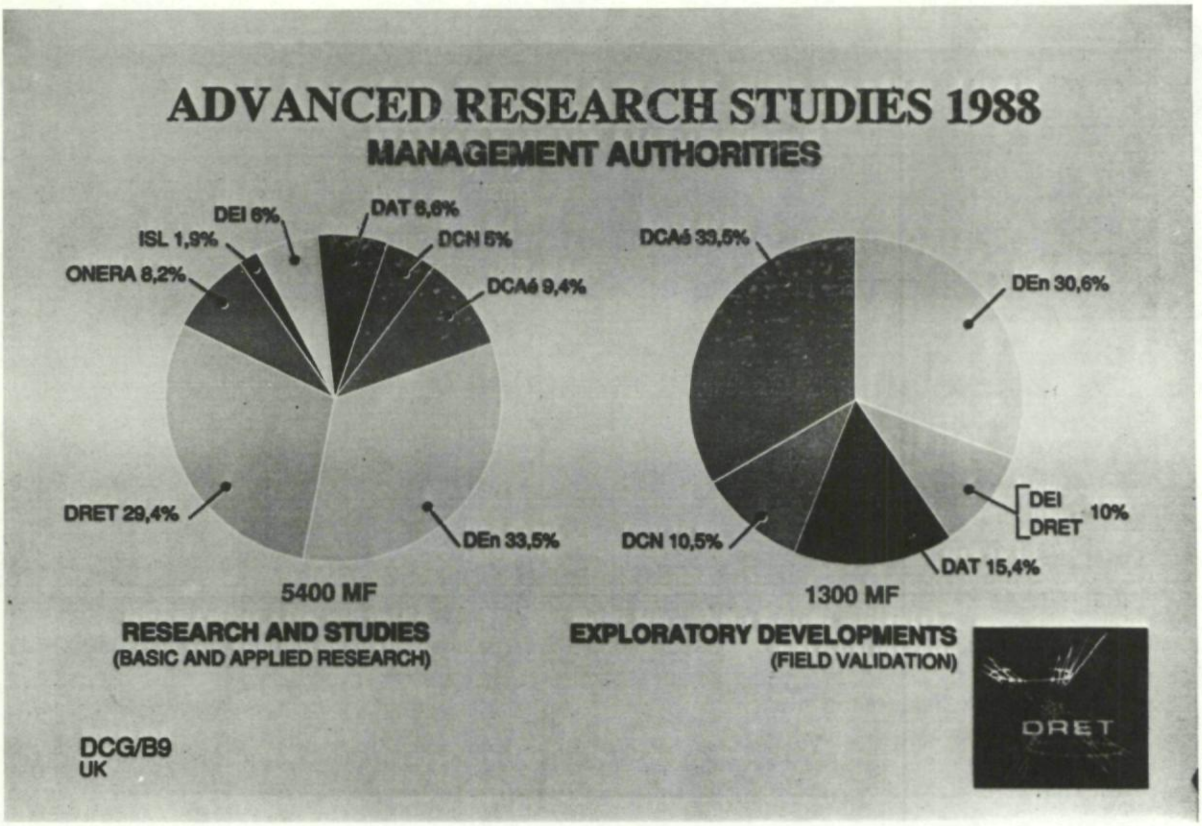


Chart 10

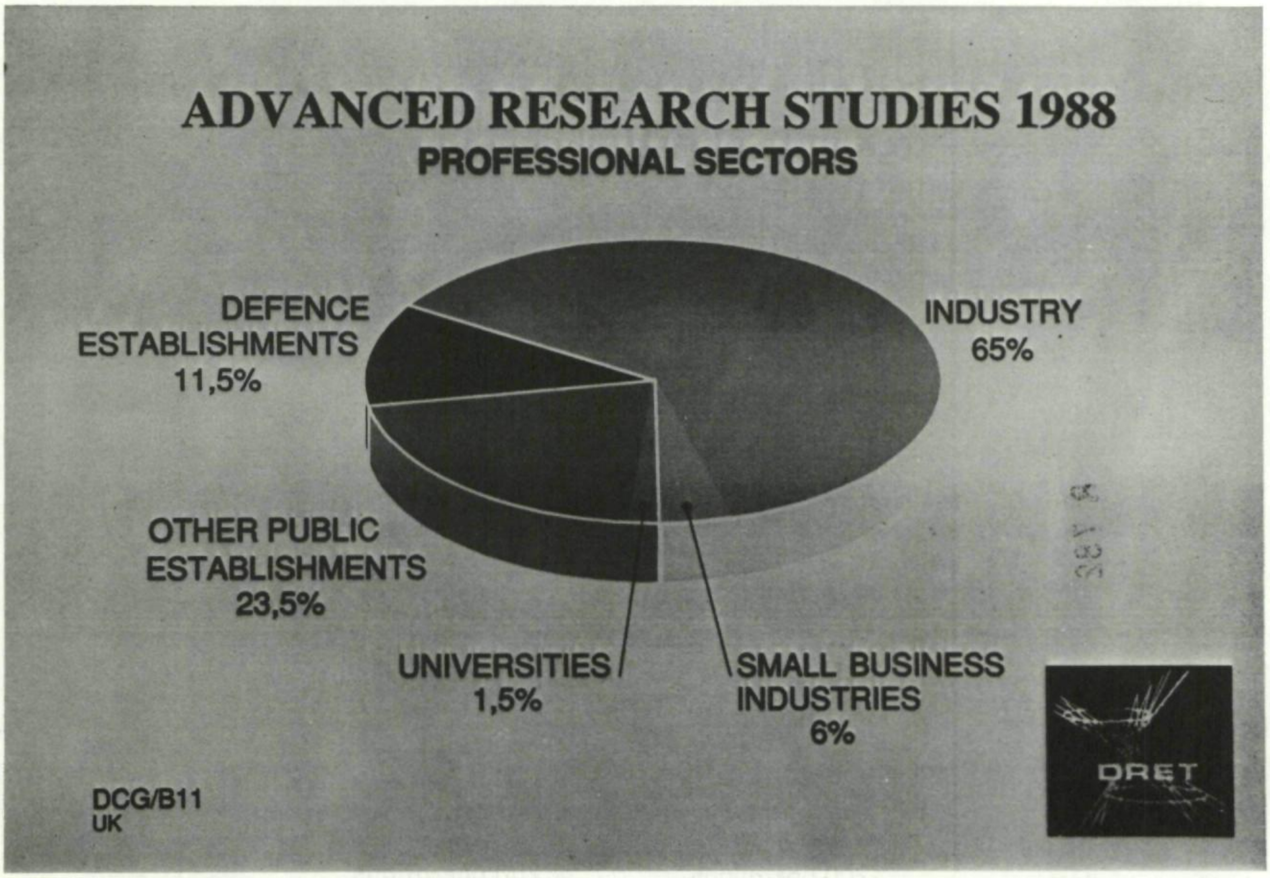


ADVANCED RESEARCH STUDIES 1988

MANAGEMENT AUTHORITIES

DCG/B9
UK

Chart 11



ADVANCED RESEARCH STUDIES 1988

PROFESSIONAL SECTORS

DCG/B11
UK

Chart 12

ANNEX 1

Case History of a Task: Rotor Optimization

The planning method described in this paper may appear rather complicated and indeed it is. But an example will better illustrate how it has worked.

The subject is the Aerodynamics of Helicopters.

Chart 1 gives the original document used for ONERA planning in 1977. The top right hand corner indicates the link with national planning: orientation and planning.

Chart 2 gives indications as to the content of these two documents, followed by the names of the persons responsible within ONERA and outside ONERA, in Government agencies or in industry.

The text itself has the following headings:

1. Nature of the problem
2. Results obtained since the beginning of 1967
3. External cooperation
4. Programme

The total amounts of provisional expenses and resources are given at the foot of the table.

The following comments apply:

- extensive cooperation with industry: SNIAS (now Aerospatiale), Dorand and with other countries: US Army, Westland
- in the programme, provisions are made for direct personnel cost 2130 KF, for computer 1075 KF, for wind tunnel tests 635 KF, etc.

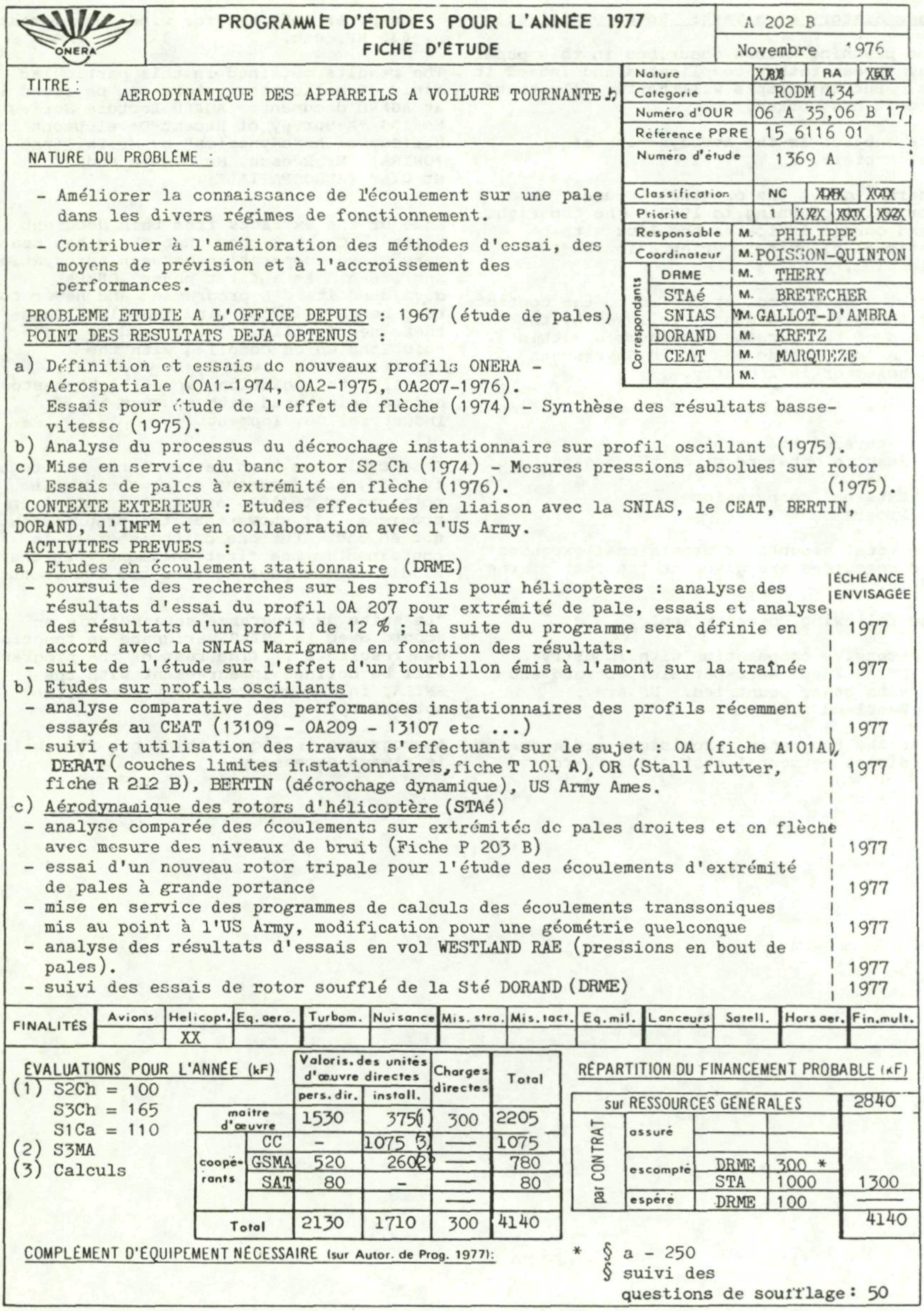
The results obtained in this particular field of helicopter rotors can be found in an AGARD document: AGARD Lecture Series No 139 "A Survey of Recent Development in Helicopter Aerodynamics" by Mr Philippe (ONERA), Mr Roesch, Mr Dequin and Mr Cler (AEROSPATIALE).

Some of the extracts from this document given in Chart 3 show that there has been very close cooperation between Aerospatiale and ONERA. As a first phase, ONERA developed its CFD programmes and new rotor test benches in the wind tunnels. Then these new facilities were used to find solutions which complied with the specifications given by Aerospatiale. Finally, the solutions were flight-tested before being used with success in industrial developments.

This cycle has been rather long; it began in 1967, the document gives the results obtained up to 1985 and work is still in progress. It shows that the programme was not so bad. But one of the secrets is contained in the first document. In the middle of the page we find the statement:

"La suite du programme sera definie en accord avec la SNIAS Marignane en fonction des resultats". (The rest of the programme will be defined in agreement with the SNIAS, in accordance with the results obtained.)

A programme is a good thing but flexibility is always necessary.



ONERA

PROGRAMME D'ÉTUDES POUR L'ANNÉE 1977
FICHE D'ÉTUDE

A 202 B
Novembre 1976

Nature	X	RA	X
Catégorie	RODM 434		
Numéro d'OUR	06 A 35,06 B 17		
Référence PPRE	15 6116 01		
Numéro d'étude	1369 A		
Classification	NC	X	X
Priorité	1	X	X	X
Responsable	M. PHILIPPE		
Coordinateur	M. POISSON-QUINTON		
Correspondants DRME	M. THERY		
Correspondants STAé	M. BRETECHER		
Correspondants SNIAS	MM. GALLOT-D'AMBRA		
Correspondants DORAND	M. KRETZ		
Correspondants CEAT	M. MARQUEZE		
Correspondants	M.		

TITRE : AERODYNAMIQUE DES APPAREILS A VOILURE TOURNANTE

NATURE DU PROBLÈME :

- Améliorer la connaissance de l'écoulement sur une pale dans les divers régimes de fonctionnement.
- Contribuer à l'amélioration des méthodes d'essai, des moyens de prévision et à l'accroissement des performances.

PROBLEME ETUDIE A L'OFFICE DEPUIS : 1967 (étude de pales)

POINT DES RESULTATS DEJA OBTENUS :

a) Définition et essais de nouveaux profils ONERA - Aérospatiale (OA1-1974, OA2-1975, OA207-1976).
Essais pour étude de l'effet de flèche (1974) - Synthèse des résultats basse-vitesse (1975).

b) Analyse du processus du décrochage instationnaire sur profil oscillant (1975).

c) Mise en service du banc rotor S2 Ch (1974) - Mesures pressions absolues sur rotor (1975).
Essais de pales à extrémité en flèche (1976).

CONTEXTE EXTERIEUR : Etudes effectuées en liaison avec la SNIAS, le CEAT, BERTIN, DORAND, l'IMFM et en collaboration avec l'US Army.

ACTIVITES PREVUES : — ÉCHÉANCE ENVISAGÉE

a) Etudes en écoulement stationnaire (DRME)
- poursuite des recherches sur les profils pour hélicoptères : analyse des résultats d'essai du profil OA 207 pour extrémité de pale, essais et analyse des résultats d'un profil de 12 % ; la suite du programme sera définie en accord avec la SNIAS Marignane en fonction des résultats. — 1977
- suite de l'étude sur l'effet d'un tourbillon émis à l'amont sur la traînée — 1977

b) Etudes sur profils oscillants
- analyse comparative des performances instationnaires des profils récemment essayés au CEAT (13109 - OA209 - 13107 etc ...) — 1977
- suivi et utilisation des travaux s'effectuant sur le sujet : OA (fiche A101A), DERAT (couches limites instationnaires, fiche T 101 A), OR (Stall flutter, fiche R 212 B), BERTIN (décrochage dynamique), US Army Ames. — 1977

c) Aérodynamique des rotors d'hélicoptère (STAé)
- analyse comparée des écoulements sur extrémités de pales droites et en flèche avec mesure des niveaux de bruit (Fiche P 203 B) — 1977
- essai d'un nouveau rotor tripale pour l'étude des écoulements d'extrémité de pales à grande portance — 1977
- mise en service des programmes de calculs des écoulements transsoniques mis au point à l'US Army, modification pour une géométrie quelconque — 1977
- analyse des résultats d'essais en vol WESTLAND RAE (pressions en bout de pales). — 1977
- suivi des essais de rotor soufflé de la Sté DORAND (DRME) — 1977

FINALITÉS	Avions	Helicopt.	Eq. aero.	Turbom.	Nuisance	Mis. stra.	Mis. tact.	Eq. mil.	Lanceurs	Satell.	Hors aer.	Fin. mult.
		XX										

ÉVALUATIONS POUR L'ANNÉE (kF)

(1) S2Ch = 100
S3Ch = 165
S1Ca = 110
(2) S3MA
(3) Calculs

		Valoris. des unités d'œuvre directes		Charges directes	Total
		pers. dir.	install.		
maître d'œuvre		1530	375(1)	300	2205
coopérants	CC	-	1075 (3)	—	1075
	GSMA	520	260(2)	—	780
	SAT	80	-	—	80
				—	
Total		2130	1710	300	4140

RÉPARTITION DU FINANCEMENT PROBABLE (kF)

sur RESSOURCES GÉNÉRALES				2840
par CONTRAT	assuré			
	escompté	DRME	300 *	
		STA	1000	1300
	espéré	DRME	100	—
				4140

COMPLÉMENT D'ÉQUIPEMENT NÉCESSAIRE (sur Autor. de Prog. 1977):

* § a - 250
§ suivi des questions de soufflage : 50

Chart 1

HELICOPTERS

Orientations

While continuing with studies designed to improve aerodynamic and technological performance, active studies on militarisation should now be launched.

Planning

In order to improve aerodynamic performance and achieve high velocities, studies - including the use of CFD - will continue on:

- blades: shape (effort on the definition not only of the profile but of all the parameters defining the blade)
- rotors
- reduction of the fuselage and total rotor drag.

Chart 2

A SURVEY OF RECENT DEVELOPMENT IN HELICOPTER AERODYNAMICS

UNE SYNTHESE DES DEVELOPPEMENTS RECENTS EN AERODYNAMIQUE DES HELICOPTERES

par PHILIPPE J.J., ROESCH P.*, DEQUIN A.M.* et CLER A.*

AGARD LS 139, Braunschweig (RFA), Rome (Italie), St Louis (USA), mai 1985.

AEROSPATIALE recently tested a 365N "DOLPHIN" with blades having sweptback parabolic tips defined by ONERA [35]. Here again, blade control load penalties were incurred, but power savings were recorded both in hover and in forward flight as indicated by figures 44 and 45. The result was a 2% increase in takeoff weight, a reduction in the rotor power requirement between 1% and 6% depending on airspeed and gross weight and a noise reduction of over 1 EPN dB.

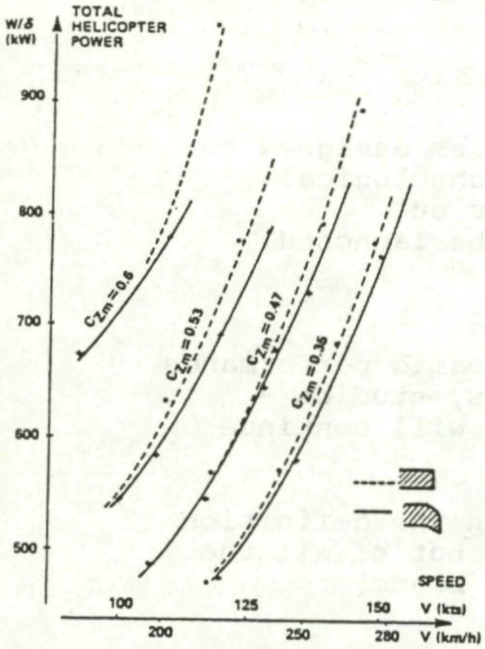


Fig. 44. AS-365N performance improvement in forward flight with parabolic sweptback tips, from [35]

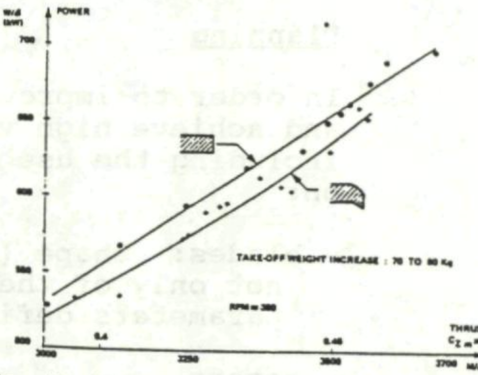


Fig. 45. AS-365N performance improvement in hover with parabolic sweptback tips, from [35]

1.3 ROTOR DESIGN

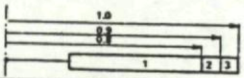
This heading covers the geometrical definition of the rotor: diameter, number of blades, chord, airfoil distribution, blade twist and planform which may include a complex tip design. Blade airfoil selection remains a major aspect of the problem. It is still based on 2-D steady performance, which is the only one that can be effectively computed at present. The following discussion is limited to airfoil selection criteria, blade twist, planform and tip shape.

1.3.1 Airfoil Selection

The choice of airfoils is determined by the helicopter operational requirements as stated in the general specifications. The airfoil operating conditions are very much dependent on the flight configuration so that it is impossible to define a single optimal airfoil and that a tradeoff between conflicting requirements is always necessary.

In practice, depending on the blade spanwise section considered, the goal is to balance the advancing blade airfoil requirements (high drag divergence Mach number at small lift coefficients) with those of the retreating blade (high Clmax at low Mach numbers) while maintaining a good lift/drag ratio at the intermediate values of lift coefficient and Mach number on the fore and aft blades and in hover.

Figure 53 summarizes the specifications set by AEROSPATIALE to ONERA several years ago to design a set of helicopter airfoils. References [76,77] provide ample information on ONERA's design methodology. Figure 54 shows that the basic airfoil of the OA family, the OA209 airfoil, was defined by an inverse method [74] by specifying a velocity distribution at low Mach number and near zero lift.



FLIGHT CONDITIONS	PREPONDERANT AERODYNAMIC COEFFICIENT			SECTIONS				
				1		2	3	
FORWARD FLIGHT	Mdd at CL = 0		>	0.75	0.80	0.85	0.90	0.92
	$\lvert C_{m_0} \rvert$		<	0.01	0.01	0.01	0.01	0.01
HOVERING	L/D RATIO AT M_0 = 0.5 - 0.6 CL = 0.6		>	80	75	80	85	85
MANEUVER	$C_{L\,MAX}$	M_0 = 0.3	>		1.5	1.4		
		M_0 = 0.4	>	1.6		1.3	1.0	0.96
		M_0 = 0.5	>		1.3			
GEOMETRICAL CONSTRAINT	t/c			13	12	9	7	6

Fig. 53. AEROSPATIALE specifications for airfoil design, from [76]

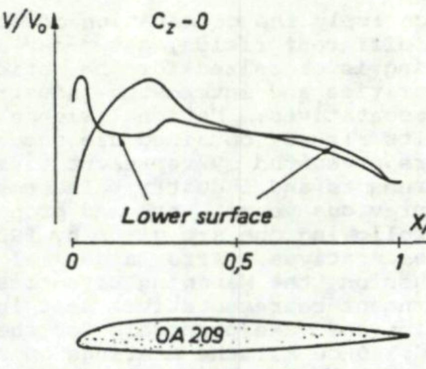


Fig. 54. Design of OA-209 airfoil, from [78]

The other airfoils were defined with direct methods by geometrical transformation of the OA209 with the exception of the OA213 which was again defined by an inverse method, specifying a velocity distribution at M=0.5 and Cl=1, as shown in figure 55. The next step consisted in estimating the airfoil performance characteristics by means of a program that solves the full potential equation using a non-conservative scheme with weak boundary layer coupling [80], comparable to the classical GARABEDIAN & KORN codes. The predicted airfoil performance is then checked by wind tunnel tests. Figure 56 summarizes the main performance characteristics of the OA2XX airfoils which are shown here compared with the VRXX airfoils developed by BOEING-VERTOL [54,81] and with the more recent DM-HX airfoil series designed by the DFVLR and MBB [82].
One can measure here the progress made in the design of advanced airfoils since the time when the old NACA 0012 used to equip so many helicopter rotor blades. The same figure also indicates AEROSPATIALE's design objectives: it can be seen that the new performance goals concern airfoils whose relative thickness is between 9% and 13% with a high Clmax at Mach 0.4 associated with a low Cmo to avoid high control loads, and with the highest possible drag divergence Mach number at near zero Cl.

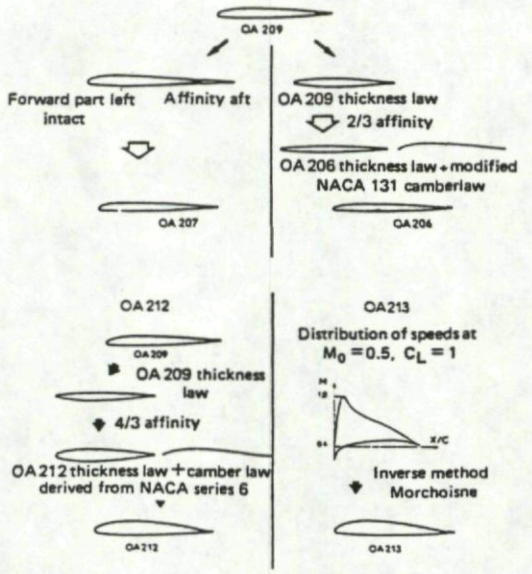


Fig. 55. Design methodology of OA-207, OA-206, OA-212 and OA-213 airfoils, from [78]

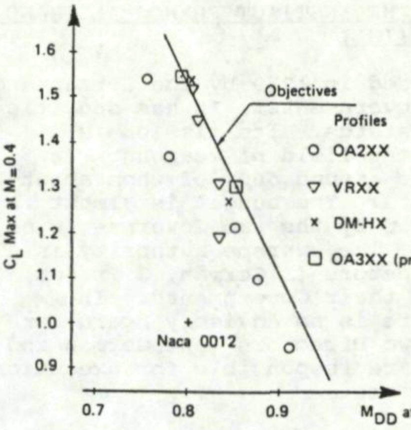


Fig. 56. Main aerodynamic characteristics of new airfoils for helicopter blades

It is in fact questionable that thin airfoil sections at the tip of the blades should be better in high speed forward flight as AEROSPATIALE rotor tests in the MODANE S1 wind tunnel have shown. Figure 57 gives the definition of the rotors tested. Figure 2 clearly shows that a thick airfoil over most of the blade is preferable (rotor 7A versus rotor 6B), and that the constant 9% thick airfoil section at the tip was more efficient at high speed than the tip tapered from 9% to 6% which is in contradiction with the theoretical predictions. It is recalled that the drag divergence Mach number of the OA206 airfoil is 0.91 compared with 0.89 for the OA207 and 0.85 for the OA209. A satisfactory explanation of these results will probably be possible only when 3-D unsteady flow methods are developed.

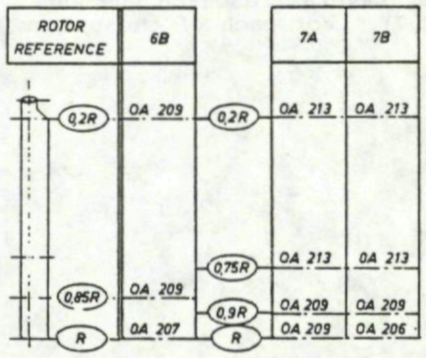


Fig. 57. AEROSPATIALE model rotor blade definition for S1 Modane WTT, from [5]

New airfoil numerical optimization techniques presently in development appear very promising as a design optimization tool to elaborate a satisfactory compromise between the low-speed high Cl and high-speed low Cd performance requirements. ONERA has applied such techniques to the optimization of the OA207 airfoil [83] and achieved a 16 % reduction in Cdo at M=0.85 and a 6% reduction in Cd at M=0.4 and Cl=0.83. ONERA is now working on the design of a new airfoil family (OA3XX) with computed Clmax and Mdd performance at least equivalent to the VRXX and DM-HX airfoils (figure 56).

ANNEX 2

PLANNING AT THE INSTITUT FRANCO-ALLEMAND DE SAINT LOUIS (ISL)

ISL was founded in 1959 by the German and the French Governments. It has specific bi-national status. Its mission is research in the field of weapons. The staff numbers around 500, of whom about 70 are scientists. The budget is almost totally funded by the two Governments on an equal basis. The supreme authority is a Board of Directors (3 German, 3 French) representing their Governments. In addition there is an Advisory Board for Research. Two Directors (one German and one French) are responsible for execution of the programme.

It is interesting to compare the planning procedure of ISL with the planning of a purely national establishment like ONERA; there are some fundamental differences.

In ISL:

- all funding comes directly from Government sources
- industry is highly interested in the results of research but competition between national companies must be considered
- the small size of the establishment implies a simplified planning procedure.

The programme is prepared by the Managing Directors in connection with the Advisory Committee for Research, and approved by the Board of Directors.

The activity of the Establishment is oriented by several research themes (typically 7). For each of these themes (which imply the cooperation of specialists from different fields) a two-day annual meeting is organized for the national authorities and interested industry representatives. National wishes and results already obtained are summarised in papers presented by representatives from Governments and industry. The results of the previous years' work and proposals for the following one are given by ISL representatives. After a general discussion, the Managing Directors and Government representatives meet in closed session and make proposals for the Advisory Board. Once all the meetings on the different themes have taken place, the Directors prepare a general programme taking into account the wishes formulated and the limitations related to funding and personnel. This balanced programme is again discussed in total by the Advisory Committee and approved by the Board of Directors.

Concluding Remarks

The discussion of the ISL programme provides an occasion for informal contacts which are not only fruitful for ISL itself but also for the government and industry representatives. Early contacts in the field of research provide valuable information and help to avoid duplication of research work in the two countries or between ISL and certain national institutions.

It is important not only for efficiency's sake but also because nothing is more discouraging for a scientist than realising that he is rediscovering what is already known.

INTERNATIONAL COOPERATION IN AERONAUTICAL RESEARCH AND DEVELOPMENT CARRIED OUT BY INTERNATIONAL ORGANISATIONS

by

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Avenue de Tervuren 273
B-1150 Brussels

CONTENTS

1. INTRODUCTION

Over the last three decades the European Aeronautics Industry has recorded a number of major successes. The build-up of a powerful capability in the field of large transport aircraft (Airbus), commuter aircraft and helicopters are well-known examples in the civil sector. Similarly, there have been successes in the military field, such as the major Tornado and Mirage aircraft programmes. These achievements have encouraged the expectation of a bright and successful future. All these positive results and achievements were only possible because of an early recognition of the need to collaborate and cooperate in the field of research, technology and development.

"Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO Community."

AGARD - 1952

"Improving cooperation among member nations in aerospace research and development;"

AGARD - 1952

"permit an effective use of funds for research and development procurement (...) in order to promote European defence equipment collaboration (...)"

IEPG - 1976

"The Community's aim shall be to strengthen the scientific and technological basis of European Industry (...) by promoting cooperation in the field of Community research technological development and demonstration with third countries and international organisations (...)"

Art 130, Rome Treaty - 1957

Figure 1 "Quotations" from NATO/AGARD, IEPG and EEC missions

Since the early fifties this need for increasing and safeguarding the scientific and technological potential has stimulated political initiatives such as

NATO/AGARD, IEPG and EEC to strengthen cooperation in aeronautical RT&D [1] which is clearly identified in their respective missions (Figure 1).

To put all these collaboration activities into perspective and to provide an order of magnitude it is interesting to note that the European Community's R&D programmes (1,500 MECU [2] in 1989 or 3 % of the total Community budget but with a prospect of increasing the R&D budget up to 5 % after 1992) are small compared with the R&D budgets of Member States (over 35,000 MECU in 1986); and the total cost of projects supported through the programmes is only equivalent to about 4% of total estimated public and private spending on civil research (about 50 milliard ECU per year). Even if all the other civil European collaborative actions are taken into account - EUREKA, COST, ESA, CERN etc. - the bulk of research continues to be financed and carried out at the national level.

It is also important to emphasise that in referring to "research and technology" this presentation 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 system is carried out; technology demonstration activities are included in this definition of research and technology.

A considerable number of multinational organisations, initiatives and activities has sprung up over recent years (Figure 2 and 3). Some of these are effective and some less so. The diverse nature, scope and affiliation of those various bodies, such as NATO (AGARD, CNAD-activities, SC), CEC, EUREKA, IEPG/EDIG, GARTEUR, AECMA, ICAS etc., requires some explanation including definitions of on-going and planned programmes, their objectives and basic concepts. The need to identify precisely where excessive duplication and overlap occur among these national efforts is pressing. It is the purpose of this presentation to review present arrangements and assess their merits and short-comings with special emphasis on the situation of Aeronautical Research and Development in Portugal, Greece and Turkey.

The following subjects will be addressed :

- **objectives and structures of cooperative programmes**
- **review of cooperation schemes in R&D**
- **description of programmes and projects**
- **funding systems schemes for R&T cooperation**
- **the specific situation concerning RT&D in Portugal, Greece and Turkey**
- **conclusions**

2. OBJECTIVES AND STRUCTURES OF COOPERATIVE PROGRAMMES

Before moving on to the subject of Aeronautics Cooperation, and in particular its individual Research and Technology programmes, it is worth reiterating that the product cycle in the aeronautics industry is extremely long-typically, of the order of 25 years - comprising 5 - 10 years to develop a new technology; 5 years for application; and 10 years of production.

Hence, there are collaboration programmes which are essentially **strategic** in character, aimed primarily at **basic technologies** and enabling technologies (such as most of the EEC and IEPG programmes). This distinguishes them from other programmes (such as EUREKA and NIAG) which are predominantly **tactical and market-driven**, aimed mainly at **application technologies and product technologies.** These differences are very significant. The longer-term planning and commitment at industry level is not possible under, or appropriate to, shorter-term programmes which have a narrower commitment at product level. A further, and crucial, implication is that, while national funding support may be sufficient for the achievement of tactical product objectives, realisation of programmes with strategic objectives requires a unified, centralised method of funding. The importance of European product collaboration has increased rapidly since the early sixties. Nowadays, almost every major aircraft programme in Europe is launched on a collaborative basis. These programmes are placed either directly under the responsibility of all partners, or, more often, under the responsibility of a consortium created by the partners. Generally, they include development and series manufacturing, but sometimes they are almost entirely limited to this latter activity (as in some helicopter and military aircraft programmes).

The launch of new aeronautical products which offer important improvements over previous products requires that new techniques and technologies are studied and validated first. These research tasks were generally undertaken on a national basis by aerospace companies themselves, often jointly with national scientific organisations, by internal financing or with the help of public funding.

During the seventies, it became more and more obvious that the costs of important research activities preceding development programmes were increasing. It also became clear that technology cooperation was necessary for the successful conduct of these activities. The required technology collaboration was therefore developed, directly between the aerospace companies, under the aegis

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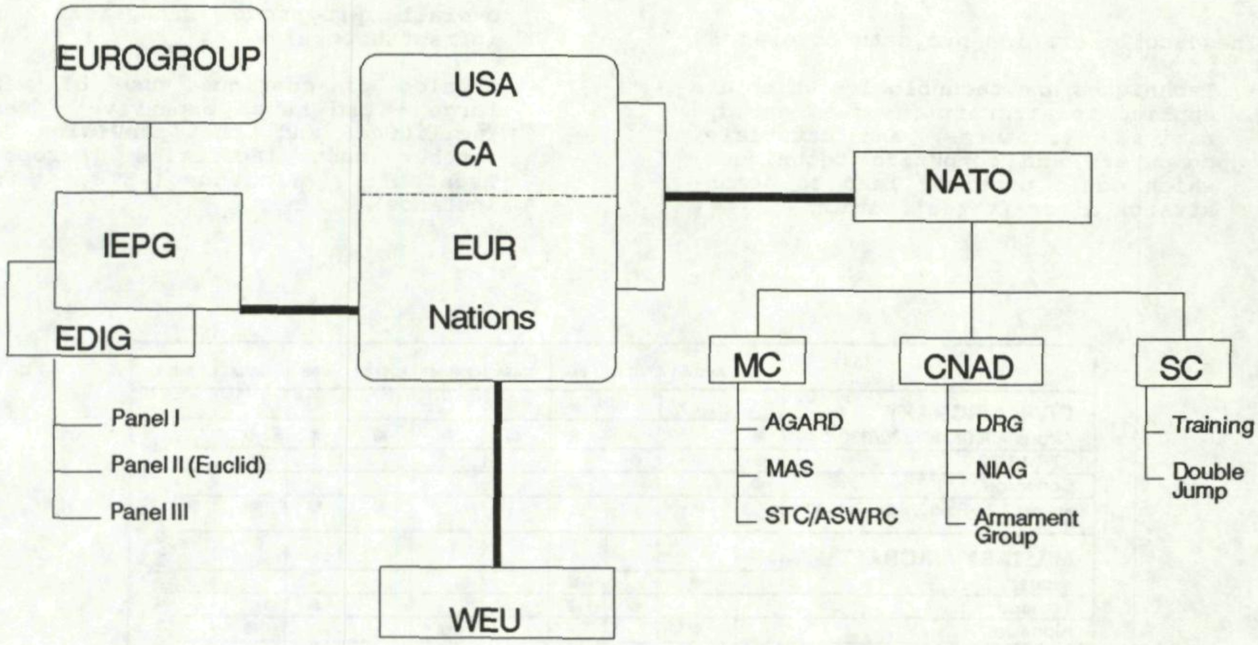
[1] Research Technology and Development

[2] Millions of European Currency Units

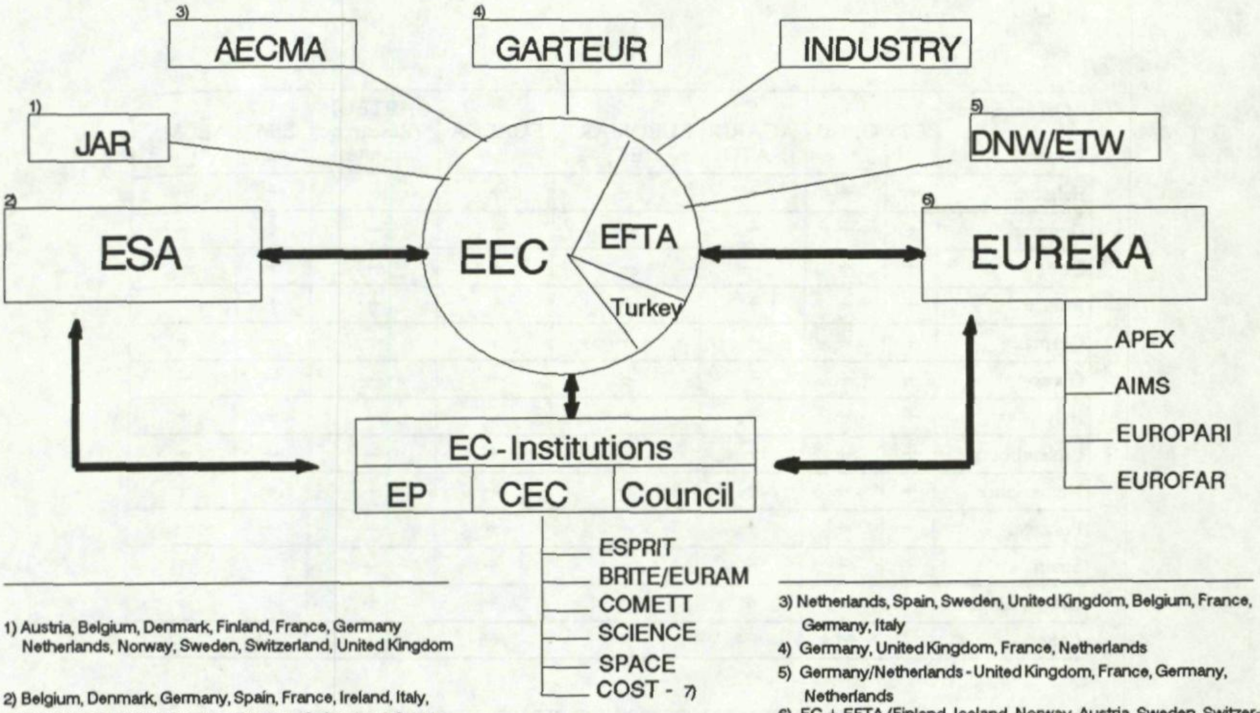
ORGANISATIONS FOR R&D COOPERATION



J.H. Wild - 90/1

Figure 2

ORGANISATIONS FOR R&D COOPERATION



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1) Austria, Belgium, Denmark, Finland, France, Germany Netherlands, Norway, Sweden, Switzerland, United Kingdom

2) Belgium, Denmark, Germany, Spain, France, Ireland, Italy, Netherlands, United Kingdom, Sweden, Switzerland, Austria, Norway (Canada, Finland)

3) Netherlands, Spain, Sweden, United Kingdom, Belgium, France, Germany, Italy

4) Germany, United Kingdom, France, Netherlands

5) Germany/Netherlands - United Kingdom, France, Germany, Netherlands

6) EC + EFTA (Finland, Iceland, Norway, Austria, Sweden, Switzerland) + Turkey

7) EC + EFTA + Turkey

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Figure 3

of European organisations such as the EC, or between aerospace research organisations and Government-run research institutions.

These collaboration projects covered :

- Techniques and technologies which are applied to aircraft (such as aerodynamics, structures, and materials, computers and computing techniques) which could possibly lead to demonstrator aircraft realisation.
- Techniques and technologies aimed at reducing development and manufacturing cost (new and automated manufacturing processes, CAD-CAM systems and tools and methods which allow better overall programme management and infrastructure).
- Studies of continued use of very large - and hence expensive - test facilities and the provision of further such facilities (European Transonic Windtunnel/ETW, for instance).

	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

Figure 4 Some of the European Aeronautics Industry's collaborative programmes

Organisation Country	EC	OECD	AGARD (NATO)	EUROMART (EC)	EUREKA	GARTEUR (Research Institutes)	ESA (Space)	AECMA
Belgium	+	+	+	+	+	–	+	+
Denmark	+	+	+	–	+	–	+	+
Eire	+	+	–	–	+	–	+	–
France	+	+	+	+	+	+	+	+
Germany	+	+	+	+	+	+	+	+
Greece	+	+	+	–	+	–	–	–
Italy	+	+	+	+	+	–	+	+
Luxembourg	+	+	+	–	+	–	–	–
Netherlands	+	+	+	+	+	+	+	+
Portugal	+	+	+	–	+	–	–	–
Spain	+	+	+	+	+	–	+	+
United Kingdom	+	+	+	+	+	+	+	+
Others	/	+14	+4	/	+6	/	+4	+2

Figure 5 European Organisations and countries involved in aeronautical RT+D initiatives

3. REVIEW OF COOPERATION SCHEMES IN R&D

The matrix in Figure 6 shows the most important existing European cooperation schemes in aeronautics research and technology and the relationship between the participants in the scheme and the type of cooperation concerned.

The various kinds of cooperation which exist can be summarised as follows :

- Cooperation by Information Exchange
- Cooperation involving government research establishments and industry
- Cooperation on the infrastructure to support production programmes
- Cooperation in provision of test and other general facilities
- Cooperation in training and education
- Cooperation under the aegis of supranational organisations

Each of these subjects is addressed in turn in the text which follows.

There now exists in Europe and to a certain extent with "outside" partners a large and increasing number of collaborative ventures.

The extensive experience gained over the past twenty years or so, and the success thus far achieved, has greatly raised the level of confidence and competence of the participants in this method of working. Collaborative working is not only seen to be practicable, but to have significant economic advantages. In this review only the most prominent examples of aeronautical cooperation can be described, a short abstract of which can be found in the Annex.

3.1 COOPERATION BY INFORMATION EXCHANGE

The simplest form of cooperation is informal discussion and the exchange of information on technology study results and findings, etc. Cooperation of this kind most commonly occurs between companies engaged on a common project, or through professional institutions and societies, universities, etc., and particularly international meetings and conferences, such as those organised by **ICAS**[1]. Another prominent promoter is NATO's Advisory Group for Aerospace R&D, **(AGARD)**.

Cooperation at this sort of broad international level does not normally extend beyond exchange of information - and even this is frequently restricted by considerations of security interests and technology transfer regulations. Within Europe, however, the situation is improving and becoming much more encouraging.

3.2 COOPERATION INVOLVING GOVERNMENT RESEARCH ESTABLISHMENTS AND INDUSTRY

The exchange of information occurring for example under the AGARD Technology Programme is directed at improving the defence posture of the NATO nations.

Another important stimulus to cooperation is the desire to work more effectively and economically. A good example of this is **GARTEUR**[2] which specifically addresses aeronautical research and technology. It came into being with the objective of optimising the resources of the national research establishments of certain nations and industry, in particular by avoiding

Type of Cooperation & Organisation Involved	Participant(s)	Government	Industry	Research Establishments	Test Establishments	Educational Organisations
Information Exchange	AGARD (NATO)	Main support	Contribution	Contribution	—	—
	Technical Societies	Contribution	Sponsor	Contribution	—	Main activity
	Universities	—	—	—	—	Main activity
Research and Technology	ACOTEG	Support	Main support	—	—	—
	AFARP	Management & Funding	—	Execution	Execution	—
	BRITE, ESPRIT and	Support	Main support	Contribution	—	—
	other CEC initiatives	Support	Main support	—	—	—
	EUREKA	Funding	Support	Contribution	—	Contribution
	IEPG/EDIG	Main support	Main support	—	—	—
	GARTEUR/CARTE	Main support	Main support	Execution	—	—
Related Activities (*Standards, Airworthiness, Education, etc*)	AECMA	Support	Main support	—	—	—
	JAR	Funding	Contribution	—	—	—
	VKI (NATO)	Funding	—	—	—	Main activity
Infrastructure, Facilities	DNW	Funding	User	User	Main activity	—
	EAN	—	Design, operation & use	—	—	—
	ETW	Funding	User	Contribution	Main activity	—

Figure 6 Current European cooperation schemes in aeronautics research and technology

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[1] ICAS = International Congress of Aeronautical Sciences

[2] GARTEUR = Group for Aeronautical Research and Technology in Europe

wasteful duplication of effort. GARTEUR, which is governed by a memorandum of understanding (MOU) between the participating nations, sponsors and coordinates certain programmes within these establishments and to a lesser extent some R&T activities within industry. Therefore it is mirrored by a corresponding industrial grouping called **CARTE** [1]. There is no GARTEUR common budget so far. GARTEUR/CARTE constitutes an example on Government-led collaboration which brings together government, industry and national research establishments in the pursuit of common objectives.

The only example of a multi-national Government establishment dedicated to research and technology is the already-mentioned franco-german Institut de Saint Louis (**ISL**).

3.3 COOPERATION ON THE INFRASTRUCTURE TO SUPPORT PRODUCTION PROGRAMMES

Mention was made earlier of the increasing need for cooperation programmes for the design and manufacture of specific products, both civil and military. Such programmes having become increasingly common, the need was recognised for cooperation in improving the infrastructure on which these programmes rely - for example, in regard to information, communication, regulations and standards, and design and production technology.

Some of this work now goes on within specific project-oriented organisations but when the demand arises bodies such as EUREKA and to some extent the **CEC-ESPRIT** and **BRITE**-programmes provide an appropriate forum, particularly at present in respect of information technologies and computer-integrated manufacturing. A number of cooperative ventures aimed at providing the technology base necessary to support the product programmes have also been developed. For instance, several companies worked together in the formation of **ACOTEG** [2] to further their common objectives in the field of advanced composite materials and the allocation of these materials to aerospace products. This group also coordinates individual company programmes to avoid undesirable duplication.

3.4 COOPERATION IN PROVISION OF TEST AND OTHER GENERAL FACILITIES

Virtually all major cooperative aeronautical production programmes involve the use of specialised facilities for test and demonstration purposes. As an example, two windtunnel facilities, the **DNW and ETW** [1] should be mentioned. The first was funded by the Dutch and German Governments and is used by many nations, including the United States. The latter will be operational in the mid-1990s and is planned to be a self-financing commercial venture.

Experience has shown that arrangements for establishing and operating common major aeronautical facilities need to be developed on a case-by-case basis. At present, the possible establishment of a **Parallel Computing Centre** to serve European interests is jointly being investigated.

3.5 COOPERATION IN TRAINING AND EDUCATION

One example of a specialised education establishment, multi-national in character and expressly serving the interests of the aeronautical community, is the **Von Karman Institute (VKI)** for Fluid Dynamics Research, in Brussels, founded by NATO. This is essentially a post-graduate teaching and research organisation with extensive experience.

Another international training and education initiative is the NATO **"Double Jump"** programme under the NATO Science Committee with the principal objective of promoting interaction between researchers from at least two countries and two research sectors (universities, governments, industry). Investigations into improved coordination of **post-graduate education in aeronautics** are under way between the CEC, some European universities, and industry, possibly including existing schools/universities, scholarships, and industrial experience programmes.

3.6 COOPERATION UNDER THE AEGIS OF SUPRANATIONAL ORGANISATIONS

3.6.1 EUROPEAN COMMUNITY PROGRAMMES

The European Community is placing increasing emphasis on an overall strategy for technological research, cooperation and innovation. The Single European Act recognises the strengthening of the scientific and technological basis of European industry as one of the aims of the Community, and specifies that a multi-annual Framework Programme to be adopted by the Community shall lay down scientific and technical objectives, define priorities, allocate funds, and specify the programmes developed within

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[1] CARTE = Collaboration on Aeronautical Research and Technology in Europe

[2] ACOTEG = Advanced Composites Technology Group

[1] DNW = Duits -Nederlandse Windtunnel
ETW = European Transonic Windtunnel

each activity. There is also generally a greater political readiness to work for the participation of non-Community countries in new technology programmes (e.g. COST and EUREKA).

3.6.1.1 METHODS OF TECHNOLOGICAL RESEARCH, COOPERATION AND INNOVATION IN EUROPE

European Community research programmes are broadly based on the following methods of organisation :

a) **Direct Action** - Research by Community scientific and technological staff in Joint Research Centres (JRC) and similar agencies (JET).

b) **Shared-cost Action** - Promotion of *research work by joint financing* measures and by contracting out work to specialist agencies. Shared-cost action facilitates cooperation between industry, research institutes and the European Community. At the same time, it opens up a new European dimension. Several programmes are based on this type of action, including ESPRIT, RACE and BRITE.

c) **Concerted Action** - The aim here is to create a European research/technology area, transcending national frontiers, by defining targets jointly (avoiding pointless duplication), arranging meetings between research teams, the exchange of scientists and ensuring wide dissemination of research findings. Examples of this type of programme are INSIS, CADDIA and EUROTRA.

3.6.1.2 COMMUNITY ACTION ON NEW TECHNOLOGIES

There are four main areas of action :

a) Creation of a European technology space.

b) Information, training, and evaluation of short, medium and long- term development of new technologies.

c) Development and use of key new technologies via Commission programmes for research and development.

d) Support for European cooperation and exchange in the fields of science and technology.

3.6.1.3 THE FRAMEWORK PROGRAMME

On 15th December 1989 the Council of Ministers reached agreement on a new Framework Programme for the period 1990 - 1994. The content of this third Framework Programme, was conditioned by the accelerating pace of technological progress in the current phase of economic growth in the industrialised countries, and the need to strengthen the *competitiveness of European industry* at the international level. The total amount of ECU 5.7 billion in the new Framework Programme is divided into two parts : ECU 2.5 billion for the years 1990 - 1992 and ECU 3.2 billion for the years 1993 - 1994.

The new Framework Programme will overlap with the preceding one (1987 - 1991). ECU 3.1 billion are still available in the budget of the old one, which means that a total of ECU 8.8 billion will be available for Community research during the next five years (i.e. ECU 1.75 billion annually for the years 1990-1994). Activities begun within the new Framework Programme will thus be added to those currently running.

The new Framework Programme is characterised by the regrouping of activities around a limited number of strategic axes, thus guaranteeing activities. Regrouped under three main headings (enabling technologies, management of natural resources, management of intellectual resources), six activities will be covered : information and communications technologies; industrial and materials technologies; environment; life sciences and technologies; energy; human capital and mobility.

In absolute terms the enabling technologies (information and communications technologies; industrial and materials technologies) will still be the main areas of Community action, as they were under the previous Framework Programme.

The new one will be implemented by means of 15 specific research programmes (there were 37 in the previous Framework Programme). This means a concentration of Community activities which will increase the interdisciplinary nature of the research, and reinforce the synergy between different approaches and related technologies.

It also allows the Community to diversify its means of supporting research. Besides the specific programmes involving all Member States (which will typically finance up to 50 % of the cost of collaborative projects involving companies, universities and research centres), it will also be possible to run programmes which only involve some Member States; and to associate the Community with national initiatives and EUREKA projects.

3.6.1.4 SOME EXAMPLES OF AERONAUTICS-ORIENTED R&T - EEC INITIATIVES AND PROGRAMMES

- **EUROMART - Study on "European Cooperative Measures for Aeronautical Research & Technology"**

  In February 1987 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 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 cooperation.
- The current European research and technology cooperations, in order to assess their merits and to determine if they adequately cover the perceived needs.
- The requirements for improved, enhanced and expanded cooperations, and the new measures which could meet these.

The study which is now completed, confirmed 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.

There is a crucial relationship between technological competitiveness and commercial success in the aeronautics business and it is now clear that the European Aeronautics Industry 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.

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 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.

Specific proposals for cooperative work were contained in the study report. Some **sixty outline projects** were identified as candidates for new near-term and medium-term cooperative programmes (see Annex).

The Commission of the European Communities was invited:

- 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. (A first step was taken with the Council Decision of March 89 to launch a two year Pilot-Programme on Aeronautical R&T under the BRITE/EURAM programme).

- <u>The BRITE/EURAM Programme</u>

Basic Research in Industrial Technologies for Europe (BRITE) and European Research on Advanced Materials (EURAM).

This new single programme builds on the experience and the achievements already emerging in the first BRITE and EURAM programmes, and will cover cost-shared research projects concerning advanced materials technologies, design methodology and assurance for products and processes, application of manufacturing technologies and technologies for manufacturing processes. It will also carry out research aimed at the development of the European aeronautical technology base, including aerodynamics, acoustics, airborne systems and equipment and propulsion systems. The programme will include coordinated activities and feasibility awards aimed at assisting small and medium-sized enterprises.

A separate research programme in aeronautics will be prepared to follow this pilot phase.

- **THE ESPRIT II PROGRAMME**

European Strategic Programme for Research and development in Information Technologies (ESPRIT).

Adopted in 1984, ESPRIT was conceived for a 10-year period with three main objectives : to help provide European IT-industry with the technology base it needs to meet the competitive requirements of the 1990s, to promote European industrial cooperation in IT, and to contribute to the development of internationally-accepted standards.

For the second phase of ESPRIT (ESPRIT II) the sectors for support have been adapted to the rapid pace of technological development and consolidated into three sectors : Microelectronics and peripherals, Information-processing Systems and IT Application Technologies. New emphasis is being placed on strengthening European capabilities in such areas as Application Specific Integrated Circuits (ASICS), high-performance parallel-processing computers and new office workstations, while ESPRIT II also includes a new component, Basic Research Actions, designed to complement the main industrial programme.

THE MONITOR PROGRAMME

The purpose of this programme is to contribute to the identification of new directions and priorities in the common research and technological development policy and to establish more clearly the relationships between it and the other common policies and to the improvement of evaluation of R&D programmes. It comprises three activities : Strategic Analyses in the field of Science and Technology (SAST); Forecasting and Assessment in Science and Technology (FAST); and the Support Programme for the Evaluation Activities in the field of Research (SPEAR).

- **THE SCIENCE PROGRAMME**

Stimulation des Coopérations Internationales et des Echanges Nécessaires aux Chercheurs en Europe (SCIENCE).

This programme consists of a range of activities selected on the basis of their scientific and technical quality, which have as their aim the establishment of a network of scientific and technical *cooperation in interchange* at a European level. It aims to improve the efficacy of research in Member States and to help reduce the scientific and technical disparities between them. It covers all fields of the exact and natural sciences, such as mathematics, physics, chemistry, life sciences, earth and ocean sciences, scientific instrumentation and engineering sciences.

- **LARGE-SCALE SCIENTIFIC FACILITIES**

The programme consists of a range of temporary financial support arrangements granted to scientific institutions in the Community having large-scale research and development facilities or installations which, in return for the Community contribution, agree to make these facilities or installations available to scientists and researchers working in universities, public research centres or industrial laboratories.

Researchers and scientists to whom facilities and installations have been made available will be able to benefit from research grants and funds provided for in the SCIENCE plan. The programme covers all fields of the exact and natural sciences, research and precompetitive technological development.

- **TECHNOLOGICAL COOPERATION WITH NON-EC STATES AND COMPANIES (COST)**

  Two other forms of scientific and technical cooperation should be referred to. The first is the COST programme, which for some eighteen years has been the vehicle for cooperation between EC Member States and non-EC European countries in a number of research sectors.

  COST activities are making an increased contribution to the implementation of the Framework Programme and playing a specific and complementary role by encouraging scientific and technical cooperation between the Community and the members of COST by means of research projects of a multilateral character (see Annex).

  The second is the cooperation between European firms being promoted by EUREKA. EUREKA schemes receive appropriate support - in some cases financial - from governments of the participating countries and from the European Communities.

3.6.2 EUREKA

This Programme is outside the European Community Framework and is intended as a symbol of Europe's determination to bring the full effect of its innovative potential to bear in international economic and technological competition.

EUREKA was established in 1985. It is aimed at strengthening the European base of technology research through industrial collaboration. It encourages industry to cooperate on projects. All project proposals put forward by company-consortia to the respective government departments are examined and considered by the EUREKA Ministerial Conference twice a year. A label "EUREKA" is awarded to those which are approved. With this label the project qualifies for national funding. There is no common funding.

The experience of the EUREKA initiative also confirms the growing interest in European collaboration as a means of improving Europe's technological base and making the most of the opportunities offered by the Internal Market. Since EUREKA was launched in 1985, 213 cooperative cross-border projects have been announced in the fields of information technology, robotics, communications equipment and other high-technology fields. These include projects in the area of flexible automated assembly (FAMOS), as well as projects related directly to Aeronautics such as APEX, AIMS, EUROPARI and EUROFAR. The total EUREKA project portfolio has currently an estimated value of some 3.8 billion ECU, which is equivalent to around 1 billion ECU per year (about half the level expected to be generated by the Community programmes); and already some 800 organisations - two-thirds of them industrial - are involved. The number of projects coming forward confirms the growing industrial and university interest in collaboration and cooperation. In the case of EUREKA, cooperation has the added dimension of facilitating cooperation between companies and institutes in Community Member States, the EFTA countries and Turkey. Around half the EUREKA projects involve participants from each grouping.

EUREKA is an important complement to the Community's own activities in support of the objective of improving the mastery of new technologies. The European Commission plays a full role inside EUREKA on behalf of the Community in an effort to maximise the synergy between the groups of research activity.

Some examples of projects with aeronautical content are summarised in the Annex.

3.6.3 INDEPENDENT EUROPEAN PROGRAMME GROUP (IEPG)

The IEPG was established in 1976 to provide an European forum for the discussion of defence equipment matters. All European members of NATO, with the exception of Iceland, are members.

In 1984 an initiative was taken to revitalise the Group to give political direction to the National Armament Directors. Simultaneously, the "European Defence Industrial Group" (EDIG) was reactivated by European Armament Manufacturers as an industrial consulting body to IEPG.

The purpose of the Group as now constituted is to promote European collaboration so as :

- to permit more effective use of R&D funds;
- to increase equipment standardisation and interoperability;
- to promote the two-way street between Europe and North-America.

In pursuit of the new goals adopted after 1984, the European Defence Industry Study (EDIS) was commissioned. The 1987 EDIS report, "Towards a Stronger Europe", presents a framework for new initiatives towards greater European equipment collaboration. Its central features are a trans-national open and competitive market; close

EUCLID

Lead nation	CEPA	RTP	REMARQUES
RFA	CEPA 1 : Airborne Radar Tech	1.1 Mission related aspects 1.2 New materials and components 1.3 Active antenna 1.4 Programmable signal processor 1.5 Synthetic aperture antenna 1.6 Expert system for airborne radar	
FRANCE	CEPA 2 : Silicon Microelectronics	2.1 Build up technology 2.2 Qualification 2.3 Cells and library 2.4 ICCS (ASIC) 2.5 Signal processor	
PAYS BAS	CEPA 3 : Composite Materials	3.1 Behaviour under operational conditions 3.2 Damage measurement 3.3 Damage repair under operational conditions 3.4 increase temperature resistance 3.5 Electromagnetic window 3.6 Protection structures	
RFA	CEPA 4 : Modular Avionics	4.1 Conceptual studies,system aspects 4.2 Components of core avionics 4.3 Essential parts of all avionics	
GB	CEPA 5 : Electromagnetic Gun	5.1 Gun aspects: Rail 5.2 Gun aspects: Coils 5.3 Gun aspects: Electrothermal 5.4 Energy storage and switching	
FRANCE	CEPA 6 : Artificial Intelligence	6.1 AI for smart crew station 6.2 AI for logistic,training and simulation 6.3 Time critical decision aids 6.4 Autonomous systems	
ESPAGNE	CEPA 7 : Signature Manipulation	7.1 Radar signature 7.2 Optical,IR signature 7.3 Acoustic signature	Comprendrait également toute recherche sur la diminution des signatures et les contre-mesures
ITALIE	CEPA 8 : Optronics	8.1 Thermal imaging and night vision sensor 8.2 Laser (sensor communication) 8.3 Optical processing 8.4 Fiber optic data network 8.5 Fiber optic sensors	
NORVEGE et FRANCE	CEPA 9 : Surveillance Satellite	9.1 Hardened sensors,SAR,optical sensors 9.2 Hardened ground system including data distribution 9.3 Data processing realtime including information processing	
PAYS BAS et GB	CEPA 10 : Underwater Acoustics	10.1 Active long range sonar 10.2 Active short range sonar 10.3 Passive sonar	
PAYS BAS	CEPA 11 : Simulator training technologies		

EUCLID: European Cooperation for the Long-term in Defence
CEPA: Common European Priority Area
RTP: Research Technology Project

Figure 7

coordination of research; and encouragement of the Developing Defence Industry nations (DDIs) - Greece, Portugal and Turkey. The EDIS report and the Action Plan derived from it are central to the increasing role of the IEPG. The new plans for the IEPG are reflected in changes to the organisational structure. The three Panels which direct the day-to-day work of the IEPG are now concerned with : Panel I - Operational Requirements and Programmes; Panel II - Research and Technology; and Panel III - Economic Matters, including implementation of the Action Plan. Further support is available from subsidiary groups under each Panel. Another structural change is the establishment of a Permanent International Secretariat in Lisbon. But these organisational developments are of lesser importance than the details of the Action Plan itself. The most fundamental change is the opening-up of the European defence equipment market to contractors from all IEPG nations. There are two measures by which the same openness across all the IEPG nations should be achieved. First, every IEPG country has now nominated a focal point where companies from other member states can register an interest in becoming suppliers. Second, nations will start producing on a regular basis defence contracts bulletins, so that companies from one IEPG country will be able to bid for a tender as though in their own domestic market. There are doubts about its precise effects. This is why the IEPG has to consider carefully the difficult issues of 'juste retour' and technology transfer.

Another issue highlighted by the Action Plan is support for Developing Defence Industry nations (DDIs) - Greece, Portugal and Turkey. A specific Working Group is looking at ways to encourage the DDIs to play a full part in the European defence scene. Several countries have for example offered places on project management training courses and in research establishments for DDI officials and scientists. Another area upon which the Action Plan places great emphasis is Research and Technology (R&T) currently covered under the Cooperative Technology Projects (CTPs) and the recently launched EUCLID-Programme. This programme has already budgeted 120 MECU for 1990 and singled out eleven Common European Priority Areas (CEPA) as listed in Figure 7.

The main objective is to launch multinational exploratory developments from which cooperation will ensure common development and then production of truly European pieces of equipment and systems.

4. FUNDING SCHEMES FOR R&T COOPERATION

The funding of research and technology programmes in industry follows a three-stage escalating process.

As a **first stage**, each company attempts to fund as much as possible of the required programmes from its own resources. The merits of this arrangement are:

- All work is under direct company control, enabling fast reaction and realignment where necessary.
- Indisputable ownership rights are maintained on developed technology.
- Assessment of resources, and commitment thereof, is positive and clear.

The **second stage** is initiated by the inevitable limitations in direct Company resources, which then leads to each Company seeking national government funding of part of its overall programme. The effects of this development are :

- All work is still under the control of the company, but each project must be individually approved by the national contracting authority.
- Ownership and exploitation rights must be shared with national Government departments, and possibly with Government-recommended partners, with attendant legal complexity and effort.
- Prediction and commitment of available resources is less clear.

With the limitations on available national Government funding resources, coupled with the pressure on available specialist manpower due to expanding technology, there is an increasing need to seek cooperation across national frontiers as a basis for sharing the work load and for obtaining additional funding support. The key features of this **third stage** are :

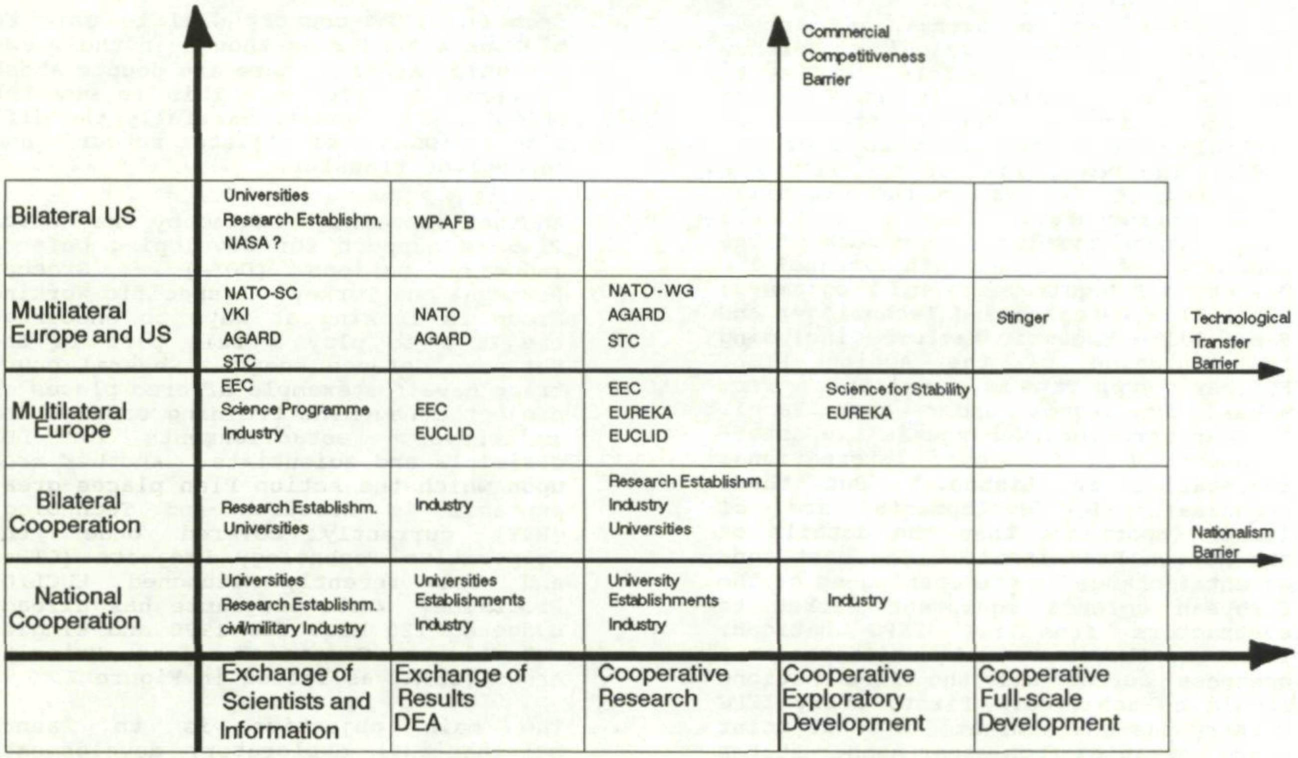
- A proportion of the work in each Company must be under shared control, with approvals as required by the multi-national funding authority, involving more complex bureaucratic and management complexity and effort due to distance, and to differences in language and legal systems.
- Both the prediction of available resources and their commitment involve longer timescales.

It is important to recognise that this three-stage escalating process is driven by the special circumstances of the aeronautics industry, namely, the long-term planning and long-term financing necessitated by the extreme length of the product cycle (25 years in total, comprising 5-10 years for a new technology; 5 years for application; and 10 years of production).

5. STATUS OF RT&D COOPERATION IN PORTUGAL, GREECE AND TURKEY

The intention of the following illustrations (Figure 8, 9 and 10) is to show in a two-dimensional way the inter-

R & D COOPERATION GREECE



Bilateral US	Universities Research Establishm. NASA ?	WP-AFB			
Multilateral Europe and US	NATO-SC VKI AGARD STC	NATO AGARD	NATO - WG AGARD STC		Stinger
Multilateral Europe	EEC Science Programme Industry	EEC EUCLID	EEC EUREKA EUCLID	Science for Stability EUREKA	
Bilateral Cooperation	Research Establishm. Universities	Industry	Research Establishm. Industry Universities		
National Cooperation	Universities Research Establishm. civil/military Industry	Universities Establishments Industry	University Establishments Industry	Industry	
	Exchange of Scientists and Information	Exchange of Results DEA	Cooperative Research	Cooperative Exploratory Development	Cooperative Full-scale Development

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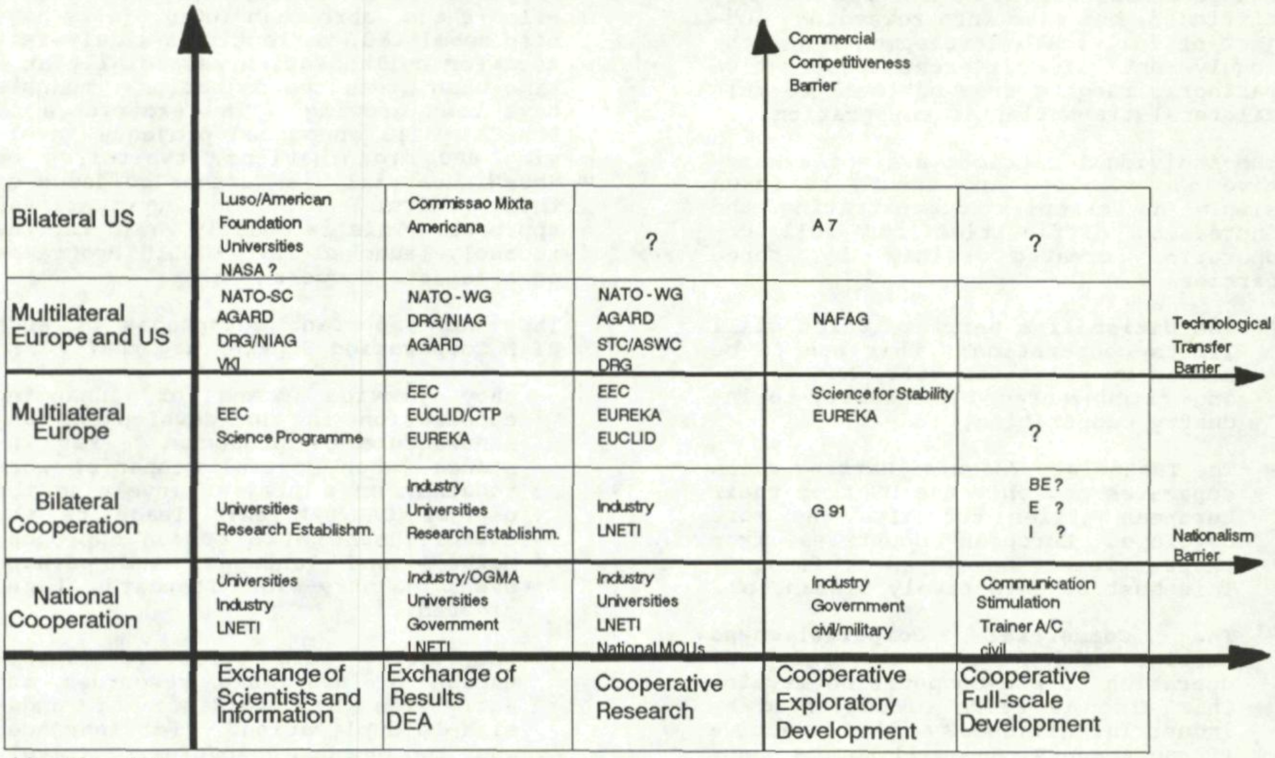
Figure 8

R & D COOPERATION PORTUGAL



	Exchange of Scientists and Information	Exchange of Results DEA	Cooperative Research	Cooperative Exploratory Development	Cooperative Full-scale Development
Bilateral US	Luso/American Foundation Universities NASA ?	Commissao Mixta Americana	?	A 7	?
Multilateral Europe and US	NATO-SC AGARD DRG/NIAG VKI	NATO-WG DRG/NIAG AGARD	NATO-WG AGARD STC/ASWC DRG	NAFAG	
Multilateral Europe	EEC Science Programme	EEC EUCLID/CTP EUREKA	EEC EUREKA EUCLID	Science for Stability EUREKA	?
Bilateral Cooperation	Universities Research Establishm.	Industry Universities Research Establishm.	Industry LNETI	G 91	BE ? E ? I ?
National Cooperation	Universities Industry LNETI	Industry/OGMA Universities Government LNETI	Industry Universities LNETI National MOUs	Industry Government civil/military	Communication Stimulation Trainer A/C civil

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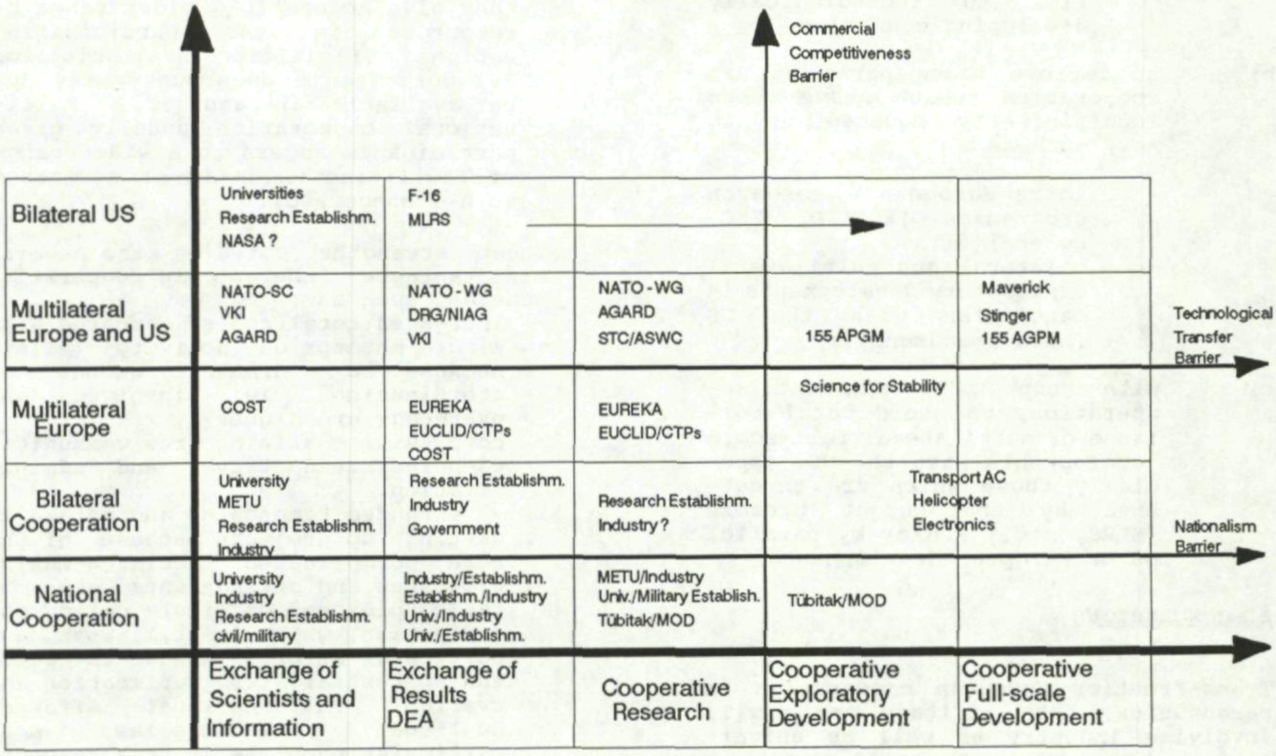
Figure 9

R & D COOPERATION TURKEY



	Exchange of Scientists and Information	Exchange of Results DEA	Cooperative Research	Cooperative Exploratory Development	Cooperative Full-scale Development
Bilateral US	Universities Research Establishm. NASA ?	F-16 MLRS			
Multilateral Europe and US	NATO-SC VKI AGARD	NATO-WG DRG/NIAG VKI	NATO-WG AGARD STC/ASWC	155 APGM	Maverick Stinger 155 AGPM
Multilateral Europe	COST	EUREKA EUCLID/CTPs COST	EUREKA EUCLID/CTPs	Science for Stability	
Bilateral Cooperation	University METU Research Establishm. Industry	Research Establishm. Industry Government	Research Establishm. Industry ?		Transport AC Helicopter Electronics
National Cooperation	University Industry Research Establishm. civil/military	Industry/Establishm. Establishm./Industry Univ./Industry Univ./Establishm.	METU/Industry Univ./Military Establish. Tübitak/MOD	Tübitak/MOD	

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Figure 10

dependence of the form of cooperation (from the relatively easy subject of exchange of scientists to the increasingly difficult, but also more rewarding, subject of full-scale development) and the involvement of different cooperative partners, ranging from national to multilateral-transatlantic cooperation.

The individual matrices are not exhaustive nor complete and should be taken simply as examples demonstrating the increasing difficulties for full cooperation created mainly by three barriers :

- **The Nationalism Barrier**, which still limits cooperation; this has to be broken by political will, but is being circumvented by industry-to-industry cooperation.
- The **Technology Transfer Barrier** which separates not only the US from their European allies but also the more developed European countries from their lesser-developed partners. This must be selectively dismantled.
- The **Commercial Competitiveness Barrier**, which tends to limit cooperation to pre-competition levels. This also is being circumvented by industrial alliances with respective IPR-agreements, and will not be - nor should be - totally dismantled.

The medium-term goals are

a) to overcome the three barriers through

  - industrial alliances
  - increased information to all potential partners concerned to understand the necessity of technology flow to technologically developing countries.

b) to improve those parts of R&D cooperation which have been insufficiently covered up to now, such as :

  - intra-european research programmes (EUCLID, EEC, Eureka)
  - bilateral and multilateral exploratory developments in particular with the US (Nunn-amendment).

c) with respect to armament cooperation, to avoid total collapse of multilateral full-scale developments with the US, especially those which are threatened by the budget process (MLRS, etc.) and/or by parallel US or European developments.

6. CONCLUSIONS

Trans-frontier European cooperation in aeronautics, both military and civil, involving industry as well as universities, has increased significantly in the past few years. The experience has been overwhelmingly positive. The European Community's own cost-sharing programmes have been oversubscribed. For example, in response to the call for proposal for the BRITE/EURAM-Aeronautics Pilot-Phase, more than 100 projects have been submitted, reflecting a widely-felt need for collaboration, especially at a time when pressures on national budgets have been growing. The experience of EUREKA - 213 announced projects involving 800 organisations, two-thirds of them industrial -is further evidence of this thirst for a supranational approach. This is equally valid for the recently-launched IEPG/EUCLID Programme on Armaments Cooperation.

The most important advantages of such RT&D Cooperation Schemes are that :

- they provide means of enhancing cooperation in the development and manufacture of products. (For instance, when several companies work together on a project involving the use of CAD/CAM this leads to the establishment of a common approach, methods and language, and perhaps even industry-wide standards being created).
- they allow more effective exploitation of available resources and activities by avoidance of undesirable duplication. (For instance, when two or more companies separately conduct research into, for example, noise suppression in aircraft cabin structures, there inevitably will be large overlaps in the ground covered, in terms of test equipment, computer programmes, etc. A joint approach to the solution of the problems not only affords savings in regard to the hardware and software required but also in respect of expensive skilled manpower).
- they give access to a wider range of resources in the participating nations. (Facilities available for R&T purposes in one country may not be available in another. Multinational cooperation usually gives participants access to a wider range of facilities which is of advantage to all concerned).

These strengths outweigh the several disadvantages inherent in cooperation schemes, such as :

- increased total costs compared with single-enterprise activity (mainly because a greater amount of coordination is involved and overheads are higher).
- complexities arising from communication increased travel and administration.
  - extended timescales and delays in setting up projects because of the more complicated decision-making processes and arrangements, etc.
- the complex and difficult policy coordination, which is still weak, and particular efforts needed to reduce the potential for duplication and overlap in national efforts. Dual-Use technologies pose particular problems in this respect.

With respect to Dual-Use, the common features in the technological requirements of the defence and civil sectors affect several key areas : sensor and signal/image processing, complex system design and information processing, man-machine interfaces, vehicle technology, advances design and manufacturing technology, electronics/ microelectronics/optoelectronics/bio-electronics, communication, advanced materials, medical technology, electrical and mechanical engineering, and energy conversion.

The development of these Dual-use technologies is funded in Europe through defence and/or civil R&D programmes, depending on the country concerned and the degree of resources devoted to military R&D.

The need to improve coherence between civil and defence programmes, where they overlap, in order to optimise the use of resources (manpower and financial) has been recognised at national level. However, the most significant duplication arises not in national programmes but in those between European countries. To the extent that civil applications are taking the lead in driving the development of several Dual-Use technologies, civil programmes to promote European technological cooperation, in particular Community programmes and EUREKA, contribute to a more efficient use of resources. Their impact is, however, inevitably limited, given their size and scope.

In those technological fields which are more driven by defence applications, much remains to be done to establish effective cooperation between countries. An important step forward in this direction is the IEPG Euclid-Programme.

There are a number of factors which have constrained coordination to date. These include : differences between civil and military R&D; different patterns of involvement by the public and private sectors; different traditions in higher education; different sectorial priorities reflecting in part specific economic and social concerns.

Finally, it should be noted that, while within any particular cooperative venture there will be an avoidance of duplication, unless events are very carefully monitored there exists the possibility that, as cooperative schemes proliferate, the same areas of work will come to be addressed under different schemes drawing on different budgets !

A strong Technology Community based on broad cooperation is an indispensable element in the strategy for 1992, particularly because of its link with the *liberalisation of public procurement.*

While an international disposition can to some extent be taken for granted in aeronautics, certain small countries have developed particularly high skills of cooperation and communication which can be utilised in the management of joint European research projects. In their aeronautics industry, international cooperation on R&D is the rule; and their University researchers follow developments in the larger Member States without national or linguistic bias.

It requires a fundamental change in attitude on both sides, which is only possible in the context of a long-term strategic commitment of the kind initiated by the Community's aeronautics programme. It involves a shift from a thinking in terms of technology transfer to one of joint technology acquisition.

While the European Community can provide elements of a generally-applicable policy framework for aeronautics which is often missing in the small countries, the absence of coherent government policy, itself the result of pessimism regarding the possibilities of small *countries, remains a handicap.*

REFERENCES

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- European Communities Economic and Social Committee "Europe and the new technologies 1988"
- European Community Research Programmes within the "Framework Programme 1987 - 1991", 1989
- ICA Ph. Roger, Status and Objectives of R&T Cooperation within the Alliance, ISSC 1989

ANNEX

- EEC R&T Framework Programme
- EUROMART Synopsis
- EUREKA
- IEPG - Proposed Principles for Funding and Managing EUCLID
- NATO - Science Committee
- ICAS
- Von Karman Institute (VKI)
- AGARD
- GARTEUR/CARTE

CURRENT FRAMEWORK PROGRAMME (1987-91)

	(million ECU)		%
1. **Quality of life**		375	6,9
1.1. Health	80		
1.2. Radiation protection	34		
1.3. Environment	261		
2. **Towards a large market and an information and communications society**		2 275	42,3
2.1. Information technologies	1 600		
2.2. Telecommunications	550		
2.3. New services of common interest (including transport)	125		
3. **Modernization of industrial sectors**		845	15,6
3.1. Science and technology for manufacturing industry	400		
3.2. Science and technology of advanced materials	220		
3.3. Raw materials and recycling	45		
3.4. Technical standards, measurement methods and reference materials	180		
4. **Exploitation and optimum use of biological resources**		280	5,2
4.1. Biotechnology	120		
4.2. Agro-industrial technologies	105		
4.3. Competitiveness of agriculture and management of agricultural resources	55		
5. **Energy**		1 173	21,7
5.1. Fission: nuclear safety	440		
5.2. Controlled thermonuclear fusion	611		
5.3. Non-nuclear energies and rational use of energy	122		
6. **Science and technology for development**		80	1,5
7. **Exploitation of the sea bed and use of marine resources**		80	1,5
7.1. Marine science and technology	50		
7.2. Fisheries	30		
8. **Improvement of European S/T cooperation**		288	5,3
8.1. Stimulation, enhancement and use of human resources	180		
8.2. Use of major installations	30		
8.3. Forecasting and assessment and other back-up measures (including statistics)	23		
8.4. Dissemination and utilization of S/T research results	55		
Total		5 396	100

NEW FRAMEWORK PROGRAMME (1990–94)

	(million ECU)		%
I. Enabling Technologies			
1. Information and communications technologies	2221		39
– Information technologies		1352	
– Communications technologies		489	
– Development of technological systems of general interest		380	
2. Industrial and materials technologies	888		16
– Industrial and materials technologies		748	
– Measurement and testing		140	
II. Management of natural Resources			
3. Environment	518		9
– Environment		414	
– Marine science and technology		104	
4. Life sciences and technology	741		14
– Biotechnology		164	
– Agricultural and agro-industrial research, including Fisheries		333	
– Biomedical and health research		133	
– Life sciences and technologies for developing countries		111	
5. Energy	814		13
– Non-nuclear energies		157	
– Nuclear fission safety		199	
– Controlled nuclear fusion		458	
III. Management of Intellectual Resources			
6. Human capital and mobility	518		9
– Human capital and mobility			
Total		5700[1])	100

[1]) including ECU 60 million for the dissemination and exploitation and ECU 550 million for the Joint Research Centre.

Some examples of projects with aeronautical content are as follows :

a) APEX - an information exchange proposal aimed at providing the necessary infrastructure to support the full range of engineering data and its use in collaborative projects.

b) EUROPARI - a drive towards total integration of the manufacturing process from the preliminary design stage through manufacturing and quality assurance.

The EUROPARI framework comprises :

- . SPIDER - integrated small metal parts design and manufacture
- . EIFAS - a flexible assembly system
- . SPACE - automated electrical cable harness manufacture
- . ECRAS - automated composite-material parts manufacture
- . PARADI - automated production management of groups of workshops

c) AIMS - the objective is to supply European aerospace manufacturers with a distributed knowledge-based management system for the development and maintenance of embedded software.

d) EUROFAR - a high-quality air transport system combining fixed-wing and rotorcraft technologies. It would permit short or vertical take-off from sites near city centres and would compete with existing surface transport.

e) FORMENTOR - methodology and real-time software based on artificial intelligence to monitor complex systems such as aircraft, nuclear plants, and oil rigs and to prevent malfunctions.

f) AAA - an advanced amphibious flying boat for use in environmental roles in which landbased aircraft cannot operate.

g) COMPOSITE CERAMICS - application in axial flow gas turbines.

EUROMART

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.

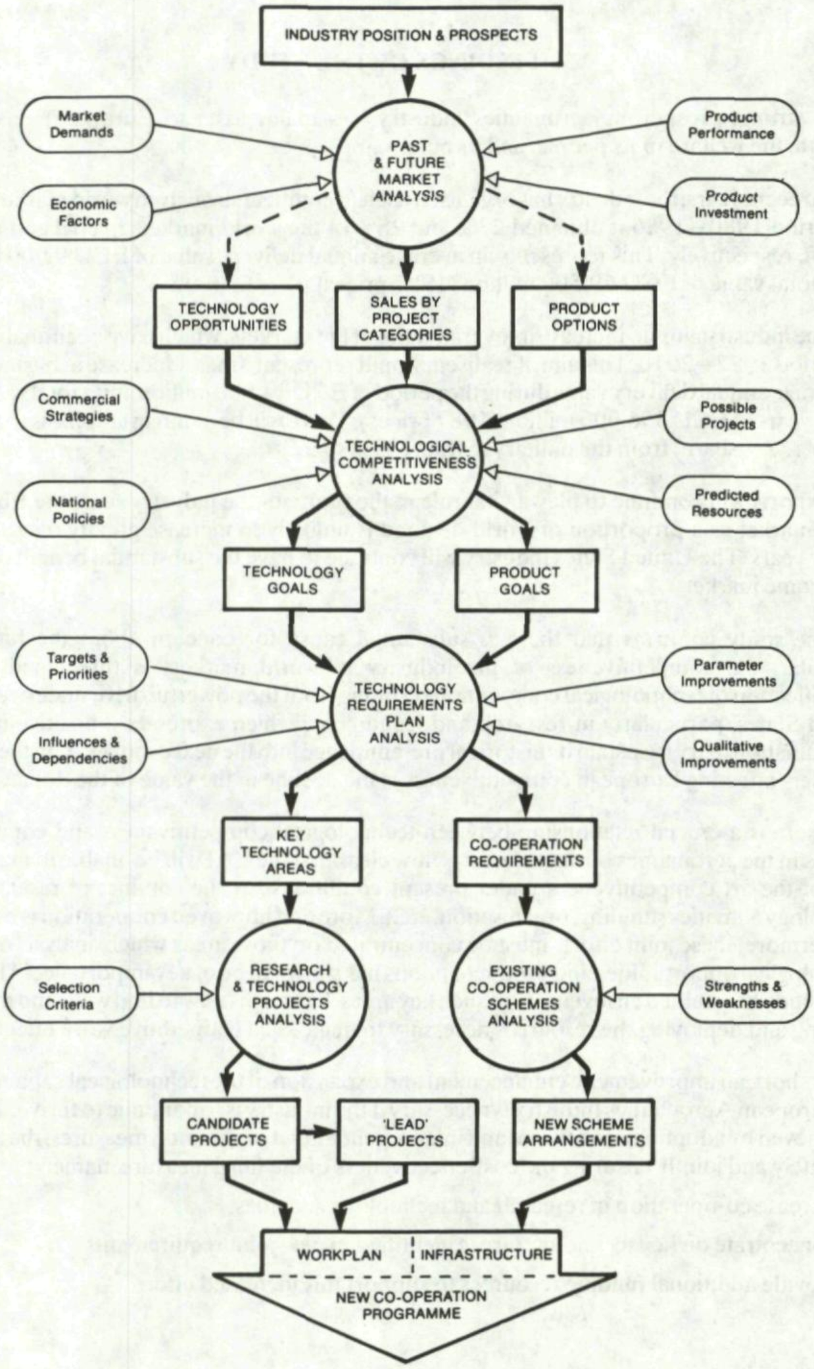

Fig.S1 EUROMART Study methodology

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.

MULTILATERAL AGENCIES AND PROGRAMMES

Technological Cooperation between European Industries in the Field of Innovation

EUREKA

1. BASIC LEGAL INSTRUMENT	EUREKA - Cooperation between European firms and research institutes in the field of advanced technologies. EUREKA was set up on 17 July 1985 by the first EUREKA Conference of Ministers held in Paris and attended by Ministers from 17 countries and Members of the Commission of the European Communities; at the second EUREKA Conference of Ministers in Hanover on 6 November 1985 a declaration of principles relating to EUREKA was approved. At present (November 1987) the 12 EC Member States and the EC Commission are taking part in EUREKA, along with Finland, Norway, Austria, Sweden, Switzerland, Iceland and Turkey.
2. OBJECTIVES	The objective of EUREKA is to raise, through closer cooperation between European enterprises and research institutes in the field of advanced technologies, the productivity and competitiveness of Europe's industries and national economies on the world market, and hence strengthen the basis for lasting prosperity and employment. EUREKA is intended as a symbol of Europe's determination to bring the full effect of its innovative potential to bear in international economic and technological competition.
3. SPECIFIC CHARACTER, CONDITIONS	The exchange of technologies between European enterprises and institutes is a prerequisite for a high technological standard of European industry. EUREKA projects are intended to encourage and enlarge this exchange. EUREKA is open to all efficient capacities including those existing in small and medium-sized enterprises as well as in smaller research institutes. EUREKA projects serve civilian purposes and are directed at both private and public sector markets. EUREKA projects will satisfy the following criteria: — Compliance with the general objectives set out above. — Cooperation between participants (enterprises, research institutes) in more than one European country. — Some identified expected benefit from pursuing the project on a cooperative basis. — The use of advanced technologies. — The aim of securing a significant technological advance in the product, process or service concerned. — Appropriately qualified participants - technically and managerially. — Adequate financial commitment by participating enterprises. EUREKA projects are prepared by an intensive exchange of information among enterprises, institutes and - where appropriate - potential users. The projects are then finalized through consultations among the relevant parties. The governments of the countries of the enterprises/institutes participating in an agreed project and, when appropriate, the Commission establish its compliance with the objectives and criteria laid down for EUREKA. They then jointly inform the Conference of Ministers through the High Representatives Group, which consists of representatives from the participating countries. Such information includes a project description, an analysis of compliance with the objectives and criteria of EUREKA, and an indication of any additional measures involving third parties. EUREKA projects are not intended as a substitute for existing European technological cooperation, such as programmes sponsored by the European Communities, COST, CERN, ESA projects, bilateral or multilateral cooperative projects, or its further development. Their purpose is instead to extend or supplement it. The European Communities may participate as a partner in EUREKA projects, e.g. with their own research capacity, research and development programmes and financial facilities.

EUREKA (contd.)

4. AREAS COVERED	EUREKA projects are intended to relate primarily to products, processes and services in the following areas of advanced technology: — information and telecommunications — robotics — materials — manufacturing — biotechnology — lasers — environmental protection and transport technologies — energy research — marine technology. EUREKA also embraces important advanced technology research and development projects aimed at the creation of the technical prerequisites for a modern infrastructure and the solution of transnational problems. EUREKA cooperation currently comprises 164 projects (as at November 1987) including, for instance, the European Research Network (COSINE). Expenditure on these projects is estimated at just under 4,000 million ECU. The projects are largely concentrated in the fields of manufacturing technology and robotics (24%), information technology (21%) and biotechnology (15%).
5. ECONOMIC IMPACT	Promoting, facilitating and hence strengthening industrial, technological and scientific cooperation on projects directed at developing products, processes and services having a worldwide market potential and based on advanced technologies. Make European industries more competitive on the world market and hence strengthen the basis for lasting prosperity and employment.
6. STRUCTURE AND FORM OF COOPERATION	The parties to a EUREKA project determine the form of cooperation. The coordinating body is the EUREKA Conference of Ministers. Its members are representatives of the governments of the participating countries and of the EC Commission. It is the responsibility of the Conference of Ministers to develop further the substance, structures and goals of EUREKA and to assess the results. The High Representatives of each of the participating countries and of the EC Commission meet approximately every three months in order to assist the Conference of Ministers in carrying out its tasks and to prepare its meetings, including a briefing on projects to be notified to the Conference of Ministers. Since July 1986 there has been a EUREKA secretariat in Brussels, comprising seven specialists and six administrative staff. The secretariat acts as a clearing house by collecting and disseminating information on EUREKA projects and proposed projects. In addition it assists enterprises and institutes in establishing contacts with potential partners for EUREKA projects. To ensure consistency between EUREKA and Community measures, an official from the EC Commission has been seconded to the EUREKA secretariat. The Commission also provides the secretariat with financial and technical resources, e.g. a data base service.
7. FUNDING GUIDELINES	As a rule no EC funds are available for financing EUREKA projects. The enterprises/institutes participating in a EUREKA project finance the project form their own funds or by recourse to the capital market. EUREKA projects are supported by the governments of the participating countries and - where the Commission is a participant - by the European Communities too. The Commission will also examine, in the context of its current policy on the development of financial instruments, the possibility of mobilizing new, private sources of finance.

EUREKA (contd.)

8. RESULTS AND PROSPECTS	The establishment of a large homogeneous, dynamic and outward-looking European economic area is essential to the success of EUREKA. Hence the completion of the internal market and the implementation of the Luxembourg declaration between the European Communities and the EFTA countries will benefit EUREKA. In particular this means that EUREKA should give an impetus to current efforts in the following areas: — elaborating joint industrial standards at an early stage; — eliminating existing technical obstacles to trade; — opening up the system of public procurement. Actions under EUREKA will be carried out in accordance with the principles of international free competition.
9. POSITIONS a) of the Economic and Social Committee	The Economic and Social Committee *welcomes the initiative EUREKA represents in bringing together industrial enterprises which may be competitors today but tomorrow must take advantage of an expanding European market so that they compete successfully on the world markets* (Information Report on New Technologies, 16 January 1986, CES 851/85).
b) of the European Parliament	*The European Parliament is of the view that EUREKA should benefit most of the Member States. Hence the creation of a European scientific and technological area should be speeded up as a framework for the EUREKA initiative* (Resolution of the EP, OJ No. C 175 of 15 July 1985). The European Parliament also asks that EUREKA be exclusively geared to high-technology cooperation projects of a civilian nature (EP Resolution, OJ No. C 190 of 20 July 1987, page 77).
10. ADDRESS FOR FURTHER INFORMATION	EUREKA Secretariat 19 H, Avenue des Arts, Bte 3 1040 Brussels Belgium

Sources:

Declaration of Principles relating to EUREKA, Hanover, 5 - 6 November 1985

Information Report on New Technologies, drawn up by the Section for Energy and Nuclear Questions of the Economic and Social Committee, CES 851/85, 16 January 1986

Resolution of the European Parliament, OJ No. C 175 of 15 July 1985; No. C 190 of 20 July 1987

EUREKA - Technologische Zusammenarbeit in Europa, German Federal Ministry for Research and Technology, February 1987

PROPOSED PRINCIPLES FOR FUNDING AND MANAGING THE EUCLID

(IEPG/PII. SUBGROUP ON FUNDING AND PLANIFICATION/Oct.89)

1. The EUCLID will consist of several Common European Priority Areas (CEPAs) in each of which there will be a number of Research and Technology Projects (RTPs).

2. The general conditions for the EUCLID will be defined in the Programme MOU (PMOU). Individual RTPs will be covered by Implementing Arrangements to the PMOU.

3. Each RTP will be undertaken by international contributors represented by a single legal contractor, chosen by competition wherever practicable. The single legal contractor will be responsible, where appropriate, for placing subcontracts with the other participating contractors.

4. CEPAs will be established for a period between five and ten years. Every two or three years the results of the RTPs will be reviewed and renewed plans set out. Requests will be put out for bids for the new period

   The MOU will include arrangements to allow new participants to contribute to the RTP.

5. Each RTP will be managed by a Lead Nation on behalf of Participating Nations. The Lead Nation will deal with the single legal contractor representing national industries and laboratories of all countries whose governments have decided to participate in the RTP.

6. The Lead Nation will use its own contract rules and regulations as amended to ensure the rights of other participating Nations, in accordance with the PMOU.

COST AND WORK SHARES

7. The participation of a nation in a RTP implies its participation in the corresponding CEPA :

   The intended participation of the nations in a RTP will be on the basis of an equal share of the anticipated costs, unless if the nations participating in a specific RTP decide another breakdown (for example, to facilitate the participation of a DDI nation to this RTP).

8. Each nation will fund its workshare to the RTP.

9. The participating industries will be expected to contribute, using their own funds in accordance with national rules.

INTELLECTUAL PROPERTY RIGHTS (IPR)

10. The results of all work carried out by a participant contractor in pursuance of an RTP will be property of that participant, or the joint property of participating contractors as appropriate.

11. Participant contractors will be required to produce full reports of all work contributed to the RTPs with which they are concerned. These reports will, in clearly stating, the results obtained and the conclusion drawn, including all foreground information and such background information as is required (a) for the purposes of RTP and (b) to enable the foreground information to be used for further research and/or development. The reports will identify, where applicable, any lines of research that were found to be unsuccessful.

12. Participating contractors will be encouraged to cooperate closely within the RTP. Potential contractors will be required to indicate in their responses to Requests for Proposals (RFPs), how they propose to cooperate, and these proposals will be taken into consideration in the evaluation of bids.

13. Participant contractors will also be required to provide assistance in the assimilation of their reports, if requested to do so by participating Governments. Contractors will be required to provide such assistance only within a maximum period of six months from the availability of the report. Assistance may be provided at the premises of either the contractor or the participating Government. Any travel and subsistence costs incurred by either party will be met by the participating Governments.

14. All Governments participating in an RTP will have a right of access to the information contained in the reports produced by the participating contractors. They will have the right of use, or have used on their behalf, this information for their own Defence purposes free of charge.

15. All Governments participating in an RTP will, in addition, have the right to use, or have used, the information in the reports produced by the participating contractors for other governmental purposes on prior agreement of fair and reasonable terms with the owner.

16. If the assistance of the participant contractors is needed in connection with further research or for exploitation he will provide such assistance in fair and reasonable terms.

17. Governments participating in a CEPA will also have rights with regard to information generated by an RTP to which they have not contributed. Those Governments will, at no cost, be entitled to have access to the full reports generated by the RTP for the purpose of managing the CEPA. Those Governments will be entitled to use, or have used, the reports for their own defence purposes, subject to a compulsory licence from the owner on fair and reasonable terms, including a levy to those nations participating in the RTP. For other purposes free negotiation will prevail.

18. The single legal contractor will make available to the Lead Nation, on a regular basis for dissemination to IEPG Nations, information outlining the progress of the RTP for which it is responsible.

19. Participating contractors will make arrangements amongst themselves regarding information and material exchanges within RTP so as to ensure the efficient performance of their contractors. The exchange of information and materials for RTP purposes will be at no cost.

MANAGEMENT OF A CEPA

20. Panel II will choose CEPA topics for approval by the NADs.

21. For each CEPA a Steering Committee will be established representing those nations expressing interest in the CEPA. The chairman of this Committee, who will be appointed by Panel II, will report to Panel II on the management of the CEPA. The Steering Committee will prepare an outline description of the technical scope and estimated costs of the component RTPs. Each nation will indicate in which RTPs it is likely to participate, thereby setting a target figure for its contribution to the CEPA.

22. The Steering Committee will task working groups of experts from the nations participating in each RTP with the specification of their projects.

23. Nations will review these specifications and subject to the approval of their national authorities will express their intention of commitment in the form of an LOI.

24. On the basis of recommendations of the CEPA Steering Committees, Panel II appoints nations to lead each of the RTPs.

25. Using these specifications, Lead Nations will invite competitive proposals.

26. Each RTP will be managed by a representative of the Lead Nation who will chair an Advisory Group representing the Participating Nations.

27. This Advisory Group will select the winning proposals and inform the CEPA Steering Committee.

28. Nations will commit themselves to RTPs by signing implementing arrangements to the MOU.

29. In each RTP, each Participating Nation bears a cost share equal to the cost of the work that will be done by its national industries or laboratories, according to the selected proposal.

30. The Lead Nation on each RTP will place and manage the contract for the RTP. Each Participating Nation will put at the disposal of the Lead Nation funds to cover the work undertaken in that nation.

NATO Science Committee

Since 1958, the Interantional Scientific Exchange Programme, guided by the NATO Science Committee, has promoted international collaboration and interaction among scientists as part of a wide spectrum of non-military, non-political activities covering science, environment and culture.

The Science Committee programme, which has been focussed mainly on academic exchanges and basic science was extended experimentally in 1982 to include researchers from industry and government laboratories. This extended programme, concisely identified as a "double jump" programme, has the principal objective of promoting interaction between researchers from at least two countries and two reserach sectors (university, government or industry).

In this spirit, the NATO "Double Jump" Programme neither competes with, nor replaces, existing national or international programmes. Its aim is rather to offer new, diversified opportunities to extend existing international scientific exchange activities.

ICAS

The International Council of the Aeronautical Sciences (ICAS) provides a forum for discussing common problems in aeronautical science and technology. Its membership, open to all countries, now comprises the national associations dedicated to the advancement of aeronautics of twenty-six countries.

VKI

The von Karman Institute for Fluid Dynamics offers teaching and post-graduate traning in basic and applied research, mainly in Fluid Mechanics (Aerospace, Environmental, Turbomachinery). It is funded by some of the NATO-countries and contracts.

AGARD

The Advisory Group for Aerospace Research and Development is a NATO Agency under the authority of the Military Committee.

According to its Charter, the mission of the AGARD is to bring together the leading personalities of the NATO Member-Nations in the fields of sciences and technology relating to aerospace for the following pruposes :

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and developement (with particular regard to its military application).
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving cooperation among member nations in aerospace research and developement;
- Exchanging of scientific/technical information;
- Providing assistance to member nations in aerosapce reserach and development;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

GARTEUR/CARTE

GARTEUR was formed in 1973 as a multinational organisation (France, Germany, United Kingdom, The Netherlands) and covers the following disciplines :

Aerodynamics
Flight Mechanics
Structures and Materials
Propulsion
Helicopters

It brings Industry and Government Establishments together and provides a valuable role in international collaboration by minimising duplication and maximising the use of resources. It has no common budget, funds are modest in size and allocated on a purely national basis, and it represents only a few member-states (United Kingdom, France, Germany and The Netherlands).

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The papers cover background material and experiences in planning and execution of aeronautical research and developments obtained by the various American and European authors. They served as a basis for a Seminar held in Greece, Portugal and Turkey which aimed at assisting the authorities in planning aeronautical research and development. Various aspects of national and international cooperation in aerospace are highlighted. The Seminar, sponsored by AGARD Headquarters, was implemented by the Consultant and Exchange Programme.

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