Propulsion Aerodynamics Branch
Research Program Summary Sheets
1993

NASA Langley
16-Foot Transonic Tunnel Complex

Langley Research Center
Hampton, VA
INTRODUCTION

Each year since 1988, the Propulsion Aerodynamics Branch (PAB) of the NASA Langley Research Center has created a document which is a compilation of one page research program summary sheets. The publication is intended to help improve communications and awareness between the PAB and our "customers" (industry, academia, the Department of Defense, and other NASA centers). The research programs discussed within this document address technology issues found in five of the six current NASA Program Thrusts (Subsonic Transport, High-Speed Civil Transport, High-Performance Military Aircraft, Hypersonic and Transatmospheric Vehicles, and Critical Disciplines), hence, funding for this research comes from several funding sources within NASA.

These research summaries typically provide information such as program objectives, facilities used, measurements made, current program status and updates, analytical codes used, references, and names of individuals to contact for further detailed information. It should be emphasized that this document provides summary information only. Details of a particular program or programs should be obtained by contacting the appropriate researcher listed. The document is arranged into the following sections:

I. On-Going Research Programs
   A. High Performance Aircraft Related Programs
      Internal Performance
      Propulsion Airframe Integration
   B. Subsonic, High-Speed Civil, and Military Transport Programs
   C. Analytical Programs
   D. Other Programs- Generic Hypersonics, Acoustics, Water Tunnel, Facilities

II. Completed Research Programs
   A. High Performance Aircraft Related Programs
   B. Subsonic, High-Speed Civil, and Military Transport Programs
   C. Analytical Programs
   D. Other Programs- Generic Hypersonics, Acoustics, Water Tunnel, Facilities

A complete list of PAB research programs and references can be maintained by simply adding the "Completed Program" sheets from the previous program summary documents to this year's document.
I. ON-GOING RESEARCH PROGRAMS

A. High Performance Aircraft

Internal Performance
Static Investigation of Vectoring Single Expansion Ramp Nozzles (VSERN)

Objective: Determine the static internal performance of vectoring SERN nozzles.

Organizations: Langley/PAB; Rolls-Royce, Inc.

Variables:
- Nozzle geometric parameters
  - Throat area, ramp length
- Bend geometric parameters
  - Bend angle, hood length
- NPR = 1.0 - 15.0

Measurements:
- Nozzle/bend forces and moments (6 components)
- Nozzle/bend weight-flow rate
- Static pressures on bend, ramp, hood

Status:
- Test completed
- Data reduction completed
- Conference paper AIAA-88-3000
- NASA TM on hold
NOZZLES FOR AEROCOMROL

3 Hinge 2-D C-D Concept

OBJECTIVE: Evaluate six multiaxis thrust vectoring nozzle concepts at static (M=0) conditions to determine pitch and yaw thrust vectoring capabilities and nozzle internal performance.


VARIABLES: M = 0.0
NPR = 1.8 - 10.0 Power setting, Area ratio, Geometric pitch vector angle, Geometric yaw vector angle, Sidewall deflection/cutback, Aspect ratio, Skew angle, and Other configuration dependent variables.

MEASUREMENTS: Forces and moments (6 components)
Mass flow rate
Static pressures

STATUS: Completed NASA TP-2991 on two gimbaled concepts.
Completed NASA TP-3369 on 3-hinge(internal flap) concept.
Completed NASA TP-3411 on 2-D C-D skewed throat concept.
NASA TP on two advanced concepts in editorial cycle.

RESULTS: Gimbaled concepts provided resultant vector angles equal to the geometric (metal) vector angle for no loss in resultant thrust. The 3-hinge concept provided significant amounts of yaw vector capability but also had significant thrust losses.
OBJECTIVE: Determine the effectiveness of a novel thrust-vectoring technique and its effect on internal performance.

ORGANIZATIONS: Langley/PAB and Rockwell

VARIABLES: $M=0.0$ (static)
$NPR=1.0$ to 7.5

MEASUREMENTS: Forces and moments
Nozzle mass flow
Nozzle internal pressure distributions

STATUS: Static test completed June '88
Data reduction completed Aug. '88
Report in review process
OBJECTIVE: Evaluate the performance of several advanced nozzle concepts.

ORGANIZATIONS: Langley/PAB and Pratt and Whitney/FL

VARIABLES: M=0.0 (static)
NPR=1.0 to min. of 7.0

MEASUREMENTS: Forces and moments
Nozzle mass flow
Nozzle internal pressure distributions

STATUS: Model completed Aug. '88
Static test completed 09/17/90
Data reduced Oct. '90
Report in review process.
STATIC INVESTIGATION OF CIRCULAR-TO-RECTANGULAR TRANSITION DUCTS FOR NONAXISYMMETRIC NOZZLES

STATIC TEST

OBJECTIVE: To determine overall internal performance of 2-D/C-D nozzle and circular-to-rectangular transition ducts.

ORGANIZATIONS: Langley/PAB

VARIABLES: Phase I - Duct length, wall shape, duct cross-sectional area distribution
Phase II - Duct length, duct/nozzle aspect ratio, nozzle power setting (duct flow velocity), duct offset

MEASUREMENTS: Forces and moments (6 components)
Duct internal pressures
  total - at entrance and exit
  static wall
Duct/nozzle weight flow rate
Duct flow visualization

STATUS: Phase I - NASA TP-2534 (Burley, Bangert, and Carlson)
         AIAA 85-1346 (Burley and Carlson)
Phase II - Test will be repeated

CONCLUSIONS: Phase I:

1. Nozzle internal performance decreased as duct length decreased from l/d = 1.0 to l/d = 0.5.
2. For l/d < 0.75 large regions of separated flow observed (potential wall heating problems).
3. Reducing duct exit cross-sectional area by 25% (relative to duct inlet area) improved internal performance and reduced flow separation in the duct.
Static Investigation of Secondary Flap Surface Geometry on Multi-function 2-D C-D Nozzles

Objective: Determine the effects of secondary (divergent) flap surface geometry on internal performance of multi-function 2-D C-D nozzles

Organizations: Langley/PAB; General Electric Co.; Fluidyne

Variables: Secondary (divergent) flap surface geometry:
- Internal divergence angle varied with and without external boattail angle variation
- NPR = 1.0 - 9.0
- Nozzle expansion ratio: 1.1, 1.35, 2.0 at LaRC
  - 2.5, 3.0 at Fluidyne

Measurements: Nozzle forces and moments (6 components)
- Nozzle weight-flow rate
- Static pressures

Status: Test completed 6/89
- Data reduction completed
- NASA TP in preparation
Internal Static Performance of STOVL Nozzle Concepts - Phase II

OBJECTIVES: Evaluate internal performance of ventral nozzle concepts and complete ventral/cruise nozzle system

ORGANIZATIONS: Langley/PAB, General Electric/OH, Lockheed/GA

VARIABLES: Mach = 0 (static)
Nozzle pressure ratio = 1.5 to 6.0
2D-CD cruise nozzles, throat area, vector angle = 20 deg
Constant area vanes ventral nozzle, throat area, vector angle
Cylindrical ventral nozzle, throat area, vector angle
Segmented ventral nozzle, throat area, vector angle
Hover, transition, and cruise configurations

MEASUREMENTS: Cruise and ventral nozzle forces
Nozzle weight flow rate
Internal total and static pressures
External surface pressures adjacent to ventral exit
Fuselage section surface static pressures

STATUS: Static testing completed. Results presented in AIAA paper number 91-2134. NASA report to be released in 1994.
LMAN NOZZLE - STATIC TEST

OBJECTIVE: To determine the static internal performance of a SCF nozzle with thrust vectoring (both pitch and yaw) and reversing.

ORGANIZATION: Langley/PAB, Pratt and Whitney/Fla., and USAF/WRDC/APL

VARIABLES: Power setting, expansion ratio, thrust vector angles, partial and full reversing.
M = 0.0
NPR = 2 to 11.

MEASUREMENTS: Forces and moments (6 components)
Nozzle weight flow rat
Internal static pressures

STATUS: NASA publication in Branch Review.
DOUBLE DRIBBLE NOZZLE - Static Test

OBJECTIVE: To determine the static internal performance of a 2-D plug nozzle with both pitch and yaw thrust vectoring.

ORGANIZATIONS: Langley/PAB and Pratt and Whitney/FL

VARIABLES: Thrust vector angles
M=0.0 (static)
NPR=2.0 to 11.0

MEASUREMENTS: Forces and moments (6 components)
Nozzle mass flow
Nozzle internal pressure distributions

STATUS: Model design completed 10/09/90.
Model fabrication completed 11/13/91.
Test completed 09/03/93.
SCF II
Static Investigation of Convertible Plug and Spherical Plug SCF Nozzles

**Objective:** To evaluate the internal static performance for Convertible Plug and Spherical Plug SCF Nozzles.

**Organizations:** NASA Langley/ PAB, McDonnell Aircraft Co., Pratt & Whitney

**Variables:**
- Static test conditions (M = 0.0)
- NPR: 2.0 to 12.0
- Basic nozzle geometry: 2-D Convertible Plug and 3-D Spherical Plug
- Yaw vector angle: 0° and 10° - Convertible Plug only
- Flap length - Convertible Plug only
- Area ratio - Convertible Plug only
- Plug length - Convertible Plug only

**Measurements:**
- Forces and moments (6 components)
- Nozzle mass flow rate
- Internal static pressures
- Paint flow visualization

**Status:**
- Test completed September 14, 1990
- Data reduction completed
- AIAA conference paper 93-2431
- NASA TP in preparation
OBJECTIVE: Evaluate the static nozzle internal performance of several 2-D C-D nozzles as expansion ratio, throat area, and plate length are varied.

ORGANIZATIONS: NASA Langley/PAB, General Electric

VARIABLES:  
M = 0.0  Power setting Area ratio
NPR= 1.2-11.0 Other configuration dependent variables

MEASUREMENTS:  
Forces and moments (6 components)
Nozzle mass flow rate
Nozzle internal static pressures
Flow visualization

STATUS: NASA technical paper nearly completed.
Fluidic Thrust Vectoring of a 2D-CD Nozzle Using Shock Vector Control and Coanda Surface Blowing

OBJECTIVE: To evaluate shock vector control and coanda surface blowing as means for obtaining pitch and yaw thrust vectoring on a two-dimensional convergent-divergent nozzle at static conditions.

ORGANIZATIONS: Langley/PAB
ROHR, Inc.

VARIABLES: Nozzle pressure ratio: 1 to 10
Secondary to primary flow rate ratio: 0 to 0.1
Nozzle expansion ratio
Pitch flap injection location
Coanda flap length
Coanda flap angle

MEASUREMENTS: Forces and moments
Primary and secondary weight-flow
Internal surface static pressures
Flow visualization

STATUS: Testing complete
Technical paper in progress
HIGHLY INTEGRATED DEPLOYABLE EXHAUST NOZZLE (HIDEN) STATIC MODEL TEST PROGRAM

OBJECTIVE: Evaluate the internal performance of an ASTOVL deployable exhaust nozzle concept in both the forward thrust and vertical lift modes.

ORGANIZATION: NASA Langley/PAB and Rolls-Royce, Inc.

VARIABLES:
- $M = 0.0$ (Static)
- NPR = 1.5 to 8
- Offtake droop and trail angles (2 plenums)
- 4 HIDEN nozzle geometries
- Centerbodies simulating core and fan offtake duct positions
- Blocker doors

MEASUREMENTS:
- Forces and Moments (6 Components)
- Static Pressures
- Flow visualization
- Exit rake surveys

Data reduction and analysis completed.
AIAA Paper 93-2570
Proposed NASA TP in branch review.
OBJECTIVE: To determine the static internal performance of a vectoring axisymmetric ejector (dual-flow) nozzle.

ORGANIZATION: Langley/PAB, Pratt and Whitney/Fla.

VARIABLES: Power setting, ejector flow area, ejector flow rate, throat area, pitch vector angles of 0° and 18°, M = 0.0, and NPR = 2 to 10.

MEASUREMENTS: Forces and moments (3 components) Nozzle weight flow ratio Nozzle internal static pressures

AN EXPERIMENTAL ANALYSIS OF
PASSIVE SHOCK-BOUNDARY LAYER INTERACTION CONTROL
FOR IMPROVING THE OFF-DESIGN PERFORMANCE
OF JET EXHAUST NOZZLES

Objective
Passive control of shock - boundary layer interaction and
shock induced boundary layer separation at overexpanded
NPR's using a passive cavity and multi-dimensional
convoluted contouring.

Organizations
Langley/PAB, The George Washington University

Facility
16 Foot TT Model Prep Area Static Test Stand

Variables
Static Conditions
NPR=1.0 to 9.5
Passive Cavity Geometry
Convolution Geometry

Measurements
Forces and Moments
Internal Static Pressures
Focusing Schlieren Internal Flow Visualization

Status
Testing Completed August 1992
M.S. Thesis published September 1993
NASA Publications forthcoming
Static Investigation of A Two-Dimensional Convergent-Divergent STOVL Nozzle

Objective: Determine the static internal performance of 2-D C-D nozzle with externally-mounted hood for pitch-vectoring or partial reversing.

Organizations: Langley/PAB; Pratt and Whitney

Variables: Nozzle geometry
- Dry and A/B power settings (4 test throat areas)
- External hood angle
  - 45°, 90°, 120°
- Internal-flow blocker geometry

Measurements: Forces and moments (6 components)
- Nozzle mass-flow rate
- Internal and external static pressures

Status: Test completed July 1991
- Data reduction completed
- Data analysis in progress
Low Observable Lightweight Affordable Nozzles
(LOLA)

SUMMARY: A contract study jointly funded by Langley/PAB and USAF/WL/POTA to develop and validate lightweight, efficient, multifunction exhaust system technologies that facilitate the achievement of survivable, supportable, and affordable advanced tactical aircraft. The contract was awarded to the team of General Electric and Lockheed-Fort Worth, and is divided into several tasks. Task 1 - Quantify the ability of a variable cycle engine to mitigate penalties associated with a fixed aperture nozzle. Task 2 - Define and evaluate candidate nozzle concepts, and select two for further study, finally down-selecting to a single configuration for testing. (In a parallel investigation, conduct a sub-scale static test to determine the effectiveness of fluidic throat area control for a nozzle with both a fixed aperture and a fixed geometric throat area.) Tasks 3-6 - Conduct sub-scale configuration testing, including nozzle internal performance (static test at Langley/PAB), film cooling effectiveness, and heat transfer.

ORGANIZATIONS: Langley/PAB, USAF/WL/POTA, General Electric, and Lockheed-Fort Worth

STATUS: Task 1 complete.
Task 2 in progress.
Static Investigation of an Active Flow Control Device in a Supersonic C-D Nozzle

Objective: Determine the important geometry parameters involved with supersonic cavity-ramp vortex generators in a 2-D C-D nozzle. The purpose of these devices is to enhance mixing and provide separation control with a low loss vortex generator.

Organizations: Langley/PAB, University of Kansas Flight Research Lab, Langley/Aeroacoustics Branch

Variables: Single cavity vertex angle, cavity depth, cavity planform; Double cavity relative orientation; Multi-cavity

Measurements: Nozzle forces and moments (6 components) Nozzle mass-flow rate Internal nozzle static pressures (taps and pressure sensitive paint) Laser Vapor Screen (qualitative vorticity measurement) Far and near field acoustic measurements (Aeroacoustics Branch)

Status: Funding from Directors Discretionary Fund for FY 1993 and FY 1994 Water tunnel flow visualization complete Supersonic wind tunnel flow visualization complete Fixed geometry nozzle test planned for January 1994 Active control nozzle design to be initiated in February 1994
ASTOVL Primary Nozzle Exhaust System

OBJECTIVES: Determine the static internal performance of two different two-dimensional exhaust nozzles designed for use on ASTOVL aircraft.

ORGANIZATIONS: Rolls Royce Incorporated under contract to ARPA.

VARIABLES:
- Mach = 0
- NPR=TBD
- Upper Flap: Serrated, straight
- Lower Flap: Serrated, straight
- Flap length, angle
- Flap length

MEASUREMENTS: Surface static pressures on internal flap surfaces and in transition section. Force and moment measurements. Mass flow and discharge coefficient.

STATUS: Models in design, test is scheduled for May 1994.
ASTOVL Bypass Offtake Lift System

OBJECTIVES: Determine the static internal performance of two different offtake lift systems for ASTOVL aircraft. Rolling moment will be measured due to uneven flow between the two nozzles. Blowing will be done only at 90° down.

ORGANIZATIONS: Rolls Royce Incorporated under contract to ARPA.

VARIABLES: 
Throat area parametric to vary flow
Mach = 0
Differential combinations of flow blockage
NPR = TBD

MEASUREMENTS: Internal surface static pressures in the flow pipes. Removable total pressure rake to look at flow losses at various places in flow pipe.

STATUS: Models in design, test is scheduled for May 1994.
Variable Internal Contour Nozzle and Spherical Convergent Flap Nozzle

OBJECTIVE: To determine the static internal performance of two thrust vectoring nozzle concepts: a nozzle with a variable internal contour (VIC) capability for thrust vectoring and throat area control; and a variation on the spherical convergent flap nozzle (SCF).

ORGANIZATIONS: Langley/PAB
Pratt & Whitney
Lockheed

VARIABLES: VIC: throat position and shape
throat area
trailing edge geometry
pitch thrust vector angle
yaw thrust vector angle

SCF: throat shape
throat area
pitch thrust vector angle
yaw thrust vector angle

MEASUREMENTS: Forces and moments
Nozzle weight flow
Internal static pressure distribution
Surface flow visualization

STATUS: Test complete
Report in progress
Static Investigation of Scarfed Nozzles with Internal Yaw Tab Deflectors

Objective: To determine the performance of internal yaw tab deflectors in externally scarfed nozzles

Organizations: Langley/PAB; General Electric, Evendale, Ohio

Variables:  
- Divergent flap trailing edge scarf angle: 30°, 45°, and 60°  
- Side wall scarf geometry: Single and double sawtooth  
- Nozzle area ratio: 1.35, 2.00, and 2.40  
- Pitch vector angle: 0° and 10°  
- Yaw tab chord width: Short, medium, and long  
- Yaw tab geometry: Straight and tapered  
- Yaw tab deflection angle: 20° to 90°

Measurements:  
Forces and moments (6 components)  
Nozzle mass-flow rates  
Internal static pressures  
Paint flow visualization

Status: Test completed December 1993  
Data reduction in progress  
NASA TP planned
Fluidic Control of Nozzle Throat Area - Static Test

OBJECTIVE: To determine the effectiveness of fluidic throat area control for a nozzle with both a fixed aperture and a fixed geometric throat area. (In support of LOLA program)

ORGANIZATIONS: Langley/PAB, USAF/WL/POTA, and General Electric

VARIABLES: M = 0
NPR_{primary} = 1.0 to 10.0
NPR_{secondary} = 1.0 to 23.0
Fluidic injection angle
Injection slot size

MEASUREMENTS: Forces and moments (6 components)
Nozzle internal static pressures
Nozzle weight flow
Oil flow visualization

STATUS: Model fabrication complete.
AN EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION
OF THE AEROPROPULSIVE AND AEROACOUSTIC PERFORMANCE
OF HSCT MIXER/EJECTOR NOISE SUPPRESSORS

Objective

To better establish the relationships between mixing, ejector pumping, noise reduction, and thrust performance.

Organizations

Langley/PAB/Aeroacoustics Branch
The George Washington University

Facilities

16 Foot TT Static Test Facility
Langley Jet Noise Lab

Measurements

Noise
Thrust Performance
Internal Pressures
Shear Layer / Mixing Flow Visualization
Focusing Schlieren Flow Visualization
3 Component LDV / Hot Film

Status

Research program in planning
CFD to be initiated in Summer 1994
Experimental Testing in Spring/Summer 1995
I. ON-GOING RESEARCH PROGRAMS

A. High Performance Aircraft

Propulsion Airframe Integration
PAB-001 INLET STUDY

OBJECTIVE: To evaluate performance and flow quality of an advanced inlet concept at transonic speeds.

ORGANIZATIONS: Langley/PAB

VARIABLES: $M = 0.6$ to $1.3$ Inlet mass flow
$\alpha = 0^\circ$ to $15^\circ$ Inlet bleed mass flow
$\beta = 0^\circ$ to $\pm5^\circ$ Inlet diverter heights
Inlet leading edge geometry

MEASUREMENTS: Dynamic Pressures at Compressor Face
Total Pressure at Compressor Face
Internal Inlet and Diffuser Static Pressures
Throat Total Pressures

STATUS: Test complete
Steady state data reduction complete
Report on steady state data submitted for Branch review.
Acquisition of Spectrum Analyzer in early 1993 should expedite final dynamic data reduction.
COOPERATIVE PROPULSION INTEGRATION PROGRAM (CPIP), INLET MODEL

OBJECTIVES: Test the bottom mounted twin inlet configuration on the same wing body planform as previously tested.

MEASUREMENTS: Compressor face steady state and dynamic pressure measurements in both inlets. Bleed mass flow measurements. Throat rake total pressure measurements (removable). Inlet mass flow measurements. Internal inlet and diffuser static pressures. External static pressures on wing and fuselage. Six component force and moment measurements. Only vaned diffuser was tested because of time constraint.

VARIABLES: Independent remotely varied mass flow for each inlet. Vaned and unvaned diffusers, cowl lip parametrics.

STATUS: Test complete.
Data reduction complete for steady state pressure data.
Balance data will not be published because of fouling problems.
New 14 channel spectrum analyzer will be delivered in January 1993 to begin dynamic data reduction.
Steady state data report 80% complete. Plan publication in 1994.
Wind-Tunnel Investigation of Secondary Flap Scarfing Geometry on Multi-function 2-D C-D Nozzles

Objective: Determine the effects of secondary flap scarfing and contouring on wind-on performance of multi-function 2-D C-D nozzles.

Organizations: Langley/PAB

Variables:
- Secondary (divergent) flap contour (internal, internal/external and external warping)
- Secondary (divergent) flap planform (single and double sawtooth)
- Nozzle expansion ratio: 1.20 and 2.00
- NPR = 1.0 - 20.0
- $M = 0.0, 0.60, 0.80, 0.90, 0.95, & 1.20$
- $\alpha = 0^\circ, 5^\circ, & 10^\circ @ M= 0.6 & 0.9$
- $\alpha = 0^\circ @ M= 0.8, 0.95, & 1.20$

Measurements: Nozzle/afterbody forces and moments (6 components)
Nozzle mass-flow rate
External and internal nozzle static pressures
Paint flow visualization

Status:
- Subsonic Testing Completed July 1992
- Supersonic Testing Completed January 1993
- Data Analysis Initiated
Forebody Strake at Subsonic/Transonic Speeds

OBJECTIVE: Provide a parametric data base on the effectiveness of a forebody strake for providing control forces and moments at subsonic and transonic speeds.

ORGANIZATIONS: Langley/PAB

VARIABLES: Strake design (planform, span, chord, camber and incidence)
Strake azimuthal position (0° to 90°)
Angle of attack: 0° to 25°
Mach number: 0.3 to 0.85

MEASUREMENTS: Forces and moments
External static pressure distributions

STATUS: Wind tunnel test complete
Data analysis in progress
EFFECT OF NOZZLE CROSS-SECTIONAL SHAPE ON BOATTAIL DRAG FOR NONAXISYMMETRIC AFTERBODIES

OBJECTIVE: Using experimental and analytical methods investigate the effect of high-order loftings in the nozzle cross-sectional shape on external aerodynamic drag.

ORGANIZATIONS: Langley/PAB

FACILITY: Langley 16-Foot Transonic Tunnel

VARIABLES:
- M = 0.0 to 1.25
- NPR = 1 to 11
- α = 0°
- Exit shape
- Flap length
- Expansion ratio

MEASUREMENTS:
- Afterbody forces and moments
- External static pressures
- Flow visualization
- Nozzle mass flow

STATUS:
1. Model fabrication complete. Tests scheduled for late 1992 in the 16TT.
2. Analytical afterbody performance predictions will continue.
CFD-Validation Experiments for Nozzle Afterbody Flows

Organizations: Langley Propulsion Aerodynamics Branch, AAD; Aeroacoustics Branch, ACOD; Experimental Methods Branch, FldMD

Objective: Provide detailed, baseline measurements of the afterbody flow field to validate CFD codes and turbulence models

Configurations: Nonaxisymmetric afterbody
1. Jet blowing model- blade supported
2. Dummy-sting model: blade supported
3. Sting supported model

Measurements:
1. Surface & model: dynamic and steady pressures, hot films, skin friction, oil flows, aerodynamic balance
2. Off-body and boundary layer: total pressures, mean and fluctuating velocities, and Schlieren data, sheet-laser flow visualization

Instrumentation: Steady and dynamic pressure transducers, hot film gages, aerodynamic force and skin friction balances, boundary layer rakes, lasers, shadowgraph and Schlieren systems

Status:
1. Extensive Navier-Stokes computations made for complete model.
2. Internal nozzle tests completed data analysis in progress.
3. Wind-tunnel model design 85% complete.
4. Funding revoked, project put on hold.
Simultaneous Pitch/Yaw Thrust Vectoring on a 2D-CD Nozzle and a Single Expansion Ramp Nozzle at Transonic Speeds

OBJECTIVE: Evaluate the transonic performance of two simultaneous pitch/yaw thrust vectoring nozzle concepts: a two-dimensional convergent-divergent nozzle and a single expansions-ramp nozzle.

ORGANIZATION: Langley/PAB

VARIABLES: Mach 0.6 to 1.3
NPR: 1.0 to 8.0
Pitch vectoring: 0°, 20°
Yaw vectoring: 0°, 10°, 20°
Hinge location
Power setting

MEASUREMENTS: Forces and moments
Nozzle weight-flow
External static pressure distributions

STATUS: Design complete
Fabrication waiting for funding
Propulsion Integration for Aerocontrol Nozzles (PIANO)

OBJECTIVE: Develop a database so that drag and induced jet-effects correlations can be made for a single-engine, low-observable fighter with multi-function, multi-plane vectoring nozzles.


VARIABLES: Nozzle design and integration
- $M = 0.6$ to $1.2$
- $\alpha = 0^\circ$ to $25^\circ$, $\beta = 0^\circ$ and $+5^\circ$
- $NPR = 1.0$ to $6.0$
- Secondary-to-primary flow ratio $= 0.10$ to $0.25$

MEASUREMENTS: Forces and moments (6 components)
- Nozzle weight flow rate
- Afterbody and nozzle external static pressures
- Nozzle internal static pressures

STATUS: Phase I test complete ($\alpha = 0^\circ$, $\beta = 0^\circ$). Re-design of core hardware and fabrication of new nozzles in progress.
RIPPLED NOZZLE AFTERBODY

OBJECTIVE: Evaluate the installed performance of an afterbody with convoluted nozzle boattail and internal divergent flaps

ORGANIZATION: NASA Langley/ PAB

FACILITY: NASA LaRC 16Ft. Transonic Tunnel

VARIABLES: M = 0.60 to 1.30
Nozzle Pressure Ratio 1.5 to 10
Angle of attack
Nozzle length
Rippled vs baseline nozzle
Nozzle boattail angles 10, 20, 30 degrees

MEASUREMENTS: Forces and moments (6 components)
Nozzle mass flow
Static pressures
Flow visualization

SUPERCRIUSER FIGHTER CONFIGURATION WITH 2-D C-D NOZZLES HAVING VARIOUS ASPECT RATIOS

OBJECTIVE: Evaluate the effects of nozzle aspect ratio on the longitudinal aerodynamic characteristics of a supercruiser fighter configuration at transonic speeds.

ORGANIZATIONS: Langley/PAB

VARIABLES: M = 0.6 to 1.2 Nozzle aspect ratio
NPR = 1 to 10 Nozzle power setting
AOA = 0 to 10° Nozzle pitch vector angle
Canard deflection

MEASUREMENTS: Forces and moments in longitudinal plane
Nozzle mass flow

STATUS: Static tests indicate high restraints on balance normal force and pitch measurements due to metallic bellow stiffness.

Short bellows life due to unknown problems. Two different metallic bellows designs failed during static tests.

Model internal redesigned and fabrication of new hardware including nonmetallic bellows design completed in Oct 1990.

Static test (1993) indicates new bellows have acceptable force and moment restraints.
HIGH AREA RATIO EXPENDABLE NOZZLES

OBJECTIVE: Determine the internal and external performance of nozzles designed for a supersonic cruise missile mission.

ORGANIZATIONS: Langley/PAB/SHAB and Allison

VARIABLES: M = 0.6 to 1.3 (16'TT) Nozzle designs
M = 2.16, 2.5, 2.86 6 fixed geometry nozzles
NPR = 1 to 46 1 variable geometry nozzle
AOA = 0° Expansion ratio = 2.75

MEASUREMENTS: Nozzle thrust-minus-drag balance
Nozzle internal static pressures

STATUS: Tests in 16'TT completed on 6/3/89
Tests in Unitary tunnel completed in Feb. 1990 and data transmitted.
Some results published in AIAA 90-1904 and AIAA 91-0125.
Tests of longitudinally slotted nozzles completed in first half of 1991 in the 16'TT.
INVESTIGATION OF THRUST VECTORING VANES FOR F-18/HARV (HIGH ANGLE OF ATTACK RESEARCH VEHICLE)

OBJECTIVE: Evaluate the effectiveness of three externally-mounted vanes in providing multi-axis thrust vectoring for the F-18/HARV twin-engine axisymmetric nozzle propulsion system.

ORGANIZATIONS: Langley/PAB

FACILITY: Langley 16 Foot Transonic Tunnel

VARAIBLES: M = 0 to 0.70
Alpha = 0° to 68°
NPR = 1 to 5
Vane deflections = -10° to 25°
Mil and Max A/B power settings

MEASUREMENTS: 6-component forces and moments
Nozzle base pressures

STATUS: Tests completed 10/15/91

AIAA-92-3095

Preliminary results indicate beneficial external flow to pitch forces and adverse effects to yaw forces

NASA TP in progress
Alternate Control Technology - ACT Missile Program

**OBJECTIVE:** Develop innovative control concepts for air-to-air missiles that will dramatically improve air combat effectiveness using aerosurface controls, reaction jets or thrust vectoring.

**ORGANIZATIONS:** Langley/PAB, WL/MNAV Eglin AFB, McDonnel Douglas

**FACILITY:** Langley 16 Foot Transonic Tunnel

**VARIABLES:**
- \( M = 0.1 \) to \( 1.25 \)
- \( \text{Alpha} = -10^\circ \) to \( 90^\circ \)
- NPR = 1 to 300
- Nose and tail jet location
- Fin deflections = ±40°
- Nose shape

**MEASUREMENTS:** 6-component forces and moments
- Surface pressure measurements

**STATUS:**
- Model available
- Tests scheduled for February 1994
PAB FOREBODY/INLET INTEGRATION MODEL

OBJECTIVES: Inlet/Forebody single engine general research model to look at inlet integration parametrics across the speed range from low speed to supersonic.

ORGANIZATIONS: Langley/PAB, (Design provided by McAir under contract for Study of Inlet Installations), funding for model fabrication from Air Force Wright Labs.

VARIABLES:
Mach = .4 to 4.5
Alpha = -10° to 40°
Beta = ±15°

Inlet mass flow
Auxiliary inlet
Bleed plates
Cowl lip parametrics
Alternate diffusers
Bump Inlet

MEASUREMENTS: Dense static pressure instrumentation on the bottom of the model. Surface static pressures internal and external to the inlet, and diffuser internal surface static pressures. Removable throat rakes, diverter channel total pressure rakes, 40 probe total pressure steady state/dynamic engine face rake. Removable boundary layer rakes on forebody and on bottom external surface of inlet.

STATUS: Model was submitted for final design in 11/92. Model design 95% complete. A new inlet design will be provided by McDonnell Douglas for follow on work with the Air Force. Interest has been expressed by several companies for building various parts to test on the model. Waiting for funds from the Air Force to begin fabrication. Not on schedule to be tested at this time.
TAIL INTERFERENCE REVISTED

OBJECTIVE: To reduce the adverse tail interference effects on a typical single-engine afterbody/nozzle configuration, by using area-ruled or elliptical cross section afterbodies. To validate the CFD design methods used to obtain these bodies.

ORGANIZATION: Langley/PAB

VARIABLES: Three afterbody configurations
M = 0.5 to 1.20
NPR = 1.0 to 8.0
Angle of attack -3° to 9°

MEASUREMENTS: Force and moments on metric afterbody/nozzle configurations
Static pressures on metric afterbody/nozzles configurations

STATUS: Fab underway and should be completed by early 1994.
Investigation for Drag Reduction on a Twin-Tail, Twin-Engine Body-Empennage Model

OBJECTIVE: Collect pressure distributions on a twin-tail, twin-engine body-empennage model in support of CFD design by analysis effort.

ORGANIZATION: Langley/PAB
Dynamic Engineering, Inc.

VARIABLES: Mach: 0.6, 0.8, 0.9, 1.2
Alpha: 0°, 4°, 8°
NPR: 1 to 8
Horizontal tail position
Vertical tail position

MEASUREMENTS: External static pressure distributions on afterbody and nozzles

STATUS: Tunnel test complete
Report in progress
**Twin-Engine Attack/Fighter Afterbody**

**OBJECTIVE:** To determine the jet-induced effects on the aerodynamic characteristics of an advanced attack/fighter afterbody.

**ORGANIZATIONS:** Langley/PAB, Boeing Military Airplanes

**VARIABLES:**
- Nozzle boattail angle (nozzle power setting/expansion ratio)
- Tail configuration (horizontal tails on/off, vertical tail position)
- Dummy sting for aero reference comparison

**MEASUREMENTS:**
- Afterbody forces and moments (6 components)
- Afterbody and nozzle external static pressures
- Nozzle weight flow, total temperature, and charging section static pressure
- Afterbody pressure-sensitive paint

**STATUS:** Test complete
I. ON-GOING RESEARCH PROGRAMS

B. Subsonic, High Speed Civil, and Military Transports
OBJECTIVE: Obtain static pressure distributions for fourteen engine air inlets designed to operate at high subsonic speeds.

ORGANIZATIONS: Langley/PAB, Lockheed/CA, General Electric/OH, Pratt and Whitney/CT, Lockheed/GA

VARIABLES: M = 0.60 to 0.92
AOA = -3 to 3 deg
MFR = 0.25 to 0.72

Inlet external contour
Inlet forebody shape
Inlet lip shape
Inlet contraction ratio
Laminar flow contour (2)

MEASUREMENTS: Static pressures on internal and external surfaces of forebody
Afterbody external total pressure rakes to obtain momentum profiles
Internal total and static pressures for mass flow ratio (MFR) computation
Chemical sublimation to determine laminar flow extent on two inlets

STATUS: a. Tests completed and pressure data transmitted to engine and airframe participants. Some data published as parts of several conference papers by participants.
b. NASA TM-4488 published containing pressure data on three inlets.
c. Pressure distributions (M = 0.78) and chemical sublimation flow visualization tests on one laminar flow inlet design indicate a favorable pressure distribution over 70 percent of its length.
TURBOPROP TRANSPORT MODEL

OBJECTIVE: Determine the installation effects of wing-mounted and/or aft-fuselage mounted advanced counter-rotating turboprops on the aerodynamic characteristics of a low-wing transport.

ORGANIZATION: Langley/PAB/AAD

VARIABLES:
Configurations:
- Wing-mounted turboprop nacelles
- Aft-fuselage mounted turboprop nacelles
- Nacelle incidence and cant
- Horizontal stabilizer incidence
- Propeller advance ratio (power effects)
- Propeller pitch angle and rotation direction

Conditions:
- $M = 0.50$ to $0.82$
- $\alpha = -4^\circ$ to $5^\circ$

MEASUREMENTS:
- Total configuration forces and moments (6 components)
- Individual turboprop forces and moments (1 component)
- Extensive wing, pylon, nacelle surface static pressures

STATUS:
1) Aft-fuselage mounted configuration fabricated.
2) Wing-mounted configuration fabricated.
3) Contoured wing- and aft-mounted nacelles to be designed.
4) Static modal stress pre-testing of the aft-fuselage mounted configuration completed. Dynamic modal stress pre-testing of the aft-fuselage mounted configuration completed in January, 1993.
5) A full stress analysis which included the results from the dynamic modal pre-testing indicated that the pylon-to-nacelle attachment is not of sufficient strength to withstand wind tunnel testing. However, the results from the dynamic modal testing are not consistent and may need to be performed again.
ISOLATED TURBOPROP NACELLE

OBJECTIVE: Determine the aerodynamic characteristics of an isolated counter-rotating turboprop nacelle in a tractor or pusher configuration.

ORGANIZATION: Langley/PAB/AAD

VARIABLES:
Configurations: Wing-mounted turboprop nacelles
Aft-fuselage mounted turboprop nacelles
Nacelle incidence and cant
Propeller advance ratio (power effects)
Propeller pitch angle
Propeller rotation direction

Conditions: M=0.50 to 0.82

MEASUREMENTS: Total configuration forces and moments (6 components)
Individual turboprop forces and moments (1 component)
Nacelle mounted pressure rakes to survey propeller flow field

STATUS:
1) Design of models completed
2) Static and dynamic stress analysis approved.
3) Due to safety considerations, the strut was redesigned. Included in the redesign was a change in the airfoil shape of the strut to a symmetric supercritical airfoil.
4) Fabrication of the tractor configuration completed.
5) A test date using the tractor version of this model is not feasible until aft-mounted pusher tests are completed on the large scale turboprop model.
6) Prior to testing this model, a static modal test on this model must be completed as per NASA Model Engineering safety requirements.
LOW WING SEMISPAN TRANSPORT MODEL

OBJECTIVES: Determine the installed performance and best location, orientation for ultra-high-bypass turbofan nacelles on a low wing semispan transport model with a 35° swept supercritical wing designed for $M=0.85$ cruise. Establish power effects using flow-through and powered (turbine simulators) nacelles. Compare nacelle drag increments to current technology turbofan nacelles.

ORGANIZATIONS: Langley/PAB, Airframe and Engine contractors.

TEST VARIABLES: $M=0.50$ to 0.90, $\alpha=-4.0^\circ$ to approximately $+6.0^\circ$, bypass ratio (BPR = 6 to 15), spanwise nacelle span locations ($2y/b=0.30, 0.35$), and nacelle incidence and toe-in angles.

MEASUREMENTS: Forces and moments (5 component semispan balance), approximately 300 wing static pressures, and 200 nacelle/pylon static pressures.

STATUS: Semispan support system and balance fabrication in progress. Semispan model and turbine powered simulator (TPS) detail design in progress. TPS to be built during 1994. Semispan model fabrication to be completed in early 1995. A wind tunnel entry to checkout the semispan support system and establish tunnel operating characteristics is schedule for the fall of 1994.
M=0.85, LOW-WING TRANSPORT MODEL

\[ \lambda_{\text{ref}} = 35^\circ \]
AR approx. 9
Taper ratio = 0.3
Model scale = 0.038

OBJECTIVE: Determine the performance and best location/orientation of twin, ultra-high-bypass, flow-through turbofan nacelles on a low-wing transport model with a 35° swept supercritical wing for \( M_{\text{des}} = 0.85 \). Compare nacelle drag increments to current technology turbofan nacelles increments in the more challenging higher Mach number flow field of 0.85 cruise Mach number.

ORGANIZATION: Langley/PAB and airframe contractor

VARIABLES: \( M = 0.50 \) to 0.90
\( \alpha = -4.0^\circ \) to approximately +6.0°
Nacelle span location: 0.35 and 0.40
Nacelle incidence and toe-in to be determined

MEASUREMENTS: Forces and moments (6 components)
Approx. 400 wing surface static pressures
Approx. 200 nacelle and pylon surface static pressures

STATUS: Model construction was completed about August 1993, and 4 sets of nacelles fabricated for MDC were delivered to NASA about November 1, 1993. Model entry into tunnel occurred on December 13, 1993, and testing was completed February 23, 1994.
COUNTERROTATING TURBOPROP INSTALLATION ON A SWEPT WING

OBJECTIVE: To increase the understanding of flow interactions involved with counterrotating turboprop nacelle integration on a swept wing and to provide experimental data for verification of computational prediction techniques.

ORGANIZATION: Langley/PAB/AAD

VARIABLES:
Configurations:
- Over-the-wing nacelle
- Under-the-wing nacelle
- Front to rear propeller pitch relationship to reduce propeller wake swirl
- Propeller advance ratio (power effects)
- Propeller pitch angle of each fan
- Propeller rotation direction

Conditions:
- $M = 0.50$ to $0.80$
- $\alpha = 0^\circ$ to $5^\circ$

MEASUREMENTS: Individual turboprop forces and moments (3 components)
Extensive wing and nacelle surface static pressures

STATUS: 1) Counterrotating motors modified to safety standards.
2) Model design still on hold.
ENGINE-AIRFRAME INTEGRATION FOR TURBOPROP TRANSPORT

OBJECTIVE
Design based on CFD analysis of turboprop-airframe integration.

ORGANIZATION
Langley/PAB and ViGYAN, Inc.

VARIABLES
M = 0.6 to 0.8.
\( \alpha = -3.0 \) to \( 4.0 \) deg.
Engine location: Wing or aft mounted.
Engine power: Pressure, temperature and swirl; \( \text{or} \)
Force and work distributions.
Geometry: Nacelle and strut.

PREDICTIONS
Flow field for fuselage+wing+vertical tail+horizontal tail+strut+nacelle.

STATUS
The Euler code is operational. Strut leading edge extensions have been fabricated. Wind tunnel testing of struts is planned but has not been scheduled for 1994.
Aerodynamic Performance of a HSCT 2D Suppressor/Ejector Nozzle Concept

OBJECTIVES: Evaluate aerodynamic performance of a 2D Suppressor/Ejector exhaust nozzle concept having application to the High Speed Civil Transport (HSCT)

ORGANIZATIONS: Langley/PAB, NASA Lewis, General Electric/OH

VARIABLES: Mach = 0 (static) to 0.80
Angle of attack = -5 to +5 degrees
Nozzle pressure ratio = 1.0 to 6.0
Suppressor/Ejector Chute Area Ratio
Suppressor/Ejector Chute Expansion Ratio
Divergent Flap Length
Nozzle Expansion Ratio
Centerbody (wedge)

MEASUREMENTS: Nozzle thrust and drag forces
Nozzle weight flow rates
Internal total pressures
Suppressor/Ejector chute static pressures
Divergent flap internal and external surface pressures

Aerodynamic Performance of a HSCT 2D CD Mixer/Ejector Exhaust Nozzle - Phase II

OBJECTIVES: Evaluate aerodynamic performance of a 2D CD Mixer/Ejector exhaust nozzle concept having application to the High Speed Civil Transport (HSCT)

ORGANIZATIONS: Langley/PAB, NASA Lewis, General Electric/OH

VARIABLES: Mach = 0 (static) to 0.70
Angle of attack = 0 degrees
Nozzle Pressure Ratio = 1.0 to 7.0
Mixer Area Ratio
Suppressor Area Ratio
Suppressor Chute Expansion Ratio
Divergent Flap Length

MEASUREMENTS: Nozzle thrust and drag forces
Nozzle and Suppressor weight flow rates
Internal total pressures
Suppressor chute static pressures
Mixing area shroud surface static pressures

HSCT Suppressor/Ejector Nozzles

Mixer exit shapes

Objectives: Evaluate static thrust performance of two 2D mixer suppressor/ejector nozzle concepts having application to the High Speed Civil Transport (HSCT)

Organizations: Langley/PAB, Aeroacoustics Branch, and P&W Fla.

Variables: Mixer geometry
Shroud position
Vortex generators
Acoustic shroud panels

Measurements: Forces and moments
Nozzle total pressure ratio
Shroud static pressures
Mixer exit static pressures
Shroud exit pitot-static surveys
Shroud inlet hot wire traverse

Innovative High Bypass Turbofan
Thrust Reverser Static Test Program

- Wing Mounted Reverser System
- Fan and Core Flows Captured
- Better Flow Turning (??)

Multiple segment deflector system used to collect exhaust flow and turn it through the wing

- Thru-Wing Flow Turning Devices
- Additional Flap Segments to Improve Flow Turning

OBJECTIVES: Investigate innovative thrust reverser concepts applicable to high bypass turbofan installations. Concepts to be studied include core mounted blocker systems and wing mounted through-wing deflector/flap systems

ORGANIZATIONS: Langley/PAB, General Electric/OH, Pratt & Whitney/CN, Rolls Royce/GA, Rhor/CA

VARIABLES: Mach = 0 (static)
Separate Flow Nacelle with High Bypass Exhaust Nozzle (BPR 9)
Dual Flow Simulation (Fan & Core)
Fan and Core Nozzle Pressure Ratios = 1.2 to 1.8
Nozzle, Pylon and Wing Section
Conventional Cascade Thrust Reverser (Baseline Concept)
Core Mounted Blocker Thrust Reverser Concepts
Wing Mounted Deflector/Flap Thrust Reverser Concepts
Wing Positions (Axial & Vertical)

MEASUREMENTS: Six Component Balance Forces and Moments
Fan and Core Flowrates
Thrust Reverser Effectiveness
Blockers/Deflectors Static Pressures

STATUS: Design of model hardware complete. Fabrication of model hardware to be completed in FY 94. Testing to be started in early FY 1995.
OBJECTIVE: Design and build a turbofan simulator suitable for use in the 16-Foot Transonic Tunnel at Mach numbers from M=0.50 to 0.90. The high-pressure air-powered simulator must be capable of using different size fans and fan cowls to simulate fan bypass ratios (BPR) from baseline (-6) to Very High Bypass Ratios (-15 to 18) using the same turbine system for all fan sizes.

ORGANIZATION: Langley/PAB

VARIABLES: Fan diameters determined for bypass range of 6 to 12 is approx. 6 inches to 10 inches. Fan diameter for the BPR = 9 simulator selected for fabrication is 8.697 inches.

BOEING MODEL 1873 1.7% REF H

OBJECTIVE: Determine longitudinal aerodynamic characteristics and wing static pressure distributions at transonic speeds. The small size of the model and large size of tunnel should permit testing to higher subsonic and lower supersonic Mach numbers.

ORGANIZATIONS: Langley/PAB and Boeing Commercial.

VARIABLES: M = 0.8 to 1.25
α = -2 to 10 degrees
Nacelles on and off

MEASUREMENTS: Forces and moments (6 components)
Wing surface static pressures
Nacelle base pressures

STATUS: Test completed Dec. 10, 1993
I. ON-GOING RESEARCH PROGRAMS

C. Computational Fluid Dynamics
DEVELOPMENT OF THREE-DIMENSIONAL CODE FOR LAMINAR AND TURBULENT FLOW CALCULATIONS (PAB3D CODE)

OBJECTIVE: Develop a three-dimensional multiblock CFD code to simulate complex propulsion system configurations. This code can simulate attached as well as separated turbulent flow cases.

ORGANIZATIONS: Langley/PAB and Analytical Services and Materials, Inc.

VARIABLES: Free-stream conditions, Jet operating conditions, etc.

PREDICTIONS: Lift and Drag, Static pressures, Nozzle mass flow and thrust, etc.

STATUS:
1. The space marching scheme calculations give very good agreement with experimental supersonic/subsonic data yet requires less than 5% of computer time required by the fully time-dependent Navier-Stokes solver.
2. Three different algebraic and different forms of the standard and nonlinear k-ε turbulent models are included in the code.
3. Adaptive grid method is included which improves the predictions of the code (Pao).
4. A nozzle performance module is added to the code predicting six component forces and moments (Carlson).
5. Generalized multiblock patching package (Paø).

INVERSE DESIGN OF INSTALLED TURBOFAN NACELLES
FOR TRANSPORT AIRCRAFT

OBJECTIVE
Design the outer cowl of the nacelle, when it is installed on the full airplane configuration, in order to recover the pressure distribution for the isolated nacelle.

ORGANIZATION
Langley/PAB and ViGYAN.

VARIABLES
M = 0.85.
α = cruise.
Engine location: Under-wing.
Engine power choices: Pressure, temperature and swirl;
or,
Force and work distributions;
or,
Unpowered (flow-through).

PREDICTIONS
Flow field for fuselage+wing+pylon+fan cowl+core cowl.
Geometry for nacelle.

STATUS
The structured multi-block Thin-Layer Navier Stokes 2-Dimensional code from Langley/CAB is being used for the analysis. TLNS3D will be coupled with the Langley/TAD Direct Iterative Surface Curvature (DISC) Design Driver.
DIRECT SOLUTION OF THE NAVIER-STOKES EQUATIONS USING FINITE-DIFFERENCES

Spectral

48 x 96 x 97

Finite Difference

72 x 144 x 145

OBJECTIVE: Investigate the use of finite-difference methods for simulating laminar-turbulent transition by direct solution of the incompressible Navier-Stokes equations.

ORGANIZATIONS: Langley/PAB

APPROACH: Numerical investigations of laminar-turbulent transition typically employ spectral methods for spatially discretizing the governing equations. Spectral methods are more accurate than finite-difference or finite-volume methods, but are difficult to use with complex geometries and difficult to implement on parallel-processing computers. The suitability of using finite-difference methods in performing transition simulations is investigated by comparing finite-difference and spectral results from simulations of Taylor-Green vortex flow and transition in plane Poiseuille flow. The finite-difference codes developed for this study utilize 4th-order central differences on advection and viscous terms, 2nd-order central differences on the pressure term.

RESULTS: 1. As is illustrated by the above contour plots of vertical shear along the peak plane, the finite-difference results reliably reproduce the spectral results.
2. On the medium-fine grids employed in the present investigation, the finite-difference solutions require somewhat more than twice as many grid points in each spatial direction. However, the ratio of finite-difference to spectral grid points increases as the grid is refined.
3. In order to be competitive with spectral codes, the finite-difference code requires incorporation of a 4th-order treatment of the pressure.

PUBLICATIONS: Doctoral Dissertation completed
NASA TP in progress
APPLICATION OF A NEW ADAPTIVE GRID FOR AERODYNAMIC SHOCK CONTAINING SINGLE JETS

OBJECTIVE: Provide CFD flexibility to accommodate supersonic jet plume aerodynamic prediction for arbitrary nozzle exit shapes. The adaptive grid will also enhance solution accuracy with significant reduction of total number of grid points in the flow domain. Validation against experimental data is part of the scope of this project.

ORGANIZATIONS: Langley/Propulsion Aerodynamics Branch, Analytical Services & Materials, Inc., Langley/Aeroacoustics Branch

VARIABLES: Nozzle exit geometry, grid pattern and density, Mach number, nozzle pressure ratio, turbulence models including the two equation k-ε formulation.

MEASUREMENTS: Data of pressure and Mach number distribution for circular, elliptic, and rectangular jets.

PREDICTIONS: Flow variables in jet plumes within first 40 radii.

STATUS:
1. Solution self-adaptive grid generation is stable and efficient. Computational results for circular, square, and elliptic jets completed.
4. A NASA TP draft will be completed for review in March 1994.
MULTI-BLOCK GRID GENERATION FOR PROPULSION INTEGRATION

OBJECTIVE: Develop efficient and automated grid generation capability for propulsion integration with partial and complete aircraft configurations. Published surface definition and grid generation systems such as SMART and GRIDGEN will be used. However, it will be necessary to develop special methods for unique geometry and flow situations.

ORGANIZATION: NASA Langley/Propulsion Aerodynamics Branch

VARIABLES: Component geometry definition, grid density distribution, boundary layer, wake, and vectored thrust.

PREDICTIONS: Grid functionality will be verified by applications with flow solvers such as PAB3D, CFL3D, and GASP.

STATUS:

1. Completed grid generation package for circular to high-aspect-ratio rectangular transition ducts. Obtained initial flow solutions for one family of transition ducts by using the PAB3D Navier-Stokes code.
OBJECTIVE: Develop the capability for the prediction of moments and forces developed by nozzle flow for afterbody geometries.

ORGANIZATIONS: Langley/PAB

COMPUTATIONAL METHOD:
1. Presently utilizing the code PAB3D-v.8 for the solution flowfield.
2. Momentum flux, pressure forces and skin friction are integrated to produce body forces and moments.

PUBLICATIONS:
AIAA 91-0125, AIAA 91-2369, AIAA 91-3342

STATUS:
1. Discharge coefficient and thrust ratio predictions matched well for 2-D C-D static nozzles in non-vectored and vectored configurations.
2. Overall good agreement in nozzle performance prediction for an axisymmetric vented nozzle at under- and over-expanded flow conditions, from M = 0 to supersonic Mach numbers.
3. Reverser performance predictions can now be performed due to recent revisions in the PAB3D code.
4. Multi-stream flow performance options have been installed.
5. Preliminary results for SERN performance show good agreement with experimentally measured performance results.
6. Installed performance for axisymmetric geometry within 1% of experimental data near and below design NPR.
7. Skin friction module developed. Compared with flat plate and corner experimental data. NASA TP in editorial cycle.
8. Heat transfer module developed. Preliminary results compare reasonably well for a hypersonic shock-on-lip configuration.
CFD ANALYSIS OF AFTERBODY AERODYNAMICS WITH THRUST VECTORIZING

Freestream Mach = 1.20, NPR = 4.03

BOTTOM VIEW

TOP VIEW

OBJECTIVE: Investigate afterbody flow characteristics with installed twin jets which are capable of pitch and yaw thrust vectoring. Both structured and unstructured methods will be used for the analyses. These configurations are inherently complex. The unstructured approach can have an advantage in terms of overall efficiency.

ORGANIZATION: Propulsion Aerodynamics Branch, Transonic Aerodynamics Branch.

VARIABLES: Nozzle and afterbody geometry, Mach number, thrust vectoring angle, turbulence models.

MEASUREMENTS: Existing data of pressure and Mach number on afterbody surfaces and boundary layer; thrust, vector angle, and other forces and moment measurements.

PREDICTIONS: Navier-Stokes and Euler solutions for the entire flow field.

STATUS:
1. A structured grid for a twin canted nozzle geometry was generated in 1991. Preliminary Navier-Stokes computations were completed in early 1992.
2. Implemented a conservative patch grid interface capability as a preprocessor to PAB3D in 1993.
TWIN-ENGINE FIGHTER AFTERBODY/NOZZLE DRAG

OBJECTIVE: Use numerical methods to investigate alternate geometries for a twin-engine body-empennage which would exhibit lower overall drag levels than a previously tested baseline configuration.

ORGANIZATION: Propulsion Aerodynamics Branch, DEI, CSC

APPROACH: The approach used in this investigation will be to identify feasible modifications to the existing model geometry, perform an analysis at the selected flow conditions using CFD methodology, evaluate the resulting change in aerodynamic interference and drag through examination of the resulting pressure distributions and proceed to further configuration modifications if necessary. This analysis will be performed using the PAB3D code.

MEASUREMENTS: Existing data of surface pressure and forces for several geometries are available.

STATUS: 1. Grids were generated for two configurations. Preliminary Navier-Stokes solutions were obtained at the end of 1993.
2. Analysis of the computed solutions and their comparison with data will be continued in 1994. The results will be reported to the AGARD PAI working group.
INVERSE DESIGN OF INSTALLED TURBOFAN NACELLES FOR TRANSPORT AIRCRAFT USING A CHIMERA FLOW SOLVER

OBJECTIVE: Design the outer surface of the fan cowl, when it is installed on the transport configuration, in order to recover the pressure distribution of the isolated nacelle.

ORGANIZATIONS: Langley PAB and VIGYAN, Inc.

APPROACH: Utilize the OVERFLOW analysis code in an inverse design application. OVERFLOW is a Chimera method for solving the thin-layer Navier-Stokes equations, which was developed at NASA Ames. The methodology for gridding complex aerodynamic shapes with over-lapped grids is illustrated in the figure, which shows a cross section for a C-C wing grid (center left), a C-O fuselage grid (center right), a C-H collar grid to connect the wing and fuselage grids, and a H-H Cartesian grid which extends out to the far field. Interpolations between the grids are obtained with PEGSUS, a preprocessor which was developed at Arnold Engineering Development Center. Use of the Chimera method in an inverse design application is to be attained through coupling PEGSUS and OVERFLOW to the Direct Iterative Surface Curvature (DISC) Design Driver developed at Langley/TAD.

STATUS: Grids for the wing body configuration and isolated nacelle have been created; numerical solutions from OVERFLOW are in good agreement with experimental results. Ongoing efforts include coupling the nacelle grids with the wingbody grids and incorporating the DISC method into the PEGSUS preprocessor and OVERFLOW analysis codes through the use of script files.
CALCULATION OF TURBULENT WALL BOUNDED SEPARATED FLOWS USING MESH SEQUENCING AND CONSERVATIVE PATCHING

OBJECTIVE: The objective of the present work is to investigate high speed wall bounded separated flows using mesh sequencing and conservative patching.

ORGANIZATIONS: Langley AAD/PAB and ODU

APPROACH: Mesh sequencing and conservative patching techniques have been applied to complex separated flow fields. The numerical study demonstrated that mesh sequencing techniques have the potential for accelerating the convergence rate and reducing the computational time when implemented in single and multiblock codes.

RESULTS: Supersonic flow past 16 and 24 degree compression ramps were used as a model problem to show improvements obtained using mesh sequencing procedure. Representative results for pressure and skin friction distribution were obtained using k-ε and Baldwin-Lomax turbulence models. It was observed that using mesh sequencing the computational time to reach steady state solution was reduced by a factor of five while significantly accelerating the convergence rate. Smooth pressure and skin friction distribution were obtained using mesh sequencing as compared solutions obtained without employing mesh sequencing procedure.

PUBLICATIONS:


I. ON-GOING RESEARCH PROGRAMS

D. Other Programs- Generic Hypersonics, Acoustics, Water Tunnel, Facilities
HYPersonic II - High Speed Nozzles

Objective: Evaluate effects of ramp length and curvature, external expansion ratio, sidewall length and several cowl geometric variations on the performance of external expansion ramp nozzles designed for high speed applications.

Organization: Langley/PAB and P&W/Fla., and Rockwell International

Variables:
- $M = 0.0$ TO 1.2 Plug length
- $NPR = 1.2$ to 10.0 Ramp curvature (initial and terminal ramp angles)
- Upstream ramp shape External expansion ratio
- Cowl boattail and flow turning angle

Measurements:
- Force and moments (6 components)
- Nozzle mass flow
- Ramp static pressures

Status:
- Papers

Leavitt Laurence D.; and Lamb, Milton
Transonic Characteristics of NASP Nozzles
Fifth National Aero-Space Plane Technology Symposium
Oct. 18-21, 1988 Paper number 87

Lamb, Milton; and Leavitt, Laurence D.
Summary of NASP Propulsion Integration
Testing at Transonic Speeds.
Tenth National Aero-Space Plane Technology Symposium
April 22-26, 1991 Paper number 175

Lamb, Milton; Leavitt, Laurence D.; and Bennett, Barry B.
Off-Design Transonic Performance Characteristics for National Aerospace Plane Type Nozzles
(IN BRANCH REVIEW)
NASP FOREBODY MODELS

OBJECTIVES: Obtaining static pressure boundary layer and some flow field data on two NASP forebody concepts. This data is to be used to compare with CFD codes and to help decide on the best design for a full NASP inlet model.

ORGANIZATIONS: Langley/PAB, TAB, MCAIR

VARIABLES:  
Mach = .8 to 4.5  
Alpha = -4 to 10  
Full scale Reynolds number

Forebody 1  
Baseline  
Alternate Chine

Forebody 2  
Baseline  
Alternate Chine

MEASUREMENTS: Dense static pressure instrumentation on the bottom of the model with emphasis on the first and second ramp positions and the cowl leading edge. Boundary layer/shock layer rakes to be positioned at 3 axial locations on the top and bottom of the body.

STATUS: Tests have been completed in the Unitary Tunnel on all configurations. Test has been completed at NTF. Because of time constraints only the alternate chine was tested with both the alternate and the baseline nose. Preliminary data showed little or no Reynolds number effects, so not all configurations were run in the cryogenic mode. Unitary data showed confined flow configuration to gave the most uniform flow at the inlet entrance plane. Analysis of Unitary data complete, report 90% complete, publication planned for 1994.
HYPERSOニック III

OBJECTIVE: Reduce pressure drag on a NASP type nozzle. Evaluate the effects of mass injection (secondary air) on the surface of an expansion ramp nozzle designed for high speed applications. Also look at stowed flap (in ramp surface) deflection with mass injection.

ORGANIZATIONS: NASA Langley/PAB

VARIABLES: M = 0.5 - 1.3  Secondary air \( w_{p2} \) and air injection location
NPR = 2.0 - 12.0  Air injection downstream of deflected ramp flap

MEASUREMENTS: Forces and moments (3 components)
Nozzle primary air mass flow rate
Nozzle secondary air mass flow rate
Ramp static pressures

STATUS: Testing in 16 FTT was completed on Oct. 25, 1993. Further testing is planned for static test facility. Data reduction underway.
ADVANCED CONTROLS - WATER TUNNEL MODEL

OBJECTIVE: Obtain visual and laser velocimeter data to indicate relative strength of vortex (side and yaw) shed from a forebody strake.

ORGANIZATIONS: NASA Langley/PAB

VARIABLES: Forebody design
Strake angle
Strake length
Camber & incidence

strake width
strake planform
strake size
strake location

MEASUREMENTS: Visual (photographs)
3-D laser fluorescence anemometer (LFA)

STATUS: Visual and laser tests complete
Photographic data available and will be incorporated with wind tunnel data report.
NASA report on LFA results in editorial cycle.

conmod/blb/radar
Water-Tunnel Investigation of Afterbody & Plume Flowfield

Organization: Langley/ Propulsion Aerodynamics Branch, AAD

Objective:
Qualitatively verify afterbody flowfield and existence of vortices downstream of the nozzle exit

Configurations: Nonaxisymmetric afterbody
1. Jet blowing model
2. Sting supported model

Measurements:
Dye traces, 3 component off-body velocities, laser-sheet flow visualization

Instrumentation:
3-component laser fluorescence anemometer, laser-sheet

Status:
Project completed

Publications:
Proposed NASA TP approved by editorial committee
Delta Wing Vortex Flow at High Alphas

OBJECTIVE: Investigate the vortex flowfield of highly swept delta wings at high angles of attack.

ORGANIZATION: NASA Langley, Propulsion Aerodynamics Branch

FACILITY: NASA LaRC 16 X 24 inch Water Tunnel

VARIABLES: Velocity, angle of attack, sideslip, wing sweep, wing span-to-body diameter ratio, spanwise blowing, and various flow-altering devices.

MEASUREMENTS: Flow visualization data using color still and video recording of colored and fluorescent dye streaks, and laser-based quantitative flow field surveys.

STATUS: Tests were conducted from 1988-1989 that showed the unsteady vortex breakdown characteristics on highly-swept delta wings. Further tests have been initiated to elaborate on the flow mechanisms associated with these vortex flows using flow visualization. Laser Doppler velocimetry and fluorescence measurement (see related program sheet) will be used to quantify differences due to adjusting certain of the above-mentioned variables. Vorticity contours and subsequent calculations of vortex strength (circulation) will be generated from the laser flow field measurements.
RIPPLED NOZZLE AFTERBODY WATER TUNNEL 
PROPULSION SIMULATION SYSTEM

OBJECTIVE: Study the afterbody flowfield of a nonaxisymmetric rippled nozzle at various velocity ratios. Study the plume mixing characteristics of a rippled nozzle.

ORGANIZATION: NASA Langley/ PAB

FACILITY: NASA LaRC 16x24 inch Water Tunnel

VARIABLES: 
\[ V = 0.25 \text{ ft/s}, \text{ Nozzle velocity ratio} \]
Angle of attack, Nozzle length
Rippled vs baseline nozzle
Nozzle boattail angles 10, 20, 30 degrees

MEASUREMENTS: Freestream velocity
Jet velocity
Flowfield measurements with LDV
Flow visualization with laser sheet

Model testing completed in June 1992.
No further testing planned.
WATER TUNNEL PROPULSION SIMULATION SYSTEM

OBJECTIVE: Study the afterbody flowfield of an axisymmetric nozzle at various velocity ratios. Study the plume characteristics of an axisymmetric nozzle.

ORGANIZATION: NASA Langley/ PAB

FACILITY: NASA LaRC 16x24 inch Water Tunnel

VARIABLES: 
- $V = 0.25 \text{ ft/s}$
- Nozzle velocity ratio
- Angle of attack
- Nozzle boattail angles

MEASUREMENTS: Freestream velocity
- Jet velocity
- Flowfield measurements with LDV
- Flow visualization with laser sheet

STATUS: Model delivered in May 1991.
Model testing completed in June 1991.
No further testing planned.
PERMANENT RECORD FLOW VISUALIZATION

OBJECTIVE
Develop flow visualization techniques for nozzle static testing and for the transonic testing of aerodynamic and propulsion models.

ORGANIZATION
Langley/PAB and Vigyan, Inc.

VARIABLES
Internal flows
External flows
Wide range of nozzle pressure ratios
Subsonic/Transonic Mach numbers

RESULTS
Flow features such as mixing, separation, reattachment and recirculation can be clearly identified. Limited effectiveness for the location of transition and shocks.

STATUS
1) Development complete for internal and external flows and for all nozzle pressure ratios. Various types of mixtures have been found that can capture flow features to tunnels of up to M=0.90.
2) In-branch report was written that covers the various capabilities of this particular flow visualization technique.
3) Due to restricted tunnel and jet exit testing time, quantification of actual mixtures for various flow application has not yet been determined, but will be accomplished in 1994.
CALIBRATION OF THE LANGLEY 16-FOOT TRANSonic TUNNEL

OBJECTIVE: Determine the flow field characteristics of the Langley 16 Foot Transonic Tunnel. This calibration was done following major rehabilitation of the facility that included installation of a new model support system.

ORGANIZATIONS: Langley/PAB

FACILITY: Langley 16 Foot Transonic Tunnel

VARIABLES: M = 0.1 to 1.30
Wall divergence angle

MEASUREMENTS: Centerline pressure distributions
Wall pressure distributions
Diffuser pressure distributions
Power characteristics
Boundary layer characteristics
Flow angularity characteristics
Flow dynamic characteristics

STATUS: Calibration was essentially the same as previous 1965 and 1970 calibrations
Analysis of flow angularity and dynamics continuing

NASA TP in progress
AEDC 10° TRANSITION CONE

OBJECTIVE: To determine the streamwise location of boundary layer transition on a 10° (included angle) cone in the 16-Foot Transonic Tunnel. This will give an indication of the turbulence level in the tunnel.

ORGANIZATION: Langley PAB

VARIABLES: M = 0.2 - 1.3
Probe location along surface of cone
Cone location relative to tunnel centerline

MEASUREMENTS: Tunnel freestream conditions
Probe total pressure (in boundary layer)
Kulites on cone surface

STATUS: Test entry scheduled for March 1994.
HYPersonic foreverbody/inlet integration model

OBJECTIVES: Obtain forebody static pressures and inlet performance data on a contained flow forebody configuration with a three module daggerboard inlet at transonic speeds.

ORGANIZATIONS: Langley/PAB, McAir (for model design)

VARIABLES: Inlet mass flow
Mach = .4 to 1.2
Alpha = -4° to 10°
Beta = ±4°

Throat parametrics
Engine entrance and exit flowfield
Possible others TBD

MEASUREMENTS: Dense static pressure instrumentation on the bottom of the model. Surface static pressures internal to the inlet. Three separate instrumented mass flow plugs, cone probes for entrance and exit flowfield surveys.

STATUS: This test requires modification to an existing model. A new forebody bottom and chine pieces will be constructed to simulate the contained flow forebody design. Design for model modifications have been completed. Model is in the process of being retrieved from McDonnell Douglas. Expect the model to be delivered to Microcraft for modification in early January of 1994 for modification. Test is not currently scheduled.
HYPersonic IV - Static Test

OBJECTIVE: Evaluate the performance of a nozzle concept designed to operate at high supersonic speeds (high expansion ratio) with low external drag and high nozzle thrust efficiency.

ORGANIZATIONS: NASA Langley/PAB

VARIABLES: $M = 0.0$
NPR = 2.0 - 12.0
Expansion Ramp Geometry

MEASUREMENTS: Forces and Moments (3 components)
Nozzle mass flow rate
Ramp static pressures
Flow visualization

STATUS: Model design complete.
Model fabrication in progress.
Model fabrication scheduled for completion 5/1/94.
CFD analysis of performance at forward speeds underway.
OBJECTIVE: Determine location of test section wall reflected shock impingement on probe by disturbances in surface pressure distribution on probe. Probe is 64.0 inches long and is designed to have pressure coefficients equal to zero over most of its length.

ORGANIZATIONS: Langley/PAB and Boeing Commercial

VARIABLES: M=0.90 to 1.25, 
α = -10, 0, +10 degrees
Roll angles between 0 and 90 degrees
On test section centerline only

MEASUREMENTS: 101 probe surface static pressures
Shadowgraph

STATUS: Test completed Nov. 30, 1993
A WATER TUNNEL INVESTIGATION OF THE EFFECTS
OF MIXER/EJECTOR NOISE SUPPRESSORS
ON HSCT WING AND HIGH-LIFT AERODYNAMICS

Objective
To study the effects of ejector entrainment and lip suction pressure fields on HSCT wing and high-lift aerodynamics.

Organizations
Langley/PAB, The George Washington University

Facility
16 by 24 inch Water Tunnel

Measurements
Colored Dye Flow Visualization
Fluorescent Dye Flow Visualization

Status
Research program in planning
Testing in Summer 1994
II. COMPLETED RESEARCH PROGRAMS

A. High Performance Aircraft
STATIC INVESTIGATION OF POST EXIT VANES FOR MULTIAxis
THRUST VECTORING FOR THE X-31 AIRCRAFT

OBJECTIVE: Evaluate the effectiveness of post-exit vanes in providing thrust vectoring capability and provide data inputs for the aircraft flight control system

ORGANIZATIONS: Langley/PAB, US Navy, DARPA, Rockwell Messerschmitt-Bolkow-Blohm/Germany

VARIABLES: NPR = 1.5 to 6 Vane shape
Axisymmetric nozzle Hinge line location
Nozzle power setting Vane deflection angles up to 35°

MEASUREMENTS: Forces and moments (6 components)
Nozzle mass flow rate
Vane pressures
Flow visualization water injection and oil flows

STATUS: Tests conducted April 1988
All data plotted
No further work is planned
**STATIC INVESTIGATION OF NOZZLE DESIGN CAPABLE OF 105° THRUST VECTOR ANGLES (MADEN II)**

**OBJECTIVE:** Evaluate performance of a center pivoted flap vectoring concept designed for incorporation into future supersonic STOVL aircraft.

**ORGANIZATIONS:** Langley/PAB, P&W/Fla.

**FACILITY:** Langley Static Test Facility

**VARIABLES:**
- \( M = 0.0 \)
- \( \text{NPR} = 1.5 \) to 8

**MEASUREMENTS:** Forces and moments (3 components)
- Internal static pressures
- Nozzle mass flow

**STATUS:** Published NASA TP 3385, Nov. 1993

Excellent flow turning characteristics because of efficient subsonic flow turning scheme.

Generally high levels of internal performance for thrust vector angles less than or equal to 60°. Performance decreased substantially for the 105° vectored case at values of NPR > 3, probably because of overexpansion losses associated with the upstream port.
2-D C-D NOZZLE WITH A DIAGONAL HINGE THROAT

OBJECTIVE: Evaluate internal performance and flow turning effectiveness of nozzles having combined pitch and yaw vectoring capability.

ORGANIZATIONS: Langley/PAB, P&W/Fla.

FACILITY: Langley Static Test Facility

VARIABLES: M = 0.0
NPR = 1.5 to 10

Nozzle power setting
Pitch/yaw thrust vector angle
Sidewall angle and length
Throat position and geometry

MEASUREMENTS: Forces and moments (6 components)
Internal static pressures
Nozzle mass flow

STATUS: A NASA Technical Memorandum was published in April 1993.

Nozzle configuration in general had relatively high levels of internal performance when yaw vectored. Turning performance was excellent in pitch and good in yaw planes.

Sidewall deflection were needed to obtain best yaw turning and highest overall performance levels.

Static pressure data indicate that the physical throat location formed along the diagonal hinge line as expected.
WIND TUNNEL INVESTIGATION OF MULTIAxis THRUST VECTORING CONCEPTS

OBJECTIVE: Determine the wind on performance characteristics of several multiaxis vectoring nozzle concepts.

ORGANIZATIONS: Langley/PAB

VARIABLES: Subsonic, dry power, 2-D C-D nozzle

\[ M = 0.0, 0.2 \text{ to } 0.9 \quad \text{Yaw vector concepts} \]
\[ \text{NPR} = 1.0 \text{ to } 7.0 \quad \text{Pitch vector angle} \]
\[ \text{AOA} = -4.0 \text{ to } 14.5 \quad \text{Rudder deflection (baseline)} \]

MEASUREMENTS: Nozzle/afterbody forces and moments (6 components)
Nozzle mass-flow rate

STATUS: Effort terminated because of data accuracy problems. Some data in SAE Paper 881481.
EFFECT OF NOZZLE PLANFORM SHAPE ON BOATTAIL DRAG FOR NONAXISYMMETRIC AFTERBODIES

OBJECTIVE: Using experimental and analytical methods investigate the effect of spanwise variations in the nozzle 'chord' length on external aerodynamic drag.

ORGANIZATIONS: Langley/PAB

FACILITY: Langley 16-Foot Transonic Tunnel

VARIABLES: M = 0.0 to 1.25  Planform shape
NPR = 1 to 11  Flap length
α = 0°

MEASUREMENTS: Afterbody forces and moments
Static pressures

STATUS:
1. Benefits for a certain variation in boattail shape were predicted using the VSAERO panel method.
2. Wind tunnel tests conducted in Sept. 1987 partially verified VSAERO results for reduction in boattail drag.
3. High order shaping designs initiated for twin-engine configurations.

No further work is planned.
SINGLE EXPANSION RAMP FLOW FIELD SURVEY

OBJECTIVE: Determine the flow field characteristics in and around the jet exhaust from a nonaxisymmetric single expansion ramp nozzle (SERN) and provide experimental data needed for verification of computational codes.

ORGANIZATION: Langley/PAB

VARIABLES: M = 0, 0.6, 0.9, 1.2
NPR = 4, 8
Alpha = 0°

MEASUREMENTS: Pitot-pressure measurements at 5 longitudinal stations downstream of nozzle exit

STATUS: Tests not currently scheduled
INVESTIGATION OF THE INSTALLED PERFORMANCE OF SUPersonic CRUISE NOzzle CONCEPTS ON THE MCAIR ANC FUSELAGE AND A GENERIC FUSELAGE

OBJECTIVE: Evaluate the static internal performance and installed performance of supercruise nozzle concepts at transonic speeds.

ORGANIZATIONS: Langley/PAB, MCAIR/GE/P&W, and WRDC

VARIABLES: 
NPR (varies with Mach) 
Pitch vector
Long Flaps
Baseline
(ANC only)

Mach = 0.0 to 1.2 only)
Alpha = -1.0 to 8.0

P&W Tandem Disk
Pitch vector
Hinge height

P&W/MCAIR DFDH (Generic only)
skewed throat, yaw vector sidewalls
yaw/pitch vector combined, thin sidewalls

SERN (ANC)
Pitch vector
Ramp & flap length

MEASUREMENTS: Forces and moments (6 component); Nozzle balance (nozzles only), Aircraft balance (no nozzles); Nozzle mass flow measurements; External static pressures on fuselage, afterbody, L/H nozzle; Boundary layer rake on Tandem disk L/H nozzle (Generic and ANC)

STATUS: During preparation of the data for reporting it was discovered that all the pressures were incorrect. Further investigation has shown that the problem was a leaking calibration line on the ESP system. Since all the cavity and base pressures were also on ESP'S none of the force data is good either.

FUTURE PLANS: Not currently scheduled for retesting.
II. COMPLETED RESEARCH PROGRAMS

B. Subsonic, High Speed Civil, and Military Transports
LOW-WING TRANSPORT -- PYLON SHAPE STUDY

OBJECTIVE: Determine the effects of pylon cross-section and toe angle on the drag of a low-wing transport.

ORGANIZATION: Langley/PAB and ViGYAN, Inc.

VARIABLES:  
M = 0.6 to 0.8  Pylon toe angle  
α = -3.0° to 4.0°  Pylon cross-section

MEASUREMENTS:  
6 component force and moment balance  
Wing pressures  
Surface flow visualization

STATUS/PAPERS:  
Test program completed.


Journal of Aircraft, Vol. 30, No. 5, September-October 1993, Pages 676-681

NASA TP 3333, June 1993
ADP NOZZLE PERFORMANCE

OBJECTIVE: Determine the effects of nozzle offset and pylon geometry on nozzle performance

ORGANIZATION: Langley/PAB, Boeing, Pratt & Whitney

VARIABLES: M = 0.6 to 0.82 Core NPRs to 1.6
Fan NPRs to 2.1 Nozzle offset
Pylon geometry

MEASUREMENTS: 6 component force and moment balance
Static and total pressures

STATUS: Tunnel test program completed.

Data determined to be of poor quality. No report planned.
LOW-WING TRANSPORT MODEL

OBJECTIVE: Determine the best location/orientation of current technology high-bypass and ultra-high-bypass flow-through turbofan nacelles on a twin-engine, low-wing, transport model with a 21° swept supercritical wing. Compare the performance of ultra-high-bypass, flow-through nacelles to current technology nacelles.

ORGANIZATION: Langley/PAB, McDonnell Douglas/Long Beach, and Pratt & Whitney/Hartford

VARIABLES: M=0.50 to 0.80
\( \alpha = -4.0^\circ \) to \( 6.0^\circ \)
Nacelle incidence (-3° to +4°)
Nacelle toe-in (0° to 3°)
Nacelle span location (y/ b/2 = 0.34 (ATF nacelle only) & 0.40)

MEASUREMENTS: Forces and moments (6 components)
307 wing surface static pressures
80 nacelle and pylon surface static pressures

STATUS: Tests completed January-March, 1989
AIAA 89-2480, July 10-12, 1989
ASME 91-GT-241, June 3-6, 1991
AIAA 92-0153, Jan. 6-9, 1992
NASA TP-3168, March 1992
II. COMPLETED RESEARCH PROGRAMS

C. Computational Fluid Dynamics
II. COMPLETED RESEARCH PROGRAMS

D. Other Programs- Generic Hypersonics, Acoustics, Water Tunnel, Facilities
Wingtip Blowing Investigation
with a Low Aspect Ratio Swept Wing

OBJECTIVE: Study the interaction of the wingtip vortex with the counter-rotating vortices from lateral and vertical jets.

ORGANIZATION: NASA Langley, Propulsion Aerodynamics Branch

FACILITY: NASA LaRC 16 X 24 inch Water Tunnel

VARIABLES: \( V = 0.25 \text{ ft/s}, \ \alpha = 0 \text{ degrees to 5 degrees}, \ \beta = 0 \text{ degrees}, \) Reynolds number = 23,000/ft or \( 14.2 \times 10^3 \), various tip jet geometries and jet flow/freestream flow ratios.

MEASUREMENTS: Free stream mass flow rate, tip jet mass flow rate, model angle of attack, still color photographs, color video tape.

STATUS: This model is a scaled-up (by 2.632) section of the outboard 31.8\% of the original wingtip blowing wing (see program sheet by Wellons/Mineck/Neuhart, 10/16/89). The NACA 0010-66 airfoil section provided more attached flow on the wing upper surface. However, the tip vortex was not as coherent as desired. Nondimensional jet penetration was less for this wing than for the previous tip-blowing wing (aspect ratio effect?). The vertical jet appeared to take the tip flow and move it with the jet up and away from the wing. Further quantitative analysis was to be made on the jet flow using the laser Doppler velocimetry and fluorescence measurement (see related program sheet). However, the water tunnel will be closed at the end of FY1994. Therefore, no further research will be done on this model.
Three-dimensional
Laser Doppler Velocimetry System with Fluorescence Measurement

OBJECTIVE: Install and demonstrate a 3-D laser Doppler velocimeter system with fluorescence measurement.

ORGANIZATION: NASA Langley, Propulsion Aerodynamics Branch Complere, Inc.

FACILITY: NASA LaRC 16 X 24 inch Water Tunnel

VARIABLES:

MEASUREMENTS: Three components of velocity plus concentration (related to fluorescence intensity) of fluorescent dye.

STATUS: The laser-based system has been designed and fabricated by personnel from Complere, Inc. They were responsible for delivering and installing the system and demonstrating its capability by performing and documenting two experiments. The system was to be delivered with full documentation of software and hardware. The contract began in July, 1988, and was completed on February 28, 1992. The system was installed in March, 1991, and limited, preliminary tests were made of the system capabilities by Complere personnel. As of this date, software and hardware debugging has been completed by personnel working in the PAB. The two, originally-planned experiments have been completed, the data evaluated, and an uncertainty analysis completed. A NASA report, thoroughly documenting the system (including uncertainty analysis), will be published in 1994.
Wing Aspect Ratio Effects on Tip Vortex Formation

OBJECTIVE: Study the effect of wing aspect ratio on the formation of the tip vortex shed from a wing of rectangular planform.

ORGANIZATION: NASA Langley, Propulsion Aerodynamics Branch

FACILITY: NASA LaRC 16 X 24 inch Water Tunnel

VARIABLES: Free stream velocity (3 and 8.3 in/sec), wing aspect ratio (2, 4.44, 6.44), wing angle of attack (5° and 10°).

MEASUREMENTS: Free stream velocity and flow visualization data with colored dye using still photography and video recording.

STATUS: The model was a semispan, rectangular wing made in sections to allow variations of wing aspect ratio. The tip vortex for the aspect ratio 2 wing appeared less concentrated than for the other wings. The visual distinctions in vortex concentration, which may indicate vortex strength, between the higher aspect ratio wings were not as clear. Comparison with the tip vortex flow field for the low aspect ratio swept wing used for wingtip blowing (see program sheet), which had more wing area than the largest wing in this study, had a weaker-looking vortex. This may imply a sweep effect. No real conclusion can be made about vortex strength until a quantitative measurement is made of the vortex flow fields. Further studies were to be made with laser sheet flow visualization and laser Doppler velocimetry with fluorescence measurement. However, the water tunnel will be closed at the end of FY1994. Therefore, no further research will be done on this model.
OBJECTIVE: Increase maximum NPR range of facility

ORGANIZATIONS: Langley/PAB

PROCEDURE:

PHASE 1 - New flanged low pressure plenum. Design pressure = 350psi
New flanged axi. and 2-D instrumentation sections.
Axi. - Full span 9-probe rake, 2 TTJ’s, 2 statics
2-D - 3 PTJ rakes (10 probes total), 2 TTJ’s, 2 statics
Add flanges to Stratford choke calibration nozzles.
Increase AT or Cd of 8 radial choke nozzles.
Install schlieren plume visualization system.

PHASE 2 - New propulsion simulation hardware with dual flow capability, 350psi bellows system, and higher load balance.

PHASE 3 - New venturi system, valves, pipe, heater, etc. as required.

PHASE 4 - Install back-pressure control chamber. Add hot jet capability.

STATUS:
PHASE 1 - Completed.
PHASE 2 - Completed.
PHASE 3 - Completed.
PHASE 4 - Cancelled. PAB will take ownership of high NPR Nozzle Test Chamber during 1994.