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HSCT HIGH-LIFT TECHNOLOGY REQUIREMENTS

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AGENDA

The discussion topics are listed in this figure. The high-lift needs and related aerodynamic goals have been established in the recent system studies conducted for NASA. Next follows the status of the related high-lift database and available design and analysis methods. A summary of future high-lift technology requirements is presented followed by concluding remarks.

Agenda

- High-Lift Needs
- Status
- Technology Requirements
- Conclusions

Figure 1

MDC HSCT BASELINE DESIGN AND MISSION REQUIREMENTS

Current MDC HSCT baseline design and mission requirements are shown in this figure. There are 300 passengers in a three-class configuration, range is 5,500 nmi with 25-percent subsonic overland. The aircraft is to meet FAA Part 36 Stage 3 noise certification limits. The TOFL requirement is 11,000 ft. Note the significant portion of mission segments (indicated by a heavy line) where efficient low-speed, high-lift, and subsonic climb and subsonic cruise aerodynamics are required. Efficient subsonic characteristics are also required for all reserve segments to minimize reserve fuel requirements.

Douglas HSCT Baseline Design and Mission Requirements

NUMBER OF PASSENGERS = 300 (3-CLASS)
RANGE = 5,500 N Mi, TOFL = 11,000 FT (STD + 27F)
FAR PART 36 STAGE 3 NOISE CERTIFICATION LIMITS

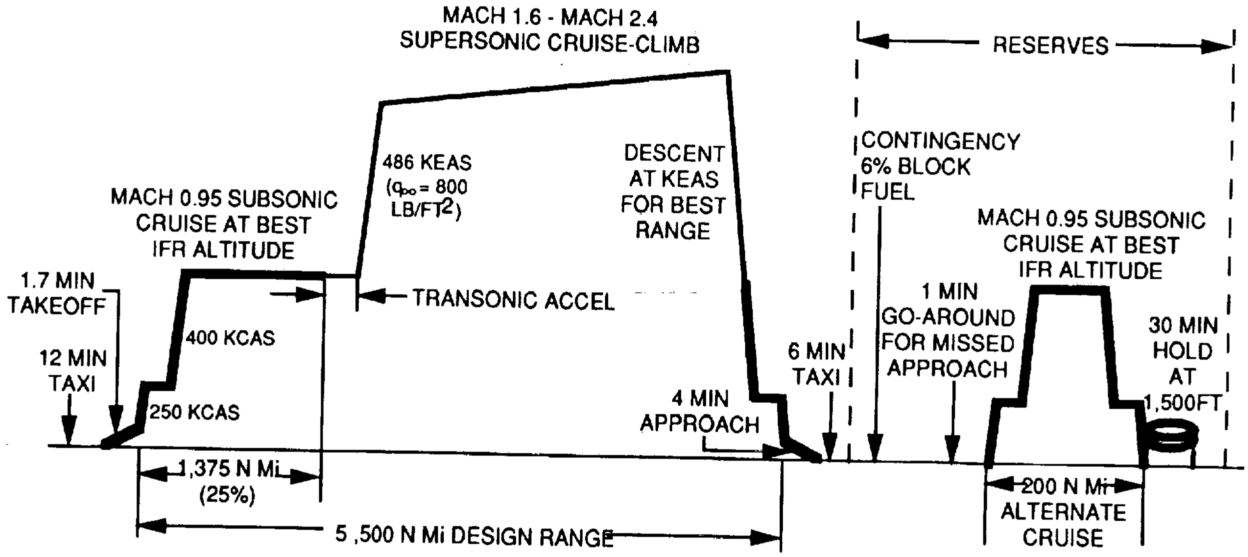
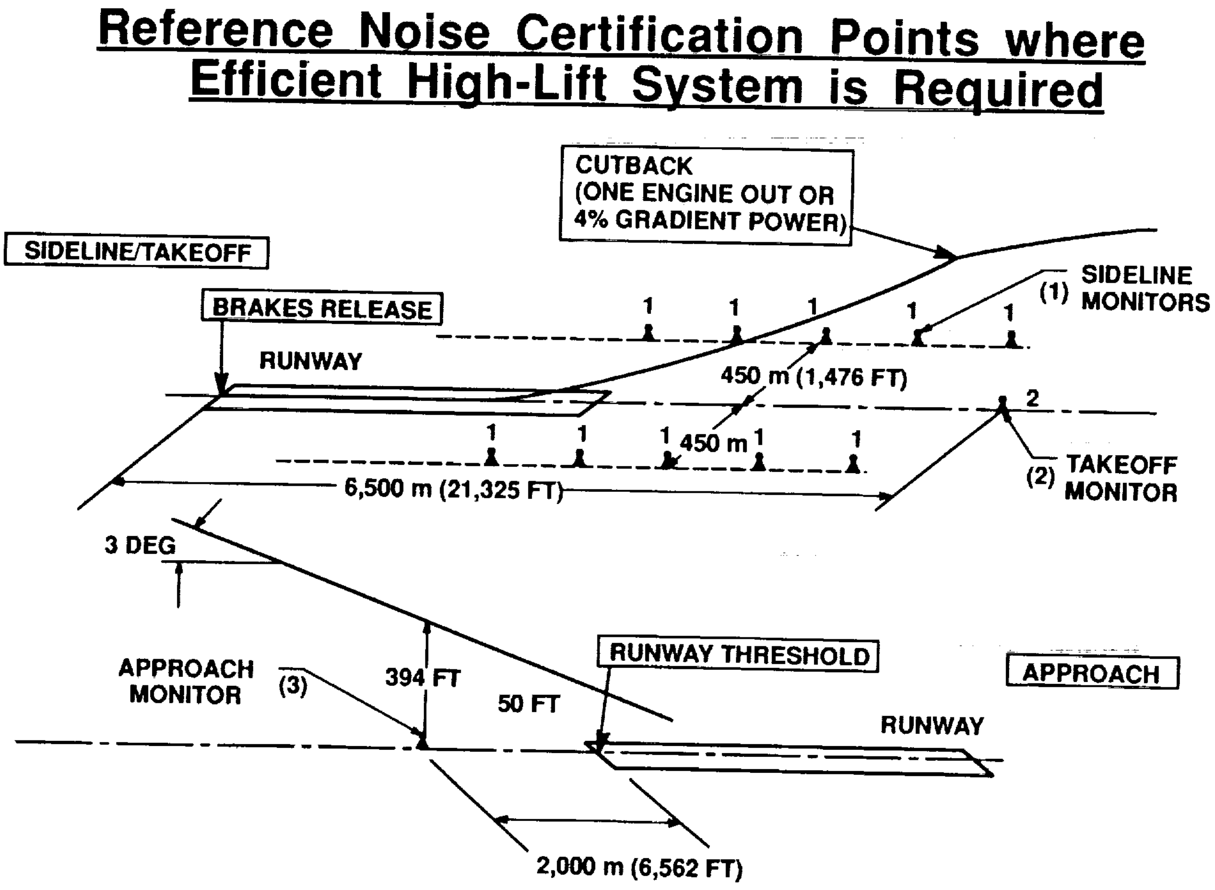


Figure 2

REFERENCE NOISE CERTIFICATION POINTS

Typical noise certification monitors at sideline, takeoff, and approach are shown in this figure. One of the objectives of the high-lift design is to improve aerodynamic efficiency so that the noise levels at these points are lowered. Results showing this effect are presented later.



Reference Noise Certification Points where Efficient High-Lift System is Required

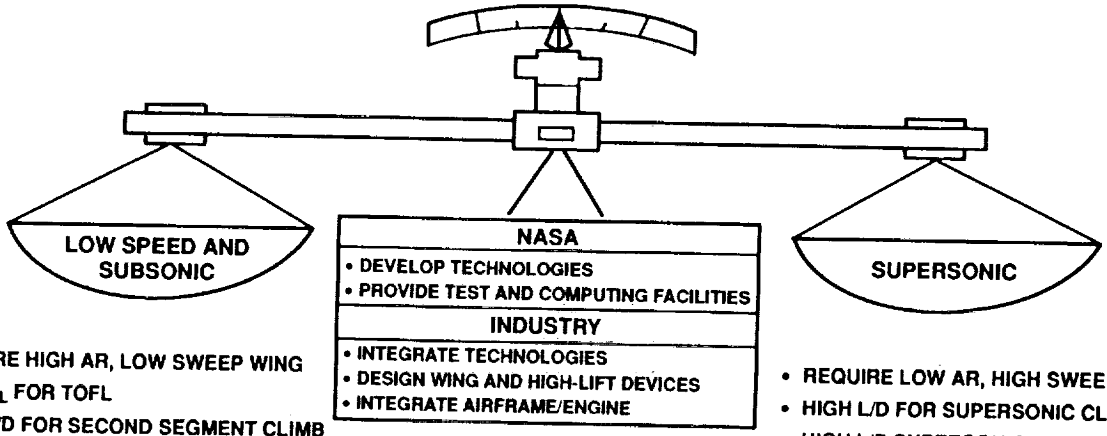
Figure 3

BALANCED AERODYNAMIC DESIGN

To make the HSCT economically viable and environmentally acceptable, the challenge is to design an HSCT wing that optimally balances low-speed, subsonic, and supersonic requirements. The figure shows that there are many low-speed takeoff and approach, and subsonic climb and cruise aerodynamic goals. These goals will have to be met by an optimum wing and high-lift system. The basic supersonic L/D requirements will also have to be met.

Balanced Aerodynamic Design is Required to Optimize Low-Speed, Subsonic, and Supersonic Performance

ECONOMIC VIABILITY AND ENVIRONMENTAL ACCEPTABILITY



NASA
- DEVELOP TECHNOLOGIES
- PROVIDE TEST AND COMPUTING FACILITIES

INDUSTRY
- INTEGRATE TECHNOLOGIES
- DESIGN WING AND HIGH-LIFT DEVICES
- INTEGRATE AIRFRAME/ENGINE

LOW SPEED AND SUBSONIC
- REQUIRE HIGH AR, LOW SWEEP WING
- HIGH C_L FOR TOFL
- HIGH L/D FOR SECOND SEGMENT CLIMB
- HIGH L/D FOR SUBSONIC CLIMB
- HIGH L/D FOR SUBSONIC CRUISE
- HIGH L/D FOR APPROACH
- HIGH C_L FOR LOW APPROACH SPEED
- HIGH L/D FOR RESERVE SEGMENT

SUPERSONIC
- REQUIRE LOW AR, HIGH SWEEP WING
- HIGH L/D FOR SUPERSONIC CLIMB
- HIGH L/D SUPERSONIC CRUISE

Figure 4

IMPACT OF HIGH-LIFT TECHNOLOGY

The impact of high-lift technology on performance, noise, and stability and control are highlighted in this figure. Note that the high-lift system will have to be integrated with other performance enhancing technologies, e.g., LFC and noise reduction devices (such as mixers/ejectors) as these technologies mature.

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 ($\therefore$ 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.

Figure 5

EFFECT OF HIGH-LIFT ON TOGW AND ENGINE THRUST

The figure shows results of recent system studies indicating a significant increase in L/D (at appropriate takeoff conditions) due to optimum leading edge deflections. This increase in aerodynamic efficiency will provide corresponding reductions in takeoff thrust and TOGW. Note that for the tailed configuration that was analyzed, best trailing-edge deflections were about 10 to 15 degrees in the trimmed mode.

Effect of High-Lift Settings at Takeoff

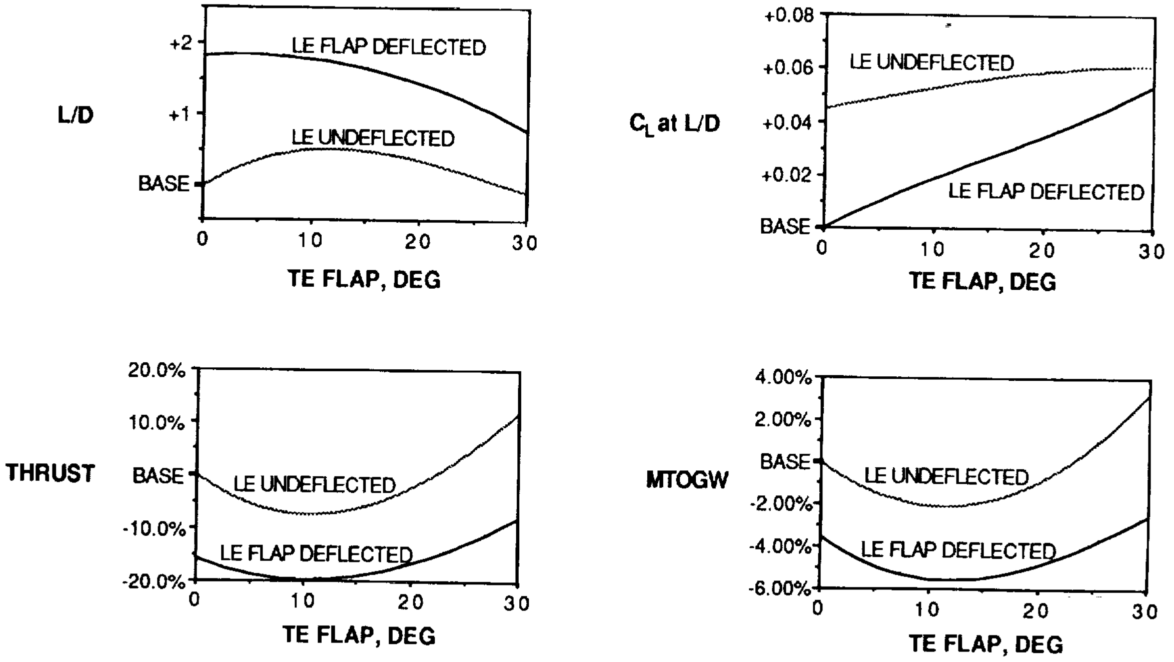


Figure 6

EFFECT OF L/D ON SIDELINE, TAKEOFF, AND APPROACH JET NOISE

The figure shows that for a given configuration, the L/D improvements can reduce the takeoff and approach noise levels. However, no significant reduction of sideline noise was obtained with the L/D increase.

Effect of L/D on Sideline, Takeoff, and Approach Jet Noise

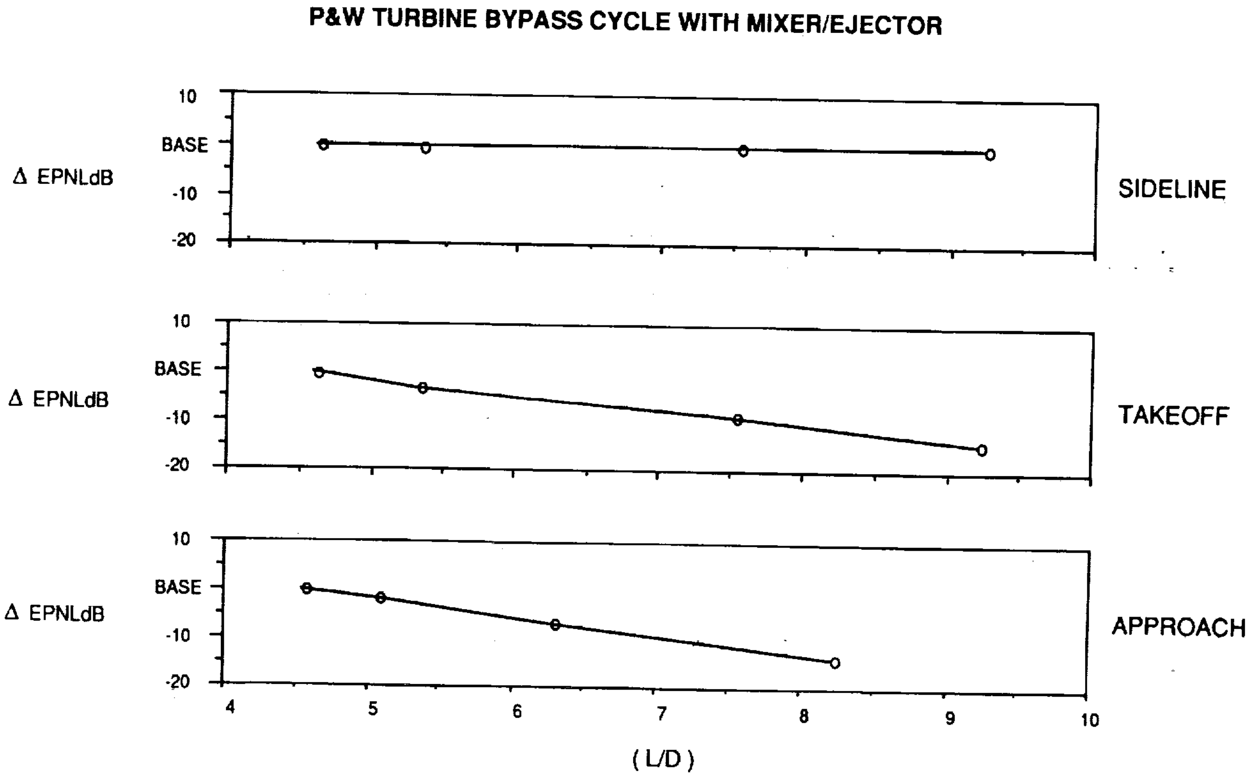


Figure 7

SUBSONIC CLIMB AND CRUISE PERFORMANCE REQUIREMENTS

As indicated earlier, there is a large segment of the mission where an improvement in subsonic aerodynamic efficiency is needed because 25-percent of the range is being flown at subsonic conditions. The figure shows that a significant increase in L/D could be obtained with optimum leading-edge deflections at subsonic speeds. There is also a beneficial increase in C_L at which L/D maximizes when flaps are deployed. This means that the flap systems required for the low-speed, high-lift segment will also have to be deployed in the subsonic mode. We should include this requirement as part of the high-lift technology development.

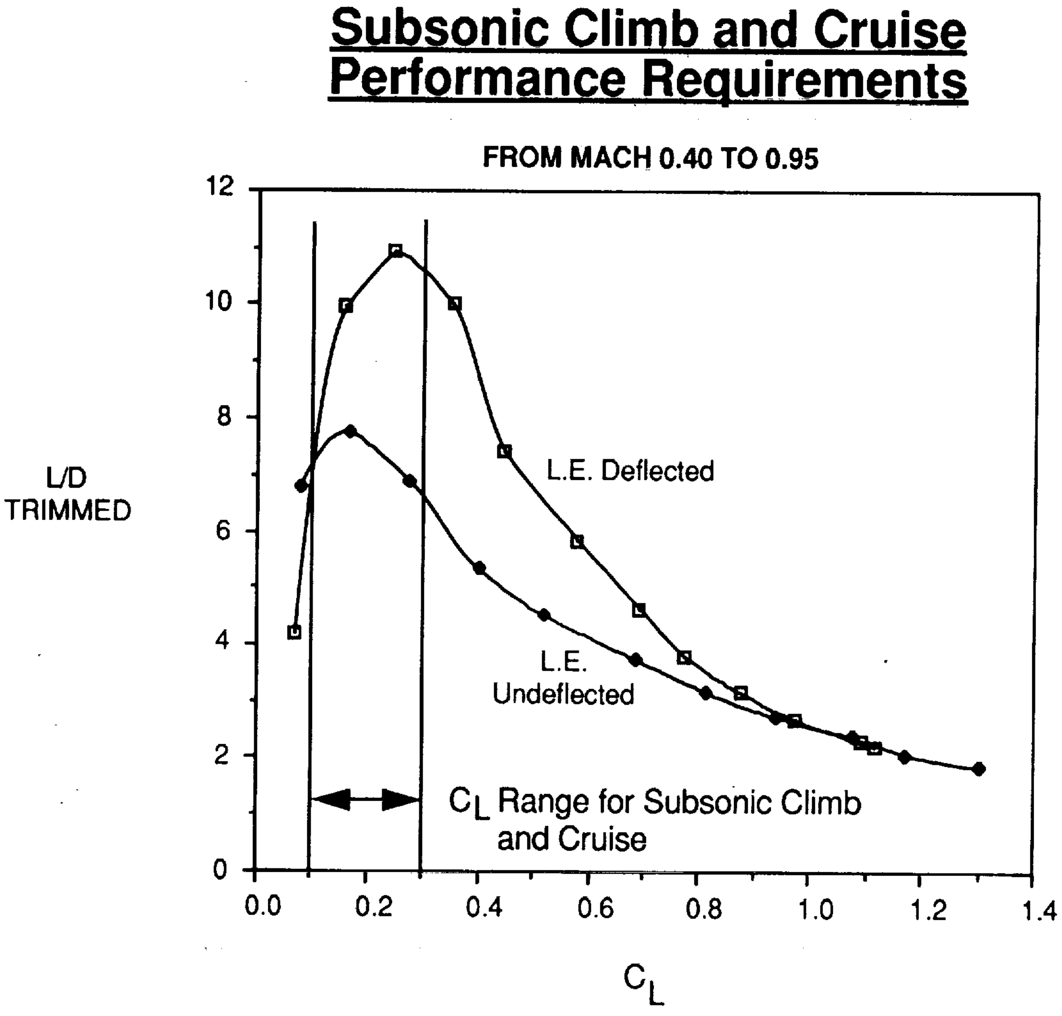


Figure 8

HSCT HIGH-LIFT AERODYNAMIC GOALS

We have established aerodynamic goals for a desirable high-lift system based on recent system studies. The goals are presented for the takeoff, approach, and subsonic climb and cruise modes. It is believed that these goals are attainable within the expected 1998 technology availability date. An important aspect here is that if the wing and its high-lift system has to perform significantly better than certain minimum requirements, the wing planform may be compromised which may lead to a large penalty on the supersonic aerodynamic efficiency, this in turn will cause large weight and economic penalties.

HSCT High-Lift Aerodynamics Goals

(Trimmed Conditions)

Takeoff

C_L Ground Angle Limit	>	0.75
$(L/D)_{\text{Second Segment Climb}}$	>	8.0
LE Suction Factor$_{\text{Second Segment Climb}}$	≥	0.8

Approach

$(L/D)_{\text{Approach}}$	>	7.5
LE Suction Factor$_{\text{Approach}}$	≥	0.8

Climb

$(L/D)_{M = 0.5 \text{ to } 0.95}$	>	14

Figure 9

HSCT HIGH-LIFT TECHNOLOGY STATUS

There is a good set of high-lift wind tunnel databases available for the past supersonic transport configurations. These data were mainly obtained at conventional wind tunnel Reynolds numbers. The flap design methodologies developed by Carlson, Frink, etc., at NASA Langley are quite useful to aerodynamic designers for guiding them toward optimum flap designs. The CFD codes will have to be calibrated for application to flowfields associated with HSCT wings and flaps.

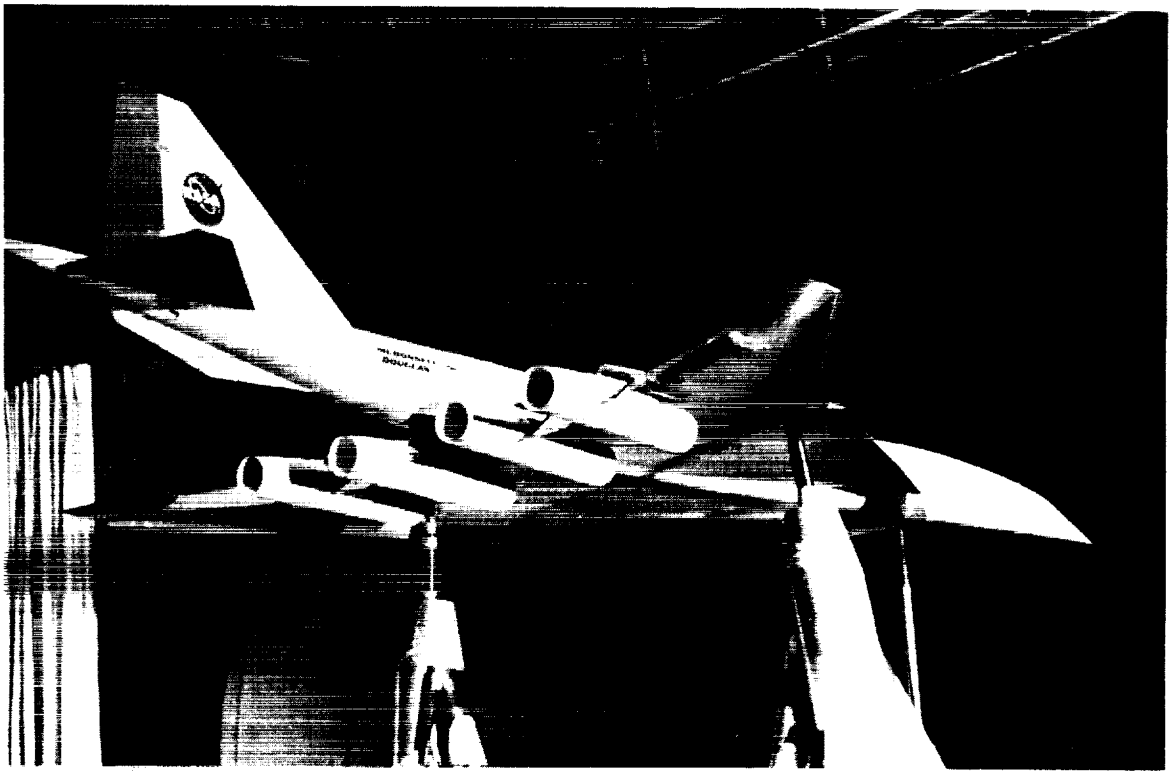
HSCT High-Lift Technology Status

- Extensive SST, SCAR, SCR, and AST databases are available.
- Flap design methodologies (by Carlson, Frink, etc.) based on linear subsonic flows and L E suction/vortex lift corrections are available.
- Navier-Stokes codes are available. However, the codes and their turbulence models need to be calibrated and verified for their application to highly 3-D, vortex-dominated, separated flowfields.

Figure 10

NASA 0.1-SCALE LOW-SPEED MODEL OF DOUGLAS AST CONFIGURATION

An example of an available model for high-lift testing is shown here. This particular 0.1-scale model is for the NASA/Douglas Mach 2.2 Advanced Supersonic Transport configuration, with the aspect ratio 1.84, leading-edge sweep 71/57-degree wing planform. The model has been tested in the Langley 30-by 60-foot tunnel with a full wing/high-lift-system/tail/nacelle configuration. A plan for testing this model with new flaps is being formulated.



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Figure 11

EXAMPLE OF NAVIER-STOKES/EULER CODES APPLICATION

An example of MDC application of the CFL3D code in the Euler and Navier-Stokes modes for a delta wing is shown here. A good comparison of the predicted vortex location using the code with the test data is shown. Further work is being done for the application of this and similar codes to the HSCT type planforms with flaps.

Example of Navier-Stokes/Euler Codes Application

Ref. MCAIR 90 - 021

Medium Mesh, $M_\infty = 0.30$, $Re_c = 1 \times 10^6$, $\alpha = 20°$

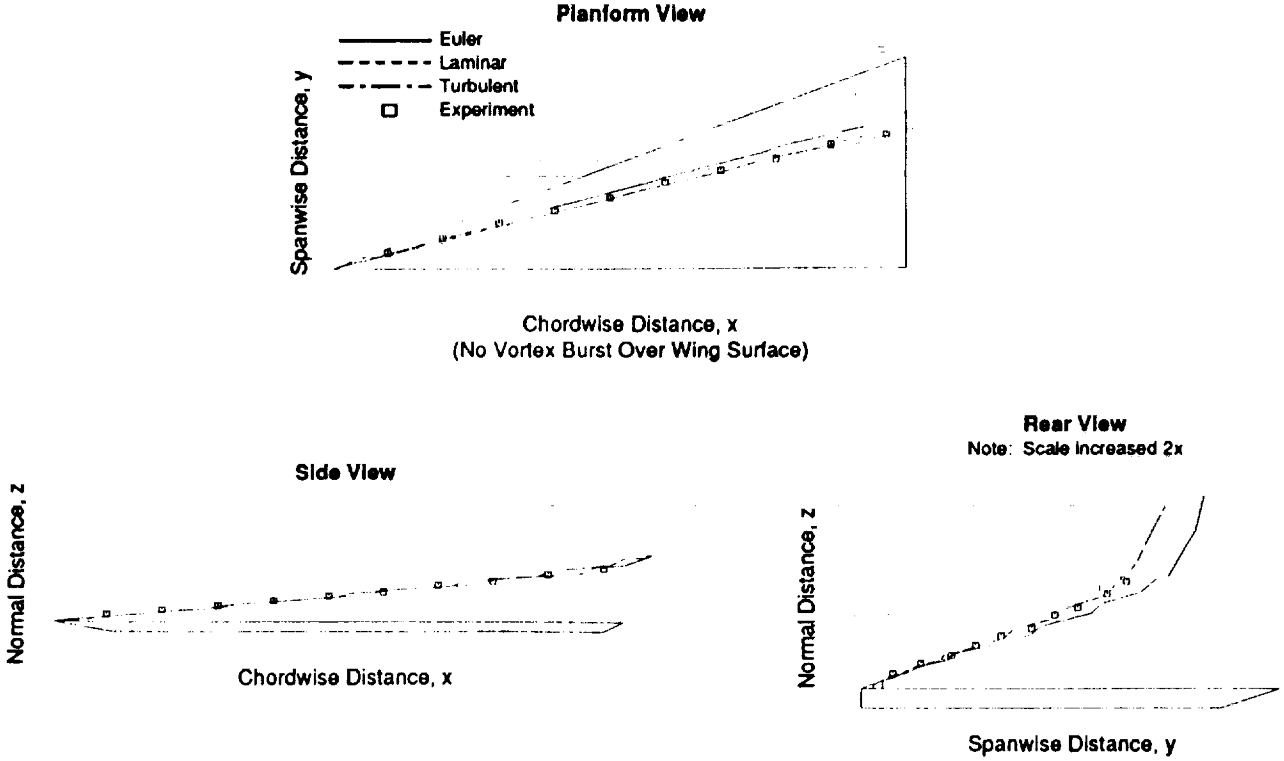


Figure 12

HSCT HIGH-LIFT RESEARCH AND TECHNOLOGY AREAS

Various high-lift research and technology areas for future work are listed in this figure. Each topic is discussed on the following pages.

HSCT High-Lift Research and Technology Areas

- Innovative Concepts Verification.
- Flap Design Methodology Application and Verification.
- CFD Calibration and Application.
- High Reynolds Number Testing.
- Subsonic/Transonic Flap Optimization.
- Flight Testing.

Figure 13

SOME CANDIDATE INNOVATIVE HIGH-LIFT CONCEPTS

Some of the candidate innovative concepts are shown here. The vortex flap concept, apex fence, deployable canards/strakes, apex blowing, etc., have a potential for improving L/D, C_L, and trim control to varying degrees. Some of these concepts have been tested by NASA in the past. Further work is required for a full assessment of the benefits and risks of each concept.

Some Candidate Innovative High-Lift Concepts

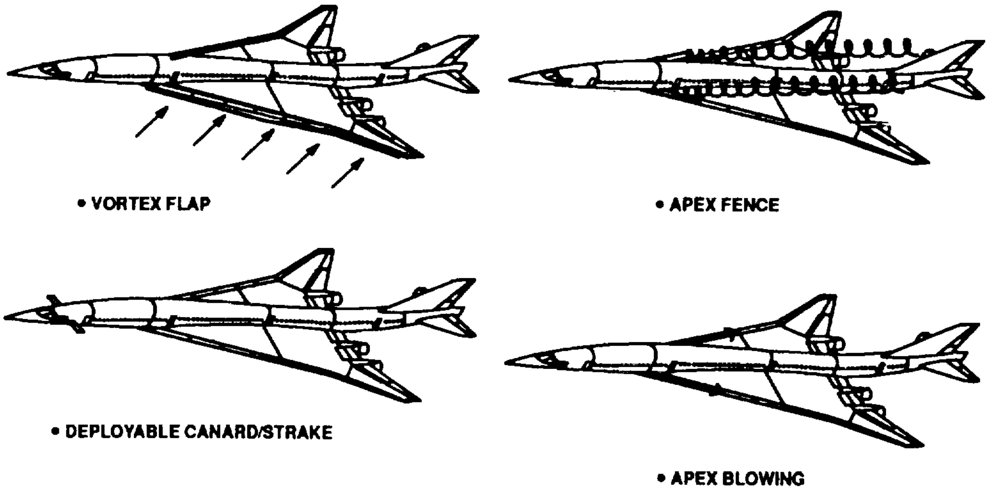
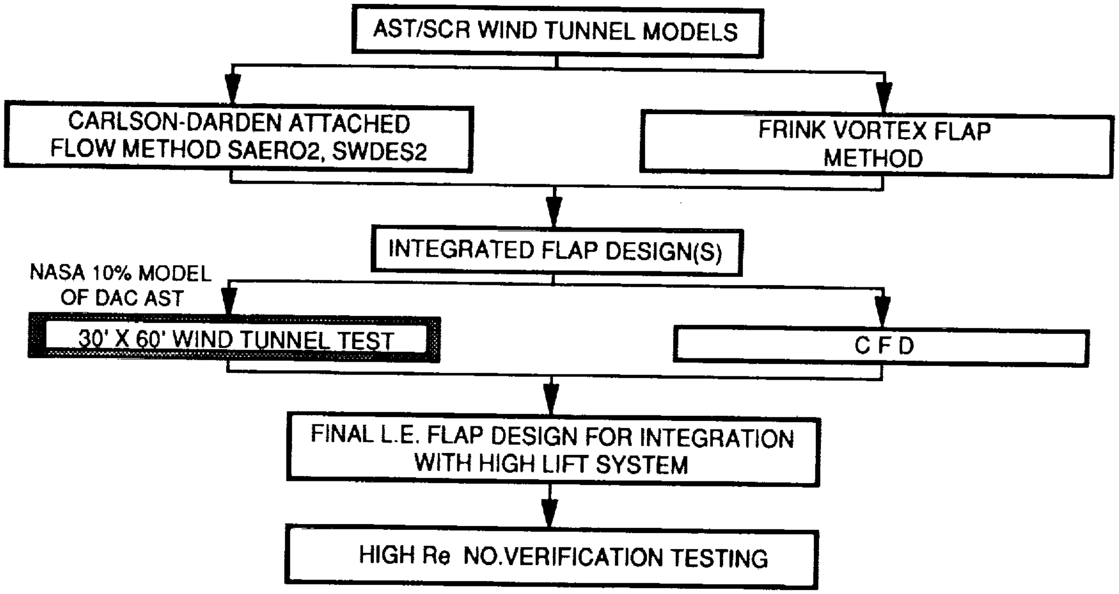


Figure 14

APPLICATION AND VERIFICATION OF CURRENT L.E. FLAP DESIGN METHODOLOGIES

The important area of applied methods development and verification is discussed in this figure. Douglas is currently applying the Carlson-Darden flap design and analysis codes and Frink vortex flap design code to the HSCT high-lift problem. The near-term objective is to select flap configurations for verification in the NASA Langley 30- by 60-foot tunnel with the NASA 0.1 model of the Douglas AST configuration. A parallel CFD application to the flap design process is also planned before final flap configurations are selected for advanced testing, e.g., high-Re testing.

Application and Verification of Current L.E. Flap Design Methodologies



AST/SCR WIND TUNNEL MODELS

CARLSON-DARDEN ATTACHED FLOW METHOD SAERO2, SWDES2

FRINK VORTEX FLAP METHOD

INTEGRATED FLAP DESIGN(S)

NASA 10% MODEL OF DAC AST

30' X 60' WIND TUNNEL TEST

C F D

FINAL L.E. FLAP DESIGN FOR INTEGRATION WITH HIGH LIFT SYSTEM

HIGH Re NO.VERIFICATION TESTING

Figure 15

CFD CALIBRATION AND APPLICATION NEEDS

CFD calibration and application needs are listed in this figure. The codes and their turbulance models will have to be verified for their application to the complex 3-D viscous, vortex-dominated, separated flowfields. We need to agressively pursue this area so that the codes can be made available for the flap design process. The goal is also to be able to analyze full wing/body/tail/nacelle configurations by the 1995-1998 timeframe. These codes will also allow us to predict aerodynamic loads with vortex effects - a very improtant input to the structural design process.

CFD Calibration and Application Needs

- Understand complex 3-D viscous flowfield around low AR, high sweep wings with and without flaps.
- Understand L E vortex development and breakdown.
- Guide flap design process.
- Study high Reynolds number effects.
- Analyze full trimmed configurations (body, tail, and nacelle effects).
- Predict aerodynamic loads.

Figure 16

HIGH REYNOLDS NUMBER RESEARCH AND TECHNOLOGY

Areas of high Reynolds number research and technology development are shown in this figure. The HSCT full-scale Reynolds number in the takeoff and approach modes is typically on the order of 100-150 million based on a wing mean aerodynamic chord. Most of the test data are available at a conventional Re of about 4 million. The effect of higher Re will have to be simulated in the NTF, 12 foot, or 40- by 80-foot tunnels. These results will help in selecting candidate concepts for flight testing.

High Reynolds Number Research and Technology Areas

- Understand dependency of vortex formation and leading-edge suction on wing leading-edge radius and Reynolds number (Re).
- Study effectiveness of flaps (L E and T E), strakes, and fences at high Re.
- Study tail effectiveness at high Re.
- Generate data for CFD code validation.
- Select final flight test configurations through parametric testing at high Re.

Figure 17

SUBSONIC CLIMB/CRUISE FLAP OPTIMIZATION TECHNOLOGY

As stated earlier, flap settings must be optimized and verified for subsonic climb and cruise to enhance performance. CFD and high-Re technology development activities should reflect this need.

Subsonic Climb/Cruise Flap Optimization Technology Areas

- Determine and validate optimum flap settings for subsonic climb and cruise.
- Apply CFD codes to the design process.
- Verify designs through high Re testing.

Figure 18

ROLE OF FLIGHT TESTING IN THE HSCT HIGH-LIFT RESEARCH AND TECHNOLOGY DEVELOPMENT

This figure addresses the role of flight testing in the high-lift research and technology areas. For many purposes, a high Reynolds number wind tunnel test may be quite sufficient. However, a cost-effective flight test could provide additional data beyond the wind tunnel testing. The flight testing could be the most appropriate means of simulating interactions between high-lift devices and an actual engine noise-reduction system.

Role of Flight Testing in the High-Lift Research and Technology Development

- High-Re wind-tunnel testing (in,e.g., NTF, 12', 40' x 80') can be utilized for:
  - Understanding basic high Re effects.
  - Sorting out configurations.
  - Generating large controlled databases for pressures and forces and moments.
- Flight testing of aircraft with appropriate AR and sweep can be suitable for:
  - Observing flow phenomena not simulated in the tunnels.
  - Generating clean data without wall, ground, and support system interference.
  - Validating final high-lift concepts.
  - Simulating interactions between high-lift devices and engine noise reduction systems (suppressors, ejectors, mixers, etc.).
- Cost effectiveness of either approach can be a major decision factor in scoping various technology development plans.

Figure 19

HSCT HIGH-LIFT TECHNOLOGY DEVELOPMENT NEAR-TERM PLAN

An HSCT high-lift technology development near-term plan is shown in this figure. B1 and B2 represent updated 1991 and 1992 baselines with their respective optimized wing planforms and engine cycles. In additon to the innovative high-lift concepts verification, the Carlson's and Frink's linear methods will be applied for flap designs in the near term. The long-term plan is to apply CFD to the wing (W) and its flaps by 1992, followed by its application to the wing-body (WB) and a full B2 baseline configuration. Most of the wind tunnel test verification may be required for the B2 configuration. However, there may be a need for an interim small-scale testing of the B1 configuration. The final configuration validation testing may involve some flight-testing and/or 40- by 80- foot wind tunnel testing.

HSCT HIGH-LIFT TECHNOLOGY DEVELOPMENT NEAR-TERM PLAN

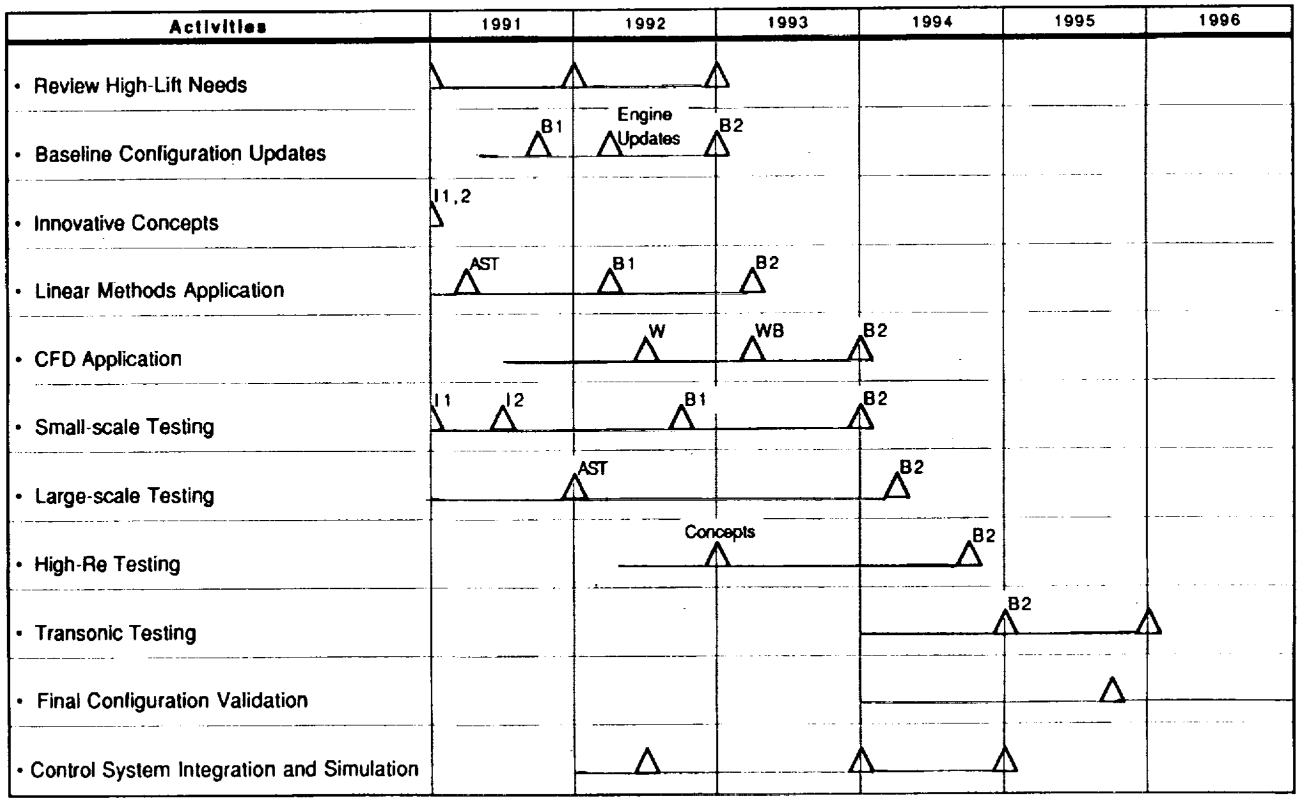


Figure 20

CONCLUSIONS

Some general concluding remarks are made in this figure. It is believed that with an aggressive technology development effort, the high-lift aerodynamic goals can be met.

Conclusions

- Efficient high-lift, high L/D system for HSCT is required to minimize TOGW, improve economics, and help meet noise goals.
- Optimum flap settings will be required to operate at max L/D in the subsonic climb and cruise segments. There is a scarcity of database in this area.
- Future enabling technology/research needs include verification of new high-lift designs, aggressive CFD application, flight test verifications, and high Reynolds number testing.

Figure 21