OVERVIEW OF NASA PTA PROPFAN FLIGHT TEST PROGRAM

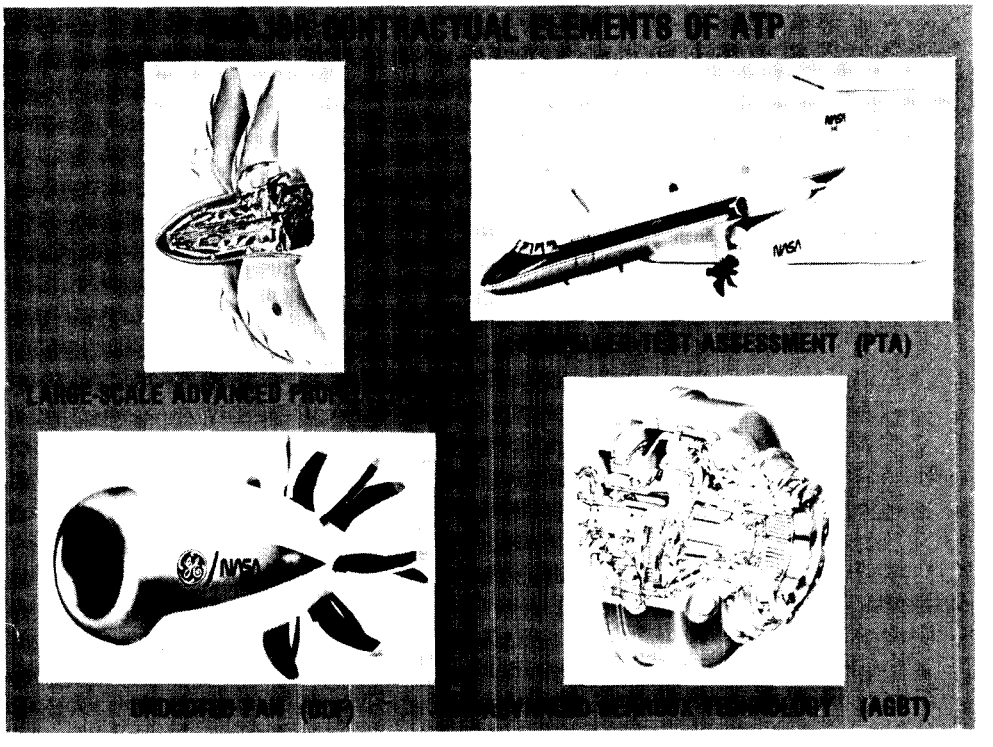
Edwin J. Graber

ABSTRACT

During the last several years high-speed propellers have made the transition from a wind tunnel curiosity to a very likely near-term, fuel-efficient propulsion system that could revolutionize the subsonic commercial air transport industry. A key ingredient in this remarkable progress is the advanced turboprop program. Working together, NASA and industry have developed and flight tested two propeller propulsion systems to provide answers to key technical questions and concerns. An industry team is currently developing a third propeller propulsion system for flight testing late this year. This is a report on the progress of one of the NASA-industry flight test programs, called the Propfan Test Assessment (PTA) Program. Lockheed-Georgia is the prime contractor for PTA with Allison, Hamilton Standard, Rohr, Gulfstream, and Lockheed-California serving as major subcontractors. In PTA, a 9-ft-diameter propfan has been installed on the left wing of a Gulfstream GII executive jet and is undergoing extensive flight testing at Dobbins Air Force Base to evaluate propfan structural integrity, near- and far-field noise, and cabin interior noise characteristics. This research testing includes variations in propeller tip speed and power loading, nacelle tilt angle, and aircraft Mach number and altitude. As a result, extensive parametric data will be obtained to verify and improve computer codes for predicting propeller structural aeroelastic, aerodynamic, and acoustic characteristics. Over 600 measurements are being recorded for each of approximately 600 flight test conditions.

MAJOR CONTRACTUAL ELEMENTS OF ATP

The Advanced Turboprop Project (ATP) has four major contractual elements. The Large-Scale Advanced Propeller Program (LAP) is a contract with Hamilton Standard for the design, fabrication, and checkout of a 9-ft-diameter advanced propfan. Under the Propfan Test Assessment (PTA) Program contract with Lockheed-Georgia, the LAP-provided propfan is being flight tested on a Gulfstream GII aircraft. In a third element, General Electric developed and static tested a unique gearless counter-rotation propfan engine called the Unducted Fan (UDF). Finally, both Pratt & Whitney and Allison were contracted to design, build, and test advanced high-horsepower counterrotation gearboxes.



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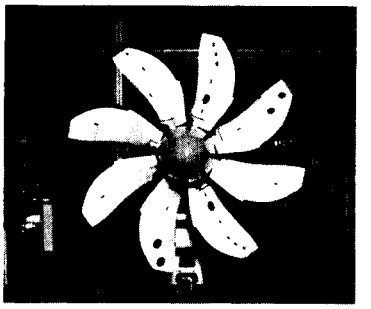
Under the LAP project, Hamilton Standard recently completed testing of the large-scale advanced propfan in France's Modane wind tunnel to verify blade structural integrity and to acquire blade steady and unsteady pressure data for verifying and improving aerodynamic prediction codes. Both a primary and backup propfan were delivered to the PTA flight test program.

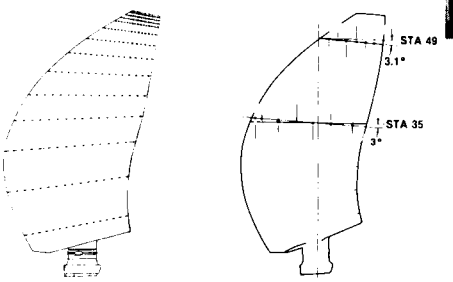
LAP PROJECT

TWO-BLADE SR-7 IN MODANE, FRANCE, WIND TUNNEL



TWO SR-7 ASSEMBLIES DELIVERED TO PTA

TRANSDUCER LOCATIONS



STEADY PRESSURE UNSTEADY PRESSURE

INSTRUMENTATION FOR MODANE TESTING

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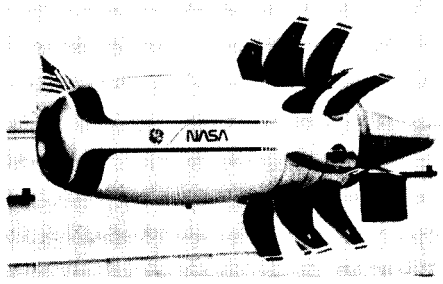
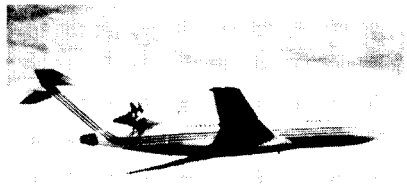
The NASA/GE unducted fan (UDF) was checked out on the GE Peebles, Ohio, static test stand before being flight tested on the Boeing 727 from August 1986 through February 1987 and on the Douglas MD-80 from May 1987 through late 1987.

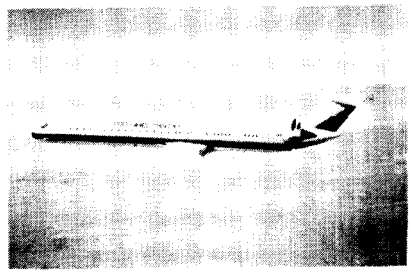
NASA/GE UNDUCTED FAN (UDF)



GE STATIC TEST AT PEEBLES, OHIO



BOEING 727 FLIGHT TEST



DOUGLAS MD-80 FLIGHT TEST

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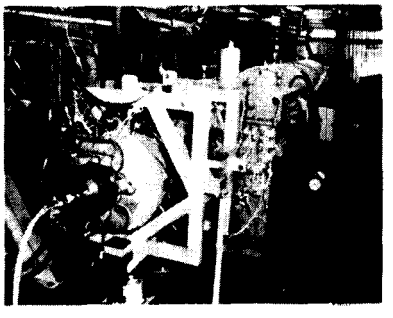
ADVANCED COUNTERROTATION GEARBOX SYSTEMS

In the Advanced Gearbox Program Allison has designed, fabricated, and tested a high-power advanced counterrotation gearbox. Allison used the results of these tests in developing the gearbox for the P&W Allison and Douglas 578DX/MD-80 flight test program.

ADVANCED COUNTERROTATION GEARBOX SYSTEMS



- **ALLISON CONTRACT**
- **COUNTERROTATING IN-LINE DIFFERENTIAL PLANETARY GEAR SYSTEM**
- **13 000-shp CLASS**
- **99 PERCENT EFFICIENCY**
- **DURABILITY GOAL OF 30 000-hr MTBR**

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FLIGHT TESTING OF ADVANCED TURBOPROPS

In four major flight test programs high-speed propellers either have been or will be flight tested within a 1-1/2-year time span. GE and Boeing led the way in August 1986 with flight tests of the UDF propulsion system on the Boeing 727 aircraft. NASA and Lockheed followed shortly thereafter with flight testing of the PTA aircraft in March 1987. In May 1987, GE combined with Douglas Aircraft to flight test the UDF propulsion system on the Douglas MD-80 aircraft. Later this year the United Technologies, Allison, and Douglas flight test program is scheduled to begin.

FLIGHT TESTING OF ADVANCED TURBOPROPS

PTA/GULFSTREAM GII

UDF/BOEING 727

UDF/MD-80 AND 578DX/MD-80

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PROPFAN TEST ASSESSMENT (PTA) OBJECTIVES

EVALUATE THROUGH THE DEVELOPMENT OF A FLIGHTWORTHY DRIVE SYSTEM AND SUBSEQUENT GROUND AND FLIGHT TESTING OF A LARGE-SCALE PROPFAN

- PROPFAN STRUCTURAL INTEGRITY
- PROPFAN SOURCE NOISE
- ASSOCIATED PROPFAN-RELATED CABIN NOISE AND VIBRATION
- FAR-36 COMMUNITY NOISE
- ENROUTE CRUISE NOISE (GROUND)

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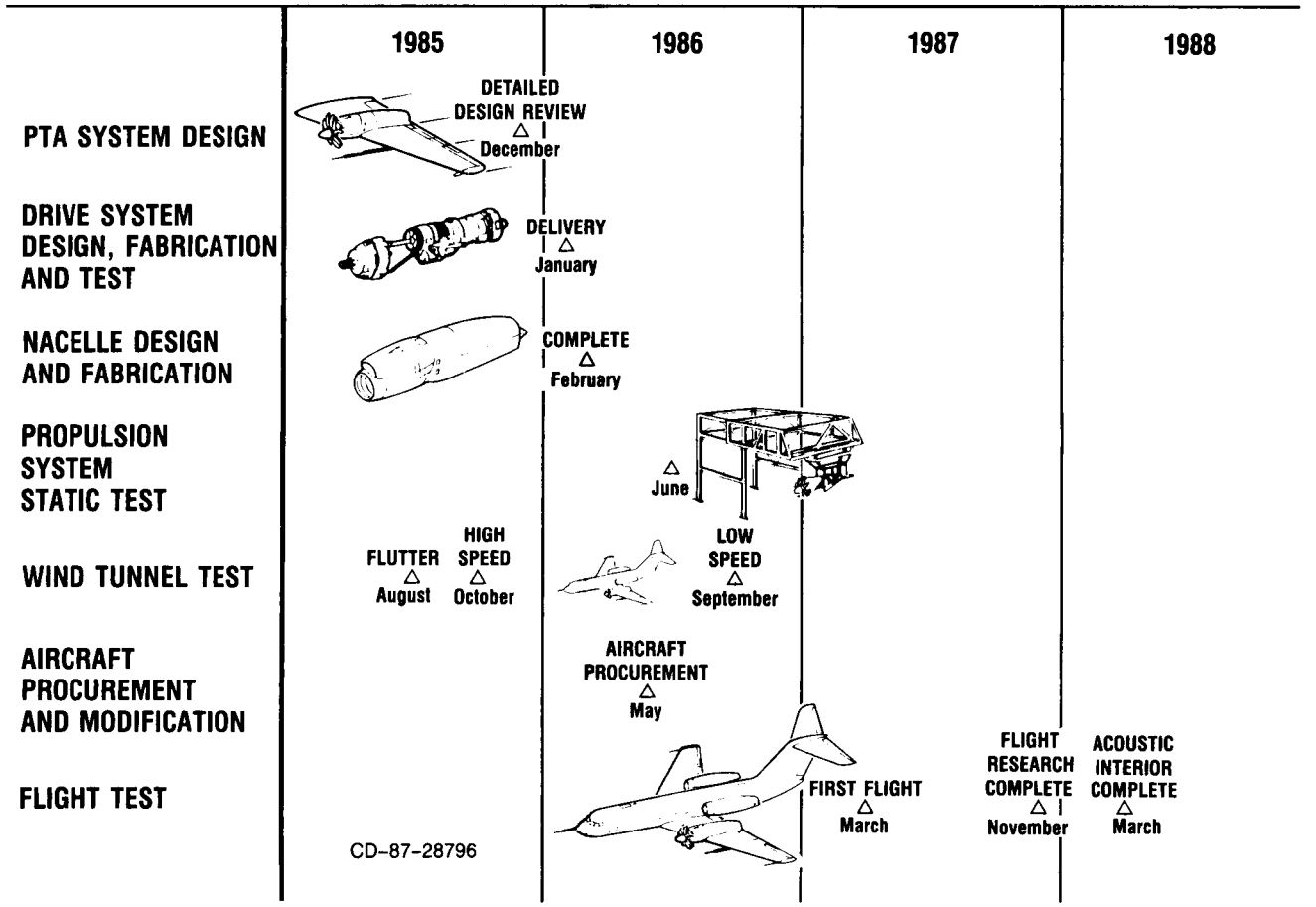
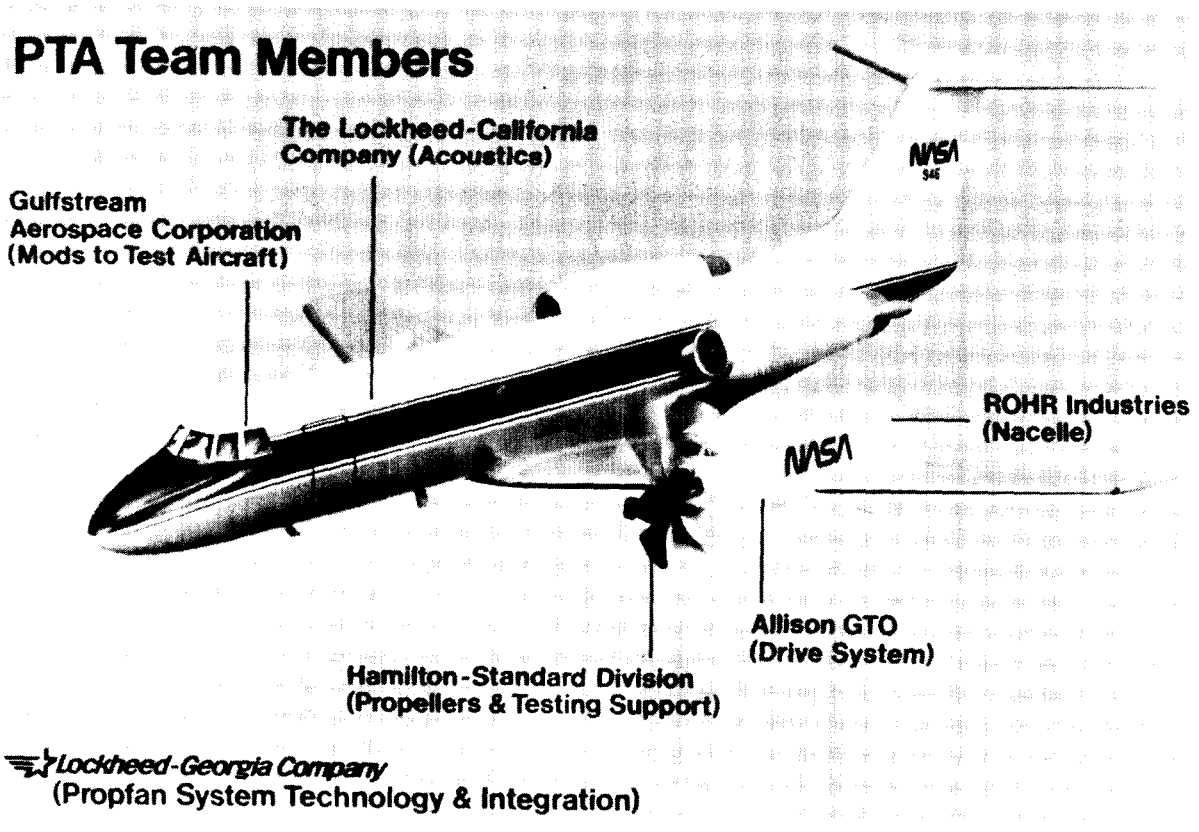
PTA SCHEDULE



PTA TEAM MEMBERS

The PTA program was a team effort involving several NASA centers, Lockheed-Georgia as the prime contractor, and five major subcontractors.



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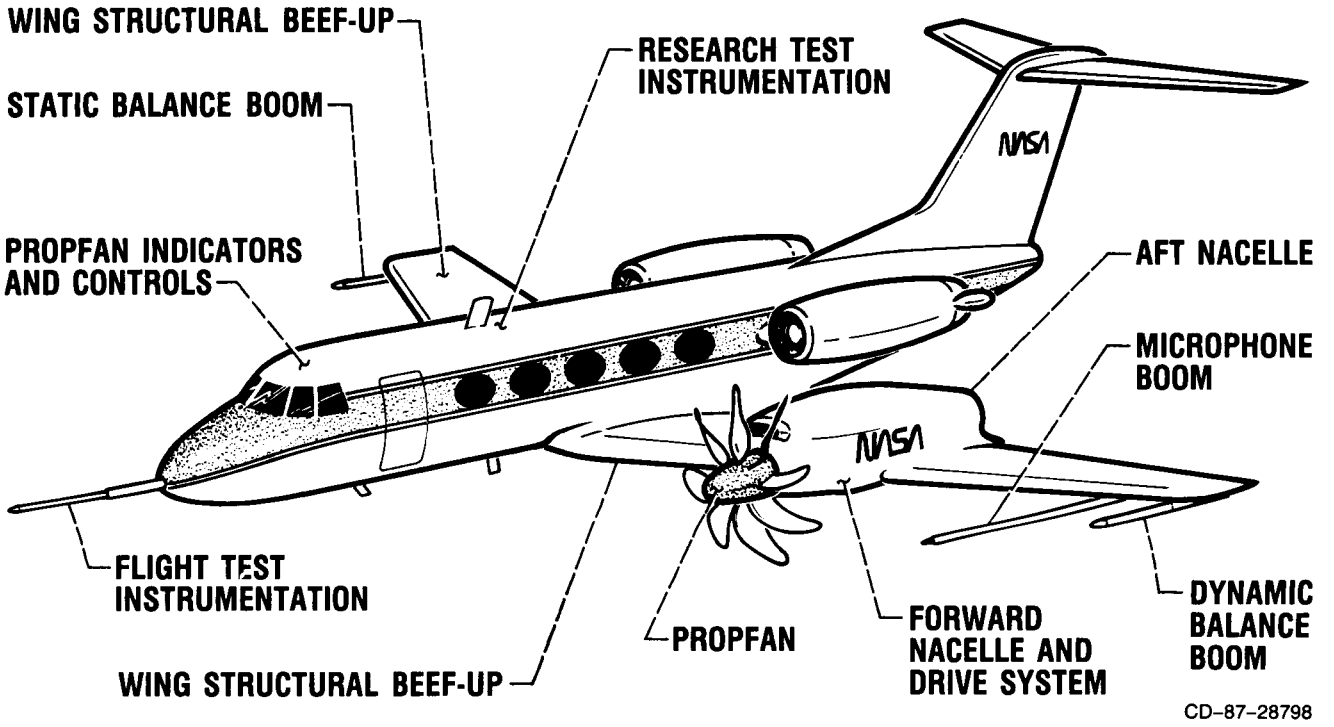
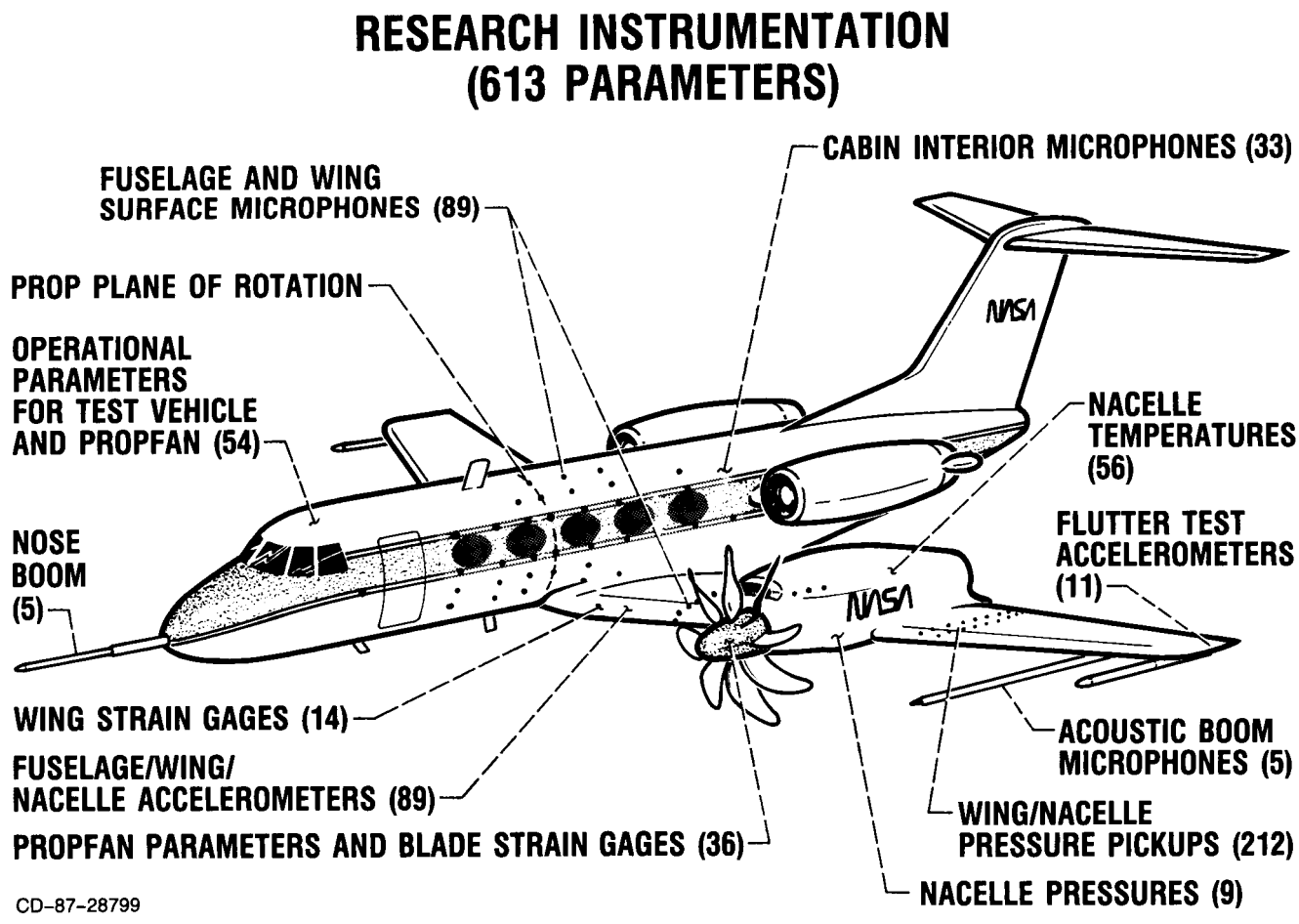
OE POOR QUALITY

To accomplish the PTA flight testing, the Gulfstream GII was extensively modified. In addition to the modifications illustrated in this figure, a 700-lb armor plate was installed to protect the fuselage in the event of a blade failure during the initial phases of testing.

AIRCRAFT MODIFICATIONS



Over 600 pieces of instrumentation were installed on the PTA aircraft for assessing propfan structural integrity, source noise, and associated cabin noise and vibration characteristics.

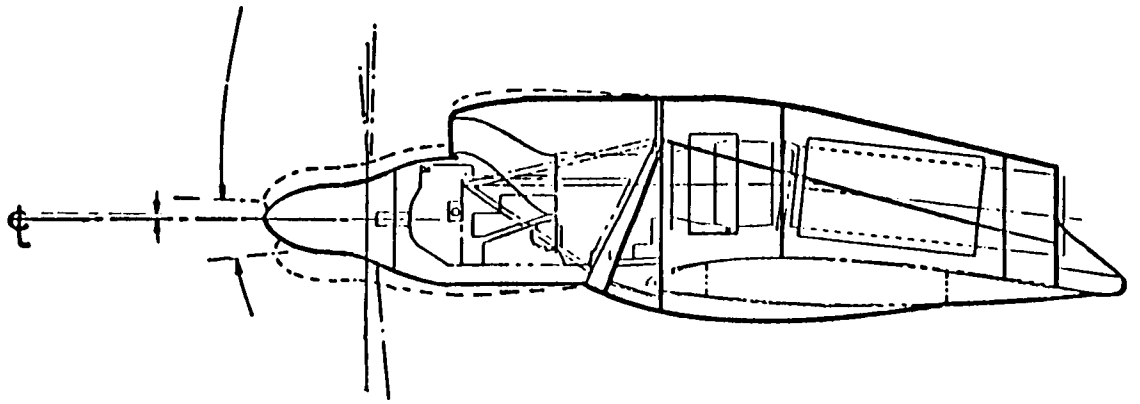


NACELLE TILT RANGE

To evaluate propfan structural integrity with respect to aerodynamic inflow excitation, a unique tiltable nacelle was used. Tilts of 2° up, 1° down, and 3° down were accomplished by changing forward-to-aft nacelle attachment fittings.

NACELLE TILT RANGE

2° UP
1° DOWN—NOMINAL
3° DOWN



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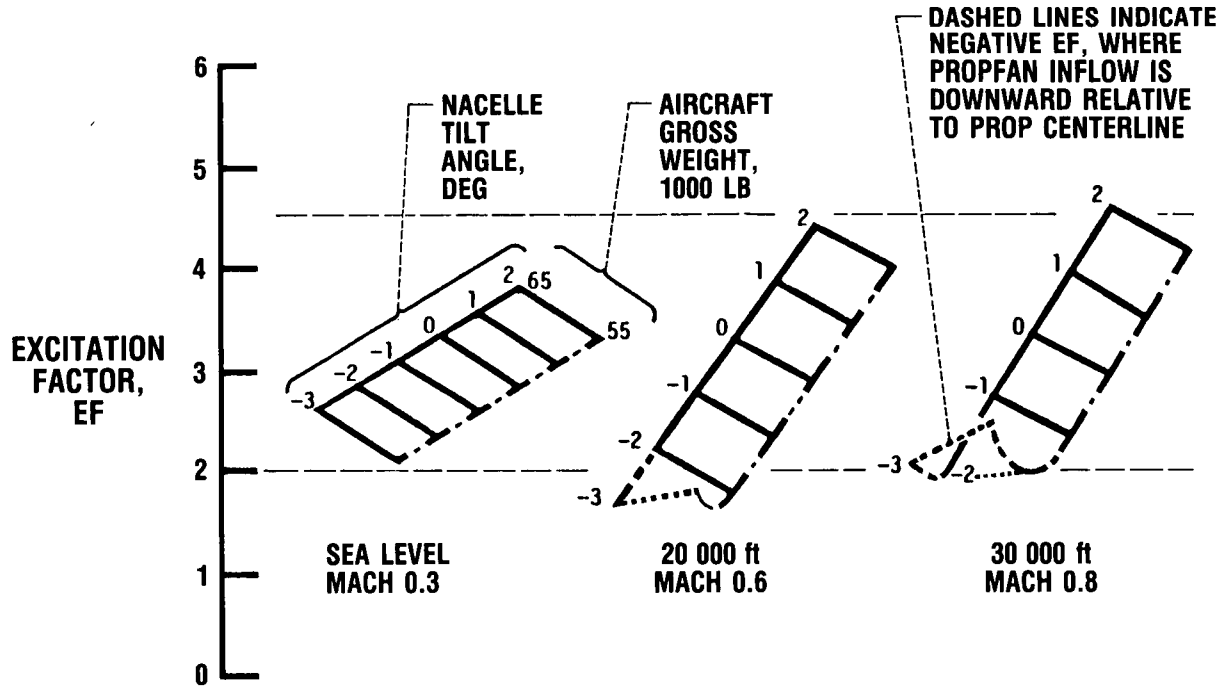
PREDICTED PROPFAN EXCITATION FACTORS

The nacelle tilts were selected to allow testing over a range of propfan excitation factors from approximately 2 to 4.5.

PREDICTED PROPFAN EXCITATION FACTORS



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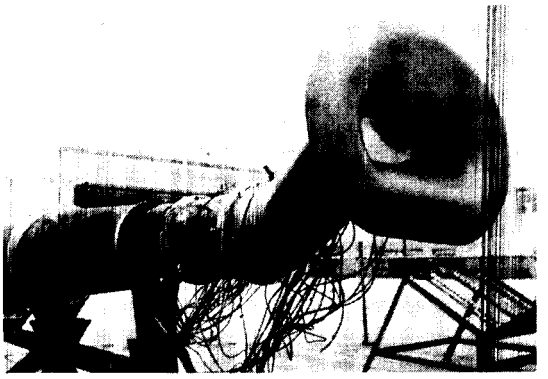
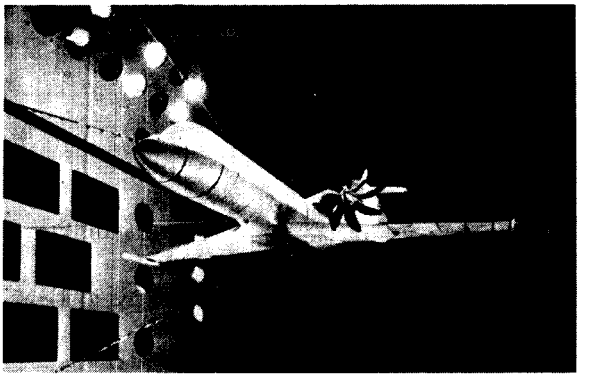
SCALE-MODEL TESTING

Several scale-model tests were conducted to help ensure a safe flight test program and to obtain data for validating aerodynamic prediction codes.

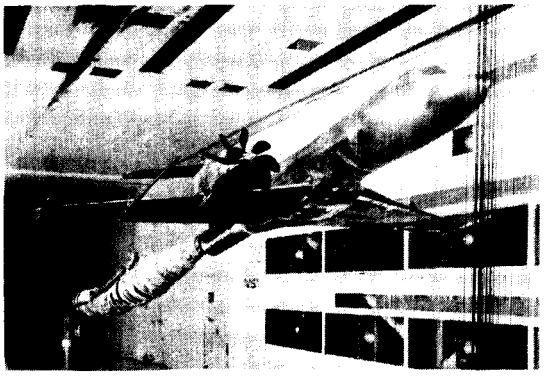
SCALE-MODEL TESTING



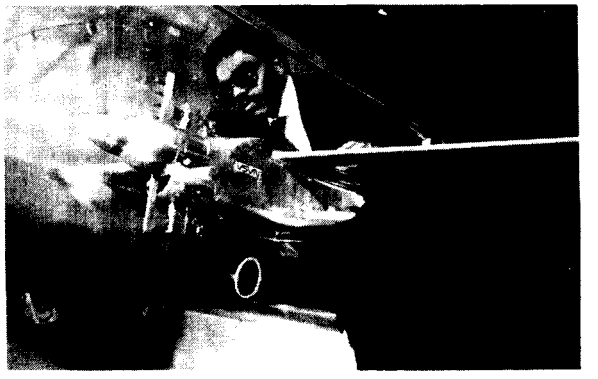
1/3-SCALE INLET



1/9-SCALE FLUTTER



1/9-SCALE STABILITY, CONTROL, AND PERFORMANCE



1/9-SCALE PROP FLOWFIELD

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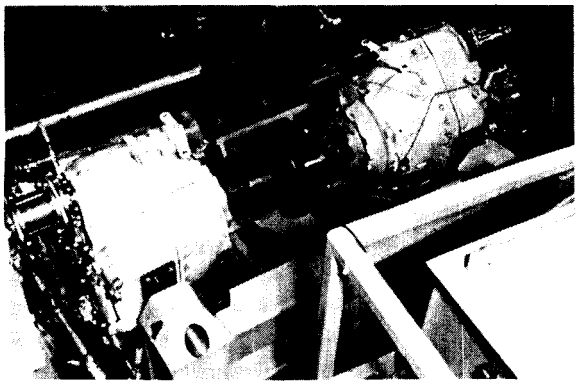
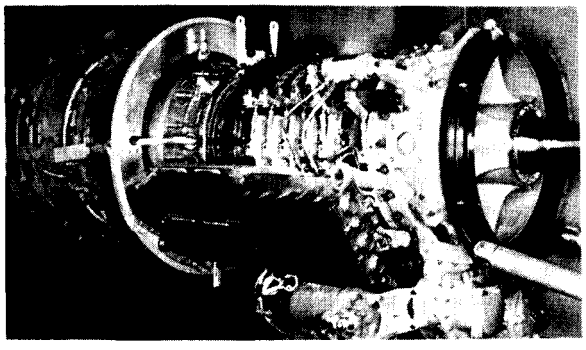
Because the gearbox and power section had to be modified to power the advanced propfan, these components were checked out in ground test facilities before being assembled with the propfan for static testing at Rohr's Brown Field facility. Propulsion system operability and function were confirmed in the 50-hr static test at Rohr.

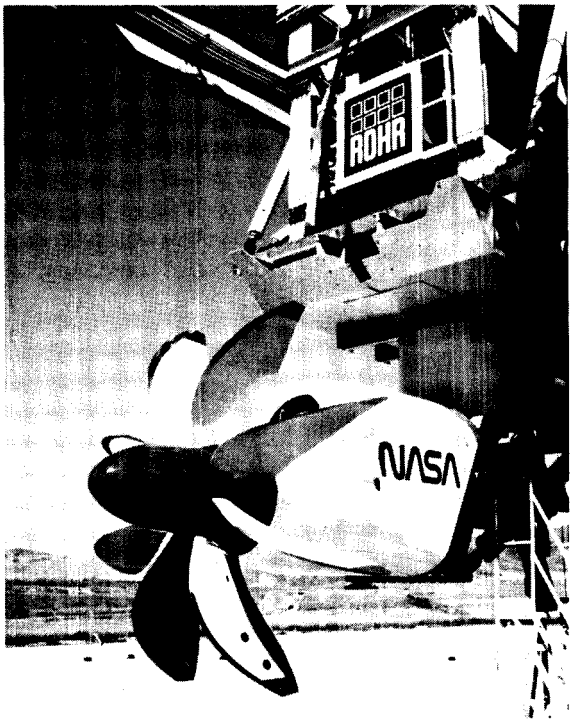
GROUND TESTING



GEARBOX ENDURANCE



ENGINE DURABILITY



PROPULSION SYSTEM STATIC TEST

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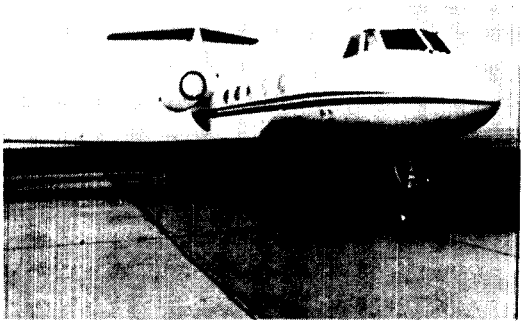
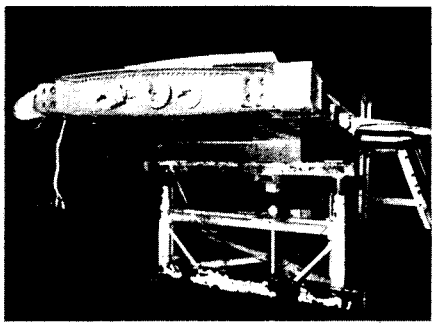
STAGES OF AIRCRAFT MODIFICATION

The serial number 118 Gulfstream GII aircraft is shown as purchased and at various stages of modification. Modification was done at Gulfstream Aerospace in Savannah, Georgia.

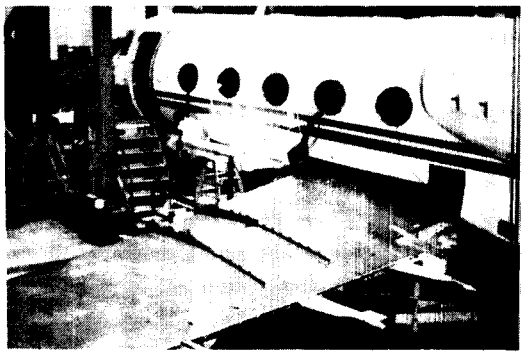
AIRCRAFT MODIFICATIONS



SERIAL NO. 118 GII



WING BEEF-UP



WING-TO-FUSELAGE ATTACHMENT

NACELLE ON WING

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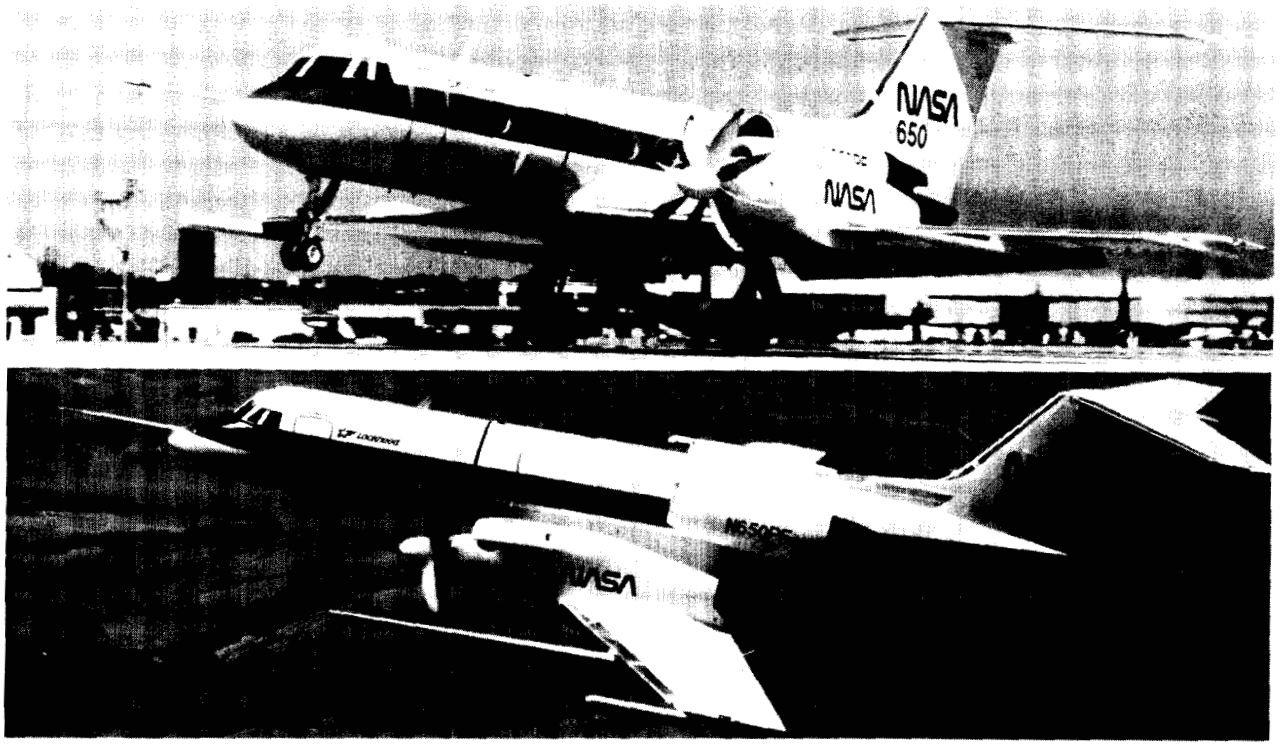
PTA FLIGHT TESTING

After aircraft modification and checkout testing, flight testing begun in March 1987. The first tests were conducted with the propfan removed to establish safe aircraft operation before proceeding with prop-on testing in April 1987. Prop-on testing was done at the Lockheed-Georgia facility at Dobbins Air Force Base.

PTA FLIGHT TESTING
BEGUN IN MARCH 1987



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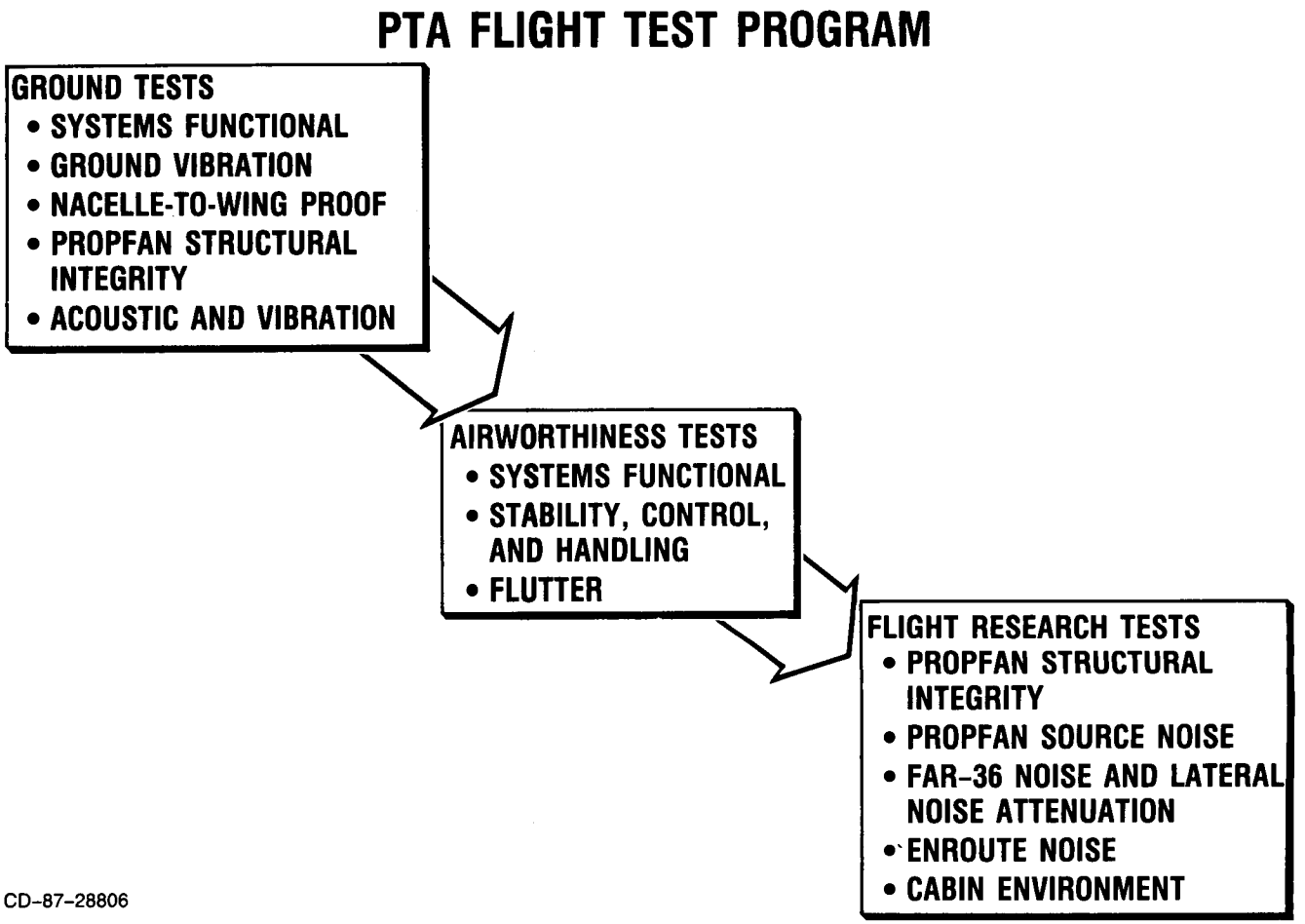
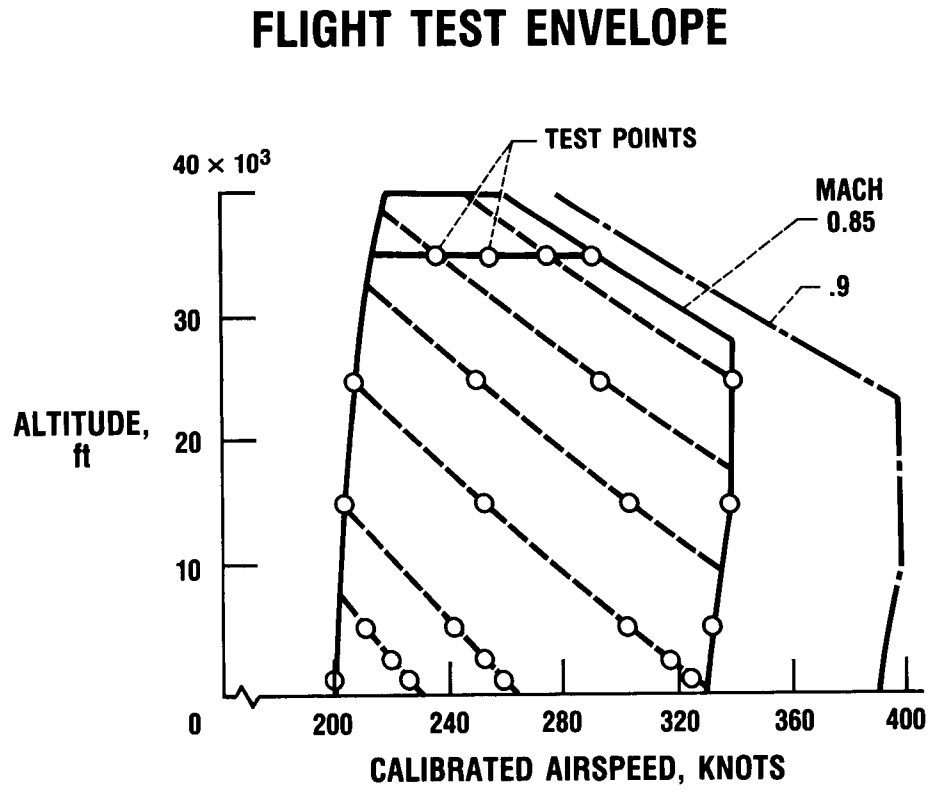
PTA FLIGHT TEST PROGRAM

The flight test program was sequenced to minimize risk. All systems were checked out on the ground before proceeding with flight testing. Airworthiness testing was then conducted to verify safe operation before starting the actual research flight tests.



FLIGHT TEST ENVELOPE

Over 500 flight test points have been recorded in the high-altitude research flight test matrix. In addition to the altitude and Mach number variations shown, propfan tip speed, propfan power loading, and nacelle tilt angle were also varied.



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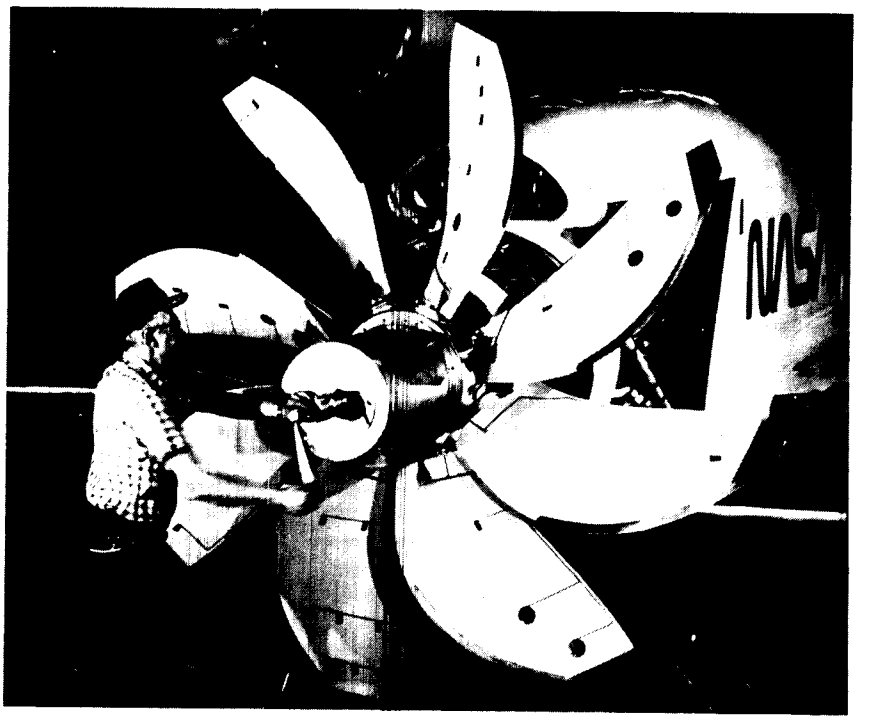
INSTALLED SR-7 PROPFAN

Forty-six strain gages were installed on the propfan with 30 of these gages continuously recording during the flight test program.

INSTALLED SR-7 PROPFAN



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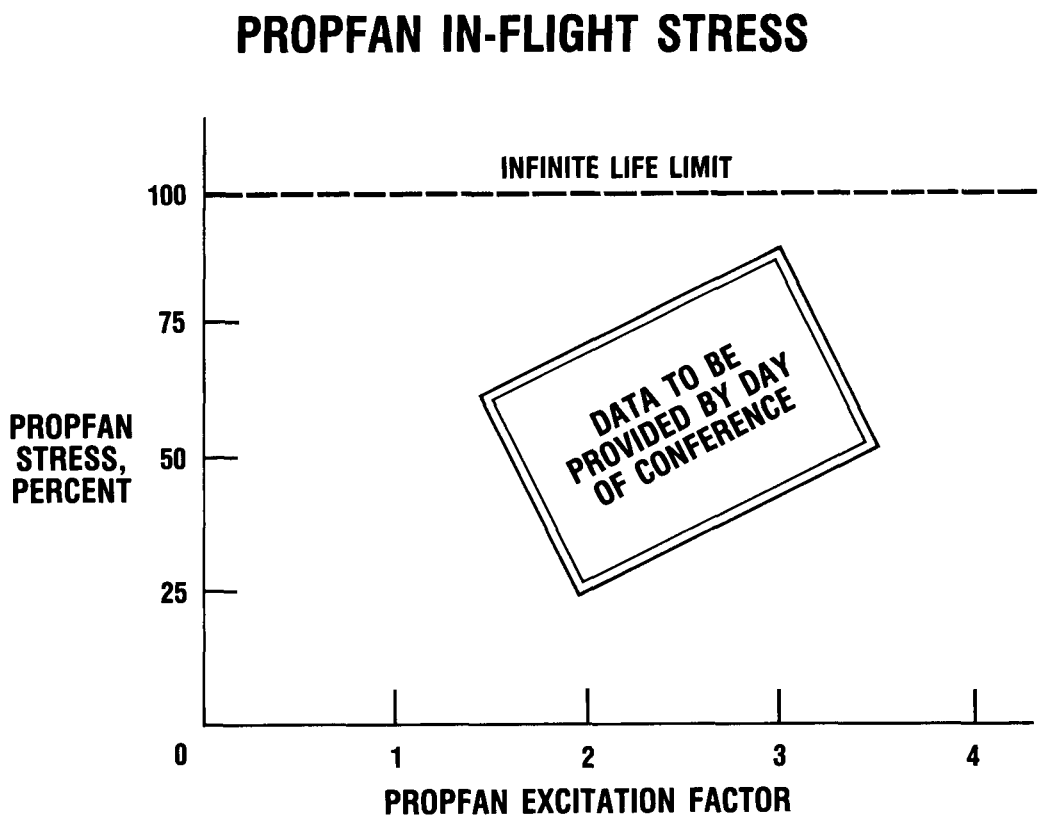
PROPFAN IN-FLIGHT STRESS

Propfan stresses were consistently below the infinite life limit throughout flight testing.



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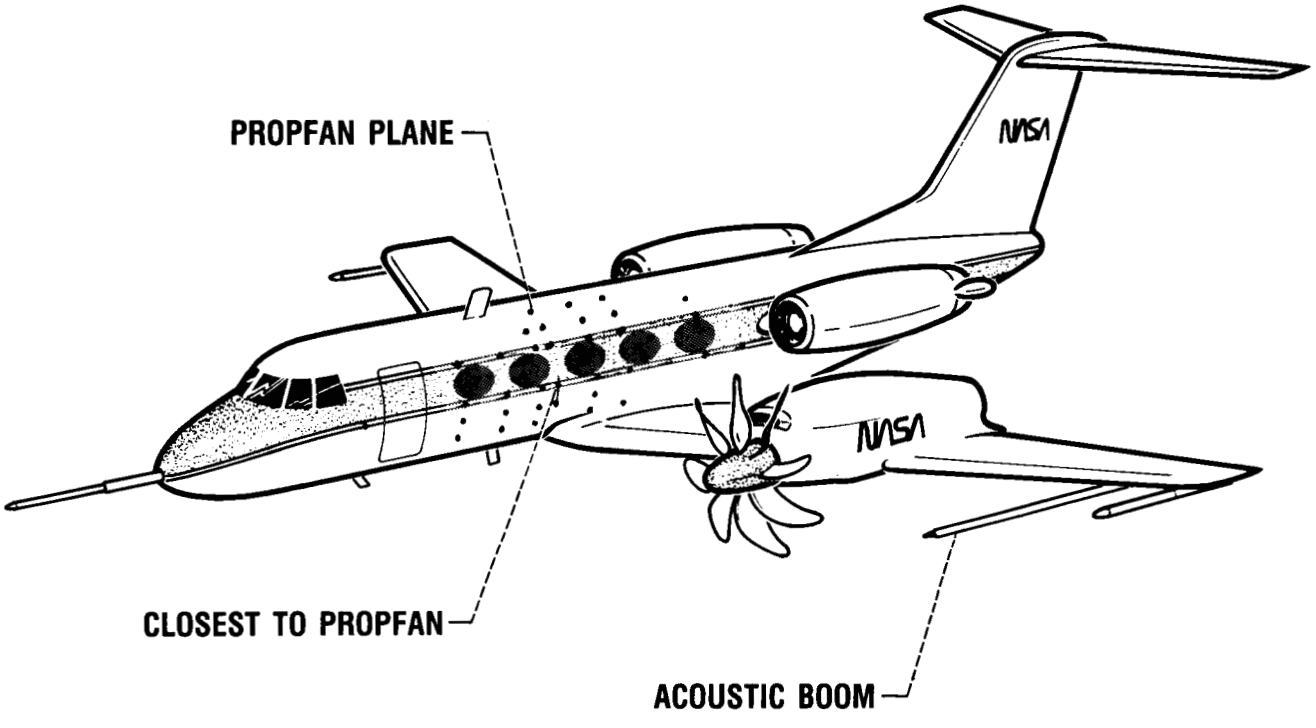
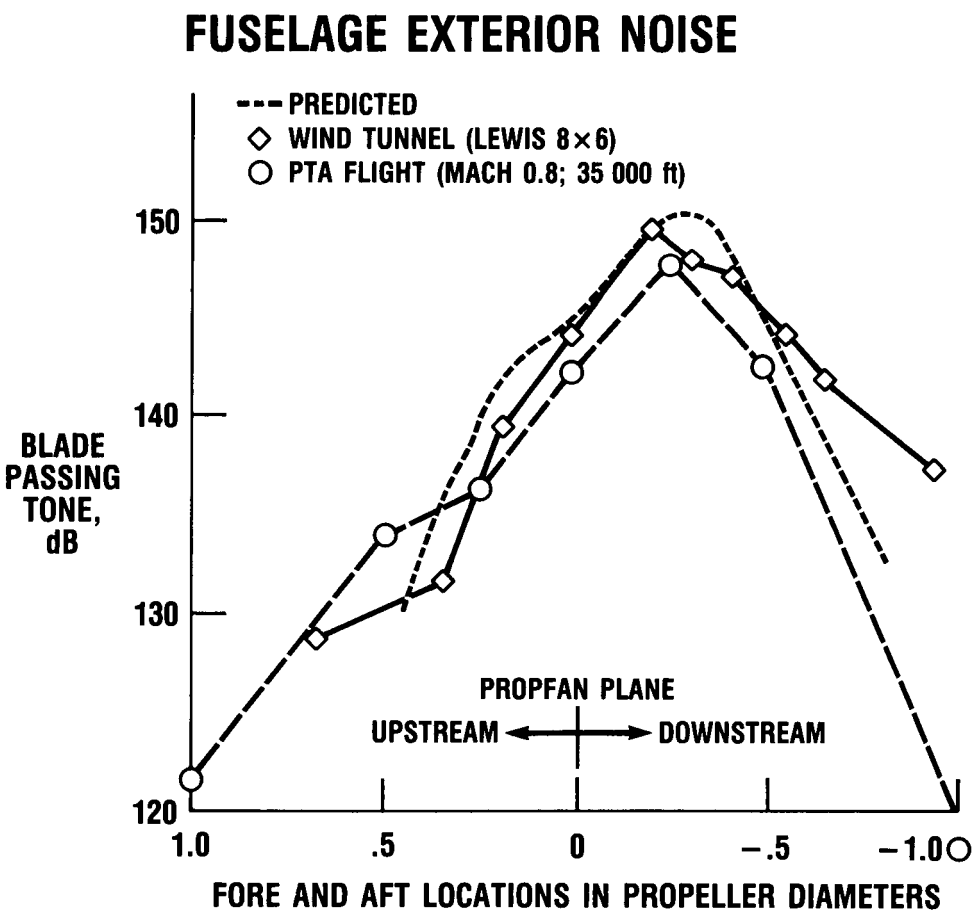
FUSELAGE SURFACE MICROPHONES

External fuselage surface microphones were installed fore and aft of the propfan plane to map source noise characteristics.

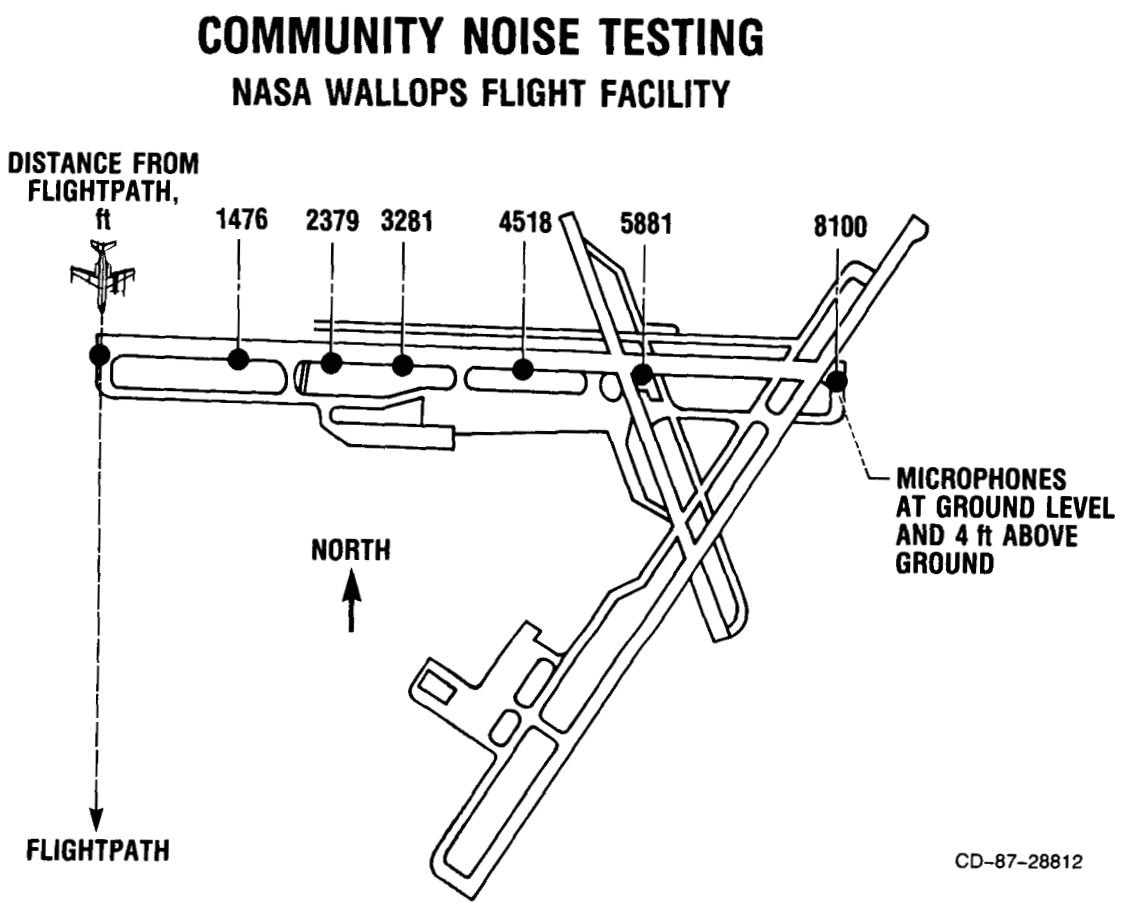


Initial flight test data agree favorably with both scaled-up data from Lewis' 8- by 6-Foot Wind Tunnel and predictions using an early Hamilton Standard analytical prediction code.



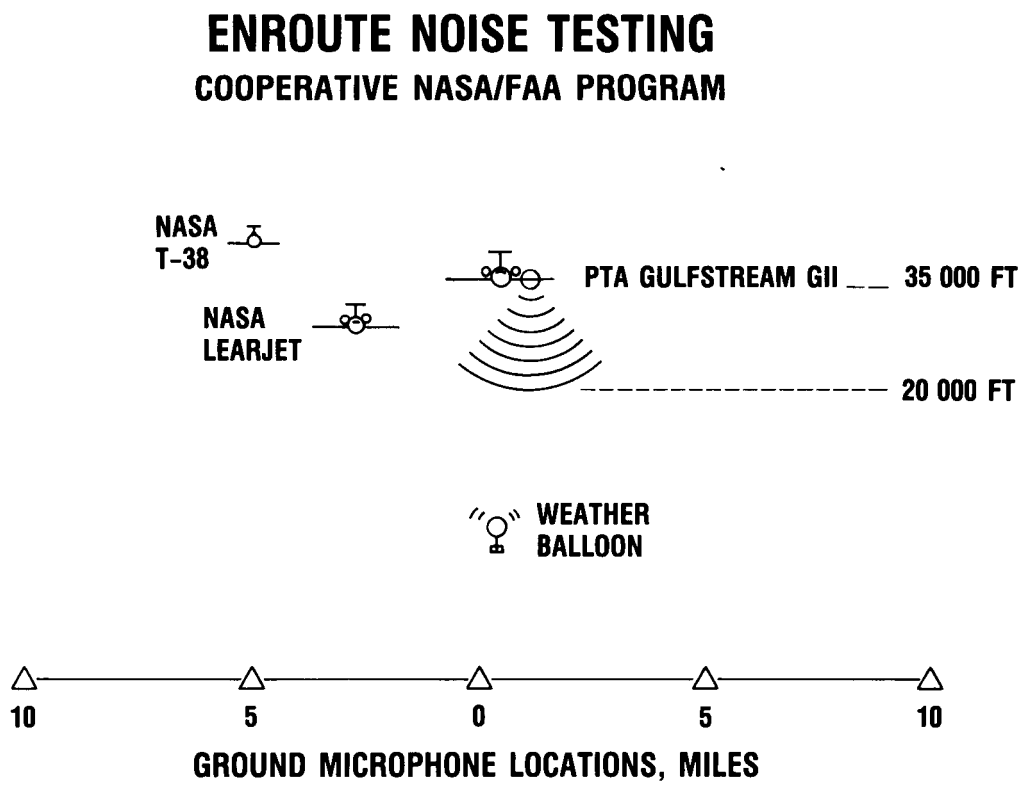
COMMUNITY NOISE TESTING

Community noise data were obtained at the NASA Wallops Flight Facility in September and October of this year. Testing was conducted at altitudes of 850, 1000, 1300, and 1600 ft with the aircraft flying in both north-south and south-north directions. The matrix of test points included variations in propfan tip speed and power level with all testing conducted at an aircraft speed of 195 knots.



ENROUTE NOISE TESTING

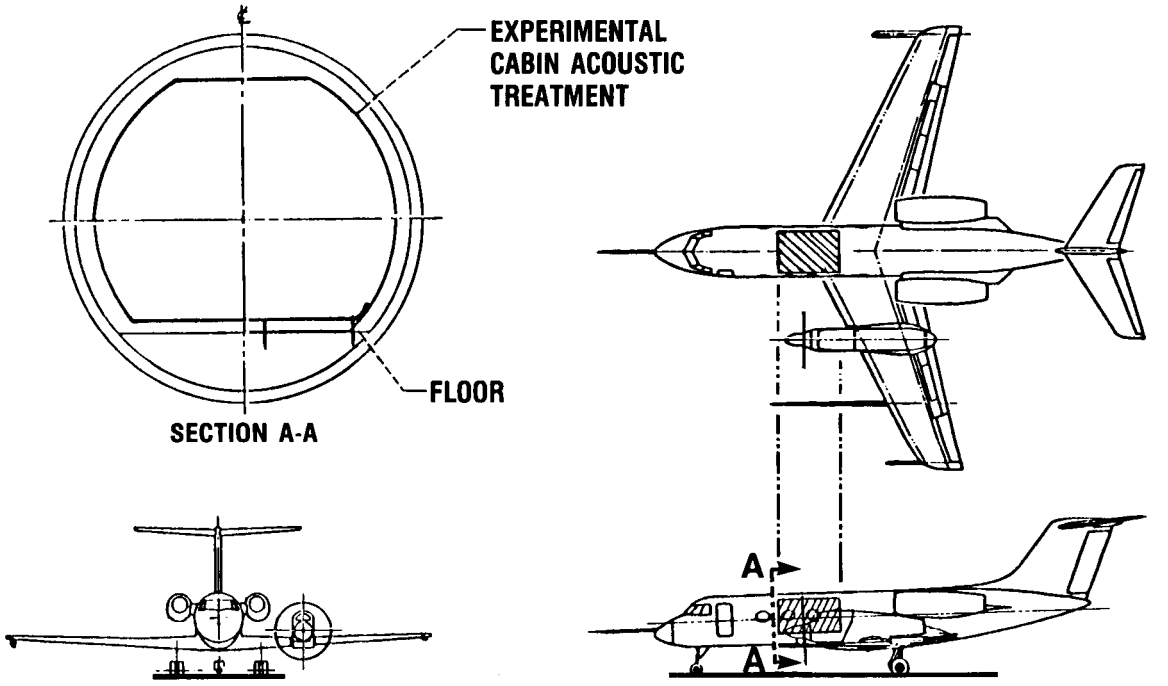
After the community noise testing a NASA/FAA cooperative enroute noise test was conducted in October 1987. In these tests the NASA Learjet was used to map out the acoustic field approximately 500 ft below and to the side of the PTA aircraft. The T-38 was used as an observer for flight safety. After mapping the acoustic field at altitudes of 20 000 and 35 000 ft and speeds of Mach 0.7 and 0.8, respectively, the PTA aircraft was flown over a microphone array to record noise levels reaching the ground. Before and after each flight test day, a weather balloon was launched to measure atmospheric conditions from sea level to the test altitude. Results of these tests will be used to verify and improve codes for predicting noise transmission characteristics through the atmosphere.



CABIN NOISE TESTING

A 10-ft section of the aircraft has been cleared for acquiring data on cabin noise characteristics. During testing to date, data have been acquired for a "bare wall" cabin. In February and March 1988 an experimental advanced cabin acoustic treatment will be installed and flight tested over a range of repeat test points. This treatment will be designed and fabricated as part of a NASA Langley contract with Lockheed-California. The results of this test will provide the critical correlation between ground-based and flight test results.

CABIN NOISE TESTING



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SUMMARY

- PTA FLIGHT TESTING NEARING COMPLETION
  - OVER 600 MEASUREMENTS
  - OVER 500 HIGH-ALTITUDE FLIGHT TEST CONDITIONS
    - PROPFAN TIP SPEED FROM 600 TO 840 ft/sec
    - PROPFAN POWER FROM MINIMUM TO 100 PERCENT
    - THREE NACELLE TILTS (TO VARY EXCITATION FACTOR)
    - SPEED TO MACH 0.89
    - ALTITUDES FROM 2000 TO 40 000 ft
  - COMMUNITY NOISE DATA OBTAINED AT NASA WALLOPS FLIGHT FACILITY
  - ENROUTE NOISE DATA OBTAINED

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CONCLUSIONS

- PROPFAN STRUCTURAL AND AEROELASTIC RESPONSE IN GOOD AGREEMENT WITH PREDICTIONS
- NEAR-FIELD NOISE PREDICTED VERY WELL AND IN GOOD AGREEMENT WITH WIND TUNNEL TESTS ON SUBSCALE MODELS
- COMMUNITY NOISE TEST DATA BEING ANALYZED BY NASA AND LOCKHEED
- FAA AND NASA USING ENROUTE NOISE DATA TO VALIDATE ATMOSPHERIC ATTENUATION CODES
- INTERIOR NOISE TESTS PLANNED FOR MARCH 1988

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