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EUROPEAN 2ND GENERATION SUPERSONIC COMMERCIAL TRANSPORT AIRCRAFT

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Introduction.

The above headline implies that there is a 1st generation supersonic passenger aircraft, namely the Concorde.

For the experts of the aerospace community this is of course not really news but it can be supposed that quite a big percentage of the flying public is not always aware of this, e.g. because the entry into service now already dates back more than 20 years, further only two airlines - Air France and British Airways - each operate only a handful of these supersonic aircraft in a niche market.
In more than 20 years of regular passenger service with the Concorde there has never been an accident or serious incident. So the conclusion is that the technical feasibility of supersonic passenger transport has been demonstrated in abundance.

In spite of technically successful operations the Concorde never matured to an economically successful level in terms of fleet size for the manufacturers. Reason being that the Concorde lacks the flexibility to adjust to an ever changing market:

The oil-crisis of the seventies with dramatically rising fuel prices killed the sensitive economics of this aircraft, relatively low passenger capacity and range performance limits it to the North Atlantic market and even on this limited market it cannot fly everywhere because of excessive take-off noise requiring exemptions from all current noise regulations and thus the need to find tolerant air-ports.

These factors are all indicative of the design challenge a supersonic passenger aircraft of the 2nd Generation will provide to the engineers: Range capability and passenger capacity which are technology dominated, environmental acceptability and last but not least economic viability.

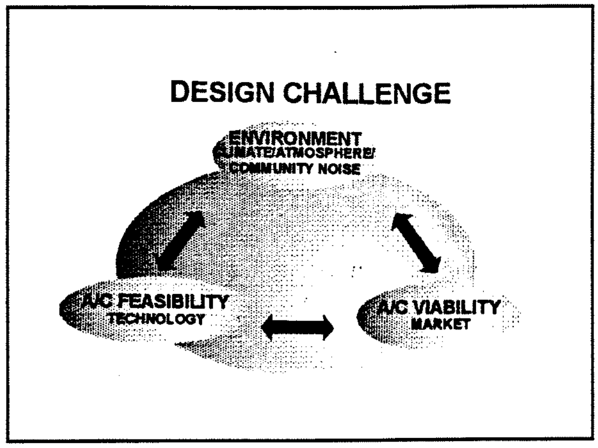

Figure 1

Market.

All this is interrelated and, more than this, all must be achieved against a well matured subsonic competition from which any 2nd Generation Supersonic Commercial Transport will have to wrestle it's market share. However, a help is the the strong evidence that air travel and especially long distance travel will continue to grow at high rates.

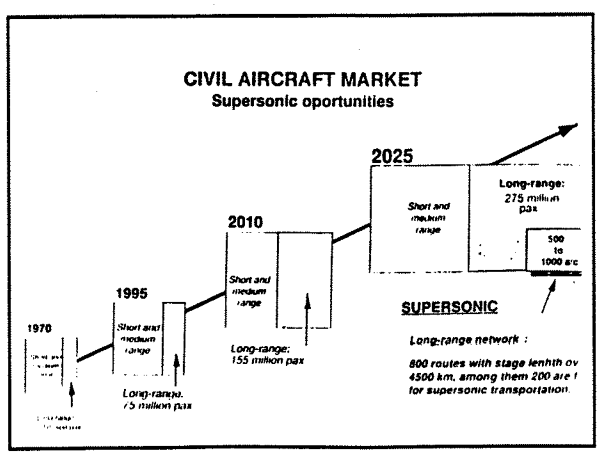

Figure 2

Analysts expect the civil aircraft market to double by the year 2010 - in terms of Revenue Passenger kms per year - relative to 1996 figures, and then again to double in the period from 2010 to 2025.

The long range market is expected to benefit disproportionally. Of this long range market 150 routes have been identified that seem to be especially suitable for supersonic operations (mainly long haul overwater routes with sufficient passenger demand).

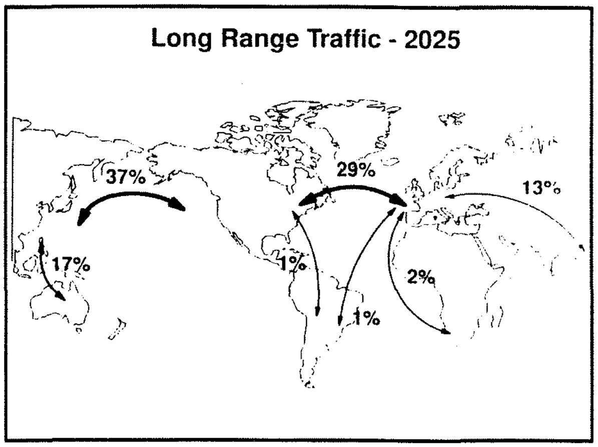

Figure 3

Depending on the aircraft characteristics and market penetration achieved a fleet of several hundred SCTs could be in operation around the year 2025.

Viability

Mandatory basis of any viability discussion is of course an acceptable level of environmental impact of a mature fleet of SCTs.

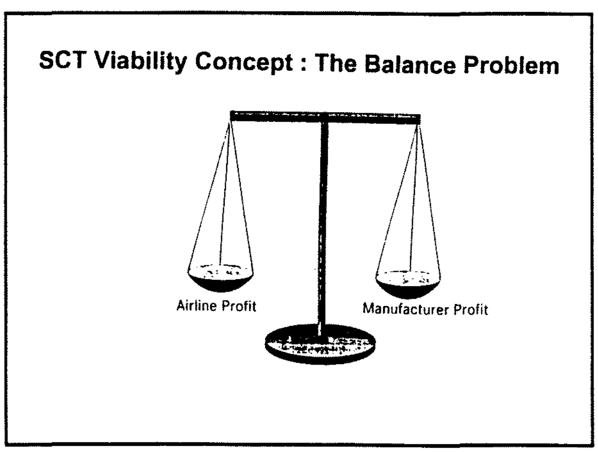

Figure 4

Provided this is given the big question will be whether a 2nd Generation SCT can strike the balance of providing an equally attractive return on investment for both the operating airline and the manufacturer.

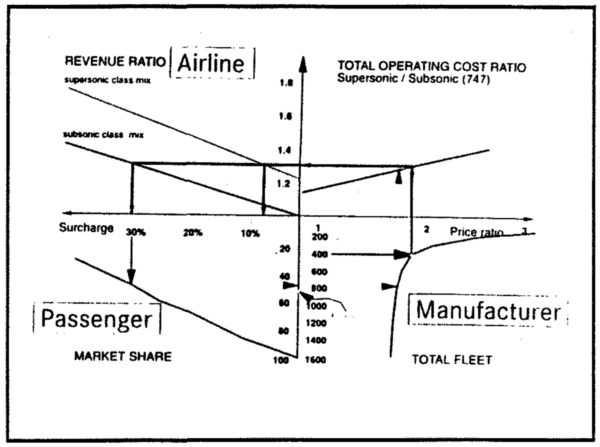

Figure 5

3 players are active in this viability game:
The Passenger
The Manufacturer
The Airline

It all starts with the **passenger** who is expected to be ready to pay a surcharge relative to a subsonic ticket for faster and thus more comfortable travel. This is in much the same manner that high speed railway travel is commanding a surcharge relative to the normal ticket price!

Depending on the acceptance of the passenger to pay more or less surcharge the market penetration or market share will vary. Low acceptance will lead to low market share which in turn affects the 2nd player, the **manufacturer,** by leaving a smaller number of aircraft to be produced. Smaller number of aircraft produced will drive the unit cost up and consequently lead to higher operating cost for the 3rd player the operating **airline** which in turn will need a higher revenue to compensate for higher operating cost of the SCT relative to the subsonic competition.

This could end rapidly in a vicious spiral with no chance of reaching viability. Fortunately, if gradients are positive, the above spiral also will work in the favourable direction and could lead to viability superior to that of the subsonic competition.

The situation is eased for the airline by the fact that the speed advantage of the SCT will attract more high yield passengers. For the subsonic fleet on the other hand this means that it will have to cope with the remaining low yield (discount) traffic.

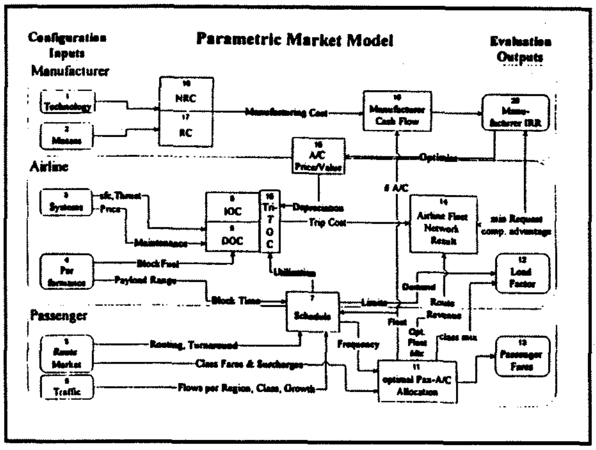

Figure 6

Interrelations and sensitivities are very complex. A way to achieve deeper insight and better understanding of the market behaviour is the computer simulation of the global air travel market which needs to model the behaviour of the 3 players: PASSENGER, AIRLINE and MANUFACTURER.

Obviously mutual influences of sub- and supersonic aircraft operated in mixed fleets must be modeled as realistically as possible and further the model should allow for SCTs of different technical characteristics such as speed, range performance and passenger capacity to be evaluated in terms of which market shares can be achieved and finally what return on investment can be expected for the airline and manufacturer. This will establish the requirements leading to the specification for the most viable configuration.

Design Specification

Specification

The aircraft Design Specification has been developed to satisfy the current best understanding of market requirements. Following discussions with a number of potential airline customers it has become clear that the worldwide route network of a 2nd generation SCT may be divided into 3 key types

1. Trans Pacific
2. Europe to West Coast USA
3. Europe to Far East

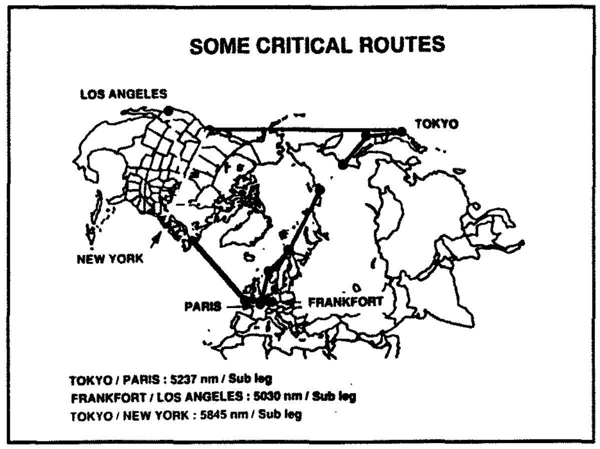

Figure 7

As each of these routes become possible so more market is captured. However, the difficulty of producing a viable aircraft becomes greater as range and the subsonic leg are increased.

Instead of designing to achieve these real distances 2 initial specifications were developed which, could they be met, would allow the aircraft to fly all routes encompassed by them.

DESIGN SPECIFICATION

RANGE	SUBSONIC LEG	
5000nm	0	285 pax 3 CLASS
6000nm	2000nm	228 pax 3 CLASS

Figure 8

It is clear that 2 significantly different designs will be required and that there is a greater challenge to achieve the longer range, particularly including the long subsonic leg. As the objective is to design an aircraft which would be economically viable realistic standards of passenger comfort have to be included.

Environmental Constraints

A new SCT will only be launched if it can be demonstrated to be environmentally acceptable. As well as meeting the same noise and emissions regulations that will be applied to subsonic aircraft flight routing must take account of the sonic boom generated. All of these issues were encountered during development of Concorde but since then environmental concerns have rightly increased and are now a major factor in deciding the aircraft's viability.

ENVIRONMENTAL REQUIREMENTS

SONIC BOOM	Based on Concorde experience and recent research supersonic flight over land will not be allowed (apart possibly from special 'corridors')
COMMUNITY NOISE	Compliance with current regulations applied to subsonic aircraft will be required. European reference aircraft has been designed to achieve Stage 3 but without margins
EXHAUST EMISSIONS	Target for engine manufacturers is <5grm NOX per kg

Figure 9

Sonic Boom

The current assumption of all manufacturers studying SCT is that supersonic flight over land will not be permitted, although there could be the possibility of a few `corridors' across uninhabited areas where it might be allowed. The magnitude of the boom can be reduced by special design, such as more rounded leading edges, but the resulting aircraft has poor performance. However, there is evidence that even a low intensity boom would still be unacceptable.

Although we are restricting supersonic flight primarily to over water one area where research is needed is into the impact of sonic boom on coastlines from aircraft approaching or leaving land masses.

Community Noise

The 2nd Generation SCT will have to comply with the same international regulations for airport noise as the contemporary subsonic fleets. No special dispensation is expected. Currently, the regulations ask for compliance with ICAO Stage 3. This is already a major challenge. By the time the new aircraft enters service regulations could well be even more stringent, a few dB less than today.

An essential contribution to meeting the regulations will come from the engine but the overall aircraft design will be strongly influenced by the need to reduce noise. Good low speed characteristics, which are in conflict with those for supersonic cruise, will be necessary for take-off and landing. Some additional reduction in noise could be expected from specific flight procedures, such as thrust modulation.

Exhaust Emissions

The minimisation of the effect of exhaust emissions on the atmosphere is the third major environmental challenge facing the aircraft. Much international research is going into the understanding of the chemical mechanisms involved.

Supersonic aircraft fly higher than subsonic and are therefore further inside the ozone layer. The most recent research results indicate that with low NOx engines (<5grm per kg fuel) the effect on ozone concentration could be less than 1%, which might be acceptable.

Aircraft Configurations

The mission specifications described earlier have led to 2 different configurations.

Trans Pacific Market

The main features of this configuration are:

Maximum Take-off Weight	350t
Span	42m
Length	92.5m

285 passengers in 3 classes, 6 abreast in tourist and business classes
Supersonic cruise Mach no. 2.0

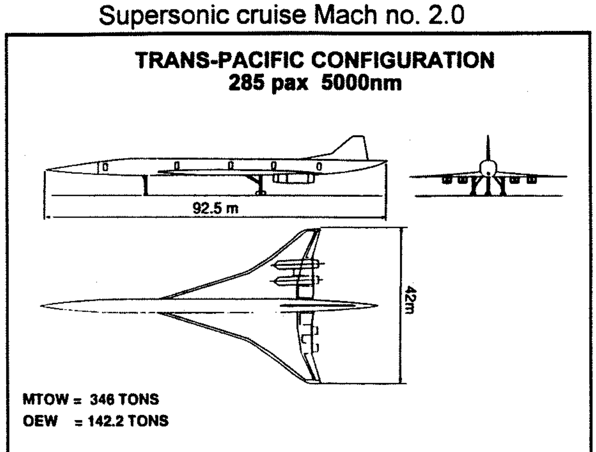

Figure 10

The fuselage and wing cross sections have been area ruled to minimise wave drag. One benefit of this is a wider forward fuselage to the advantage of the business class passengers.

Europe to Far East

The main features of this longer range aircraft are:

Maximum Take-off Weight	~380t
Span	~50m
Length	~92.5m

225 passengers in 3 classes, 5 abreast in tourist and business
Supersonic cruise Mach no. 2.0
Subsonic cruise Mach no. 0.95

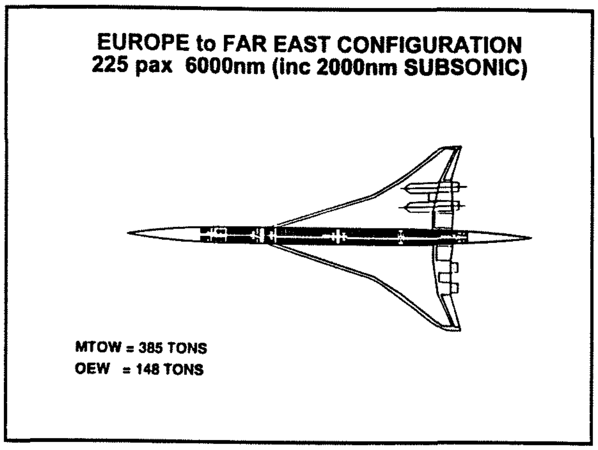

Figure 11

This configuration differs significantly from the shorter range version. The long subsonic segment of the mission has a significant effect on the wing design. The aspect ratio has been increased from 2.1 to 2.5 to improve subsonic performance and the area increased to 970 square metres to allow more fuel to be carried. Fuselage cabin width has been reduced to a 5 abreast configuration so that the forward and rear doors clear the wing and engine nozzles adequately.

AIRFRAME STUDIES

To support the configuration studies outlined above the AS/BAe/DA group are undertaking several specific studies. Amongst these are Structures, Powerplant Integration and Stability and Control.

Structures

Compared with subsonic aircraft supersonic transports require very high structural efficiency. This will only be realised by a highly inovative design using advanced materials, which integrates the four primary components: wing, fuselage, landing gear and powerplant.

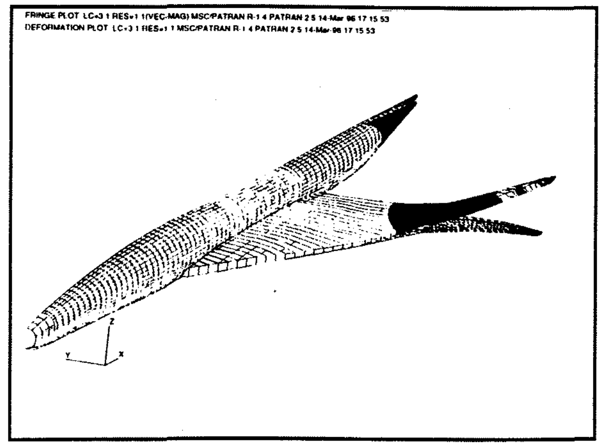

Figure 12

The wing will be large but with a thickness to chord ratio of only 2 to 3 %. It will be the main fuel tank and contain many systems. Aerodynamic constraints will impose a surface finish standard never achieved before, which will be particularly difficult to achieve with the many moving surfaces such as full span leading edge flaps, large elevons and big landing gear doors.

Large variations in temperature during the course of the flight will cause shape and aerodynamic load changes. The wing will have to be manufactured to quite a different shape from that in cruise.

The partners are working on a programme of structural analysis in order to understand better the strength and stiffness requirements. This analysis covers the static, dynamic and thermal loading conditions encountered during operation of such an aircraft. In addition, some critical areas of the design, such as the wing to fuselage joint and landing gear attachments are being studied in more detail.

Powerplant Integration

Powerplant integration is particularly critical since it has a weight and drag impact that is much higher than on subsonic aircraft. Two types of engine are being evaluated from both the airframe and enginemanufacturers' point of view.

PROPULSION

ENGINE TYPES	2 Concepts - variable cycle (low exhaust velocity at take-off) - low bypass turbofan with ejector silencer
INTAKE	Two dimensional, back to back, vertical wedges with compression geometry based on Concorde design
NOZZLE	Dependent on engine type although all will have reverse thrust capability
INTEGRATION	Wing/intake compatibility criteria based on Concorde model and flight experience

Figure 13

Noise is a major design driver. The first type of engine is designed to meet noise requirements by having a reduced exhaust velocity, while the second is simpler in concept having a relatively low by-pass ratio with noise reduction achieved by means of an ejector nozzle.

Attachment of massive engine, intake and nozzle components to the thin wing presents severe challenges to the structural, powerplant and aerodynamic engineers. In particular, maintenance of high aerodynamic efficiency under the varying structural deflections of the wing throughout the subsonic and supersonic flight regime requires a closely integrated design approach.

Stability and Control

It is essential that the aircraft has adequate aerodynamic stability and may be flown by normal airline pilots. Historically, the three European partners have developed different solutions to achieve these requirements. Configurations with tailplane, foreplane and wing alone have all been proposed as viable solutions. They all have their merits and drawbacks.

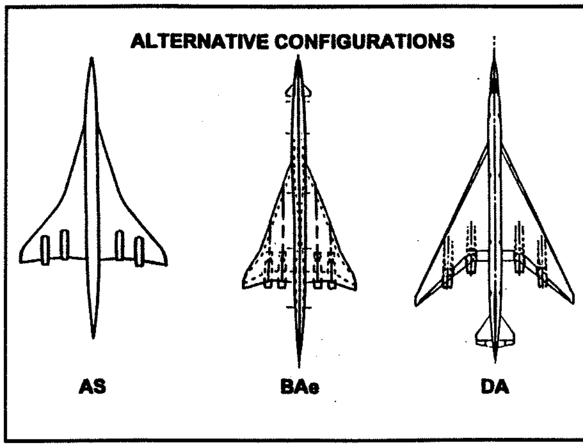

Figure 14

Selection of the optimum configuration is an extremely complex challenge involving the interaction of aerodynamics, systems, structures and handling qualities. A programme of work is under way to address these issues. The aim is to develop an aircraft configuration optimised for the S & C viewpoint using good data derived from theoretical studies supported by wind tunnel tests.

Reference Aircraft Configuration

These and other specific studies are taking place along side the market and viability driven aircaft configuration development mentioned earlier. To ensure consistency and to ensure "read across" between each separate study a Reference Configuration, which will remain unchanged for some time, is used.

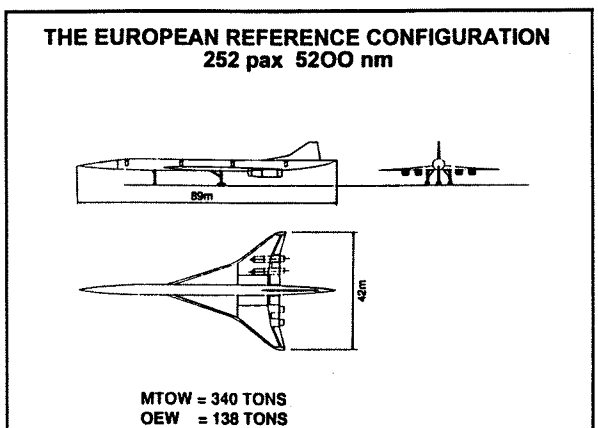

Figure 15

The main features of this Reference Configuration are:

Maximum Take-off Weight 340t
Span 42m
Length 89m
252 passengers in 3 classes, 6 abreast in tourist and business classes
Supersonic cruise Mach no. 2.0

Design, aerodynamic, weight and performance data is well documented and provides the datum for these specific project studies as well as providing a datum for the research needed to develop the technologies on which the viability of a 2nd Generation Supersonic Commercial Transport will depend.

TECHNOLOGIES - RESEARCH

The ESRP (European Supersonic Research Programme) has been established by the three partners to harmonise the European research activities and avoid unnecessary duplication of effort.
The ESRP represents the synthesis of what needs to be done to evaluate the technology options through analytical, experimantal and commercial verification.

EUROPEAN SUPERSONIC RESEARCH PROGRAMME

ESRP-Objectives

To be successful in developing a future SCT, significant technology advances are necessary.

- **The ESRP is aimed at providing and verifying essential technologies for the development of an economically and environmentally viable aircraft.**
- **The programme focuses on evaluating the technology options through analytical, experimental and commercial verification.**
- **The ESRP has been developed as an integrated multi-disciplinary approach to the production of the enabling technologies required for an SCT aircraft.**

Figure 16

ESRP has been developed as an integrated multi-disciplinary approach to the production of the enabling technologies required.

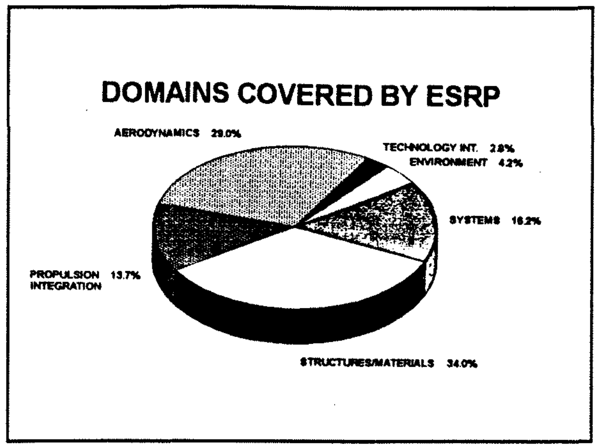

Figure 17

The programme covers 6 domains:

Aerodynamics

- To develop enabling technologies to support total configuration design of an economically and environmentally viable supersonic commercial transport aircraft
- To validate methods and choice of concept design through demonstration
- To evaluate emerging aerodynamics technologies with reference to performance and effectiveness
- To establish a knowledge base to enable the partners to make decisions and supply information to other disciplines

Powerplant Integration

- To develop technologies and concepts for a highly efficient, integrated and cost effective powerplant
- To validate the choice of concept design through demonstration by theory at both model and full scale, ensuring the economic and noise goals are met

Structures and Materials

- To develop, characterise and validate materials, design procedures, structural concepts and manufacturing processes for application to an economically viable aircraft.

Systems

- To develop and evaluate concepts for aircraft subsystems to ensure the requirements of an economically and environmentally viable aircraft are met

Enviroment

- To ensure compliance with, and to assist development of, regulatory bases for emissions, noise, sonic boom and other envirnmental issues

Technology Integration

- To integrate, assess and select technologies on the basis of economics, environmental compatibility, technical readiness and risk
- To track progress and performance of each technology domain and to re-direct work, if necessary, to ensure a cost effective and harmonised European Supersonic Research Programme

Global Collaboration

Clearly, the development, manufacture, marketing and operation of a 2nd Generation Supersonic Commercial Transport entail high risks. which are best shared. For instance, the financial investment is far beyond the resources of any one country, market projections show room for only one product and the potential global range of operations will require close collaboration between the world's certification authorities.

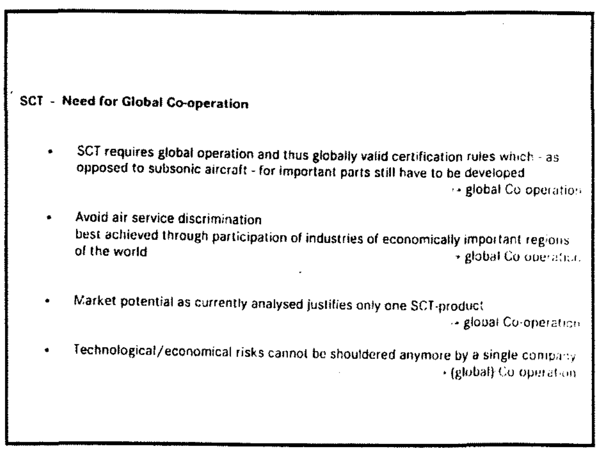

Figure 18

The world's major manufacturers of commercial aircraft are already engaged in co-operative studies on the feasibility of jointly producing a viable aircraft.

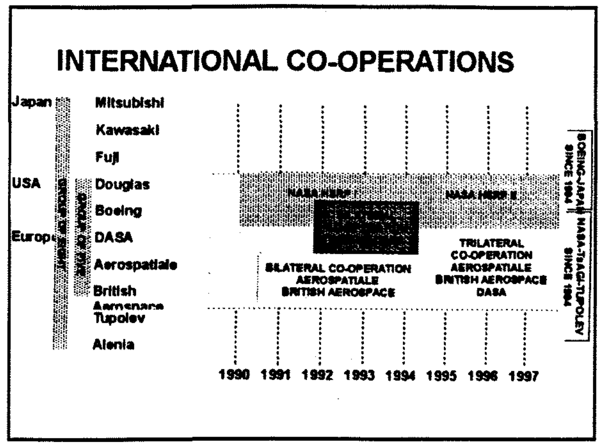

Figure 19

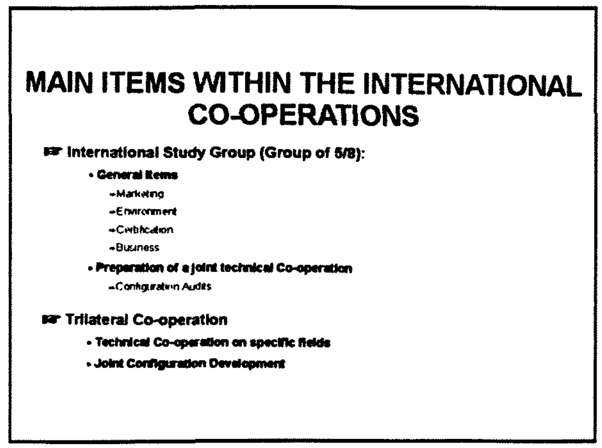

Figure 20

For a co-operation like this to be able to work together the individual research programmes will need to be coordinated and harmonised for consistency.

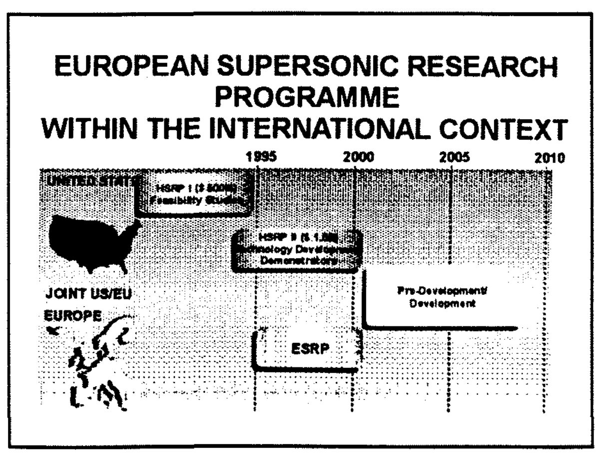

Figure 21

Conclusions

A team from Aerospatiale, British Aerospace and Daimler-Benz is studying the 2nd Generation Supersonic Transport aircraft. This team is also involved in a wider International Co-operation which is assessing the viability of such an aircraft and the potential for global collaboration.

The new aircraft will be built only when there is confidence in its economic and environmental viability to manufacturer, airline and passenger. Extensive research is required to establish this confidence.