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Update on Douglas' High-Speed Civil Transport Studies

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INTRODUCTION

This report presents a summary of high speed civil transport (HSCT) studies underway at the Douglas Aircraft Company (DAC), a division of McDonnell Douglas Corporation (MDC). The report begins with a brief review of experience at MDC with design and development of advanced supersonic transport concepts and associated technology. A review is then presented of past NASA funded contract research studies focused on selection of appropriate concepts for high speed civil transport aircraft to be introduced in the year 2000 time frame for commercial service. Follow-on activities to those studies are then presented which have been conducted under DAC independent research studies as well as under further NASA funded efforts. The report discusses design mach number selections and associated baseline design missions, forecasted passenger traffic and associated supersonic fleet sizes, and then proceeds into a discussion of individual issues related either to environmental acceptability or overall technology requirements in order to achieve the required economic viability of the program. The report concludes with a summary of current and future plans and activities.

Topics Covered

Background

Current Studies

Douglas Approach

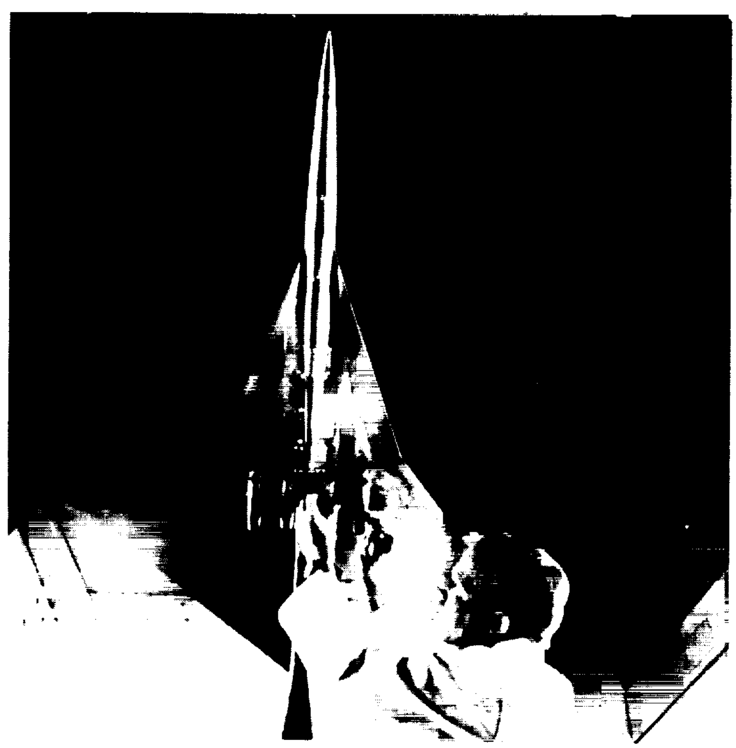
Environmental Issues

Key Technologies

Plans

DOUGLAS BACKGROUND

DAC's experience in the Supersonic Commercial Aircraft Studies spans more than 30 years, including the SST and SCAR studies in the 1960's. A significant amount of experience was gained in the 1970's by DAC in participating with the NASA AST program and related technology studies such as this Douglas/NASA 1.5 percent scale wind tunnel test illustrated below.



NASA DAC HSCT STUDIES

In 1986 MDC began studying HSCT concepts under contract to NASA Langley Research Center. The studies began with an open minded approach to determine the viability of future high speed commercial transport concepts. A wide speed or mach range was considered, with configuration studies conducted between the range of low supersonic speeds to hypersonic aircraft cruising in the range of Mach 10-12. These concepts were compared to a baseline subsonic long range transport with performance levels envisioned beyond the year 2000. A key aspect of these studies were considerations associated with environmental compatibility, primarily in the areas of noise, emissions and sonic boom. These studies were intended to determine the most viable concepts which would then warrant additional studies. The studies were not only technical in nature, but included extensive market evaluations and economic analyses intended to consider the viability of each concept as a commercial product. The end result of these studies would then enable the identification of key technologies requiring further development.

NASA-Douglas HSCT Studies

Objectives

Examine Wide Speed/Mach Range

Address Environmental Compatibility

Focus Opportunities

Qualify Market Potential

Determine Economic Viability

Identify Technology Drivers

DESIGN GOALS WERE ESTABLISHED
FOR
NASA FUNDED STUDY

For the purpose of these studies, target values for design range, number of passengers, and economic performance, were established. Goals for environmental compatibility were also established. MDC proposed that airport noise levels within FAR Part 36 Stage 3 limits would be acceptable. The emissions goals were established on the basis of total allowable mass of NOx. Aggressive goals were also set for levels of overpressure and perceived noise levels associated with low sonic boom configurations with the possibility of supersonic overland flight in mind. These goals were associated with a projected IOC between the years 2000 and 2010.

Design Goals Were Established for NASA-Funded Study

Design Range: 6,500 Nautical Miles

Passengers: 300

Environment Goals:

- **Noise** - FAR Part 36 Stage 3 Limits
- **Emissions** - $EINO_X$ = 5-10 lb/1,000 lb
- **Sonic Boom** - 0.6 psf and 9 PLdB (Fly Supersonic Overland)

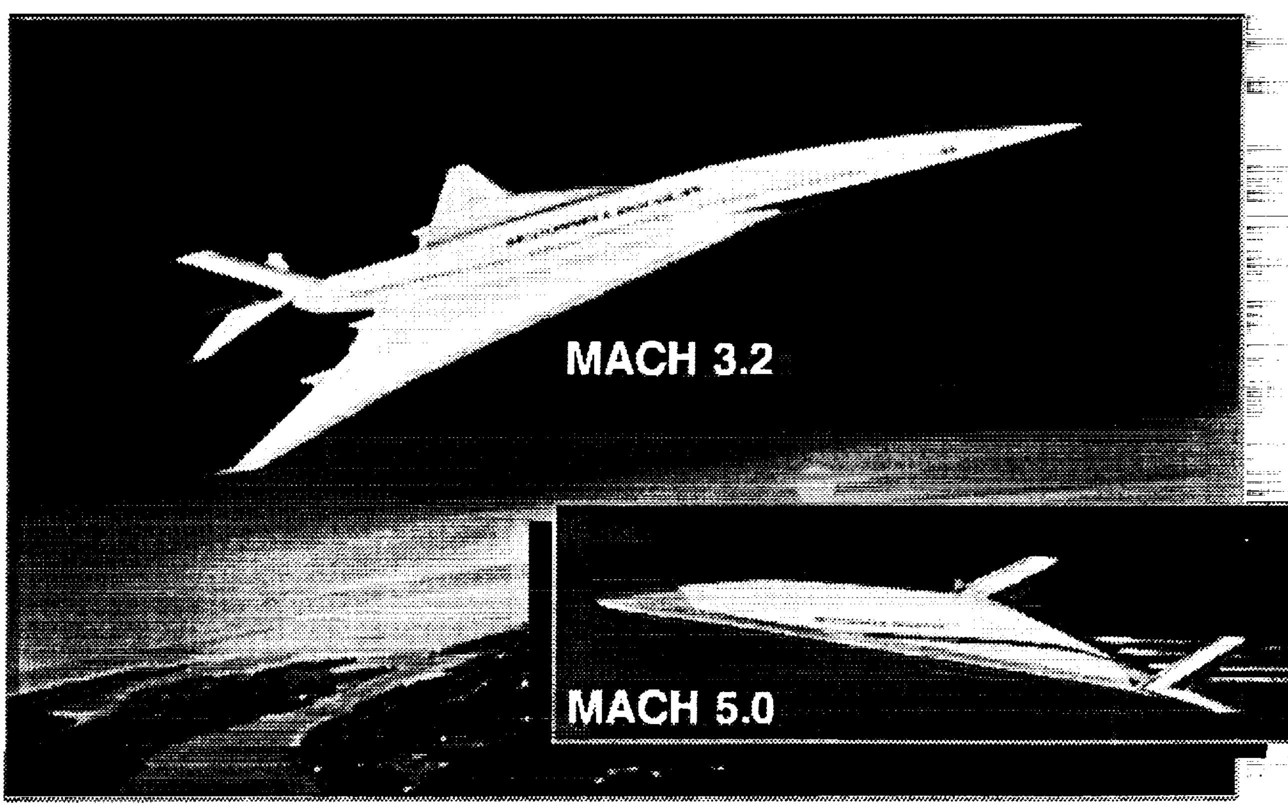
Economics: Profitable at 10-Percent Fare Premium

IOC: Year 2000-2010

HIGH SPEED CIVIL TRANSPORT

The results of these studies concluded that two HSCT concepts were superior in overall aircraft worth and warranted further studies. These were a supersonic aircraft cruising at Mach 3.2 and with conventional JP fuel, and a hypersonic aircraft cruising at Mach 5.0 with methane fuel. These aircraft concepts were carried into further systems studies and evaluations.

HIGH-SPEED CIVIL TRANSPORT



DAC HSCT APPROACH

The Mach 3.2 and Mach 5.0 high speed aircraft concepts were carried into further studies under NASA contract as well as Douglas Aircraft Company IRAD. The overall approach to these studies is described in the adjacent Figure. Generally, a goal of 300 passengers and 6500 nautical miles was maintained. As further studies eliminated the near term viability of hypersonic concepts, the viable speed range was reduced to mach numbers ranging from 1.6 to 3.2. Douglas HSCT concepts continued to be studied within that Mach range. Compatibility with existing airports, the subsonic airspace, and the overall environment were important criteria as well. A fare premium of 10 percent was considered to be a reasonable goal with respect to airline ticket price, and a typical subsonic market passenger mix was assumed.

Douglas Aircraft Company
HSCT Approach

MD-11 Payload and Range

Two to Four Times Faster

Profitable to Airlines

- **Minimum Ticket Premium**
- **"Subsonic" Market Passenger Mix**

Compatible With Existing Airport Runways

Compatible With Subsonic Airspace

Compatible Environmentally

DAC HSCT DESIGN EFFORTS
WILL FOCUS ON LOWER SPEED CONCEPTS

As design studies progressed at DAC within the speed range discussed on the previous chart, it became more and more obvious to the Douglas team that a Mach 3.2 HSCT was high risk both in terms of technology readiness to support a 2005 certification date, and in terms of its effect on the atmosphere when compared to other aircraft concepts. For this reason, Douglas studies were focused within a speed range of Mach 1.6 to 2.4 in 1990. We have conducted studies at Mach 2.2, for which we have an extensive data base from advanced supersonic transport studies conducted in the 1970's, and are also in the process of conducting design studies at Mach 2.4. The lower speed concepts under evaluation are considered to be alternative approaches from our Mach 2.2/2.4 baseline designs. A Mach 1.6 aircraft, while having less productivity and marketability than the higher speed concept, has other advantages in terms of lower engine emissions impact and lower development and production costs. Douglas continues to develop concepts for low sonic boom designs, and our most recent studies have resulted in a Mach number selection of 1.8.

Douglas Aircraft Company

The HSCT Design Efforts Will Focus on Lower Speed Concepts

Cruise Mach No.	Advantages	Disadvantages
1.6/1.8	Lowest Engine Emissions Impact Lowest Development and Production Cost and Risk Possible Low-Boom Solution	Lowest Productivity Marketability
2.2/2.4	Existing Data Base Moderate Productivity Technology Readiness Achievable With Timely Investment	Higher Development Cost and Risk Than Mach 1.6 Low-Boom Solutions May Require Multiple Cruise Mach Numbers
3.2	Highest Productivity Minimum Travel Time	High Technical Risk for 1998 TAD Worst Case for Emissions Low-Boom Solutions May Require Multiple Cruise Mach Numbers

BASELINE DESIGN MISSION AND CRUISE MACH NUMBERS
SELECTED TO REDUCE PROGRAM RISK AND IMPROVE ECONOMICS

As we proceeded with detailed design studies for a baseline aircraft concepts and associated supersonic network analyses, it was determined that overall aircraft worth is maximized at a somewhat lower design range than our previous long range goals. For that reason, we have revised our baseline design range to 5500 nautical miles while still conducting trade studies in the range of 5000 to 6500 nautical miles. Our baseline payload remains 300 passenger, and the analysis of our global supersonic network results in an average overland distance of 25 percent. As stated on the previous page, our baseline cruise Mach number combinations are 2.4 overwater/0.95 overland, 1.6 overwater/0.95 overland and 1.8 overwater and overland for the low sonic boom design.

Baseline Design Mission and Cruise Mach Numbers Selected to Reduce Program Risk and Improve Economics

Baseline Design Mission

- **5,500 Nautical Miles**
- **300 Passengers**
- **25-Percent Overland**

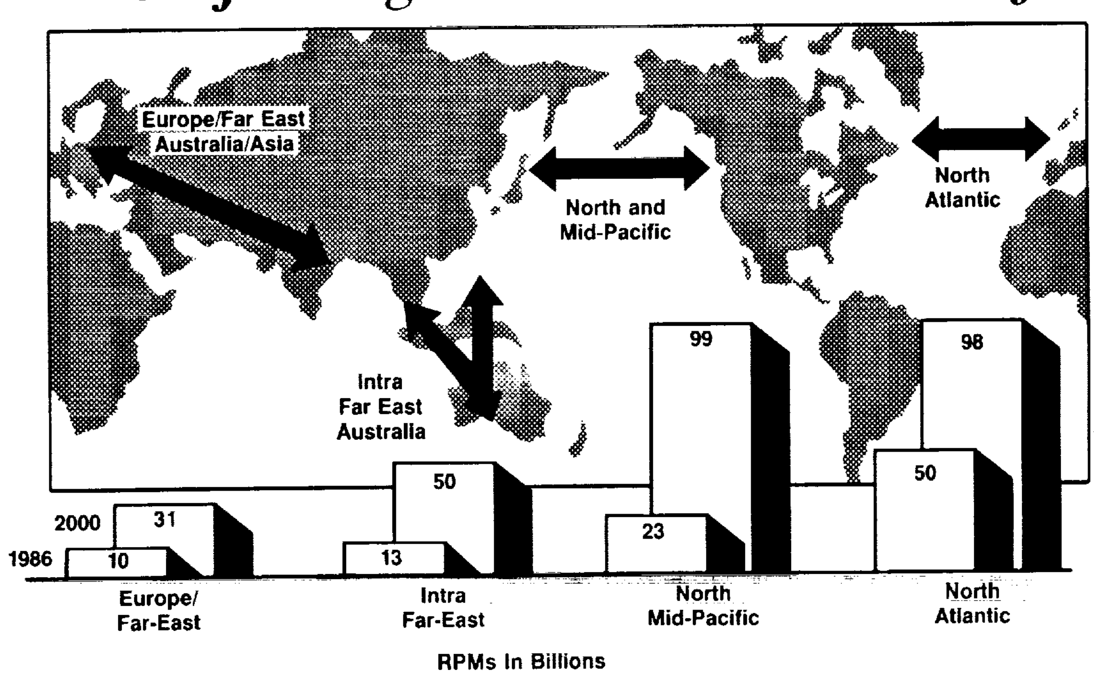
Cruise Mach Number

- **2.4/0.95 (Baseline)**
- **1.6/0.95 (Low Atmospheric Impact)**
- **1.8/1.8 (Low Sonic Boom)**

INTERNATIONAL PASSENGER TRAFFIC -
MAJOR REGIONS -
85-90 PERCENT OF TOTAL

In order to insure that division of program economic viability is maintained, we continually revisit our forecast for long range passenger traffic beyond the turn of the century. The attached figures shows passenger traffic divided up among 4 major regions with values in billions of passenger revenue miles for the year 1986 and projected values for the year 2000. This figure projects a dramatic increase in traffic in both the intra Far East and North Mid Pacific regions. If we project the traffic in these regions out to the year 2010 or 2020, we would expect to see continued growth in the North Mid Pacific and North Atlantic regions, at approximately the same rate in each region as the North Mid Pacific region matures. These predictions maintain our confidence that long range passenger traffic beyond the turn of the century support a sufficiently large number of high civil tranport aircraft to insure economic viability for the manufacturer.

International Passenger Traffic - Major Regions - 85-90 Percent of Total

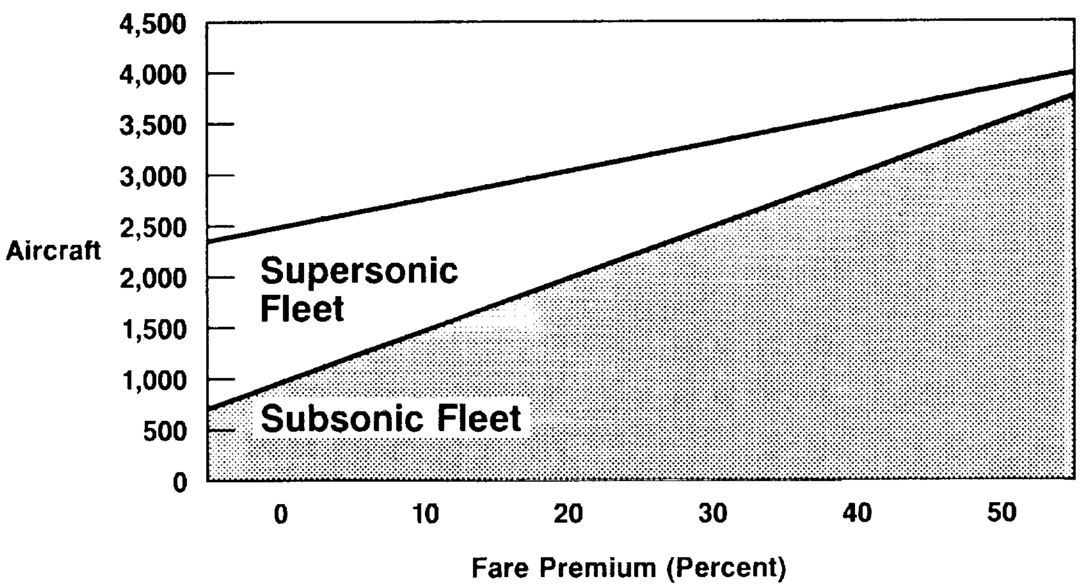


FLEET REQUIREMENTS BY THE YEAR 2025

Given a set of long range passenger traffic predictions, we may then project the amount of supersonic aircraft required to meet traffic demand as a function of fare premium shown as a percentage above conventional subsonic fares. The chart indicates that at a fare premium of 10 percent for a fleet size of greater than 1000 is envisioned.

Fleet Requirements by Year 2025

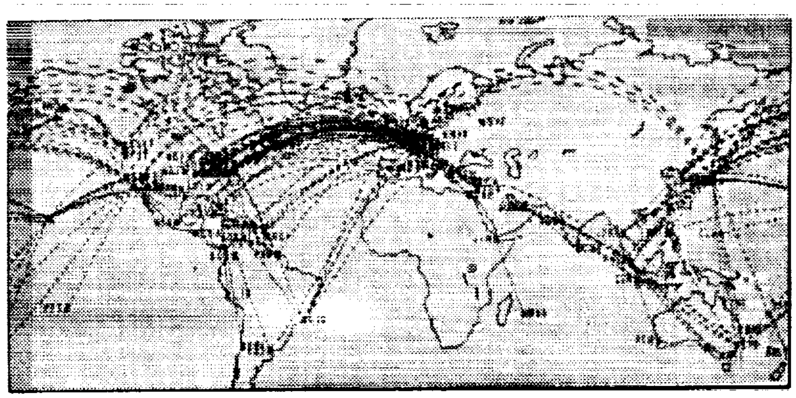
Impact of Fare Premium on Supersonic and Subsonic Fleet Mix



250 CITY PAIR SUPERSONIC NETWORK

Extensive analysis of supersonic network associated with primary long range city pairs has been completed. These analyses are used to determine the overland distances for supersonic routes and to examine alternative route structure such as supersonic overland corridors or route diversions. The results of these studies for the 250 city pairs is used indicated and average percentage overland of 25.9 percent for diverted routes which maximize the overwater segment of flight.

A 250 City-Pair Supersonic Network Used to Determine Overland Distance and Alternative Route Structures



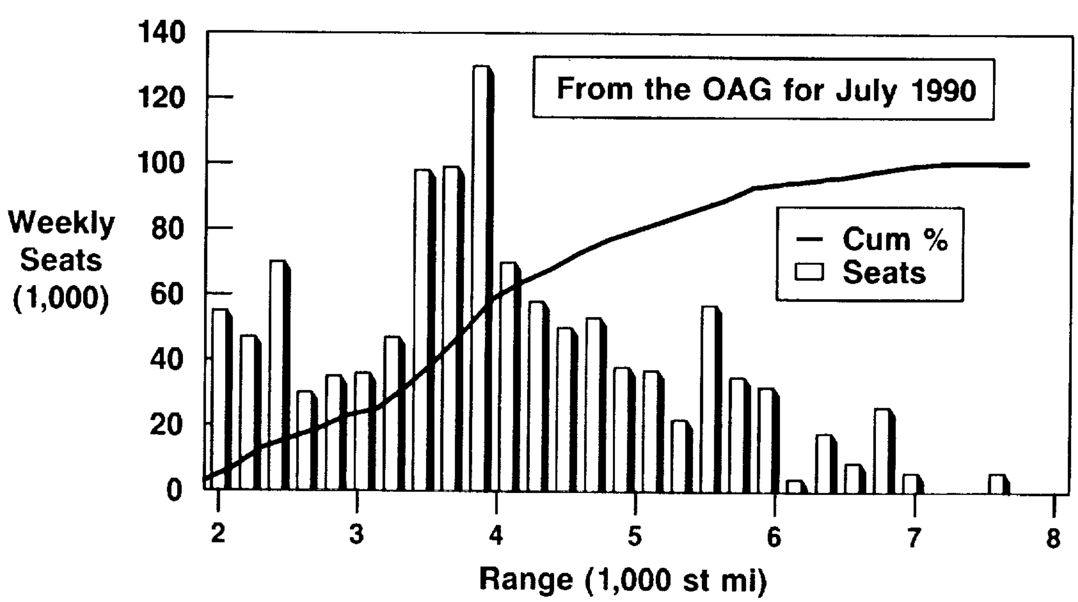
Great Circle Distance	**891,809 st mi**	**Diverted Distance**	**932,618 st mi (Increase 4.5%)**
Overland Distance	**414,266 st mi**	**Overland Distance**	**241,813 st mi (Reduction 41%)**
Percent Overland	**46.5%**	**Percent Overland**	**25.9%**

HIGH SPEED CIVIL TRANSPORT
TOP 250 AIRPORT PAIRS BY SEATS OFFERED

Studies are also conducted to examine the selection process for supersonic networks with respect to maximum design range. The attached chart plots weekly seats in thousands against the range frequencies for the top 250 city pairs by seats offered and indicates the associated range of these city pairs in statute miles. Using these data, it was determined that a design range of roughly 6300 statute miles (5500 nautical miles) would maximize aircraft worth at a cruise Mach number of 2.4. These types of studies are continually updated based on the most recent traffic forecasts and various combination of city pairs.

High-Speed Civil Transport

Top 250 Airport Pairs by Seats Offered



MDC EFFORTS ARE FOCUSED ON VALIDATING RESULTS OF PRELIMINARY STUDIES AND REDUCING PROGRAM RISKS

The near term objective of DAC HSCT studies is to develop an understanding of and solutions to key environmental constraints in the area of noise, emissions and sonic boom. Additionally baseline design concepts will continue to be refined and assessed in terms of their economic viability in environmental compatibility. Long lead technology development efforts have been initiated in selected areas.

MDC Efforts Focus on Validating Results and Reducing Program Risk

Develop Understanding of and Solutions to Environmental Constraints

Refine Design Concepts to Ensure Selection of the Most Viable Product

- **Cruise Mach Number**
- **Range**
- **Payload**
- **Technology**
- **IOC**

ENVIRONMENTAL ACCEPTABILITY DESIGN GOALS

Our initial goals for environmental acceptability are shown on the attached chart. With respect to emissions, an ozone depletion level of not greater than 1 percent is generally acceptable as a reasonable goal for a future fleet of HSCT's. The question here is with respect to the ability or accuracy of atmospheric models to predict these depletion levels based on a given amount of combustion products produced by a fleet of aircraft. Current subsonic FAR Part 36, Stage 3 noise limits form the basis for airport noise for HSCT airport noise limits. In addition, airport and climb to cruise noise levels must be acceptable from a community noise standpoint. Finally, aggressive goals are established for shock wave overpressure and associated loudness levels for sonic boom minimization levels. The goal of 90 PLdB was our initial guess at a possible level of human acceptance for supersonic overland flight.

Environmental Acceptabililty Design Goals

Engine Emissions

- **No Adverse Change in Ozone Concentration**

Certification/Community Noise

- **Meet Current Subsonic FAR Part 36, Stage 3, and ICAO Annex 16, Chapter 3, Noise Limits**
- **Achieve Airport and Climb-to-Cruise Noise for Community Noise Acceptability**

Supersonic Overland

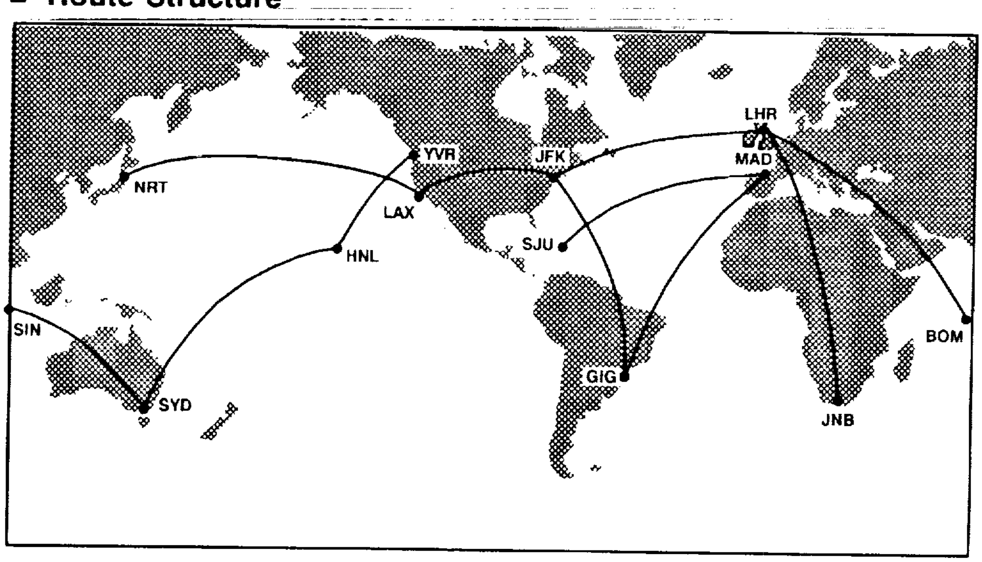
- **Minimal Environmental Impact and Acceptable Human Response**

HSCT EMISSIONS ARE PRIMARILY AFFECTED BY THREE PARAMETERS

Of the three primary issues related to environmental compatibility of a fleet of HSCT's, the issue of aircraft emissions and the associated effects on the atmosphere remain the most uncertain. The key technology associated with reducing emissions for subsonic as well as supersonic aircraft is the development of low emissions (low NOx) combustors. The engine manufacturers in conjunction with NASA have established plans to develop the required technologies for low NOx combustors over the next several years. From an airframe manufacturer standpoint, any incremental improvement in aircraft performance (drag reduction, weight reduction, etc.) will reduce the amount of emissions left in the atmosphere. Beyond that, the parameters that control atmospheric effects are the aircraft cruise altitude and mach number, and the route structure of the fleet. At a lower level of detail, the density of flights within that route structure, the location (latitude and longitude) of the flights, and the seasonality or time of year, all have a significant effect on atmospheric effects.

HSCT Emissions Are Primarily Affected by Three Parameters

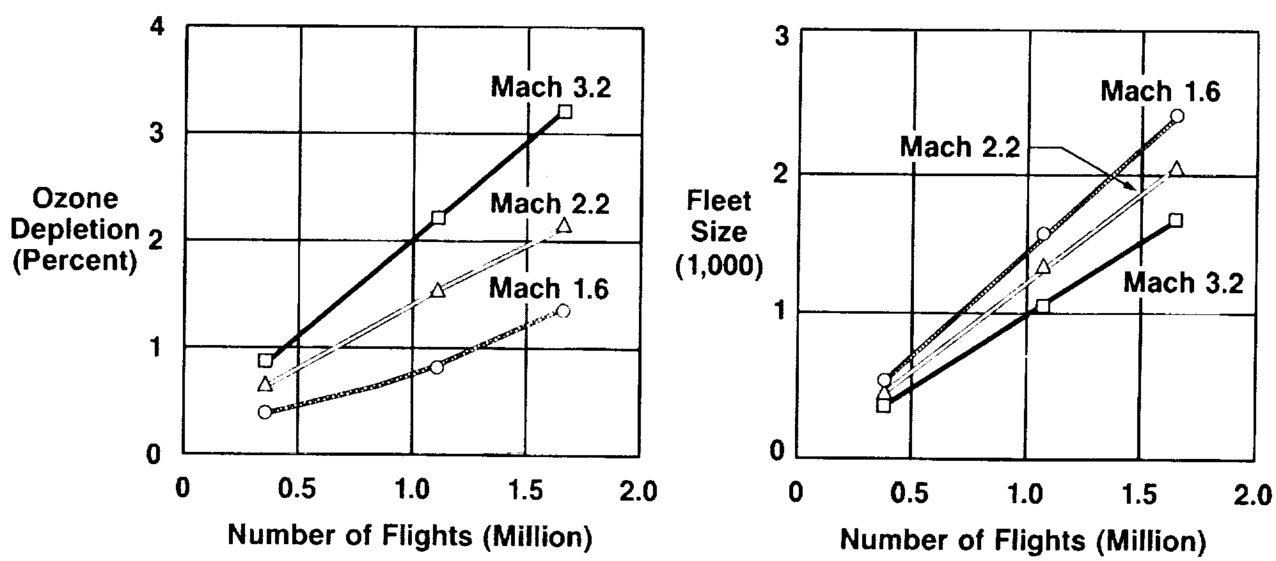
- **Propulsion System Combustion Products**
- **Aircraft Altitude/Mach Number**
- **Route Structure**



ATMOSPHERIC STUDIES PREDICT THE EFFECTS OF CRUISE ALTITUDE AND FLEET SIZE ON OZONE DEPLETION

Douglas has conducted studies in conjunction with atmospheric modelers in an attempt to gain a preliminary understanding of the levels of ozone depletion that could result from a fleet of HSCT's. The lower of the two charts shows three different fleet sizes for three different HSCT aircraft such that the total number of flights over a fixed period of years remains constant. The upper curve shows the predicted levels of ozone depletion for each scenario using a currently available atmospheric model. It should be noted that the depletion levels are percentage reductions in the ozone layer at an equilibrium state, not a recurring reduction over some period of time. This model predicts that both the fleet size and the cruise altitude have a strong influence on the level of ozone depletion. The lower predicted levels of depletion for the Mach 1.6 aircraft is the primary reason for Douglas' decision to continue evaluating that concept in our matrix of configurations.

Atmospheric Studies Predict the Effects of Cruise Altitude and Fleet Size on Ozone Depletion



Note: Assumes Successful Low-Emissions Combustor Development

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TECHNOLOGY DEVELOPMENT REQUIRED TO MEET STAGE 3 NOISE LIMITS

Our current design goals for aircraft noise are to achieve compatibility with current stage 3 limits. Engine manufacturers are currently pursuing various propulsion system concepts which appear promising in terms of meeting these objectives. The most promising candidates based on Douglas assessments are the turbine bypass engine with a mixer/ejector, and the FLADE engine cycle with a suppressor/fluid shield. NASA and the engine companies will proceed with the development and evaluation of these concepts over the next several years.

In addition to reductions in engine noise, the development of efficient high-lift systems using leading and trailing edge devices will also be required to ensure airport noise limits are met. Both low speed lift characteristics and lift to drag ratios (L/D) can be improved through the use of high-lift concepts. Improvements in lift characteristics will result in reduced takeoff field length, while low speed L/D improvements will result in a higher flight profile and a lower cutback thrust level, all contributing to noise reduction.

Technology Development Required to Meet Stage 3 Noise Limits

Promising Engine Candidates Are Emerging

- **Turbine-Bypass Engine With Mixer/Ejector**
- **Flade With Surpressor/Fluid Shield**

High-Lift Concepts Are Being Evaluated

- **Low-Speed C_L and L/D Enhancements**
- **(C_L - Takeoff Field Legth)**
- **(L/D - Higher Flight Profile/Lower Cutback Thrust)**

IMPACT OF HIGH LIFT TECHNOLOGY

The development of advanced high-lift systems will not only contribute to reducing aircraft nose levels, but will also provide benefits in overall aircraft performance and stability and control characteristics. High-lift enhancements will result in reduced thrust requirements for takeoff and climb, which will result in reduced engine size and weight, and reduced aircraft takeoff gross weight (TOGW). The use of leading edge devices for high-lift will also have a positive effect on longitudinal stability and lateral control effectiveness. These potential benefits warrant the aggressive development of high-lift system concepts, and studies involving the integration of such concepts into the basic design.

Impact of High-Lift Technology

Performance

- **TOGW, Engine Size, TOFL, and Approach Speed Are Significantly Affected by Efficient High-Lift Capability**
- **High Subsonic L/D Reduces Fuel Burn (∴ Weight) in the Subsonic Climb and Cruise Mode**

Noise

- **L/D Improvements Reduce Takeoff, Community, and Climb-to-Cruise Noise Levels**

Stability and Control

- **Leading-Edge Devices Have a Positive Effect on Longitudinal Stability and Lateral Control Effectiveness**

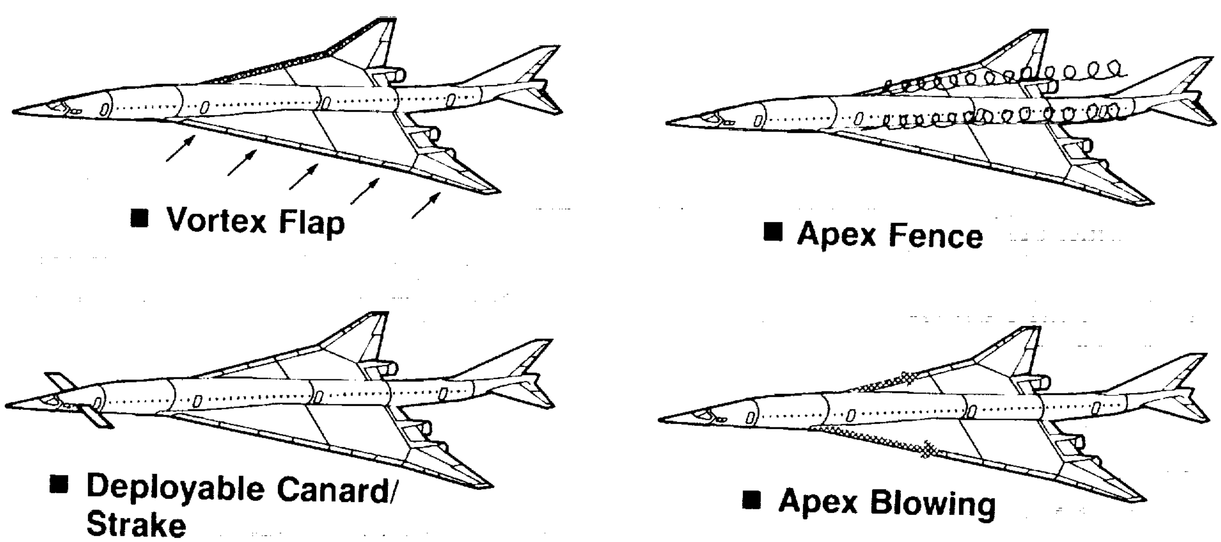
Integration

- **Must Be Integrated With LFC and Advanced Engine Nozzles**

SOME INNOVATIVE HIGH-LIFT CONCEPTS

The attached chart illustrates some of the innovative high-lift concepts currently being evaluated by Douglas for further development. The use of a vortex flap, an apex fence, deployable canards or strakes, or apex blowing are all viable concepts for improving the high-lift characteristics of an HSCT. These concepts will be studied from both a performance and design integration standpoint, with the most promising concept or concepts carried forward for further development.

Some Innovative High-Lift Concepts



AST LOW SPEED WIND TUNNEL MODEL

Douglas has a cooperative effort in place with NASA Langley to conduct wind tunnel testing of candidate high-lift concepts using the existing ten percent scale model developed by Douglas and NASA under the Advanced Supersonic Transport (AST) program in the 1970's. NASA will conduct high-lift development tests using this model in the 30' x 60' low-speed wind tunnel. Testing is planned to begin in June of this year.

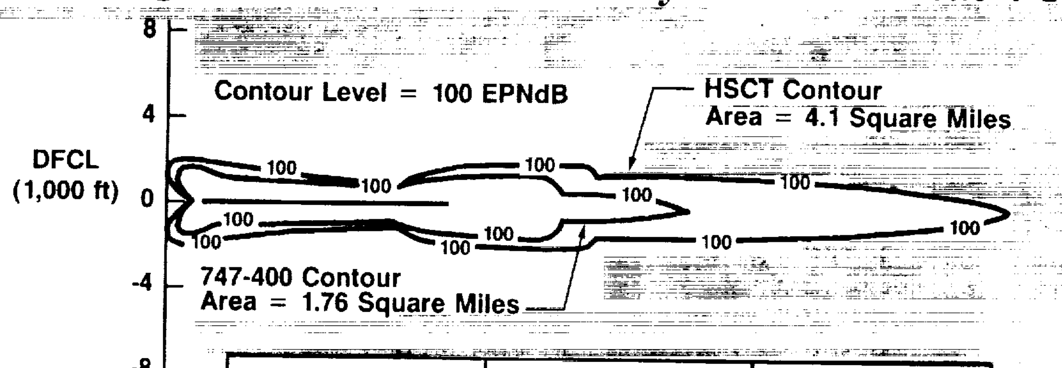
ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

COMMUNITY NOISE ISSUES MUST ALSO BE ADDRESSED

In addition to airport noise considerations, the impact of an HSCT on community noise must also be addressed. The attached plot compares the takeoff noise contours for a 747-400 and the predicted contour for a candidate HSCT configuration. This comparison shows that while both concepts are within stage 3 limits, the HSCT concept produces significantly more noise down range as compared to a typical subsonic stage 3 aircraft.

Community Noise Issues Must Also Be Addressed

Airport Noise Contour Study - HSCT Versus 747-400

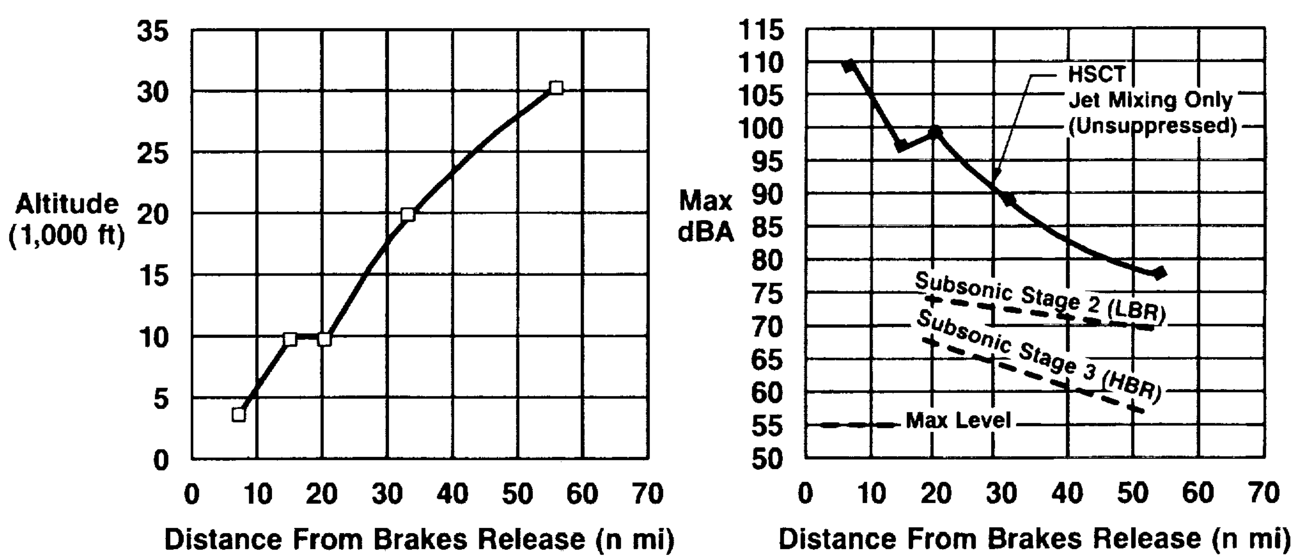


	HSCT 3.2-3A	747-400
Engines	GE VCE	PW 4256
Lift Devices	80% LE Suction	10-deg Flaps
Takeoff Velocity	230 Knots	185 Knots
Weights	800,000 lb	870,000 lb
Noise Levels		
Sideline	Stage 3	Stage 3-3.3
Takeoff	Stage 3-3	Stage 3-4.5

SIGNIFICANT NOISE SUPPRESSION MAY BE REQUIRED DURING CLIMB TO CRUISE PHASE

The attached graph plots altitude versus distance from brake release for a standard takeoff climb profile. Noise levels are then plotted for the stage 2 and stage 3 subsonic fleet, along with predicted climb-to-cruise noise levels for an HSCT. Note that only jet mixing noise in the unsuppressed mode is considered. (That is, no shock noise effects.) The plot indicates that HSCT climb-to-cruise noise could be significantly greater than the existing subsonic fleet, which at the time of HSCT certification and service entry will be limited to stage 3 subsonic aircraft. It should also be noted that the prediction codes for this regime have not been validated for HSCT engine/airframe concepts. These conditions suggest the climb-to-cruise noise should not be neglected in future noise assessments.

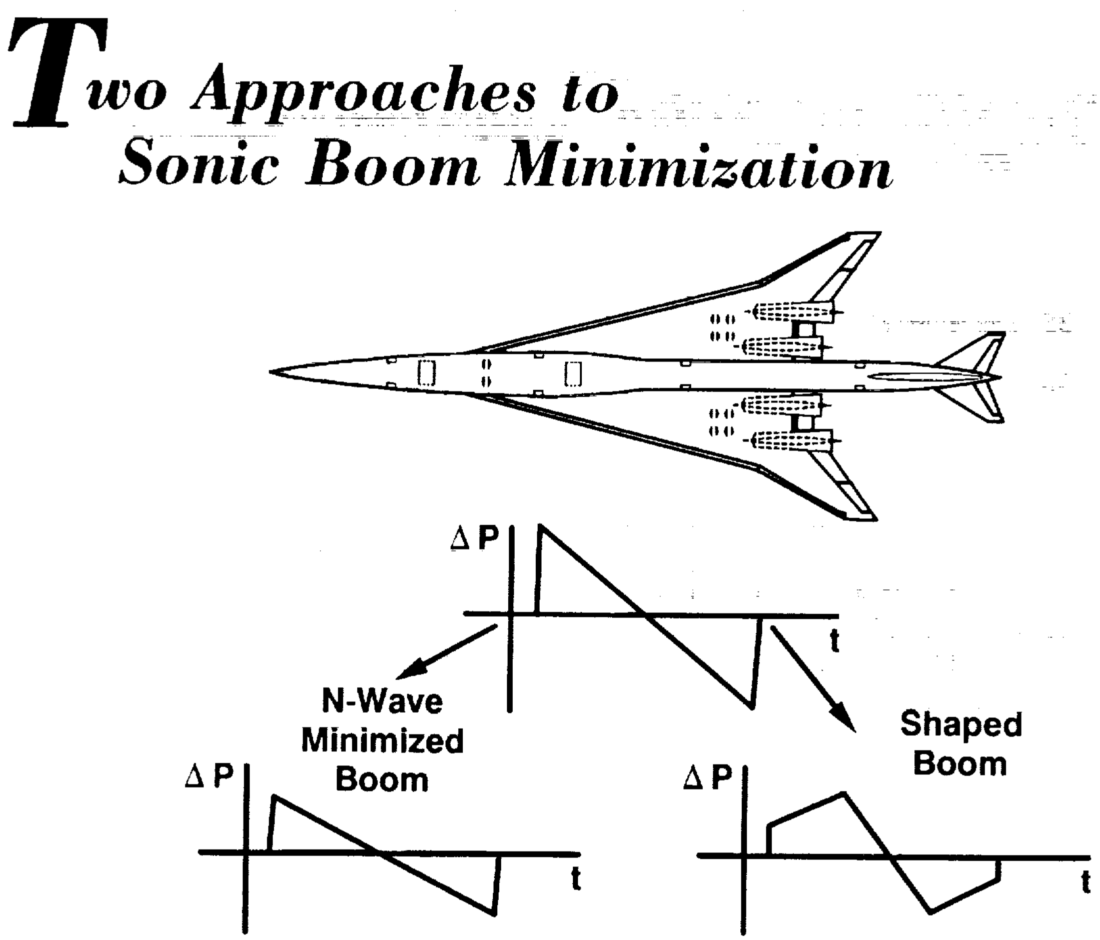
Significant Noise Suppression May Be Required During Climb-to-Cruise Phase



TWO APPROACHES TO SONIC BOOM MINIMIZATION

Doulgas has continued to study advanced concepts for reducing the level of perceived noise resulting from the sonic boom produced by an HSCT flying supersonically. This technology could result in an aircraft which could be permitted to fly supersonically over land in either an unrestricted mode, or perhaps along some predetermined supersonic overland corridors. Any supersonic overland flight in the U.S. would require extensive research into public acceptance and changes to current regulations.

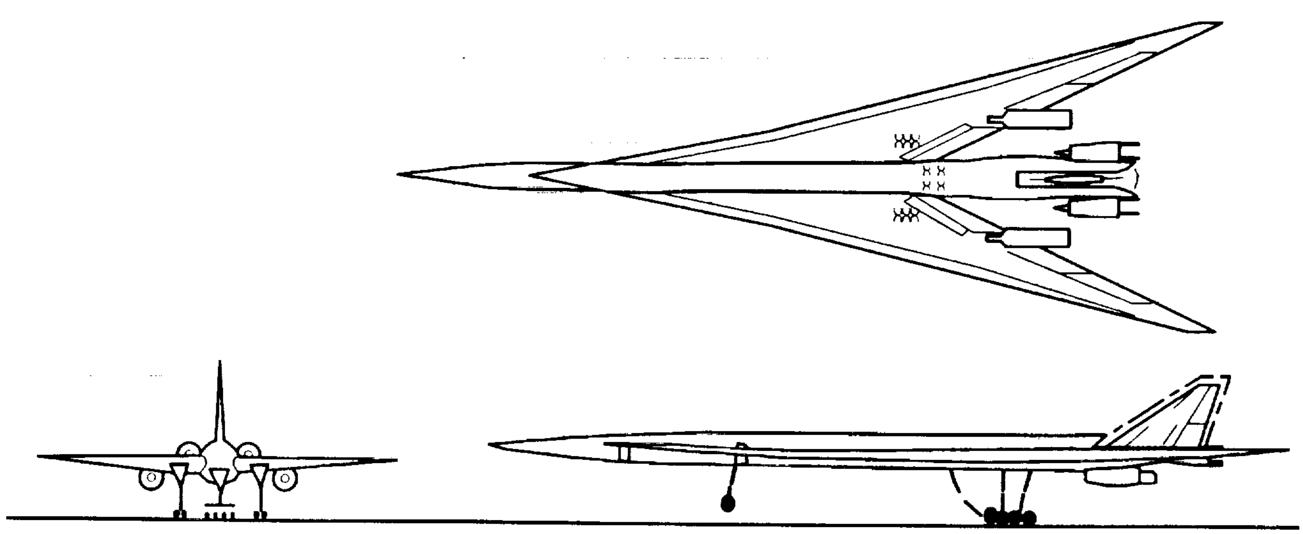
There are two general approaches to sonic boom minimization. The typical N-wave associated with a sonic boom may be modified to reduce the perceived noise level. Careful aerodynamic shaping of the aircraft and improved overall performance resulting in lower aircraft weight can help to reduce the maximum overpressure levels of the shock wave, resulting in a lower noise level sonic boom. Perceived noise level can also be reduced by increasing the rise time of the wave overpressure. This is referred to as a shaped boom, which is produced through careful shaping of the aircraft planform and distributions.



INITIAL LOW SONIC BOOM DESIGNS MEET LOUDNESS GOALS
WITH REDUCED PERFORMANCE

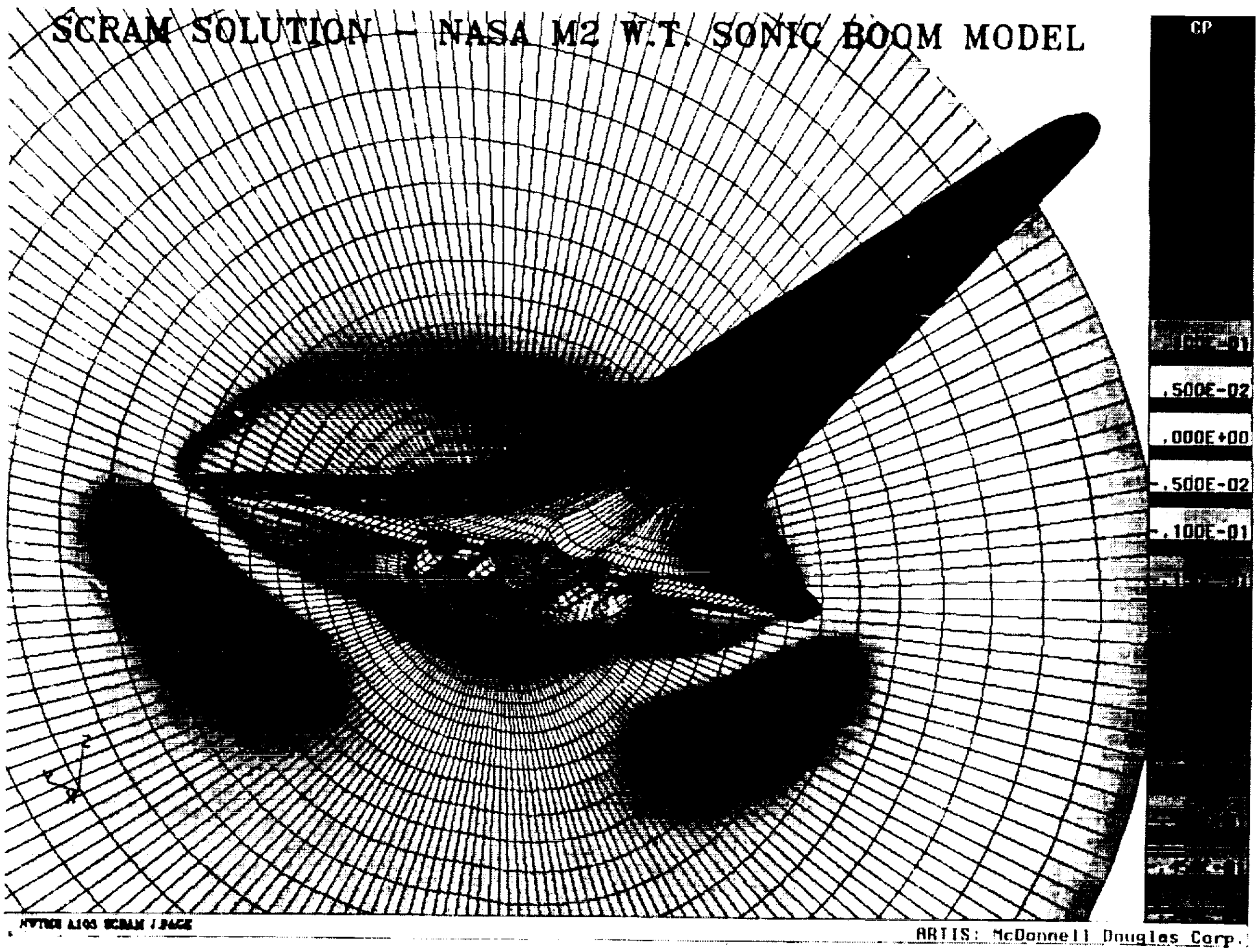
Douglas has been developing low sonic boom concepts under our NASA Langley system studies contract over the last several years. A typical configuration resulting from these studies is shown here. The high sweep, high aspect ratio wings result from the combination of cruise requirements at Mach 3.2, and careful shaping and area distribution to shape the sonic boom waveform. This configuration met our sonic boom goals of 0.6 psf and 90 PLdb, but at a reduced range level which would not support economic viability. The design has some obvious operational issues associated with it, but the achievement of the low noise level was a significant step forward. A more in depth discussion of related work will be presented in the Douglas presentation and report in the sonic boom section of the workshop.

Initial Low Sonic Boom Designs Meet Loudness Goals With Reduced Performance



SCRAM SOLUTION - NASA M2 W.T. SONIC BOOM MODEL

In addition to conducting sonic boom minimization studies, Douglas has been involved in the development and validation of advanced design and analysis methods for sonic boom prediction techniques. The attached chart shows the results of a CFD solution using the MDC SCRAM code to model the aerodynamics of the NASA M2 sonic boom wind tunnel model. We are working cooperatively with NASA to improve the fidelity of CFD codes to enhance design and analysis techniques.



HSCT KEY TECHNOLOGIES

In addition to to the key environmental technologies, Douglas is working together with NASA to identify and initiate the development of key HSCT technologies. These include but are not limited to computational fluid dynamics (CFD), advanced materials and structures, productibility and manufacturing technology, advanced aircraft systems, propulsion efficiency and thrust/weight, and laminar flow control. The pages that follow discuss some of the key issues with respect to these technologies and some of the development efforts underway at MDC.

HSCT Key Technologies

Environment

- Exhaust Emissions
- Source Noise Suppression
- Low Speed/High Lift
- Sonic Boom

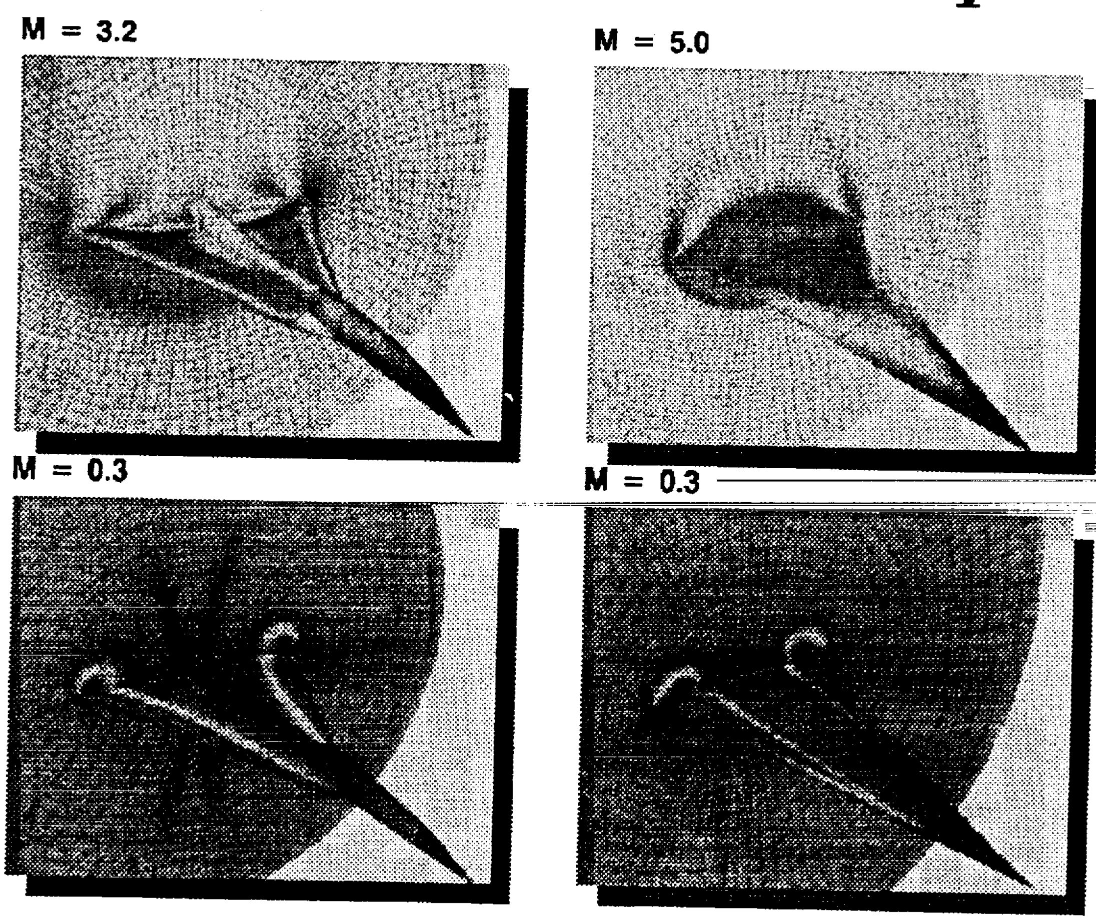
Performance Economics

- Computational Fluid Dynamics
- Advanced Materials
- Producibility/Manufacturing Technology
- Propulsion Efficiency and Thrust/Weight
- Laminar Flow Control
- Advanced Aircraft Systems

CFD SOLUTIONS AT CRUISE AND LOW SPEED FOR TWO HSCT CONCEPTS

Douglas has made extensive use of CFD for HSCT studies for some time. The solutions shown are examples of CFD analyses conducted for our Mach 3.2 and Mach 5.0 concepts for both low speed (M=0.3) and cruise speed conditions. CFD development efforts throughout the components of McDonnell Douglas cooporation have contributed to the current CFD capabilities at Douglas. The further development and validation of CFD tools for HSCT design and analysis is warranted and will continue.

CFD Solutions at Cruise and Low Speed for Two HSCT Concepts

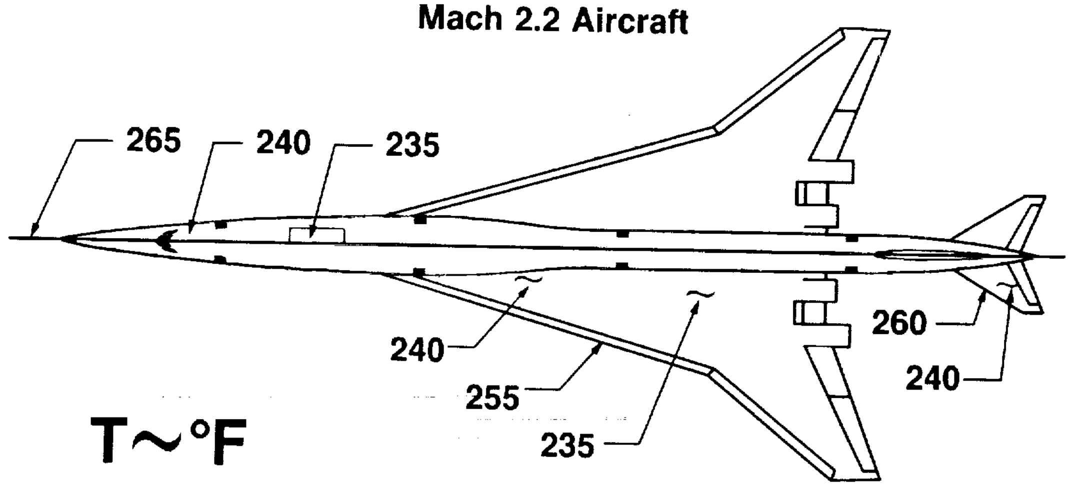


AIRFRAME THERMAL AND STRUCTURAL ANALYSIS MUST BE HIGHLY INTEGRATED

Materials and structures technology is a critical aspect of the HSCT program. In order to select candidate materials for further development toward application to an HSCT, detailed airframe design and analyses must be conducted. This chart illustrates typical skin temperatures for a Mach 2.2 HSCT at cruise. Structural design and analyses must be highly integrated with thermal analyses in order to accurately predict structural response and make proper material selections for aircraft structure. The effects of transient thermal conditions, through-the thickness thermal gradients, etc., all must be properly taken into account.

Airframe Thermal and Structural Analysis Must Be Highly Integrated

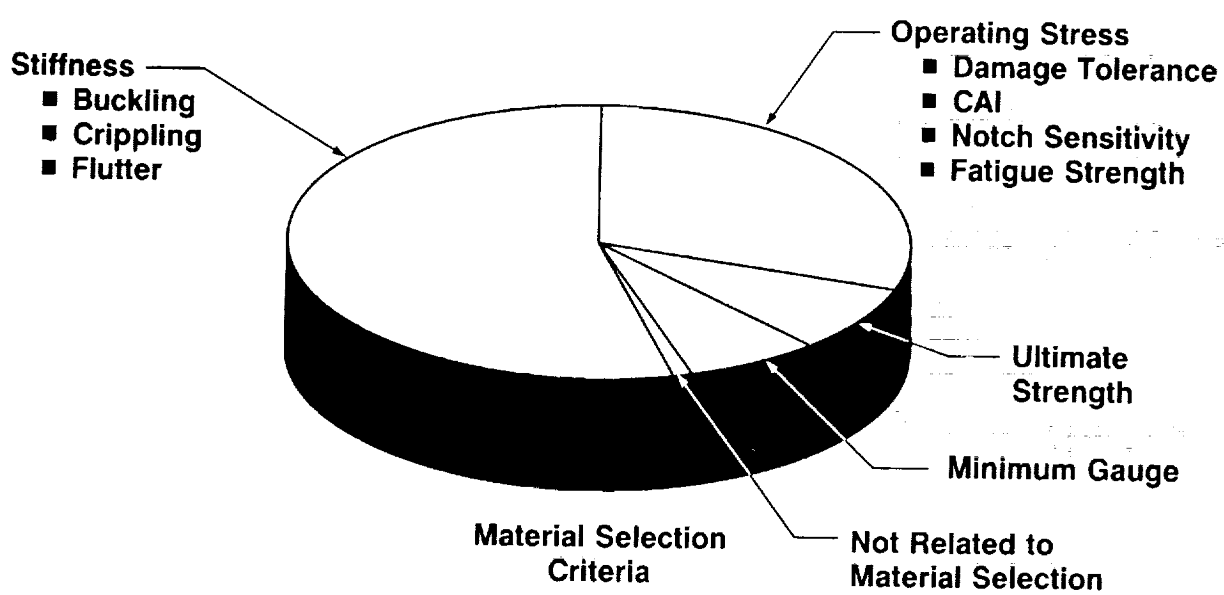
Maximum Temperature Requirements
Mach 2.2 Aircraft



STRUCTURAL WEIGHT DRIVERS FOR AN HSCT AIRCRAFT

The attached chart shows a typical distribution of critical design criteria for the structure of an HSCT. An understanding of this distribution is used to make material selections for the various parts of the airframe. This particular chart was developed for an HSCT airframe based on fiber reinforced materials application. Note that the majority of the structure is designed by stiffness criteria such as buckling, crippling, and flutter requirements. A relatively small percentage of the structure is designed by minimum gage. These serve as a guide for the design process, with the final material selections based upon more detailed design and analysis.

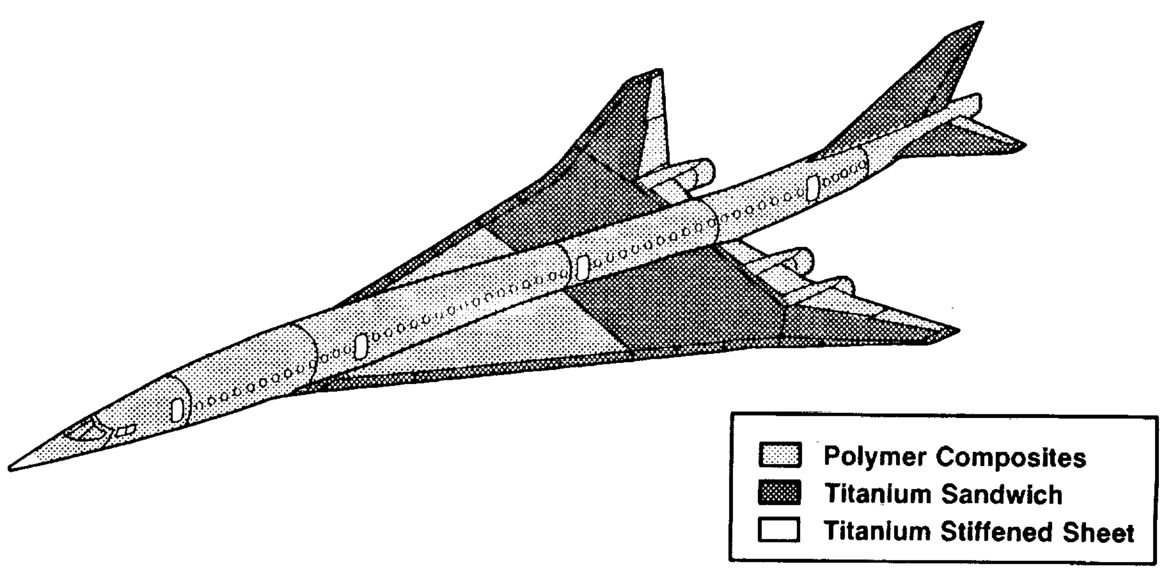
Structural Weight Drivers for an HSCT Aircraft



MDC 1991 M 2.4 MATERIAL STUDY DESIGN FEATURES MULTITPLE MATERIALS

In many cases, the most efficient airframe structure consists of a combination of materials. In the example shown below, the preferred concept was a combination of fiber reinforced polymer composite materials and titanium materials in both sandwich and stiffened sheet construction. Material selections are made with performance, durability, productibility, and cost considerations in mind. The Douglas presentation and report in the structures and materials section of the HSR workshop presents more detail on the subject of material selection.

Multiple Materials Featured in MDC 1991 M2.4 Material Study Design



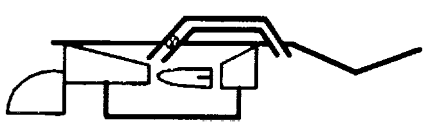
HSR PROPULSION SYSTEM STUDIES

The development of an efficient, low noise, low emissions propulsion system for the HSCT is critical to the success of the program. Douglas is working closely with engine manufacturers to design and evaluate the best engine/airframe combination. Four of the promising engine concepts being developed by the Pratt & Whitney/General Electric team in conjunction with NASA Lewis Research Center are shown below.

HSR Propulsion System Studies

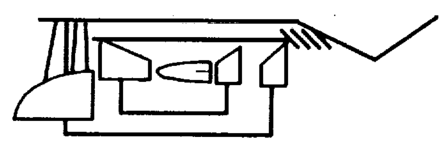
Candidate Propulsion Concepts

Turbine-Bypass Engine



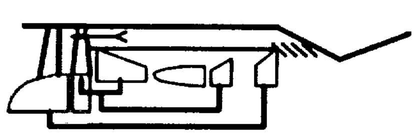
- Simple Cycle
- Low Cruise Temperature

Mixed-Flow Turbofan



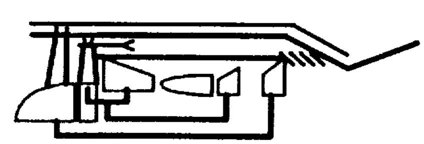
- Low Jet Velocity
- Good Subsonic SFC

Variable-Cycle Engine



- Variable Bypass
- Good Subsonic SFC

Flade Engine

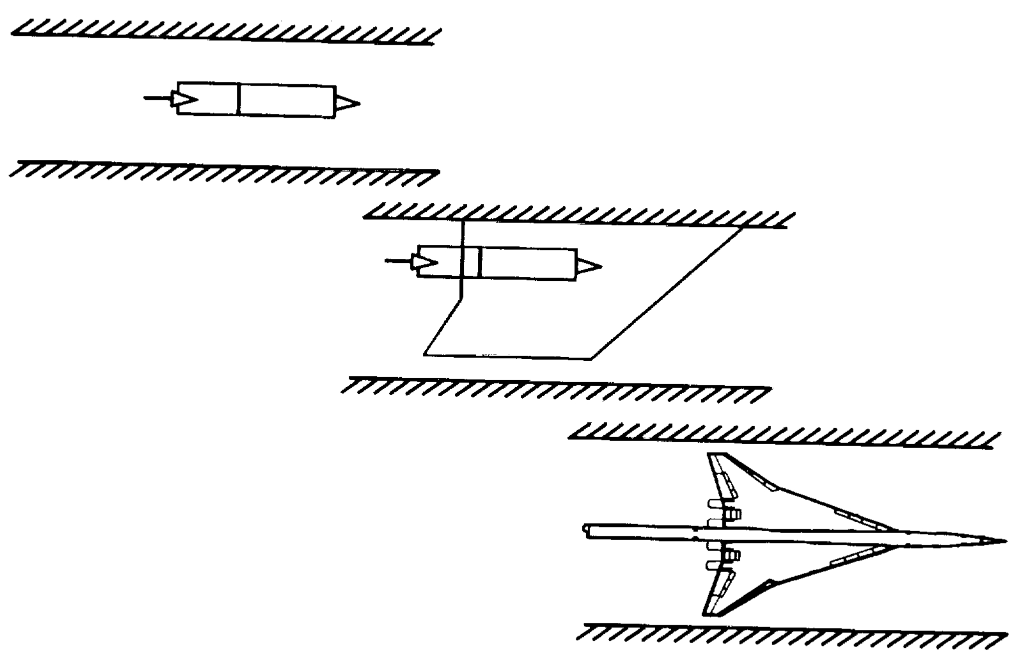


- Low Jet Noise
- Variable Bypass
- Good Subsonic SFC

DAC CONTRACT WITH NASA-LEWIS WILL ADDRESS PROPULSION/AIRFRAME INTEGRATION ISSUES

Douglas is currently under contract to NASA Lewis Research Center to conduct engine/airframe integration studies for HSCT concepts. Current plans contain and incremental wind tunnel test program for inlet concept development. Testing will begin with single inlet/nacelle testing to full planform tests with engine nacelles integrated on the aircraft.

Douglas Contract With NASA-Lewis Will Address Propulsion/Airframe Integration Issues



SUPERSONIC LAMINAR FLOW CONTROL

Laminar Flow Control (LFC) is key technology for HSCT in terms of the potentially tremendous benefits resulting from increased supersonic cruise performance. Should we fall short of our goals in other key technologies, LFC may be critical to ensuring program economic viability. Douglas studies indicate that reductions in cruise drag through the integration of an LFC system on an HSCT will result in block fuel reductions of 10 to 20 percent, depending on the aircraft cruise mach number and range. Associated benefits also include smaller engines, improved L/D, reduced TOGW, and overall improvements in operating economics. Technology development efforts required to realize these benefits have been identified, some of which are shown below.

Supersonic Laminar Flow Control (SLFC)

Benefits for HSCT

- 8% TOGW Reduction
- 12% Smaller Engines
- 14% Block Fuel Reduction
- 11% L/D Improvement
- 4% Better Economics

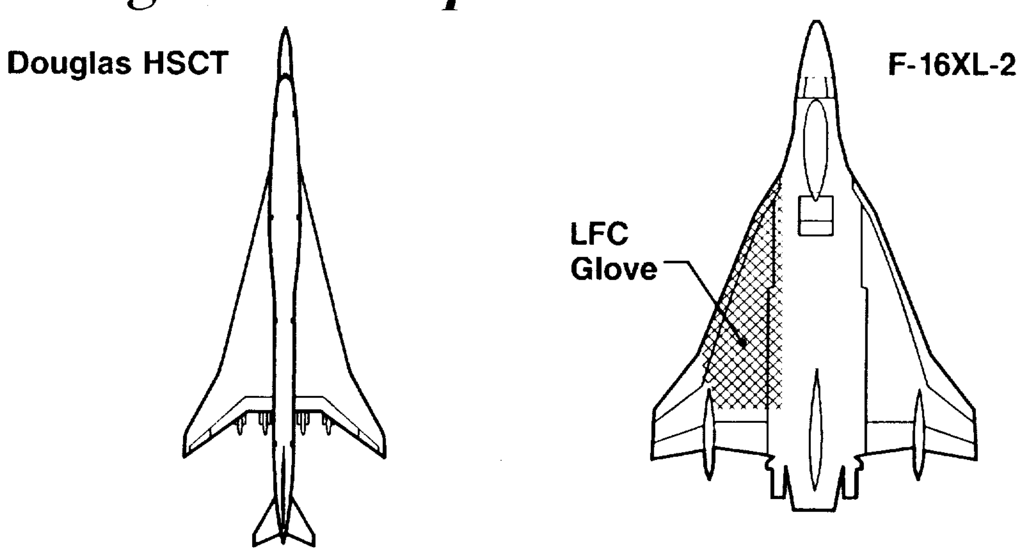
Technology Issues

- CFD for High-Speed Analysis and Design
- 3-D Boundary Layer Stability Analysis Package
- Perforated Advanced Materials Development
- Development of SLFC Structures and Ducting Using Advanced Materials
- Development and Integration of Large Suction Motors

PRELIMINARY DESIGN STUDIES UNDER NASA LANGLEY CONTRACT ARE FOCUSED ON A SUPERSONIC LAMINAR FLOW CONTROL FLIGHT TEST EXPERIMENT

Douglas is currently under contract to NASA Langley to examine the design issues associated with an SLFC flight test experiment using an F-16XL aircraft. This aircraft is considered an appropriate test bed because of the similarity in wing planform of the F-16XL to candidate HSCT designs. We are currently working with NASA to identify the type of development and test activities that would most effectively contribute to the successful application of this technology to an HSCT. The Douglas presentation and report in the LFC session of this workshop will discuss this activity in more detail.

Preliminary Design Studies Under NASA-Langley Contract Are Focused on a Supersonic Laminar Flow Control Flight Test Experiment



HSCT-RELATED AIRCRAFT SYSTEM ISSUES

The development of critical aircraft systems for the HSCT is a key to program success. Many advanced systems currently being developed for advanced subsonic transports (such as fly-by-light systems, electro/mechnical actuators, etc.) will also be applicable to the HSCT. But there are also system requirements which are unique to the HSCT, some of which are identified below. NASA Phase 2 HSR plans include a significant investment in technology development to address these issue, as appropriate.

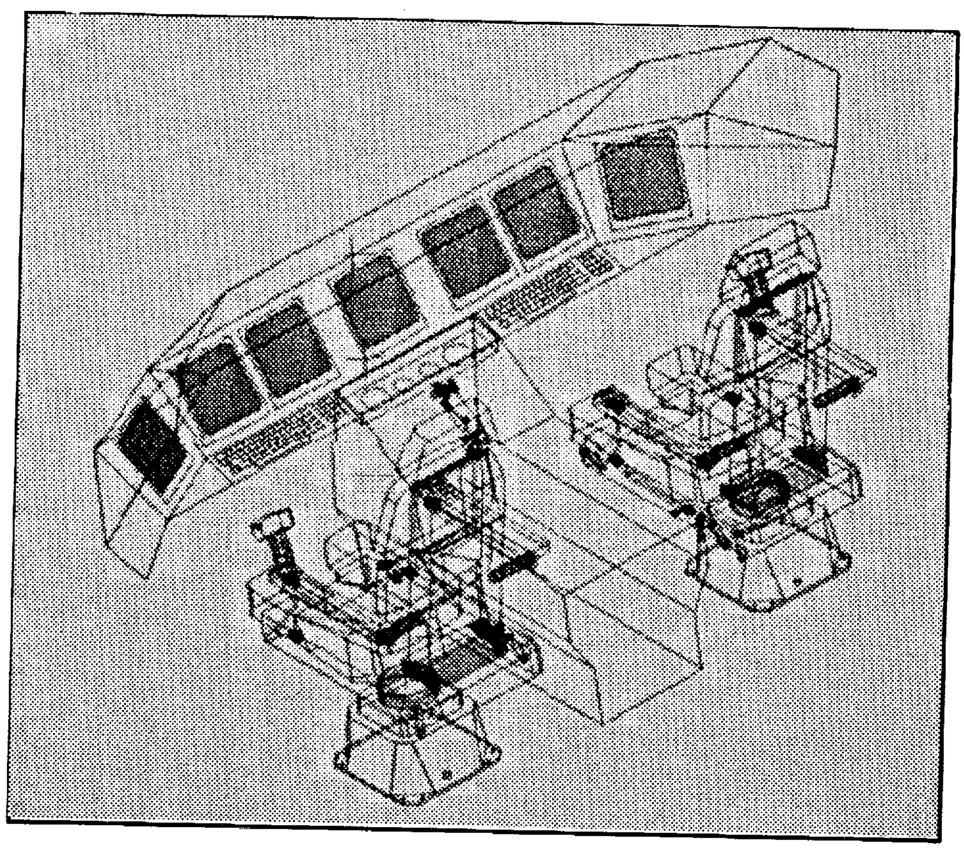
Aircraft System Issues Related to HSCT

System	Issue
Crew Systems (Flight Deck)	Restricted Visibility Space-Constrained Cockpit ATC Compatibility
Propulsion Subsystems	Integrated Control of Inlet/Engine/Nozzle/Airframe (Integrated Flight/Propulsion Control) CG Management
Flight Control	Integrated Flight/Propulsion Control Aircraft Stabilization Flexible Mode Control Takeoff/Landing Performance System Architecture

CREW SYSTEMS TECHNOLOGY

Douglas is active in the development of advanced crew systems technology for both subsonic and supersonic transport concepts. The drawing below is representative of an advanced flight deck concept for a future HSCT. These studies will continue over the next several years as the design mach number and associated technologies are selected.

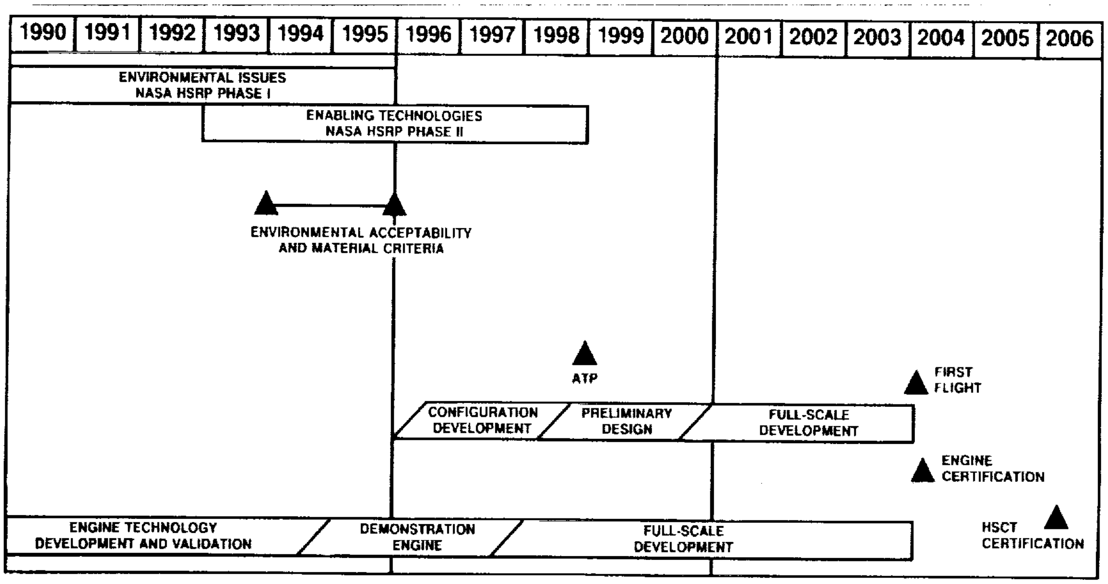
Crew Systems Technology



CURRENT STUDIES ARE BASED ON AIRCRAFT CERTIFICATION IN YEAR 2006

Douglas is currently following a parallel path approach to HSCT development. As shown earlier, we are currently evaluating multiple designs at different cruise mach numbers, and will continue this approach until program risk has been reduced to an acceptable level such that a single configuration may be selected. The critical step in achieving this condition is the timely development of environmental criteria which are accepted and adopted on a world-wide basis. Douglas is taking an active role in trying to advance this process. Despite these uncertainties, we advocate the development of long lead technologies required to meet our program milestones, particularly those which are not heavily dependent on cruise mach number. We believe that the NASA HSR program is consistent with our plans, pending the selection of a cruise mach number.

Current Studies Are Based on Aircraft Certification in Year 2006



SUMMARY

McDonnell Douglas is committed to the successful development and production of a High Speed Civil Transport for service entry beyond the turn of the century. We will maintain a parallel path approach to our configuration design studies until programs risks associated with uncertainties in environmental design criteria and technology development issues are reduced. An aggressive technology development program as outlined in NASA's long range plan for high speed research is critical to overall program success.

Summary

Near-Term Studies Focus on Environmental Issues and Economic Viability

- **Technology Requirements**
- **Operational Criteria**

MDC Study Effort Will Continue in Mach 1.6-2.4 Range

Aggressive Technology Development Effort Required

- **NASA/Industry Initiative**
- **Near-Term Attention to Long-Lead Issues**

Economic Viability Is Achievable Within Current Assumptions Given Timely Technology Development and Environmental Criteria

- **Atmospheric Effects**

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