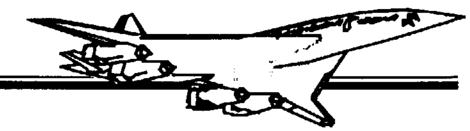

Propulsion Induced Effects (PIE) Test Program

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Year End Technical Review
Configuration Aerodynamics ITD Team

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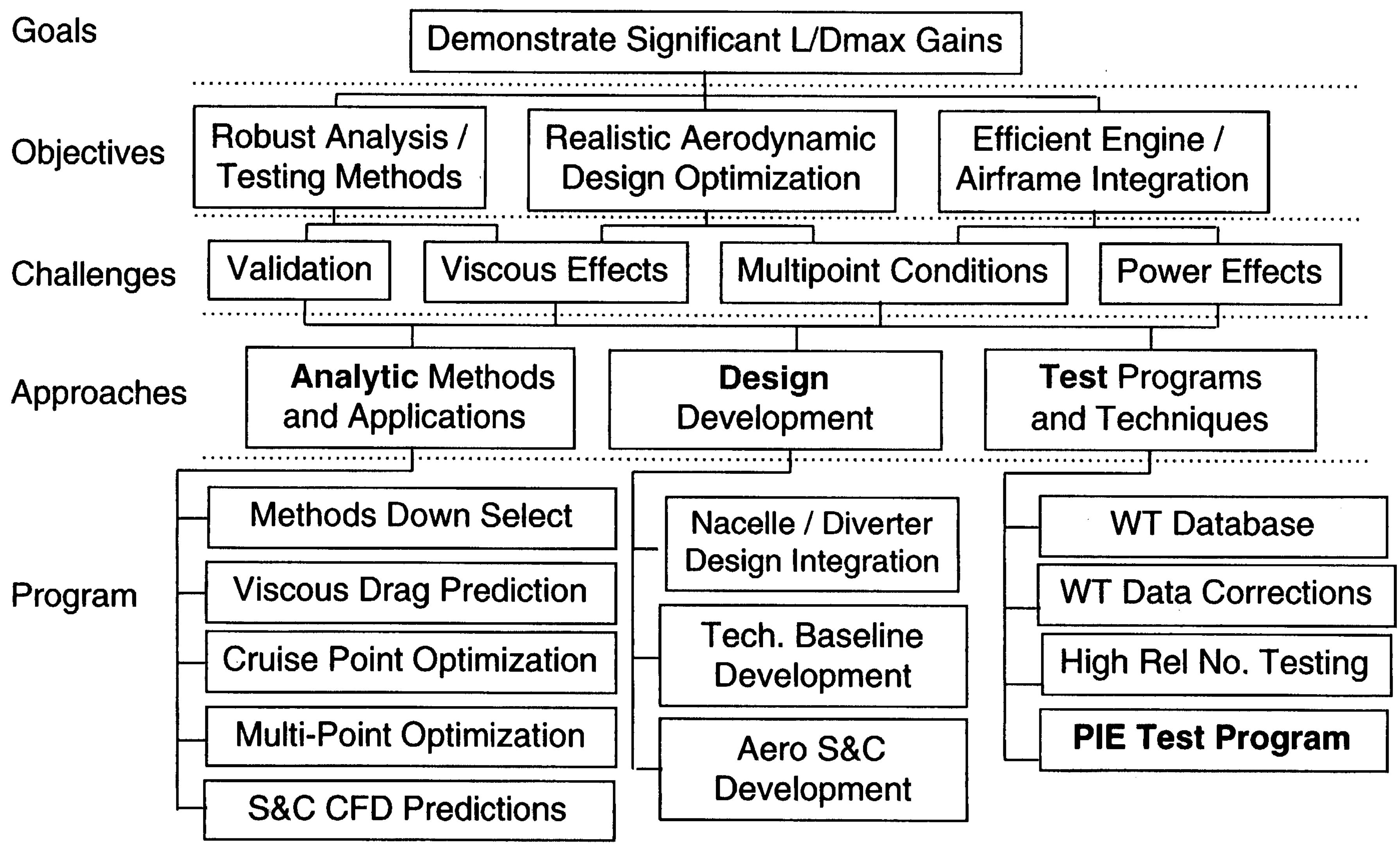
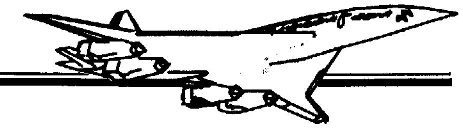
Program Hierarchy Chart - No Facing Page Description

Configuration Aerodynamics Technology Development

Session 4: Nacelle/Diverter Design and Airplane Integration



The PIE program is currently represented by several core representatives from Ames, Boeing and Micro Craft, Inc (Tullahoma Division). These individuals are primarily involved in the detailed planning and development aspects of the test program.



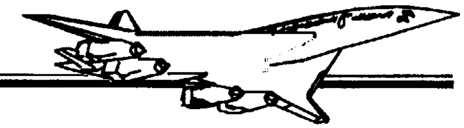
Core PIE Program Players

Ames - Program Lead
- Mina Cappuccio (POC)
- Mark Won (Applied Test)

Boeing - Industry Input
- Eric Adamson (TI)
- Chih Shieh (CFD)
- Hoyt Wallace (CPC Nozzle)

Micro Craft - Tullahoma (Model Development)
- Glenn Hardin
- Jon Lines

The Propulsion Induced Effects (PIE) test program is being lead by NASA Ames for Configuration Aerodynamics (CA). Representatives from CA, Technology Integration (TI), Inlet, and the Nozzle ITD's are working with Ames in defining and executing this test program. The objective of the CA 4-14 milestone is to assess the propulsion/airframe integration characteristics of the Technology Concept Airplane (TCA) and design variations using computational and experimental methods. The experimental aspect includes static calibrations, transonic and supersonic wind tunnel testing. The test program will generate a comprehensive database that will include all appropriate wind tunnel corrections, with emphasis placed on establishing the propulsion induced effects on the flight performance of the TCA.



CA Milestone 4-14 Mission Statement:

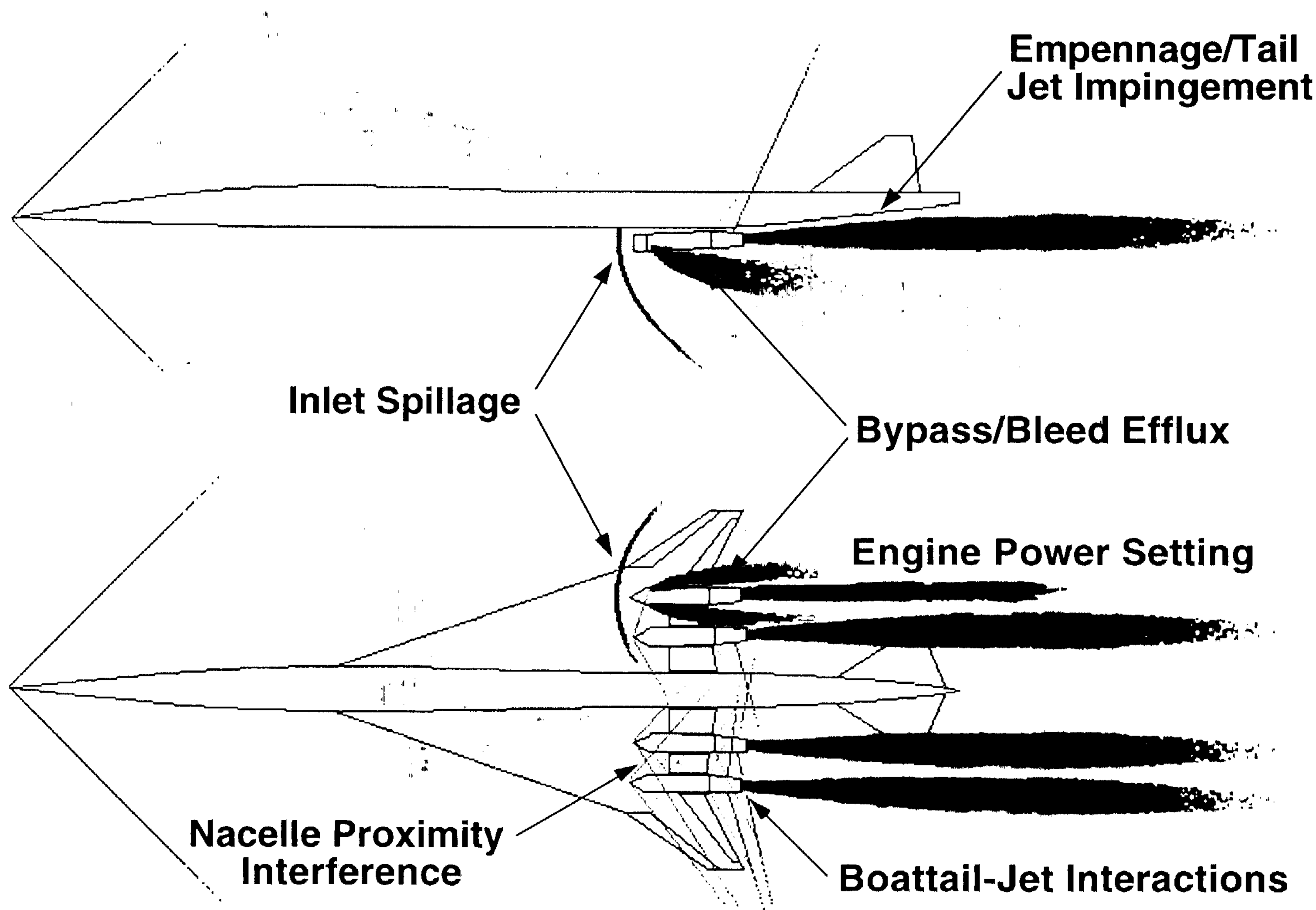
- The objective of this milestone is to assess the propulsion/airframe integration characteristics of the Technology Concept Airplane and design variations through computational analysis and experimental subsonic through supersonic wind tunnel testing

- The milestone will generate a comprehensive CFD and wind tunnel database of baseline and design variations

- Emphasis will be placed on establishing the propulsion induced effects on the flight performance of the Technology Concept Airplane with all appropriate wind tunnel corrections

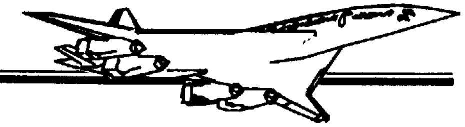
The predominant propulsion/airframe interactions considered for PIE generally include: inlet spillage; bypass and bleed efflux discharge from the nacelles; inlet spillage variation with engine power setting; jet impingement on the empennage and tail; nacelle-nacelle and nacelle-wing proximity flow interference; and nozzle boattail-jet flow interactions.

PIE Flow Physics on TCA



PIE testing is required due to the lack of information and understanding of PIE-generated forces and moments (with respect to airplane performance, stability and control). Not much is known about how PIE varies with TCA configuration changes and how much it impacts the design optimization process.

There is a lack of confidence in relying on computational methods, alone, to predict PIE behavior. CFD to experimental data comparisons are rarely in agreement with each other, and discrepancies are often left unresolved. If CFD or other empirical tool is utilized to predict PIE increments, relevant experimental data must be available to develop the numerical methods and validate the computed results.



Why Do PIE Testing?

1. Lack sufficient information & understanding of PIE on:
- TCA forces & moments (performance, S & C)
- TCA configuration changes & design optimization

2. Cannot rely on CFD alone to determine PIE increments (CFD to test data comparisons on TCA are frequently mismatched & unresolved)

3. Developing and validating empirical, CFD, or hybrid PIE prediction methods require test data

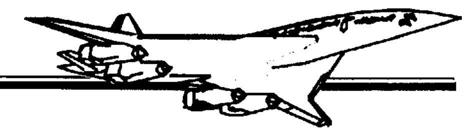
The PIE program is challenged with the task of developing a comprehensive experimental approach to obtain the PIE magnitudes on TCA forces and moments. Sufficient airplane configuration fidelity must be retained and preserved to meet performance and selected stability and control requirements. Additional work should include CFD validation and design trade studies to complement and enhance the PIE test data to extend the range of applicability beyond the experimental envelope.

The CHALLENGE

- Develop a comprehensive experimental approach to obtain PIE magnitudes on TCA forces & moments
- Preserve sufficient model configuration fidelity to address performance and selected S & C requirements
- Perform CFD validation & design trade studies to complement & enhance PIE test data

The program's framework rests on determining the PIE magnitudes on the TCA forces and moments, while preserving sufficient configuration fidelity to focus on performance and selected stability and control requirements. At transonic speeds, inlet spillage drag, installed nozzle boattail drag and nozzle plume-aft body/tail interactions are of primary interest, with the goal of resolving drag increments to within ±1.5 counts.

At supersonic speeds, inlet bypass/bleed interference and nozzle plume-aft body/tail interactions are considered to be the dominant effects. It is anticipated that these may yield PIE drag increments greater than the targeted experimental accuracy of ±0.5 counts at or around supersonic cruise conditions.



Specific Test Program Thrusts

Obtain PIE force, moment & pressure data on TCA by:

Transonic Testing ($0.9 \leq M \leq 1.2$):

- **inlet spillage/additive drag**
- **installed JE nozzle boattail/flap effects**
- **nozzle plume-aft body/tail interactions**
- **Δdrag uncertainty $\leq \pm 1.5$ cts**

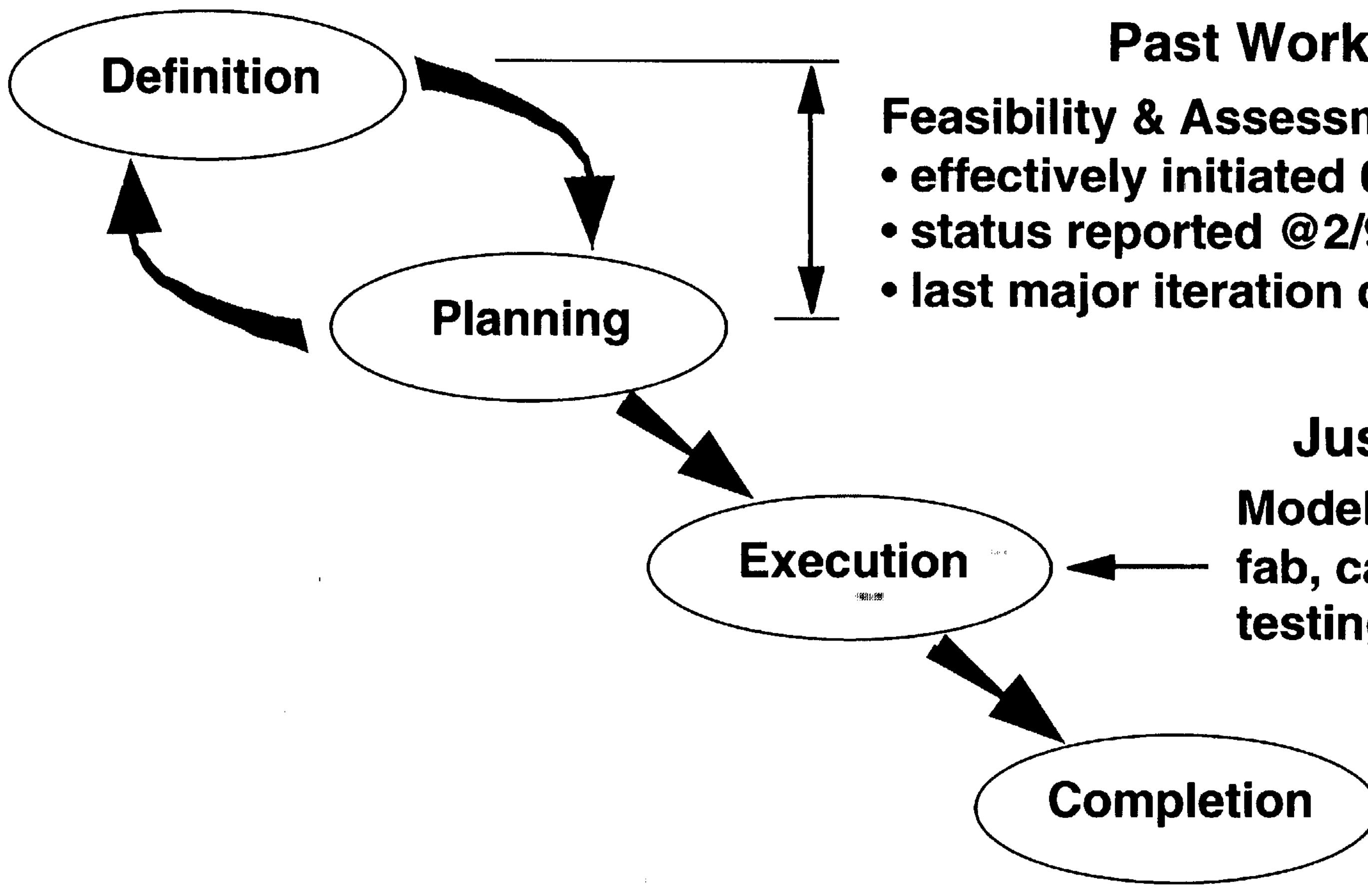
Supersonic Testing ($1.6 < M \leq 2.4$)

- **inlet bypass efflux interference**
- **ramp/cowl bleed efflux interference**
- **nozzle plume-aft body/tail interactions**
- **Δdrag uncertainty $\leq \pm 0.5$ cts**

The current activity has evolved from a series of feasibility and assessment studies, which essentially began in June 1996. This scoping effort initially centered on defining and ranking those critical technologies that would derive the most benefit from the PIE program. Conceptual model design and preliminary test planning were coupled with anticipated funding profiles to establish the likelihood of program completion within a mandated timeframe. Much of the work was presented at the 1997 Aero Performance Workshop.

Chronologically speaking, the PIE program has recently entered into the execution phase, commencing with detailed model design work. The impetus for the present effort stems from the findings of the last overall evaluation cycle, completed in August 1997. The recent feasibility and assessment defined and projected a program path for model fabrication, wind tunnel testing, CFD analysis and other related activities that will meet the CA 4-14 objectives by the end of FY00.

Program Evolution



Past Work:

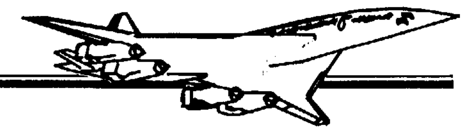
Feasibility & Assessment Cycle
- effectively initiated 6/96
- status reported @2/97 AP Workshop
- last major iteration completed 8/97

Just Underway:

Model detailed design & fab, calibration, WT testing, CFD analysis

End of FY'00

The program plan, as presented at the February 1997 Aero Performance Workshop, set several working objectives. For maximum model fidelity, the model would be sized as large as possible to obtain the best data accuracy. The test approach would concentrate on obtaining performance data, rather than expanding into the stability and control aspects of the TCA configuration. The majority of the testing would be focused in the transonic regime, where little performance data has been obtained. Since nacelle inlet bleed is activated at supersonic speeds above Mach 1.6, it was given a low priority for model development and testing. To take advantage of its operating cost benefits and operational range, the Ames 11-Ft wind tunnel was the primary choice for conducting transonic testing in FY99.



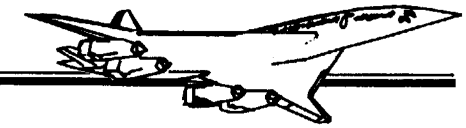
Program Plan Presented to 2/97 AP Wkshp

- Use largest possible model scale for best configuration fidelity & data accuracy
- Emphasis on performance over S & C requirements
- Focus on transonic testing (fill gap in TCA perf. data base)
- Consider installed supersonic bleed testing as a low priority
- Develop model & plan transonic testing around ARC 11-Ft entry in FY99 ("free tunnel")

The PIE test program, as of one year ago, was defined by a model concept, test plan and cost schedule. The wind tunnel model was conceived as a 5.7% scale platform to conduct powered testing with force and pressure measurements. The model featured a sting-supported, full-span wing assembly and an open-ended flared aft body with tail. Three types of nacelles were considered: two flow-through axisymmetric inlet nacelles, representing an aero reference and an inlet reference geometry, both containing a single nozzle/boattail configuration; the third nacelle was powered for jet-effects testing four nozzle/boattail combinations. The inlet reference nacelle contained an inlet centerbody and offered blown bypass and bleed capabilities.

One crucial feature of this earlier program was the implementation of a pilot nacelle to explore and evaluate the various calibration and bookkeeping methodologies anticipated for spillage testing. Testing would be conducted on selected flow-through and jet-effects nacelles at Boeing's Flight Simulator Chamber (FSC) and thrust stand facilities. Based on prior planning work, emphasis was placed on transonic testing in the Ames 11-Ft, with AEDC's 16T serving as a back-up - both facilities offered variable tunnel pressure capability required for powered testing by the 5.7% PIE model. For supersonic testing, AEDC's 16S and NASA Lewis' 10 X 10 were the only facilities that could accommodate a model of this scale.

The program funding profile was established for a base cost of approximately $4 million to cover model design, fabrication and non-operations related testing expenses at Ames and Lewis - this figure included industry support for testing and data analysis activities. Factoring test costs at AEDC, additional funds would be required for 16T (~$3.3 million) and 16S (~$3 million).



Program Highlights 1 Yr Ago...

Model concept

- 5.7% scale, powered, force & pressure model
- full-span, sting mounted, removable flared aft-body w/ tail
- 3 nacelle types: aero ref & inlet ref flow-through, JE
- axisymmetric inlet w/ removable centerbody
- 1 ref + 4 operating JE nozzle/boattail configurations
- parametric blown bypass hardware

Test plan

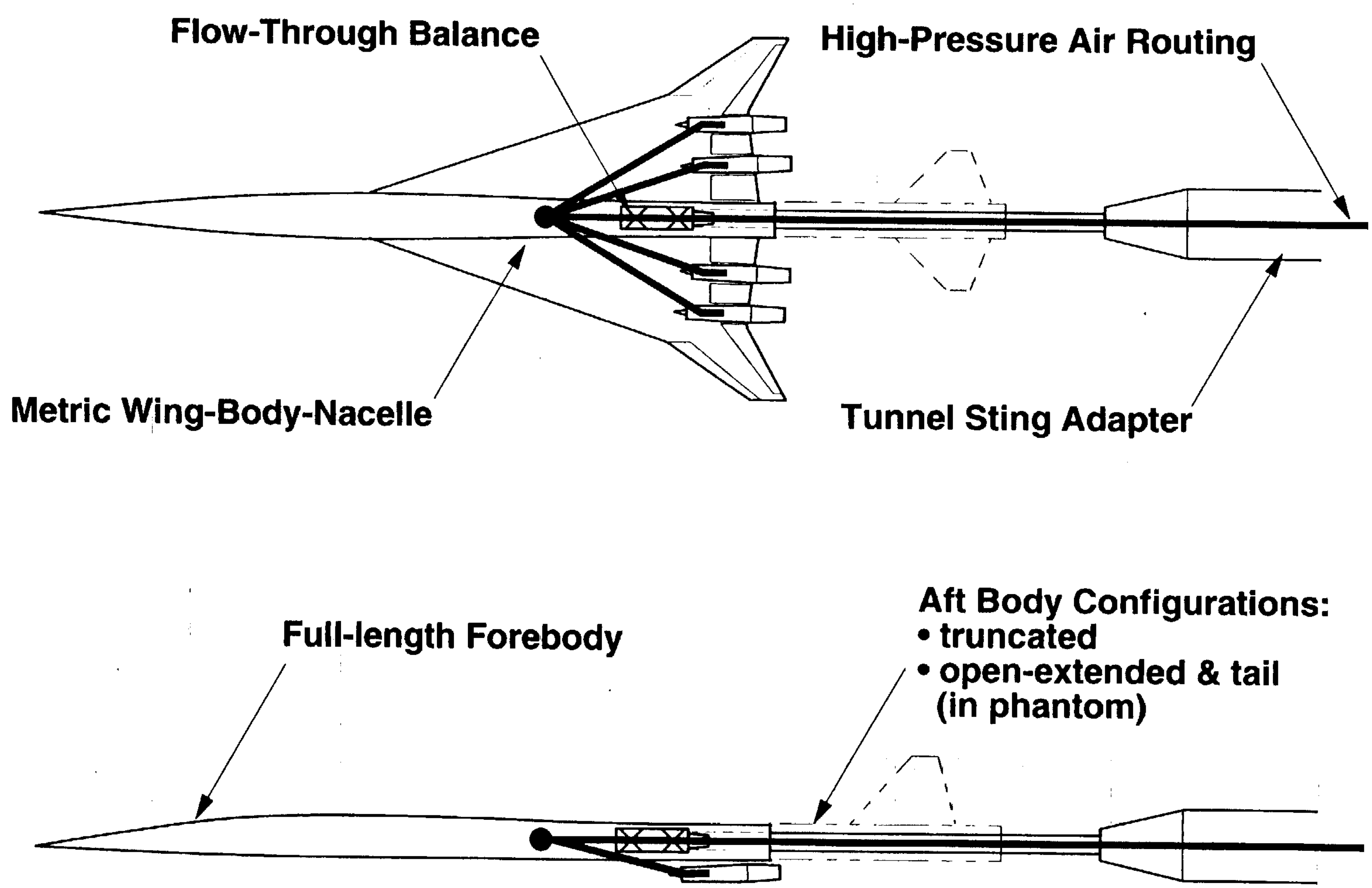
- implement pilot nacelles to explore & evaluate throttle-dependent measurement techniques (test @ Boeing FSC, thrust stand)
- transonic testing: ARC 11-Ft, AEDC 16T as alt. (< 1 atm required)
- supersonic testing: AEDC 16S or LeRC 10 X 10

Projected program costs

- model des & fab, test, indust. support ~ $4M (NASA WT)
- AEDC testing @16T: ~ $3.3M; @16S ~ $3M

The principal features of the 5.7% PIE model included: a flow-through balance; on-board high-pressure air handling capability for jet-effects testing; an all-metric wing-body-nacelle model construction; and an aft body extension with a vented posterior and a generic tail geometry to accommodate rear-sting entry into the model.

5.7% PIE Model Testing



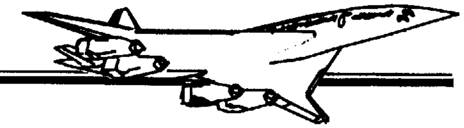
Discussions between PIE and CA representatives between May and July 1997 lead to an overall reassessment of the then-established program path. From a technical perspective, complications arising from tunnel flow quality and wall interference were anticipated for 5.7% model testing in the 11-Ft and AEDC 16T. These included tunnel Mach instability, shock reflections and buoyancy. The ability of applied computational-empirical techniques to correct for these effects and accurately resolve PIE force and moment increments was perceived to be questionable; relying on such methods to derive useful data was deemed to be extremely risky for the program.

Delays in the Ames 11-Ft Modernization schedule were expected to impact the PIE program by either slipping the 11-Ft entry to a later date or testing at the AEDC 16T; either alternative would adversely extend the projected transonic entry beyond FY00.

The appropriateness and relevancy of the PIE model configurations being considered for testing were also brought into question. Updates to the inlet design, nozzle geometry and engine cycle made the baseline axisymmetric-centerbody PIE nacelle obsolete for TCA implementation and development. The latest configuration changes at the time included a 2-D bifurcated inlet geometry and a higher aspect ratio nozzle boattail.

The open-ended empennage and generic tail were not representative of the true aft body geometry (which has complete closure and upsweep). Measured aft body force and moment increments would be arbitrary with respect to the TCA empennage geometry, and would be of little value without testing an empennage with the correct closure geometry.

The likelihood of not being able to test and evaluate transonic data from the 11-Ft before FY00 implied that testing would have to be conducted at AEDC, potentially requiring a total expenditure in excess of $10 million to complete PIE testing work.



Feasibility & Assessment (~5/97)

Technical concerns

- 11-Ft data quality at 5.7% scale is questionnable (Mach stability, shock reflections, buoyancy, etc)
- lack of confidence in CFD-empirical methods to correct transonic data or accurately assess interference effects on F & M increments

Projected 11-Ft operational status

- ARC 11-Ft production readiness during FY99 unlikely
- delay requires slide in transonic entry beyond FY00 or test at AEDC

Usefulness of configurations represented

- use updated engine inlet/nozzle/cycle? (2-D inlet, bigger AR nozzle)
- generic empennage & tail geometry (lack “true” aft body & tail)

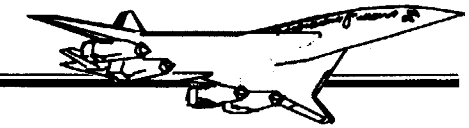
Potential +$10M pricetag due to 11-Ft & PCD schedule conflict

The combined technical, scheduling and cost risks associated with developing and testing a 5.7% scale PIE model far exceeded the funding and time constraints imposed on the CA ITD. This precipitated discussions in May-June 1997 between CA and PIE team representatives to seek other alternatives that would meet the PCD objectives at substantially lower cost and shorter timeframe than those anticipated for the 5.7% model concept.

Options included using one or a combination of existing HSR models to perform a portion of the PIE testing. These included the 1.5 and 1.7% TCA models, as well as the 1.7 and 2.7% Ref H models. Since none of these models are equipped for on-board blowing, they would be used predominantly for flow-through nacelle testing purposes to investigate spillage and aspirated bypass/bleed effects.

For jet effects testing, a large scale isolated blown nacelle rig was proposed to evaluate nozzle plume on aft body and wing in-proximity effects. Another approach for powered testing included modifying the 1.5% scale TCA (Model 23) aft body design to include high-pressure air blowing capability, at a scale comparable to the 1.7% TCA wing-body models. By combining data from either of these powered models with the unpowered TCA or Ref H models, one could possibly construct PIE increments if scale, geometry and nacelle-nacelle interaction considerations were deemed negligible.

The ultimate alternative involved the building and testing of a moderately scaled model that could be used for both wing-body-nacelle and aft body PIE testing. If carefully scaled, this model could be tested transonically and supersonically in a NASA wind tunnel.



Program Redirection Options (~6/97)

BIG ($$ + Delay + Technical Risk) @5.7% scale = need to explore other alternatives:

- use or modify existing models (1.5, 1.7% TCA, 1.7 & 2.7% Ref H) for PIE testing
- build & test isolated in-proximity blown nacelle on aft body, wing
- integrate other aft body tests into PIE model
- build a moderately scaled model for powered WBN & aft body PIE testing

In August 1997, the PIE team evaluated the alternatives for PIE testing. The team concluded that the most logical approach to meeting the program's objectives, while retaining technical viability at reasonable cost, is to build and test a powered 3% scale wing-body-nacelle-aft body model.

This model arrangement will provide the most comprehensive composite "picture" of the PIE contributions. With a common model configuration and scale to serve as a reference, obtaining incremental PIE force and moment increments are relatively straightforward (linear superposition principles apply), unlike the other proposed alternatives which involved models with different scales and geometries. Since four powered nacelles can be afforded, the installed jet effects interactions are included in the PIE simulation, unlike the proposed isolated blown nacelle rig approach.

Outcome of 8/97 Planning Cycle

Best approach to meet program objectives, retain technical viability at reasonable cost: <u>Build a new powered WBN/aft body TCA model at 3% scale</u>

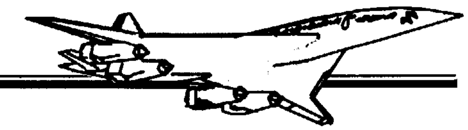
- gives the most comprehensive composite "picture" of PIE contributions
- common model baseline to reference PIE F & M increments
- avoids uncertainties associated with applying PIE data from models of different scales (1.7 vs. 2.7%) & geometries (Ref H vs. TCA)
- overall installed JE interactions are included in PIE simulation (unlike large scale isolated blown nacelle rigs)

The 3% scale PIE model includes: the addition of a strut-supported model for refined aft-body testing with a closed upswept empennage and tail; incorporating the 2-D bifurcated inlet nacelle geometry (in place of the axisymmetric-centerbody); increasing the variety of nozzle/boattail configurations for combined flow-through and jet-effects nacelle testing, with input from the CPC Nozzle team; and blown bypass and bleed capabilities.

With the reduction in model scale, tunnel pressure variability is no longer required for either unpowered or powered transonic testing; therefore, the Langley 16-Ft. has been selected for PIE testing (up to Mach 1.2). The smaller model scale will also permit supersonic PIE testing in the Ames 9 X 7, with the Lewis 10 X 10 serving as an alternate test site.

Program integration with other HSR wind tunnel activities was introduced as a risk-reduction measure. PIE configurations and test methods will be applied to other models to gain distance on the "learning-curve" for eventual PIE testing and model development work. Near term work will include building and testing separate PIE nacelles for the 1.7% scale TCA at cruise Mach to gain insight into the nacelle's design, construction, calibration and application of correction methods for the 3% scale version. Another risk mitigating measure will involve the comparison of PIE model aft body development and test techniques with a 1.5% scale TCA model, scheduled for testing later this year.

The projected program cost for the revised PIE program using a 3% model is estimated to be under $4 million, including model design, fabrication, testing and support from industry.



3% PIE Model & Test

Model concept

- supplement metric wing-body with strut-mounted metric aft-body
- augment open aft-body with “true” geometry (closed upswept) & tail
- incorporate 2-D bifurcated inlet
- increase nozzle/boattail configurations w/ CPC Nozzle input
- include blown bypass & bleed simulations

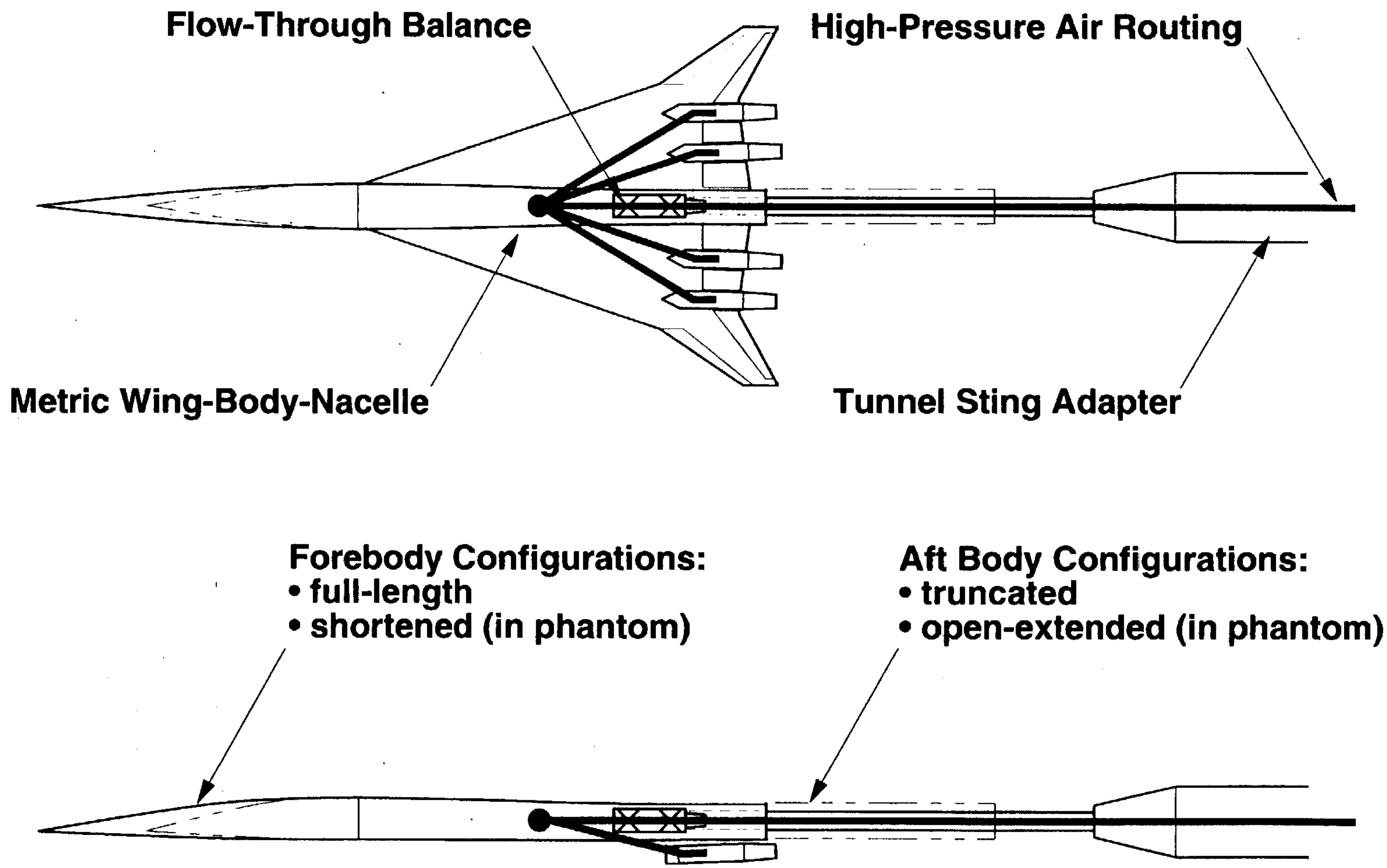
Test plan

- transonic testing: LaRC 16-Ft (~ 1 atm OK @3% scale)
- supersonic testing: ARC 9 X 7 (LeRC 10 X 10 as alternate)
- mitigate risk by exercising PIE test elements on near-term CA WT activities: 2-D inlet nacelles, WT corrections, aft body testing methods

Program cost: < $4M (model des & fab, test, indust. support)

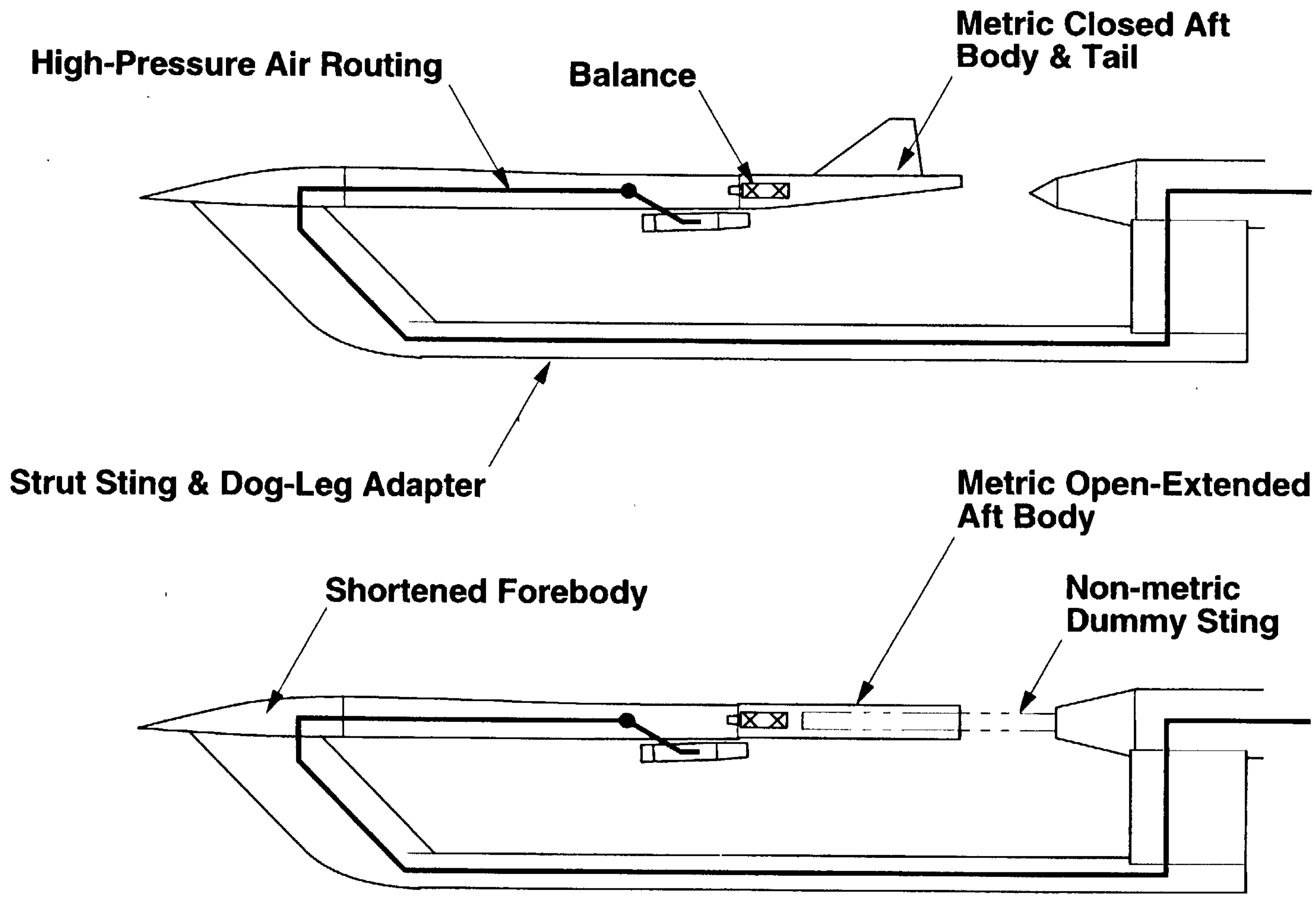
Wing-body-nacelle PIE interactions will be obtained using a metric, rear-entry sting supported model arrangement. Force and moment data will be measured using a special flow-through balance that is being designed to pass high-pressure air from the facility to the nacelles. To properly obtain aft body increments from the metric wing-body-nacelle configuration, the sting model will be tested with two forebody-aft body fuselage combinations: a full-length forebody mated to a truncated aft body; and a shortened forebody paired with a generic open-extended aft body. In addition to the balance, the model will be instrumented with external and internal (diagnostic) static pressure taps.

3% PIE Sting-Mounted Model Testing



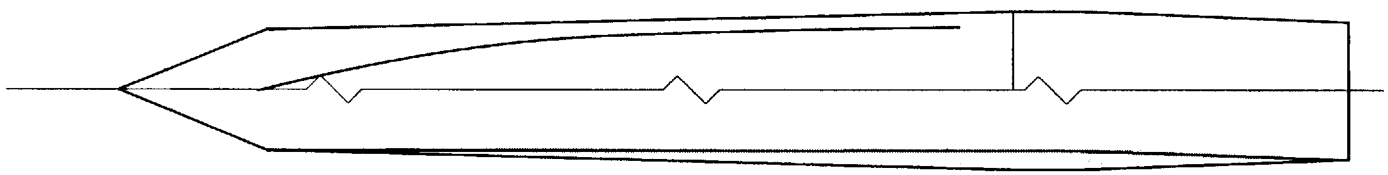
Aft body incremental data will be obtained using a strut supported model arrangement, where only the aft body is metric. Two empennage configurations will be tested: the open-extended and the closed upswept aft body with tail. The non-metric model will include the shortened fuselage, wing and nacelle portion of the model assembly. High-pressure air from the facility will be routed through the sting strut and into the non-metric wing-body for discharge by the nacelles. The aft body will be bridged to the rest of the fuselage by a conventional force and moment balance, and will include both external and internal (diagnostic) static pressure taps. In addition to the strut support hardware, a dummy sting will be tested with the metric open-extended aft body to determine if the measured pressures and forces vary in the presence of the rear-entry sting.

3% PIE Strut-Mounted Model Testing

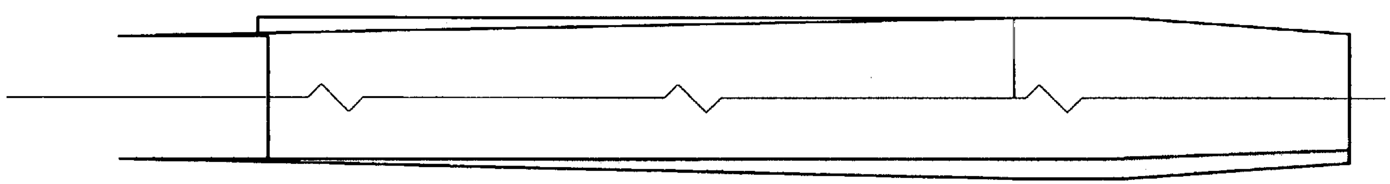


The baseline nacelle geometry for all aerodynamic testing is defined by an aero reference nacelle with a rectangular 2-D inlet and exit shape. This nacelle features a constant area flow-through duct featuring a supersonic-cruise boattail configuration, with the upper and lower flaps truncated at the nozzle sidewall trailing edge. Nacelle instrumentation is limited to internal and external static pressure taps.

Aero Reference Nacelles



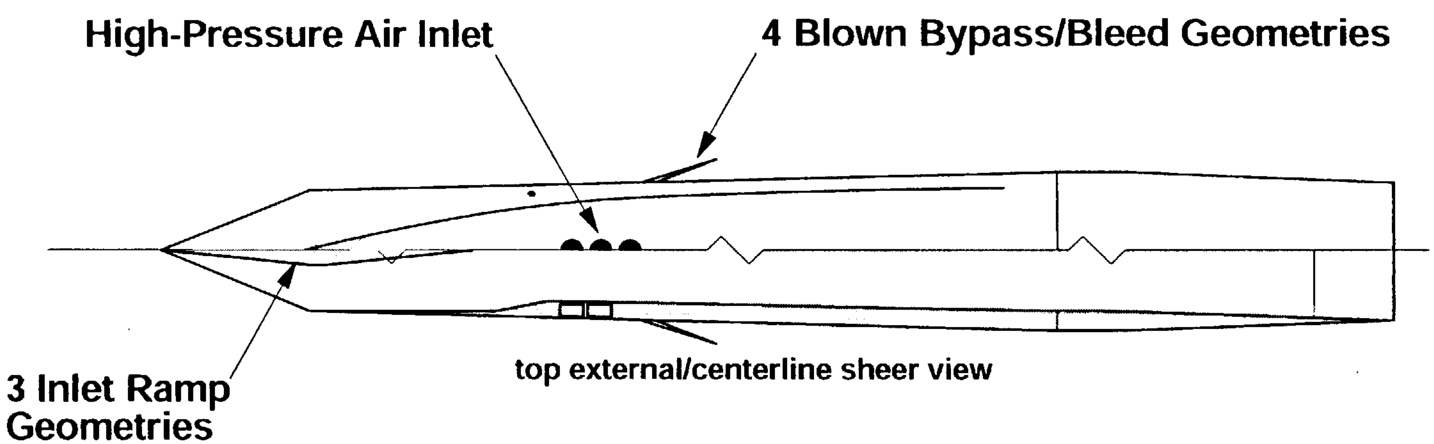
top external/centerline sheer view

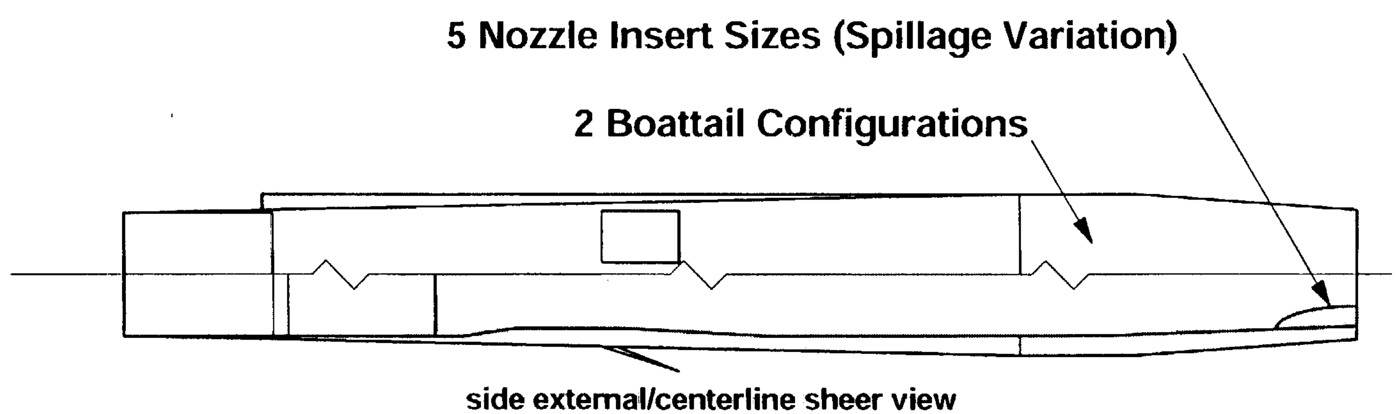


side external/centerline sheer view

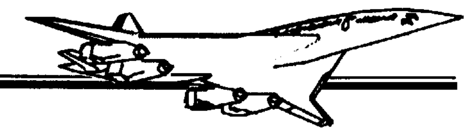
The inlet reference nacelle serves as a platform for conducting flow-through spillage and blown bypass/bleed testing. The inlet includes three interchangeable ramp configurations for 2-D inlet bifurcation. Bypass and bleed are defined by flapped doors, louver doors, porous surfaces and slotted surfaces which are all interchangeable. Bypass/bleed flow simulation is performed by directing facility high-pressure through the model and into the nacelle cowl for discharge through the bypass/bleed nozzles. To adjust the inlet spillage rate, removable inserts will be parametrically installed in the nacelle duct exit to vary inlet mass flow. In addition to the aero reference boattail and nozzle, a second parametric boattail configuration will be also tested on the inlet reference nacelle assembly. Nacelle instrumentation is limited to internal and external static pressure taps (no rakes used in the duct).

Inlet Reference, Bypass/Bleed Nacelles

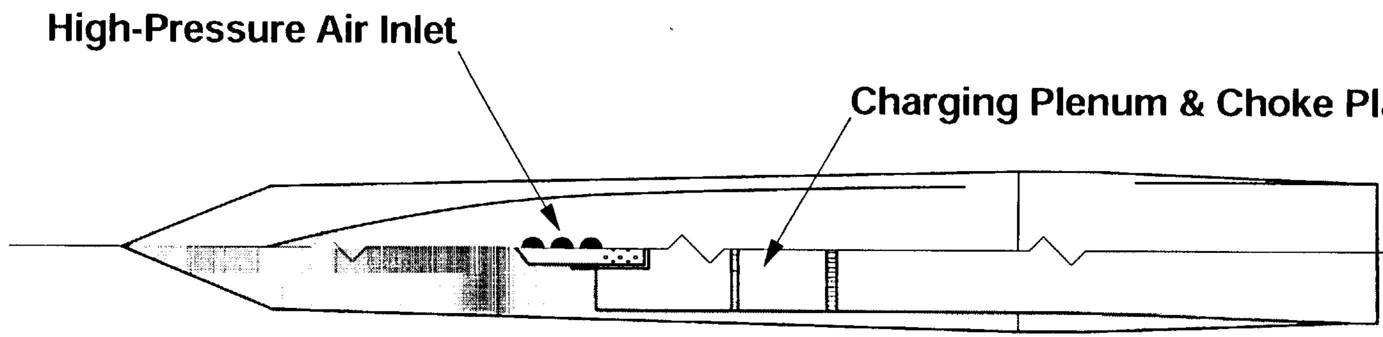




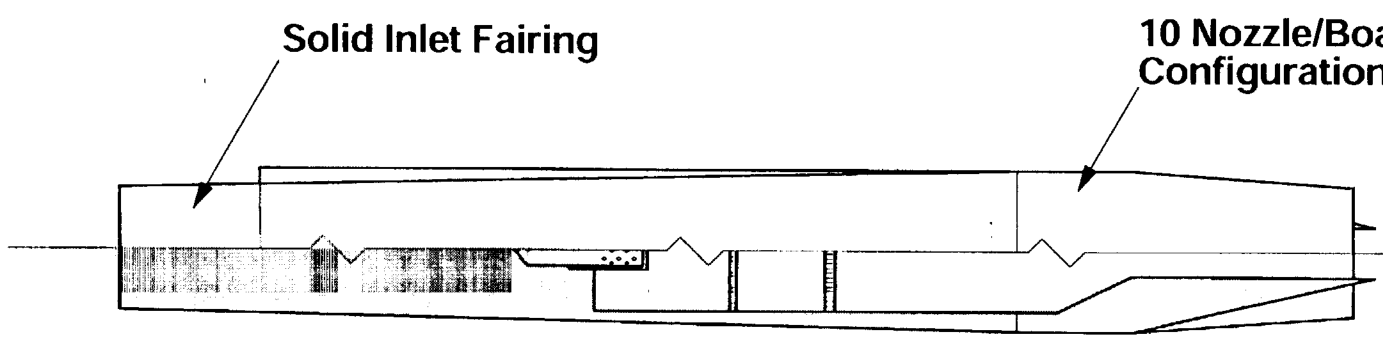
The jet effects nacelle is used for installed nozzle testing. Unlike the flow-through nacelles, the inlet aperture is covered by a solid inlet fairing. High-pressure air from the facility is directed into the nacelle, where it is then conditioned through charging plenums and choke plates before being discharged by the nozzle. In addition to the aero reference boattail and nozzle, nine additional geometries representing operating nozzle/boattail configurations (defined by the CPC nozzle team) will be also tested on the jet effects nacelle assembly



Jet Effects Nacelles



top external/centerline sheer view



side external/centerline sheer view

The present 3% PIE model includes element that are representative of the current and projected TCA design. The model will allow the parametric testing of geometric variables: inlet ramps; bypass & bleed covers; nozzle/boattail flap sidewall and flap angles with alternate trailing edge shapes; nozzle internal geometry; wing leading and trailing edge flap deflections; forebody length; aft body closure; and tail installation/stabilizer deflections. The test program will utilize these features to determine PIE increments over a range of transonic and supersonic Mach numbers, model angles of attack and sideslip, inlet spill rates, engine power settings, and bypass/bleed flow rates.

3% Model Test Variables Available

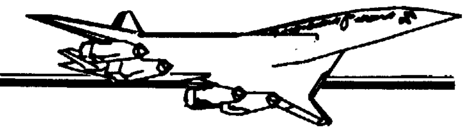
Geometry:

- inlet ramp
- bypass & bleed door
- nozzle boattail sidewall & flap angles, TE shaping
- LE, TE wing flaps
- forebody length
- aft-body closure
- vertical & horizontal stabilizer

Flow

- Mach (transonic, supersonic)
- attitude (alpha, beta)
- inlet spillage (A0/AC)
- power setting ($\geq$ design NPR)
- bypass & bleed efflux simulation

The direct costs associated with the design, fabrication and testing of the 3% PIE model and related systems have been estimated and projected through the end of FY00 (program termination). Some of the funded activities have been already identified as part of the CA PCD over-guideline request made in FY97. The CPC Nozzle team has funded the design and fabrication of the blown nacelle nozzles for FY98. Several noteworthy estimates that have not been yet firmly established due to their premature nature include the flow-through balance calibration work and facility operational costs related to Ames 9 X 7 supersonic testing. Total PIE test program cost at this time is estimated to be $3.911 million.



Funding/Activity Profile

Direct Costs ($K)

Source	Supported Activity	FY98	FY99	FY00	Comments
CA ITD	Model design & initial fab.	320			full accrual @end of FY98
	Model fab. completion		1,246		full accrual @mid-FY99
	Balance fab. & static calib.		515		fab. & calib. by Boeing
	Balance flow calib.		100		calib. by Boeing @FSC, LaRC 16T
	Nacelle calib.		342		calib. by Boeing @FSC
	WT test support		300	400	includes pre-test, test, post-test work
CPC Nozzle	Nozzle design & fab.	400			full accrual @end of FY98
Others?	LaRC 16T operation			108	9 wks @$12K/shift wk
	ARC 9X7 operation			180	3 wks @$60K/shift wk
	FY totals:	720	2,503	688	

Projected Activity Totals:

Model design & fab.	1,966	estimates not firmly established
Balance fab. & calib.	615	costs included in CA PCD OGL request
Model calib. & WT test support	1,042	
WT operations	288	

Program total: 3,911

Many calculated risks and challenges are or will be faced in the PIE test program. One of these is the ability to accurately determine the internal drag correction for the flow-through nacelles. The currently envisioned approach relies on correlating static pressure measurements with CFD predictions. Due to the relatively small scale of this model, the impact of utilizing a limited quantity and type of instrumentation to determine the internal drag is uncertain. Testing a smaller version of the PIE nacelles on a 1.675% scale TCA wind tunnel model later this summer will help refine and validate this measurement technique.

One critical aspect of PIE testing is the measurement accuracy of the new flow-through balance. Since the balance axial force capacity is essentially sized for the nominal static thrust produced by the nozzles (which is nearly four times the maximum drag load), balance sensitivity may be compromised during unpowered model testing. The quality of the balance data obtained from blown nacelle testing is influenced by the ability to accurately correct errors associated with balance stream momentum, pressure and temperature variations.

Due to the onboard flow-distribution capability within the model for blown nacelle testing, balancing the flow rates and thrust levels between the left and right wing nacelles poses additional complications. Any imbalance in model flow and thrust will be an artifact of model design tolerances and fabrication/assembly quality control processes. Manual trim valves will be incorporated into the model's air-distribution network, and should help compensate for these discrepancies.

Calculated Challenges & Risks

- Internal duct drag correction
  - method relies on “rake-less” instrumentation and good CFD correlation
  - influence of model fidelity on data quality is uncertain
  - testing of PIE nacelles on 1.7% TCA (7/98) will serve as learning tool
- New flow-through balance
  - blown balance accuracy may not be sufficient for all PIE F&M data
  - sensitivity partially compromised to accommodate JE nozzle testing
  - corrections for internal momentum, pressure & temperature effects
- Model flow & thrust balancing control
  - depends on model fabrication & assembly quality control
  - compensate for inter-nacelle imbalances w/ manual trim valves

There are other risks and challenges that the PIE test program is or will be facing:

- The Ames 9 X 7 operational status for FY00 is still in question - CA has not had much recent experience testing at the Lewis 10 X 10 tunnel
- Until aft body data for the TCA is obtained, there is some suspicion that the PIE increments may be coupled with model support interference at high transonic speeds, mainly from shocks from the strut sting body impinging on the wing-body-nacelle
- The selection of scale may compromise measurements that are sensitive to model fidelity. This includes the effect of nacelle diverter gap height, which may choke prematurely at transonic and supersonic speeds, and bias measured spillage or bypass/bleed drag increments. Due to finite material thickness, a limited quantity of pressure taps will be installed on the nacelles, and may not be sufficiently adequate to sense the pressure variations required for accurate flow measurements or correlations (mass flow, momentum, etc). Also, boundary layer trip devices may not provide effective, uniform turbulent boundary layer transition around the leading edges of the model surface
- The scatter or deadband of the measured data may larger that the required drag increment resolution ($\pm$1.5 counts transonically, $\pm$0.5 counts supersonically)
- The present model configuration may be prematurely frozen at the time of model fabrication, such that the TCA configuration is no longer represented in the PIE data

Calculated Challenges & Risks (cont'd)

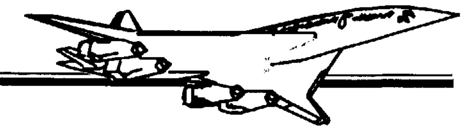
- ARC 9 X 7 availability before mid-FY00, no recent CA experience at LeRC 10 X 10
- Model support interference coupling w/ PIE increments
- Effect of model fidelity on data quality & desired test performance
  - nacelle diverter choking (relatively low test RN)
  - quantity, placement of instrumentation on measurements
  - effective BL transition methods
- Increments buried in data scatter/deadbands > 1.5 cts (transonic); > 0.5 cts (supersonic)
- Premature configuration freeze (wing planform, nacelle geometry, empennage closure)

The risks are not unique to the PIE program or its approach. The 5.7% scale PIE model, with other HSR high-speed models, have or will face similar technical and program difficulties. Despite these hurdles, many substantial benefits will be derived from the 3% PIE test. An understanding of the PIE magnitudes on TCA performance and stability and control will be learned to an appreciable extent. Valuable insight will be gained into how PIE influences configuration variability and design optimization.

The PIE effort will demonstrate how to test a four-engined HSR/HSCT type of airplane to obtain propulsion/airframe data. Unique experimental simulation and measurement techniques will be validated, such as the use of blown bypass/bleed and non-intrusive nacelle duct instrumentation.

A wealth of data will be generated for CFD calibration and development work. The experimental data base will provide the groundwork for performing design trade studies and constructing performance decks for the TCA.

The technical approach should reflect the best utilization of funds and resources to achieve the program's objectives. In the long run, the PIE test effort will serve as a risk-reduction measure for any future propulsion/integration work beyond FY00 involving an HSR/HSCT airplane configuration.



Program Risks = Value, Knowledge

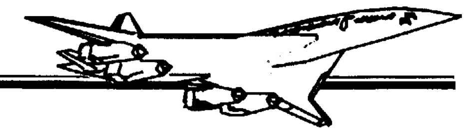
Risks are not unique to PIE program or approach currently employed - substantial benefits will be gained:

- understanding of PIE magnitudes on performance, S & C
- valuable insight into impact of PIE on overall TCA configuration variability, design optimization
- how to do future tests
  - powered 4 engine WBN/aft body configurations
  - blown bypass/bleed simulation
  - non-intrusive flow-through duct measurements
- large, comprehensive experimental data base for CFD calibration & development
- best (technical approach)/($$ & resources)
- reduces technology risk for any HSR/HSCT-type propulsion airframe integration/development work beyond FY00

Several PIE program activities are currently in progress. Micro Craft is performing the detailed design for the 3% model, and will begin fabrication work very shortly to deliver hardware and assemblies to Ames before the middle of FY99. Micro Craft is also tasked to perform the detail design for the 1.675% PIE nacelles that will be tested on TCA Model 2b, later this summer. Boeing has been tasked to perform the detailed design, fabrication and calibration of two flow-through by the end of FY99.

Testing work is scheduled to commence with the static nacelle calibration in April-July 1999, followed by the transonic wind tunnel entry at the Langley 16-Ft in October-December 1999, and ending with the supersonic entry in the Ames 9 X 7 in January 2000.

In the meantime over-guideline funds are being sought for PIE program work beyond FY98 to support continued model fabrication, testing, CFD and data analysis through FY00.



Current Program Status

Model work

- Micro Craft tasked to perform 3% PIE model detailed design & fab for model delivery before mid-FY99
- Micro Craft tasked to detail design PIE 2-D nacelles for 1.675% scale TCA model (Model 2b) to aid 3% model design
- Boeing tasked to design, fab & calibrate (static + momentum) flow-through force-moment balance for WT use at end of FY99

Projected 3% PIE test entries

- Boeing FSC static flow-through & blown nacelle calibration: 4/99-7/99
- LaRC 16T testing: 10/99-12/99
- ARC 9 X 7 testing: 1/00

OGL funding for PIE program activities through FY00

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