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NASA Cooperative Agreement No. NCC3-514

General Aviation Propulsion (GAP) Program, Turbine Engine System Element

Performance Report
Non-Proprietary Research Results

06 October 1997

Prepared for:

National Aeronautics and Space Administration
Lewis Research Center

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Introduction

The National Aeronautics and Space Administration (NASA) and Williams International entered into a Cooperative Agreement, No. NCC3--514, effective 02 December 1996, for research entitled "General Aviation Propulsion (GAP) Program, Turbine Engine System Element." Cooperative Agreement clause 1274.921, "Publications and Reports: Non-Proprietary Research Results," identifies the submission of a performance report for every year of the cooperative agreement (except the final year).

In compliance with this requirement of the cooperative agreement, Williams International submits this Performance Report for Non-Proprietary Research for the reporting period of 02 December 1996 through 30 September 1997.

Performance Report:
Non-Proprietary Research Results

GAP Program Overview

Purpose

The goal of the General Aviation Propulsion (GAP) Program Turbine Engine System Element is to conduct a shared resource project to develop an affordable gas turbine engine for use on 4 to 6 place, light aircraft that will lead to revitalization of the general aviation industry in the United States, creating many new, high-quality jobs.

Approach

The GAP Program cooperative agreement is a four-year effort in which Williams International, along with its company led project team (CPT) members from aircraft and supplier industries, and NASA contribute their technical expertise, financial resources, and facilities to demonstrate a new affordable general aviation turbofan engine. This program builds upon the research and development previously conducted by Williams International on the FJX-2 engine.

NASA Lewis Research Center is managing the GAP Program and is conducting many engine-related design and test tasks. The FAA is also an active participant in the program. The program will also be closely coordinated with the Advanced General Aviation Transport Experiments (AGATE) program that is managed by NASA Langley Research Center.

Specific Objectives

The specific objectives of the GAP Program are to (1) develop and demonstrate technologies and manufacturing processes that will enable the industry to produce commercially-affordable general aviation engines, and (2) flight demonstrate the performance of the affordable turbofan engine as installed on a light plane test bed. This work will culminate in flight demonstration of the FJX-2 engine in a light plane designed to take advantage of turbine power.

FJX-2 Turbofan Engine

The FJX-2 turbofan engine is in the 700-lb thrust class, features a high bypass ratio, and is a simple, light weight configuration weighing less than 100 pounds. The FJX-2 engine will enable future general aviation aircraft to have much greater cruise speed and range. It will also provide significantly improved passenger comfort and safety, while reducing exhaust emissions and noise as compared to today's piston-powered aircraft. A full scale mock-up of the FJX-2 engine is shown in Figure 1. The FJX-2 engine measures 41 inches in length and 14.5 inches in diameter.

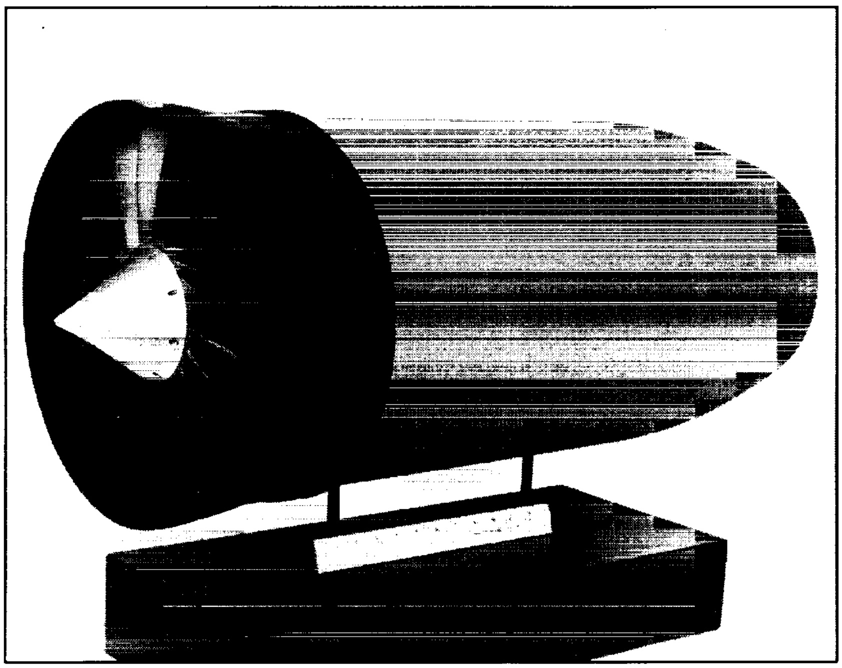


Figure 1. FJX-2 Turbofan Engine Mock-Up

Schedule

The GAP Program activities are scheduled over a four-year time period, beginning in December 1996 and concluding at the end of September 2000. Major milestones are identified for each calendar year of the program, including the display of the concept aircraft at the EAA Oshkosh Convention in 1997, the first FJX-2 engine assembled in 1998, completing initial engine tests at NASA Lewis Research Center in 1999, and the display of the concept aircraft with the FJX-2 engines at the EAA Oshkosh Convention in 2000. FJX-2 design, development, and test activity timelines are shown on the GAP Program schedule, Figure 2.

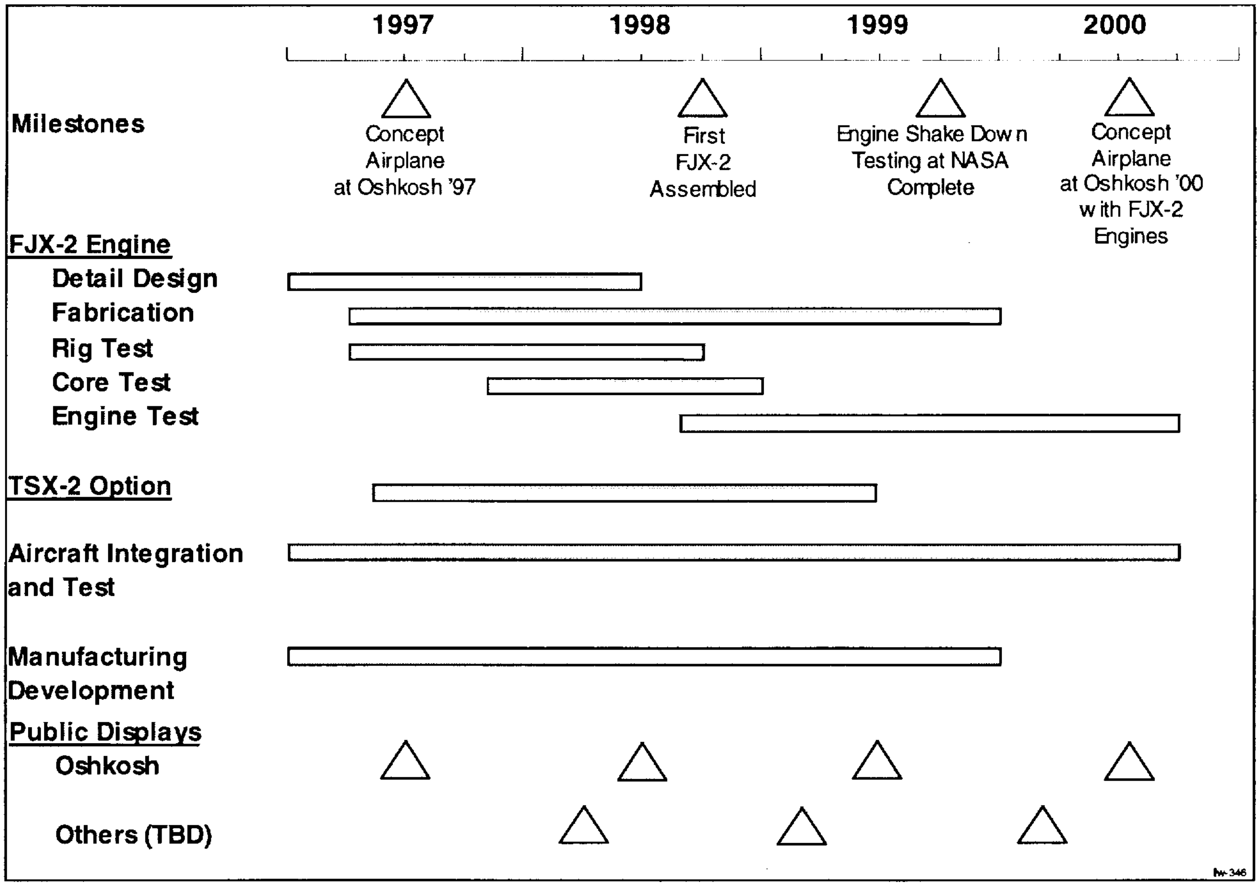


Figure 2. GAP Program Schedule

GAP Program Status

FJX-2 Engine Component Design

The FJX-2 detail design timeline shown in Figure 2, GAP Program Schedule, represents all activities supporting the individual component definitions required to manufacture and assemble the first FJX-2 engine in mid-1998. The GAP Program is currently in the component detail design and analysis phase. Component design definitions are prioritized to provide sufficient lead time to procure and manufacture each item as required to support rig, core, or engine level testing. Initiated in December 1996, the FJX-2 engine component design task was approximately 40% complete as of the September 30, 1997.

Aerodynamic design definition analysis is critical to achieving the performance goals of the GAP Program. Working with Williams International engineers, NASA Lewis researchers have assisted in engine component analysis. These analyses have resulted in design improvements including decreased complexity of component geometry and a predicted increase in efficiency. The design improvements will save Williams International 1 to 2 hardware builds, and the rapid turnaround of Lewis analyses enabled inclusion of these design improvements without driving a delay in test hardware fabrication.

FJX-2 Component Fabrication

Component fabrication was initiated on schedule (Figure 2) in mid-1997 to support planned testing of the combustor, compressor, and core rigs. Currently, NASA Lewis researchers are working cooperatively with Williams International engineers to identify required component test rig instrumentation which will be used to correlate test results to APNASA and other analytical tools.

FJX-2 Component Testing

Ignition rig testing was initiated in mid-1997 at Williams International with the baseline FJX-2 engine combustor. The purpose of this phase of testing is to demonstrate combustor light-off characteristics from a variety of ignition sources, determine location and positioning requirements for the igniter, and establish the energy required to provide reliable ignition. This rig simulates anticipated FJX-2 engine combustor pressure and temperature conditions through portions of the planned operating envelope. Once these data are obtained and analyzed, component designs will be updated and hardware produced for further development into a combustor rig. The combustor rig will allow evaluation of the combustor throughout the full FJX-2 engine operating envelope of temperatures, pressures, and altitudes. This testing is scheduled to start at Williams International in late 1997.

In 1998, compressor and core rig tests are planned to verify actual FJX-2 engine hardware performance and efficiencies versus the analytical Williams International and NASA Lewis APNASA predictions. Component designs will be adjusted as required to maximize their performance prior to full-up engine level testing.

FJX-2 Engine Testing

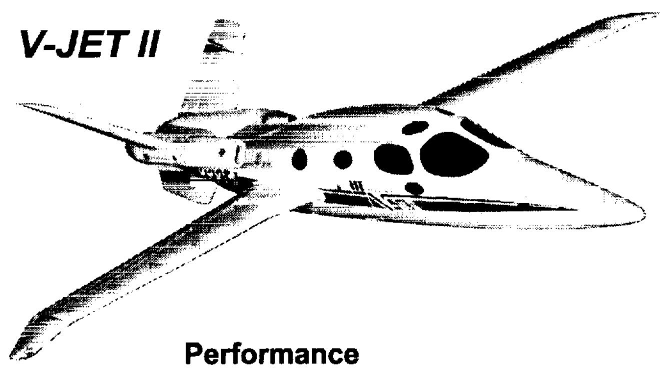
The first FJX-2 engine is scheduled to be assembled in 1998. This engine will be subjected to extensive sea level static testing at Williams International to verify fuel system, lubrication system, and electrical system operation and overall performance. Initial simulated altitude engine performance testing is scheduled for mid-1999 at NASA Lewis (Figure 2).

V-Jet II Test Bed Aircraft

A part of Williams International's contribution to the GAP Program was the design and fabrication of a test bed aircraft to demonstrate the speed and altitude performance of a 4 to 6 place general aviation light aircraft powered by FJX-2 turbofan engines. Designated as the V-Jet II, the aircraft first flew in April 1997 and is presently powered by two existing low-bypass ratio, 550 lbf thrust, FJX-1 engines developed by Williams. Besides being lower thrust, the FJX-1 engines are noisier and twice the weight of the FJX-2 engines under development, and are too expensive to produce for general aviation applications. These interim engines are being used to check out aircraft performance and systems prior to installation of the new, high bypass ratio FJX-2 engines.

The V-Jet II is named for its forward swept wing design, providing docile stall characteristics as the wing root stalls first, allowing the outboard aileron flight control surfaces to remain effective and improve recovery. Another unique feature is the close spacing of the engines at the tail with the aircraft centerline, requiring minimum pilot action in the event of a single engine-out condition. These V-Jet II features contribute to an aircraft with improved performance characteristics making it easier to fly than current piston-powered aircraft (Figure 3).

V-JET II



Seating...........6
Length............31.1 ft
Height............ 9.8 ft
Span...............35.3 ft
MTOW.............3800 lbs
Empty Wt........2200 lbs

Take Off Distance
SL/STD Day............... 2,300 ft
5000 Ft/ISA (25°C).... 3,000 ft
Climb Rate (SL)........... 3,200 fpm
Time to Climb............. 8 Min to 18 KFT

Performance
High Speed Cruise.............370 KTAS
Range - Max Fuel .... 2600 Miles
- Four on board.....1800 Miles
Fuel Economy...........................15 MPG

Powered By: Twin Williams International FJX-2 Turbofans

> 700 lb Thrust Class **> Low Noise**
> Weight < 100 lbs Each **> Low Exhaust Emissions**

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Figure 3. V-Jet II Performance Characteristics

The all-composite V-Jet II structure design provides other safety and comfort benefits as well. The unique shape of the aircraft forebody shadows the v-tail mounted engine, minimizing potential bird ingestion into the engine inlets while maintaining good boundary layer airflow. Additionally, the forward-swept wing design allows the wing spar attachment to be located aft of the aircraft cabin, increasing useful cabin area.

Through its initial testing with the FJX-1 engines, the V-Jet II has been flown to 30,000 feet altitude and up to 295 knots air speed.

Oshkosh '97 Display

The V-Jet II all-composite, turbofan-powered concept aircraft was unveiled to the public at the Experimental Aircraft Association (EAA) annual convention at Oshkosh, WI, July 31 through August 5, 1997. A full scale mock-up of the FJX-2 engine accompanied the static display of the V-Jet II aircraft (Figure 4).

Figure 4. Oshkosh '97 FJX-2 Engine Mock-Up Display

Although designed for the 700 lb thrust high bypass ratio FJX-2 engines, flight demonstrations with the interim 550 lb thrust low-bypass ratio FJX-1 engines were performed to stimulate interest on the part of aircraft companies in designing and developing production aircraft utilizing this new propulsion technology (Figures 5, 6, and 7). A strong public interest confirmed that the demand exists for an affordable, turbine-engine-powered, 4 to 6 place light aircraft based on the FJX-2 turbofan engine. The NASA/Williams GAP Program will feature the FJX-2 engines in the V-Jet II test bed aircraft at Oshkosh in the year 2000.

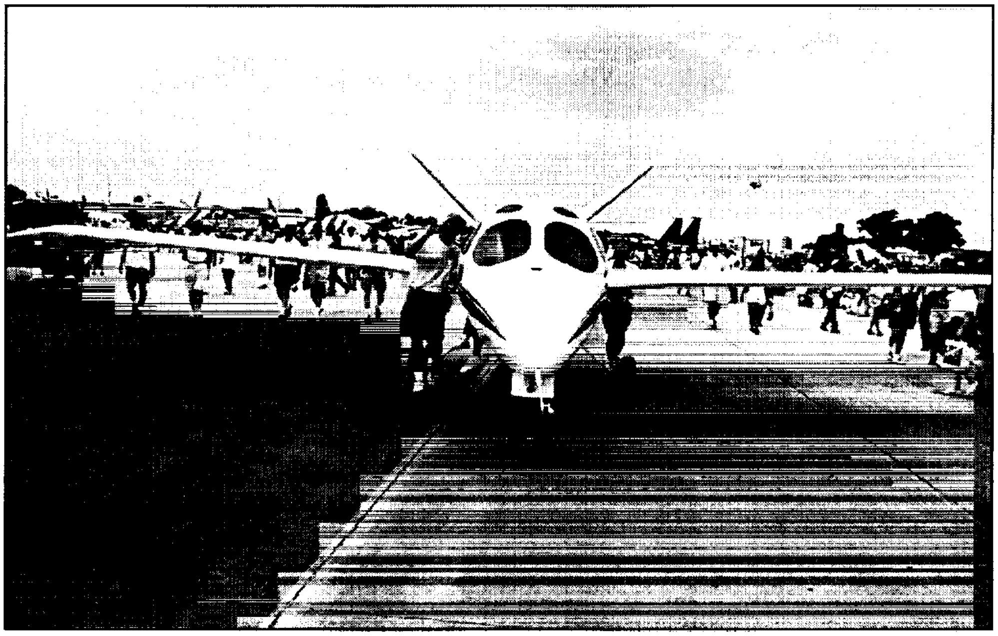

Figure 5. Oshkosh '97 V-Jet II Roll-Out to the Flight Line.

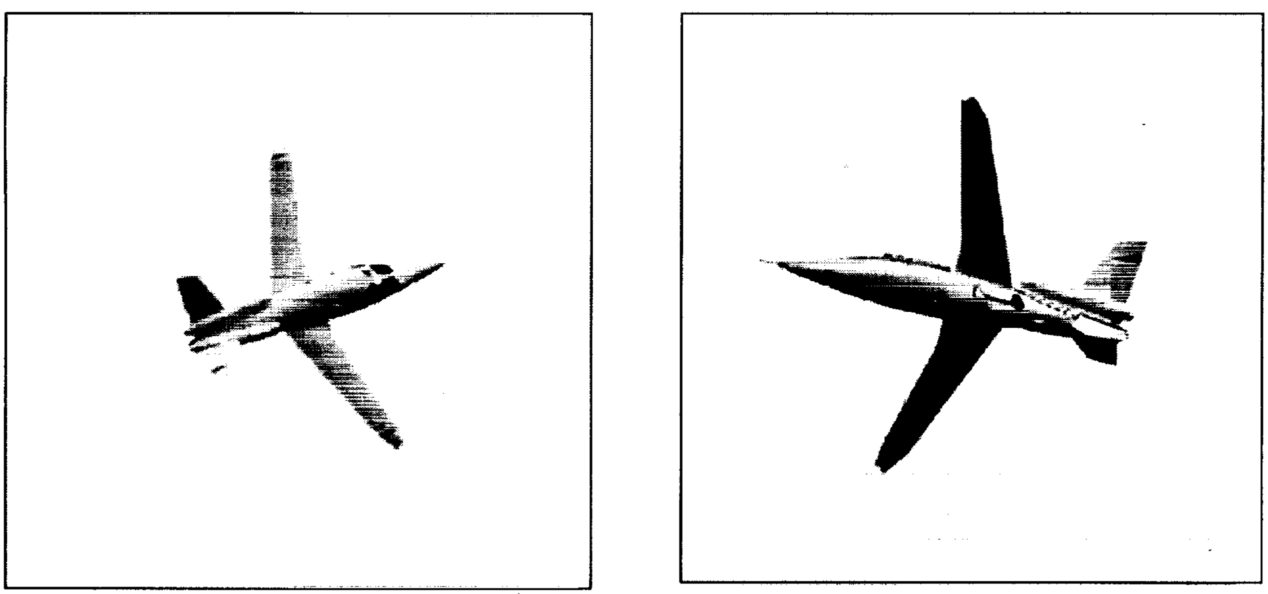

Figure 6. V-Jet II Flight Demonstration

Figure 7. Oshkosh '97 V-Jet II Returning From Flight

NBAA '97 Display

The V-Jet II and FJX-2 engine mock-up were on static display at the National Business Aircraft Association (NBAA) annual convention September 23 through 25, 1997 (Figures 8 and 9). A strong business and professional interest confirmed that the demand exists for an affordable, turbine-engine-powered, 4 to 6 place light aircraft based on the FJX-2 turbofan engine.

Figure 8. NBAA FJX-2 Engine Display

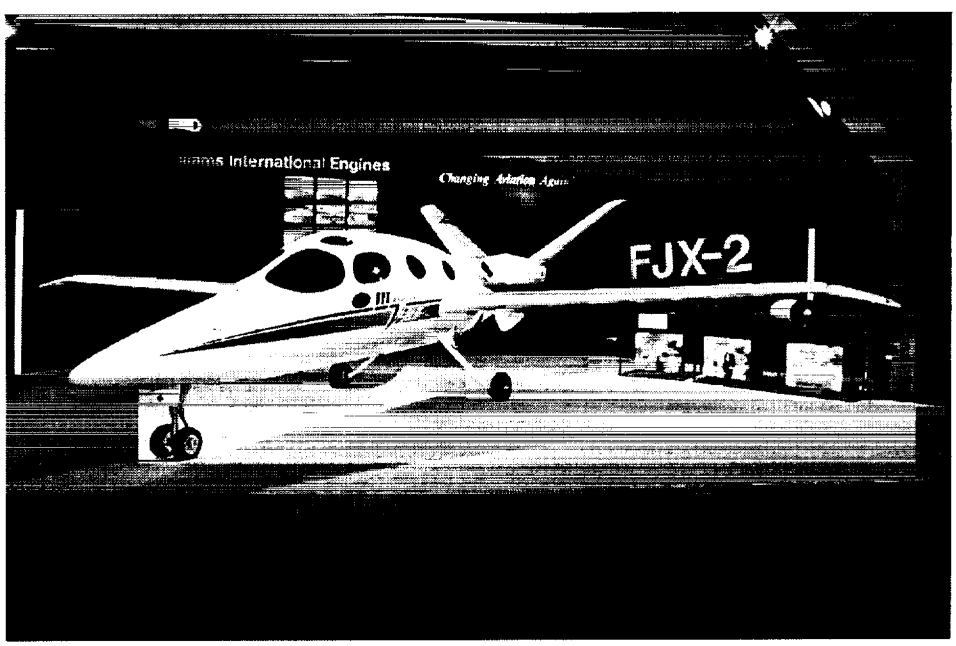

Figure 9. NBAA V-Jet II Display