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PROPULSION AIRFRAME INTEGRATION SESSION OVERVIEW AND REVIEW OF LEWIS PAI EFFORTS

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INTRODUCTION

Propulsion/Airframe Integration (PAI) is a key issue for the High Speed Civil Transport. The aircraft performance, economics, and environmental acceptability can be adversely affected if integration of the propulsion and airframe is not addressed properly or in a timely manner. Some of the goals for are listed in this figure. In particular, these goals are highly influenced by how successfully the propulsion system and airframe are integrated. These goals have been grouped by the "Aero" and "Propulsion" categories to suggest which group of technologists will likely be addressing them. In terms of the NASA High Speed Research Program, the ultimate objective for propulsion/airframe integration is to demonstrate the technologies for achievement of these goals on a "single" integrated configuration.

HSR PAI GOALS

- *Demonstrate experimentally on a "single" integrated configuration, those technologies which allow:*

-- *(Aero)*	SS Cruise L/D 10 Transonic L/D >15 Take Off L/D 10
-- *(Prop)*	Exceeds FAR 36 Stage III Favorable impact on inlet and nozzle performance

Figure 1

PROPULSION/AIRFRAME INTEGRATION TECHNOLOGY FOCUS

For the High Speed Research Program propulsion/airframe integration technology development, three basic integration technology areas have been selected for focus. First is the nacelle-airframe interference and interactions where installation effects on drag and lift are addressed. For example, the flow around the propulsion system can influence the local pressure field on the wing and result in a change in the lift and drag characteristics of the wing. The goal is to achieve integrated system drag and/or lift values to be better than their isolated values. Second is the impact of the external flowfield on the propulsion system performance and stability. An example would be wing or other aircraft component effects on inlet or nozzle performance. Third is the impact of nacelle and airframe flows on acoustics. For example, the wing flowfield effect on the nozzle take-off acoustic suppression. An ideal concept would be a suppressor design which can take advantage of both the wing flowfield characteristics and geometric shielding.

HSR PROPULSION/AIRFRAME INTEGRATION

- *Nacelle-airframe interference and interactions (lift & drag)*
- *Flowfield effects on internal performance*
- *Nacelle-airframe effects on acoustics*

Figure 2

TECHNOLOGY ISSUES - SUMMARY FROM JUNE 1990 REVIEW

To initiate the High Speed Research Program PAI planning activities, a preliminary PAI meeting was held in June 1990 for industry to provide NASA with an update on PAI technology issues, developments and requirements since the Supersonic Cruise Aircraft Research Program. We believed this joint meeting to be a good initialization point for HSR planning as well as a catalyst for industry and NASA focus on the critical role of PAI. Because of the timing, a key objective of the workshop identification of PAI issues which affect achievement of the HSR ϕ-I Program. As summarized in the figure, there were four areas identified at the meeting as "high priority" and which met this objective. These four areas have been denoted by the check-marks in the figure. For example, achievement of take-off noise levels below FAR Part 36, Stage III is a key HSR ϕ-I goal, but PAI issues such as the wing/flap trailing edge flow-field interactions with the nozzles and their acoustic suppression characteristics has yet to be identified. Compared with ten or more years ago, considerable progress has been made with the computational fluid dynamics (CFD) codes and analyses, but little experimental validation has been done to assure their applicability for HSCT designs. Nacelle placement and shape trade-offs which effect system drag and lift need to be updated from prior efforts to accommodate today's aerodynamics and cruise Mach number. Lastly, particularly for cruise Mach numbers greater than 2.2 or so, mixed-compression inlets are required for performance. If inlet unstart can not properly be handled, then cruise Mach number would be potentially decided by a PAI issue.

TECHNOLOGY ISSUES - PAI
Summary from June 1990 Workshop at Lewis

✓ ***2D vs. AXISYMMETRIC NOZZLES***
- NOISE – ENG/ENG Shielding
- – ENG/Wing

✓ ***CFD VALIDATION DATA BASE (Placement/shape)***
- ARC MODEL – MACH No.
- – 2D & Axisym

✓ ***2D vs. AXISYMMETRIC INLETS, NACELLES***

✓ ***UNSTART CRITERIA & CONTROLS, CERTIFICATION***
- – AIRCRAFT & PASSENGER RESPONSE TO UNSTART - ϕ - I STUDY

- ***CONTROLS***
- ***MACH NO.?***
- ***ACCESSORIES & SECONDARY POWER***

✓ = PRIORITY

Figure 3

PAI ACTIVITIES INITIATED FOLLOWING JUNE 1990 REVIEW

As a direct consequence of the June PAI 1990 meeting, several in-house and contract research activities and studies have been initiated. These are listed in this figure. A preliminary wing-flow/low noise nozzle experiment and analysis activity has been initiated. This paper will expand on this activity below. Regarding the second item, C. Domack will address his studies on the effects on mixed-compression inlet unstart on HSCT aircraft dynamics in a paper later in this session. Also, G. Cappuccio will present the status and plans for experimental/analytical research on nacelle shape and placement immediately follows this paper. This propulsion-airframe model used to study nacelle placement in 1973 has been located and is being refurbished. Figures and brief descriptions will follow below. And lastly, contract studies expanding on the inlet/nacelle/nozzle geometry trades have been initiated. This session of the HSR Workshop contains papers from Boeing and Douglas on their efforts.

HSR PROPULSION/AIRFAME INTEGRATION

ACTIVITIES INITIATED FOLLOWING JUNE 1990 REVIEW

1. *Wing flow / low noise nozzle experiment/analysis*
2. *Unstart effects*
3. *Nacelle placement*
4. *Inlet/Nacelle/Nozzle, Axi vs. 2D, etc.*

- CONTRACTS -

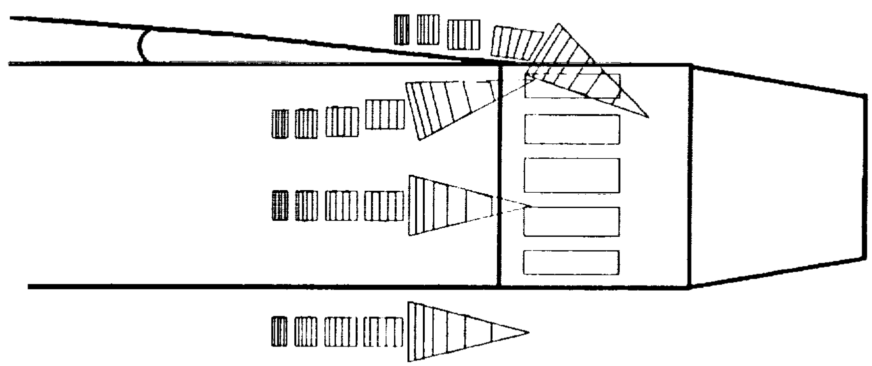
Boeing	-	Inlet Screening, Weight (TBE Emphasis)
Douglas	-	Inlet Screening (FLADE Emphasis)
Lockheed	-	Nozzle/Nacelle Integration

Figure 4

PAI AFFECTS NOZZLE ACOUSTIC SUPPRESSION

At Lewis Research Center, low noise nozzles are aggressively being pursued for take-off conditions under the HSR Φ-I program. Specifically, the research is focussing on ejector-type flow augmentation schemes to reduce jet velocities and thereby reduce noise. In current study designs as depicted in this figure, these ejector-type flow augmentors require secondary air intakes which are located aft of the trailing wing/flap trailing edge. As a consequence, the flowfield at the ejector secondary air intakes will likely be quite complex and certainly different than what occurs around the isolated nozzle jet exit rigs currently being used to study nozzle acoustics. Thus ejector secondary performance will be affected and therefore the acoustic suppression characteristics of the nozzle/ejector system. This is a prime example of how propulsion/airframe integration has a direct impact on achieving HSR Φ-I goals.

PAI AFFECTS NOZZLE ACOUSTIC SUPPRESSION



- WING AND TRAILING-EDGE FLAPS ALTER NOZZLE EXTERNAL AND EJECTOR-INLET FLOWFIELD.
- HENCE, ACOUSTIC SUPRESSION CHARACTERISTICS WILL BE ALTERED.

Figure 5

INSTALLATION EFFECTS TEST WITH JET EXIT RIG AND WING

Experimental acoustic evaluations of axisymmetric and 2D nozzles are planned for Fall of 1991 at Lewis. The basic problem discussed on the previous page can be addressed on a preliminary basis by adding a wing-section to these nozzle tests as depicted in the figure. This wing would have appropriate sweep and high-lift devices at the leading and trailing edges to allow it to be generically representative of an HSCT design. The experiment will include variable flap settings and the ability to vary the position of the wing from the secondary inlets and jet exit rig. Planned measurements include not only pressure and acoustic measurements but also LDV. From such an experiment, we expect to begin development of an PAI experimental database for aero performance, acoustic, and flowfield analyses for wing/nozzles. Specifically, the results of this experiment will be used to validate CFD codes for nozzle-wing-nacelle type flows. The main challenge is to combine analysis of internal and external flows about complex configurations; the code can then be applied to more realistic configurations. For this a generic wing/nozzle configuration, we also expect to determine the first-order effects on the acoustic characteristics of ejector nozzles due to non-uniform external flow into the ejectors and an early assessment ejector nozzle aerodynamic performance as a result of installation.

JET EXIT RIG WITH A GENERIC WING SHAPE FOR INSTALLATION EFFECTS

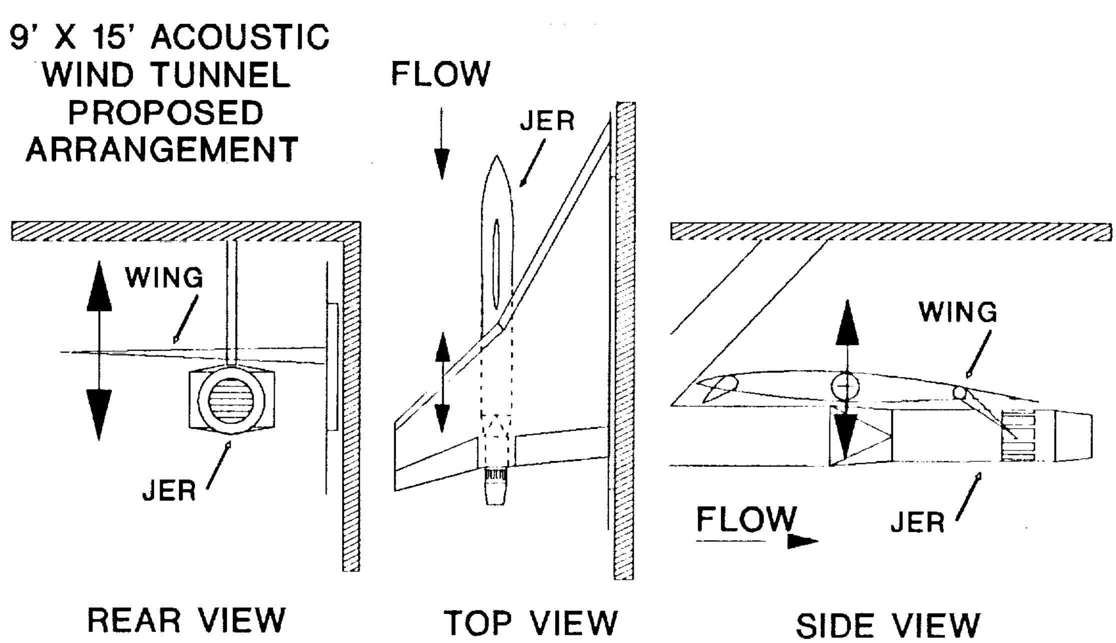


Figure 6

MIXED COMPRESSION SUPERSONIC INLET INSTABILITY

This figure introduces the subject of mixed compression supersonic inlet unstart which leads to the concern regarding certification of mixed compression inlets. Above cruise Mach numbers of approximately 2.2, mixed compression inlets provide superior performance over other types. A mixed compression supersonic inlet has a portion of its supersonic diffusion (compression) occur inside of the inlet cowl lip. Two "grossly" stable conditions can occur for this type of design. The inlet normal shock is contained just downstream of the inlet throat for the first, and desirable, condition. The second condition occurs when this normal shock is expelled from the and the inlet throat is either subsonic or choked. This second condition results in poor inlet performance, which also may be unstable (buzz), and asymmetric drag and/or lift conditions on the aircraft. Transition from the first to the second condition, called an "unstart," can be caused by an external event such as a gust or angle of attack change, or by engine airflow transients. Passenger safety and comfort issues as well as aircraft stability and control problems can result if the consequences of the unstart are severe. Considerable debate has occurred on this subject because of the potential impact on cruise Mach number, NASA Langley has been studying this problem in some depth. C. Domack will report on the initial results. Additional contract studies are planned.

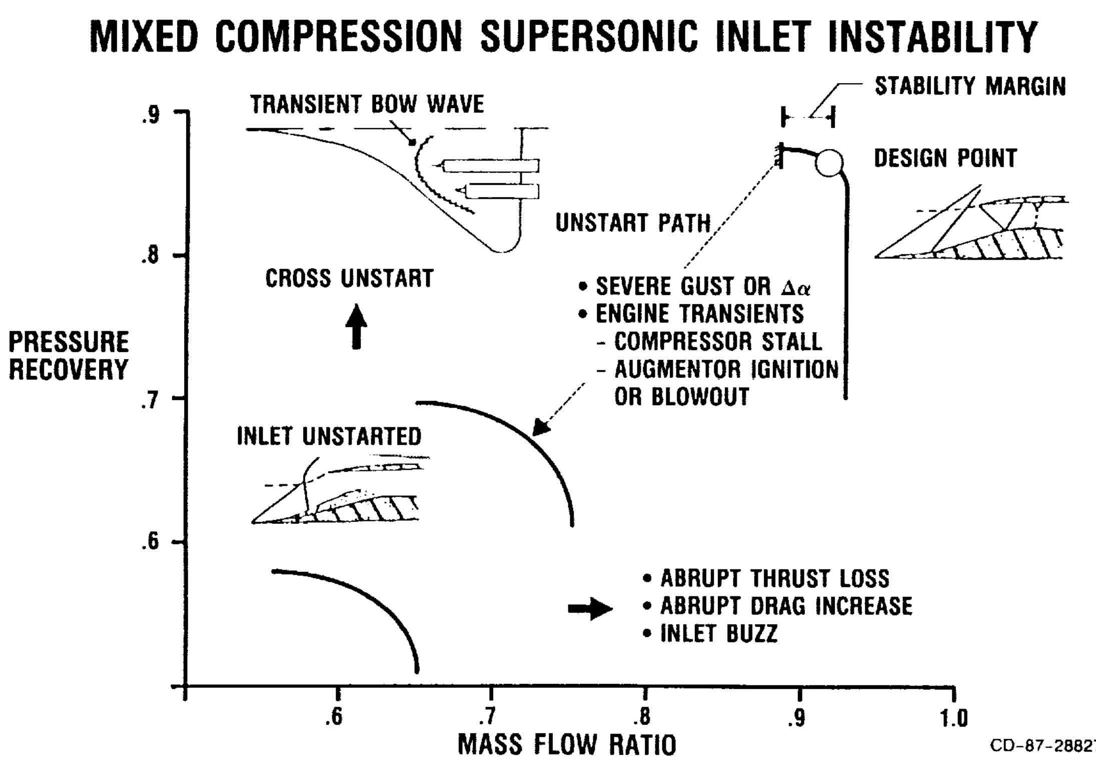


Figure 7

NACELLE/AIRFRAME INTERFERENCE TEST

A propulsion airframe interference test was conducted in the Ames 11- by 11-Foot Transonic Wind Tunnel in 1973. The purpose of the test was to measure detailed interference force and pressure data on a representative supersonic wing-body-nacelle combination at transonic speeds. The aerodynamic model is based on Boeing's model SA1150 and is a delta wing-body configuration at 0.024 scale. All hardware associated with the model has been recovered and is in the process of being refurbished. Of the four individual nacelles supported beneath the wing-body model, the two on the left-hand side were pressure instrumented, and the other two were force instrumented. The four nacelles were supported beneath the wing-body independently by the nacelle support system, providing flexibility of positioning the nacelles relative to the wing-body and each other. Future PAI plans associated with this model and testing in the Ames 9- by 7-Foot Wind Tunnel scheduled for June 1992 as well as additional information about nacelle shape and placement research issues and plans will be presented by G. Cappuccio in the next paper.

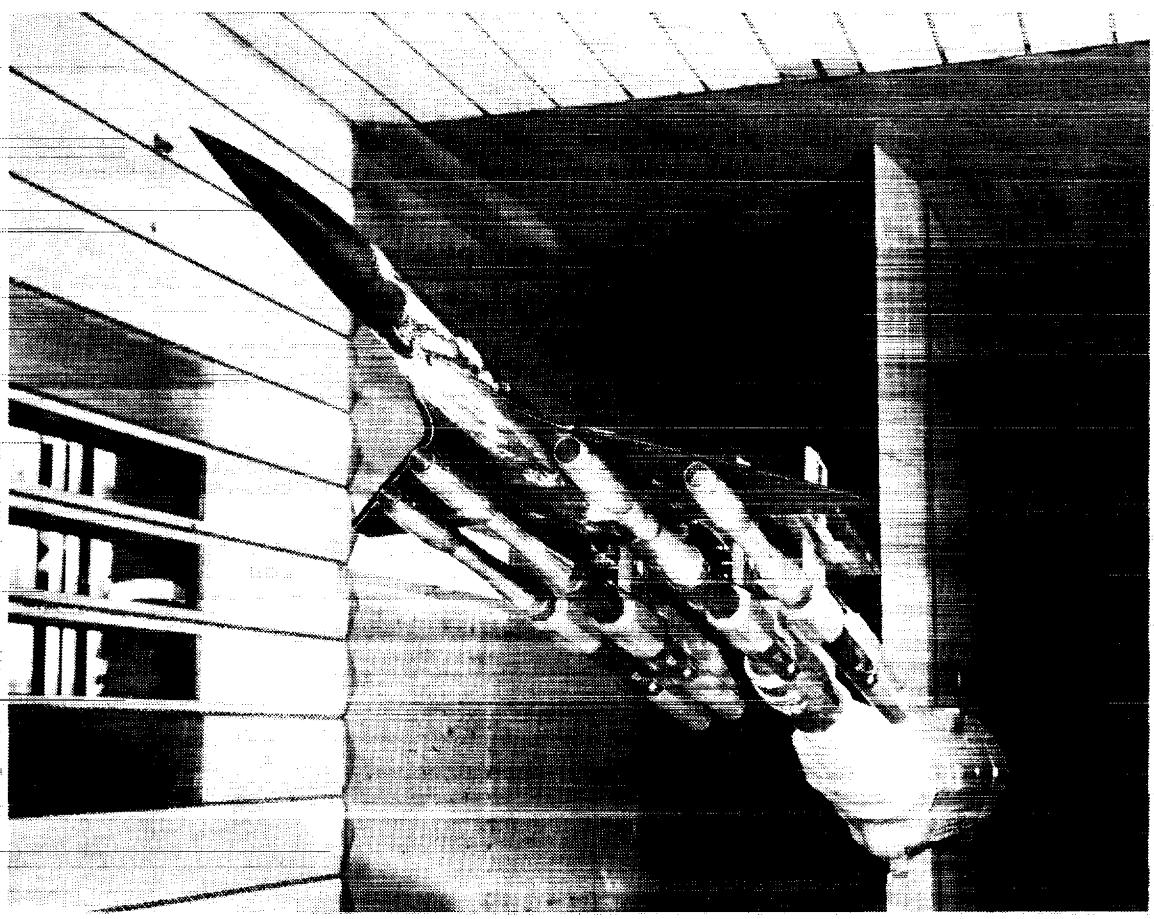


Figure 8

PROPULSION/AIRFRAME INTEGRATION PLAN OVERVIEW

Looking ahead from the near-term to the 1993 through 1999 time period and HSR Φ-II, a preliminary view of the general scope and milestones for PAI are shown in this figure. The basic concepts shown in this figure were developed as part of the HSR Non-Advocate Review effort. (The Non-Advocate Review project plan identified the basic scope for the overall HSR Φ-II Program.) This preliminary PAI plan identifies an on-going analytical tools/CFD codes assessment occurring in parallel with the experimental portions of the program. The milestone times are meant to be indicative of experimental knowledge availability in support of these analyses and as validation of technologies and concepts. For the purposes of this figure, the main experimental elements of the program have been divided between three categories of PAI identified in figure 2 above. At the conclusion of the plan (1998/99), several "systems" experiments would be accomplished including integrated tests of the inlet, engine and nozzle at supersonic speeds and at low speed (take-off). Transonic tests would be accomplished using a simulator powered sub-scale model.

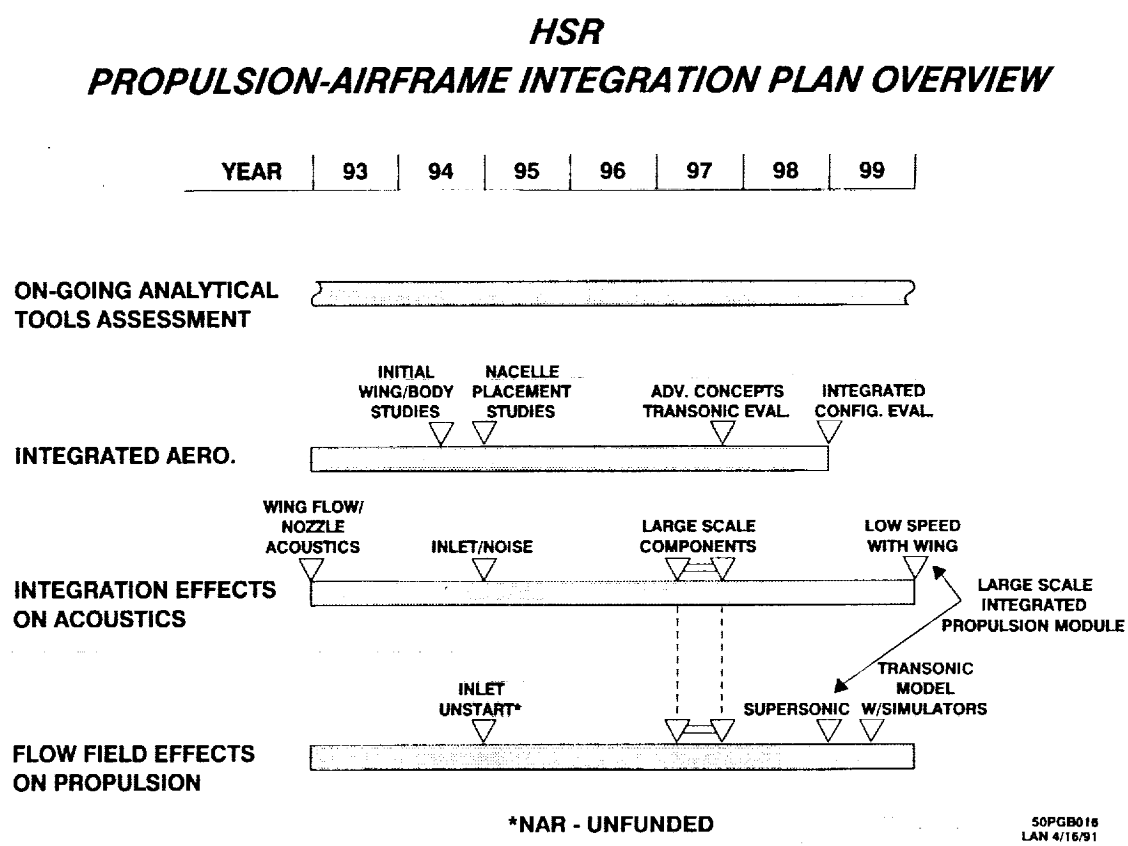


Figure 9

SUMMARY

Industry will decide on final HSCT requirements, and NASA should provide the options to minimize the HSCT risks. In this regard, the NASA HSR PAI role is viewed as delivering the following: validated airframe and nacelle design procedures and methodologies, validated diagnostic procedures and test techniques, and an experimental knowledge base for analytical code(s) validation and for design trades. The program we are pursuing is designed to address these deliverables so that the tools and technologies as well as the concepts are available to permit a low risk, environmentally and economically acceptable HSCT. In conclusion, the HSR Propulsion/Airframe Integration efforts are viewed as critical to a successful HSCT. The HSR Φ-I goals which could be affected by PAI issues are being addressed. And finally, long-lead PAI activities have been identified and steps are being taken to initiate them.

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