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XFV-12A THRUST AUGMENTED WING (TAW) PROTOTYPE AIRCRAFT

Introduction

The XFV-12A is a unique V/STOL technology prototype aircraft being developed for the Navy by the Columbus Aircraft Division of Rockwell International Corporation. This program is exploring the suitability of the thrust augmented wing/canard ejector concept to obtain a high performance aircraft with V/STOL capability. It is not intended that the XFV-12A program produce an operational production aircraft as the TAW is a research tool to explore ejector thrust augmentation technology. Of course the program goal is a flight-worthy vehicle to investigate and develop TAW aircraft characteristics in vertical, conversion and conventional flight modes.

TAW Concept

The innovative XFV-12A design features a high wing and low canard arrangement and is powered by a single Pratt & Whitney YF-401 engine. The air induction system includes two external compression inlets located along the sides of the fuselage and an auxiliary inlet located on top of the fuselage. Flow from the engine exits in to the diverter (consisting of a translating nozzle shroud, diverter doors and gas collector) which directs the engine exhaust flow aft through the plug nozzle for conventional flight or forward to the ducting/augmenter system in the wings and canards for V/STOL operation.

Thrust augmentation is directly proportional to the amount of secondary air flow. Variation of the diffuser flap angle modulates the amount of secondary airflow, which variest the lift created on each augmenter surface. With no change of engine thrust which is set at full-power height control is obtained by variation of the diffuser flaps on all four of the augmenters simultaneously. Attitude control is achieved by differential movement of the diffuser flaps on the wing and canard for pitch, the differential movement of the diffuser flaps on the right and left wings for roll, and the differential setting of the left and right wing mean augmenter angle for yaw.

Aircraft Development

The development of the XFV-12A progressed through the conceptual design, analysis, test and evaluation of major aircraft subsystems and suitability of each for integration into the flight vehicle. Scaled models, flight and full scale test rigs, simulation and system integration tests were utilized in this development process. Wing and canard augmenters were tested in a unique facility, nicknamed the "whirl rig", which consists of a boom more than 100' long which is free to rotate. Jet efflux is ducted out the boom to the test augmenter which may then be "flown" remotely by the whirl rig operator. The test rig can be instrumented to measure performance and aerodynamic flow varibles. Concurrent with V/STOL system development, wind tunnel and free-flight testing of various scale models was conducted to define the aircraft characteristics in the powered lift mode, transition mode and the conventional flight mode.

Based on these system and vehicle integration tests, the sea level/standard day VTOL takeoff gross weight was estimated to be 19,130 lbs. For the VTOL mode, the engine exhaust gas is diverted to the wing and canard augmenters (47.5% and 52.5%, respectively). Thrust loss due to pressure loss and leakage was calculated to be 8% for the wing and 12% for the canard. Based on measurements from the whirl rig, the calculated free air augmentation ratios for the wing and canard are 1.51 and 1.31, respectively. With installed thrust of 16,500# from the YF401, approximately 10,850 lbs. of lift from the canard and 9,730 lbs. of lift from the wing, for a total of 20,580 lbs. of total lift is available. The 19,130 lbs. of VTOL takeoff gross weight allows for 500 lbs of lift due to trim and 5% lift loss for control.

Augmentation ratio is defined as the total lift developed from the wing and/or canard augmenters divided by the total thrust of the augmenter primary nozzles, including endwalls and dedicated corner blowers.

Fabrication and Structural Testing

Aircraft assembly was completed in early 1977. The XFV-12A proceeded through a series of structural proof and ground tests. Structural proof loading of the fuselage, vertical tail, wing and canard at critical design conditions was accomplished to define the CTOL flight envelope. The structural attach unit which would support the aircraft for static and dynamic tether tests at NASA Langley Research Center (LRC) was proof loaded at several critical conditions relating to fuselage bending which could occur during the static tests at LRC.

In addition to the proof loading tests, a ground vibration test was conducted to aid in evaluating the flutter characteristics of the aircraft. Vibrational effects on the hydraulic system were evaluated along with control system proof loading.

Functional Testing

Engine/ducting/augmenter functional tests were performed at ground level by placing the aircraft on three tie-down pads, each containing a lift and drag load cell. The objective of these tests was to functionally evaluate the propulsion and control systems while in the vertical and horizontal (or conventional take-off) mode. Inasmuch as the aircraft was being tested for the first time as a complete article, it was not expected that the desired lift/control characteristics would be fully achieved with out minor modifications.

In addition to the basic functional tests, evaluation of temperature, velocity, noise, reingestion, cockpit procedures, and instrumentation and data reduction techniques were accomplished.

The structural proof and functional test results were reviewed by the Navy in November, 1977, and approval was granted to continue into the static tests tether at NASA LRC.

Performance and Control Testing

The Impact Dynamic Research Facility at NASA LRC was selected to conduct the XFV-12A static and dynamic tethered hover tests. This unique facility affords the capability of day to day testing in both static and dynamic modes. In addition, the facility permits static testing at any attitude and altitude in and out of ground effect, safe evaluation of large control movements, a good sized hover test envelope and, of course, pilot familiarization and training.

The tether system is based on a Navy varible speed shipboard underway replenishment winch. The hoist tether incorporates a 5 ft. stroke shock absorber which limits the cable forces to 40,000 lbf., a position sensor which drives the winch during dynamic operations, and a structural attach unit. Horizontal restraint cables are placed around the tether at the 100 ft. height in order to prevent lateral excursion of the aircraft which could result in contact with the gantry structure. For initial dynamic testing, a 5 ft. diameter ring around the tether cable minimizes lateral aircraft movement.

During static testing, the aircraft is hoisted to the desired test height by the safety tether and then restrained in the desired attitude by seven ground cables attached to the three landing gear. The upper tether and each of the lower restraint tethers contain load cells and the geometric summing of these load cell data provides lift and moment data.

For dynamic testing, the lower restraint cables are removed and the aircraft is free to maneuver within the constraints of the test site arrangement. During dynamic tests with lift to weight ratios greater than one, the position sensor signals the winch to track the vertical velocity of the aircraft. This will minimize impact of the tether on the aircraft handling qualities.

For both static and dynamic testing, instrumentation for aircraft loads, temperatures, and system performance are telemetered to the data station. Data from the cable loads, and extensive pressure instrumentation, are incorporated into the same transmissions.

Static testing at the Langley facility is directed towards developing the augmenters to their full potential, evaluating the resulting stability and control characteristics, and determing the external forces on the aircraft, both in and out of ground effect. Another important aspect of the static tests, is the evaluation of the structural integrity of the ducting and augmenter systems.

Dynamic tests will verify basic attitude and vertical control, both in and out of ground effect. The rate damping system and hover feel and trim will also be evaluated. The dynamic tests will, of course, provide pilot training and proficiency in VTOL operation.

Static Test Results

Initial static tether test results are summarized in the attached graphs. Rockwell has generated a method of estimating augmentation ratio (Φ) based on measuring the average velocity of the secondary air passing through the augmenter threat and correlationing this velocity with previous full scale test data. These "throat velocity (Φ)'s" indicate that the augmenters are performing close to the goal augmentation ratios. On the other hand, the augmentation ratios computed from load cell data indicate substantially less performance. The variance was reflected at all altitudes tested (0-30 feet). The project team expended considerable effort and time investigating the anomaly. By mechanically inducing loads into the tether arrangement and comparing the known input with the results of reduced load cell data the load measurement system was statically verified. In addition, tests of a scale augmenter model reflecting full scale conditions were run and additional instrumentation was placed on the aircraft to detect any unexpected external forces on the aircraft.

With the exception of the external forces, which resulted in a negligible amount of download on the aircraft at 30 feet, no definite conclusions could be drawn as to the validity of either set of augmentation ratio data.

After Navy and NASA review of the static test results, it was decided that an initial dynamic test should be approved in which the lower restraint cables would be removed and the aircraft would be suspended from the safety cable at a lift-to-weight ratio less than one. This would provide a qualitative assessment of control characteristics and a quantitative measurement of aircraft lift based on a single load cell. This lift measurement would serve to validate the lift measurement system.

These unrestrained tethered hover tests were accomplished on June 12, 13 and 14. Precision control of aircraft attitude was demonstrated and lift measurement system was validated.

Test Result Assessment

The static tethered hover tests have validated the TAW concept and quantified the propulsion system characteristics. The wing and canard augmentation ratios, are much less than goal values.

A comparison of a static and unrestrained test at approximately the same conditions tends to validate the lift measurement system. The comparative tests were accomplished with trim and power conditions that allowed the aircraft control system to operate within the linear portion of the augmenter lift curve slopes. This enabled very precise control of the aircraft during the unrestrained test.

A later test explored the higher lift/reduced control authority region by selecting a trim point which allowed the control system to operate in the non-linear range of the augmenter lift curve slope. Pilot work load for this test was higher; however, controlability was considered adequate.

In addition to these performance items a few comments should be made regarding other aircraft systems.

Total operating time for the XFV-12A in the VTOL mode has been approximately 46 hours with 7.5 hours at intermediate thrust throughout this tije period the Pratt and Whitney YF-401 engine has operated in a relatively flawless manner and at a performance level equal to, or greater than, original estimates. The structural integrity of the ducting system, with the exception of several internal vane failures and a rupture in one end wall blowing plenum, has been exceptional. The data acquisition system has proven very reliable and has demonstrated the degree of flexibility necessary for this type of testing.

Projections

Exit surveys of both the wing and canard at altitudes from 0-30 feet are currently being performed at NASA Langley, Research Center (LRC). This data will be evaluated and modifications incorporated into the augmenters. It is anticipated that several of the modifications can be tested at NASA LRC before the expiration of the current test phase in mid July.

After this test phase is complete, the augmenters will be removed from the aircraft and sent to Columbus to be tested on a full scale test stand. Analysis of the exit surveys and full scale tests will define the various augmenter problems. Modifications resulting from evaluation of these tests will be incorporated into the augmenters and tested as full scale flight hardware.

When demonstration of increased performance is achieved, the flight hardware will be incorporated into the aircraft for continued tethered hover testing at NASA LRC.

Several options for follow-on testing are being explored. Use of the full-scale tunnel here at NASA Ames for exploring the transition between VTOL and CTOL flight is being considered. Free flight is planned to follow tether and wind tunnel testing.

Features of the TAW approach to VSTOL, especially augmented thrust, a relatively benign exhaust "footprint" and greatly enhanced STOL performance due to circulation lift make the TAW a very attractive V/STOL concept which the NAVY will continue to explore.

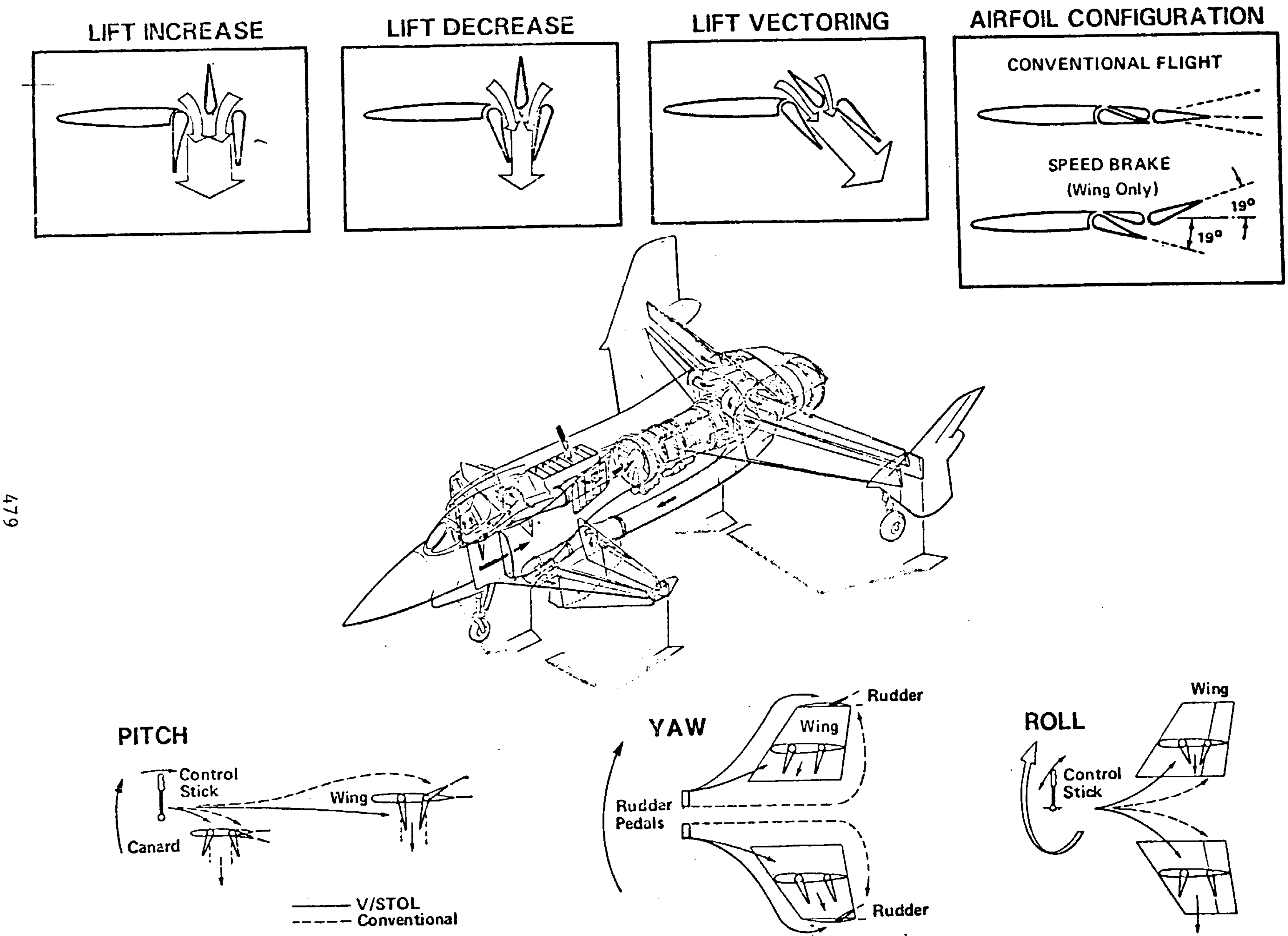

Figure 1.- Lift and control.

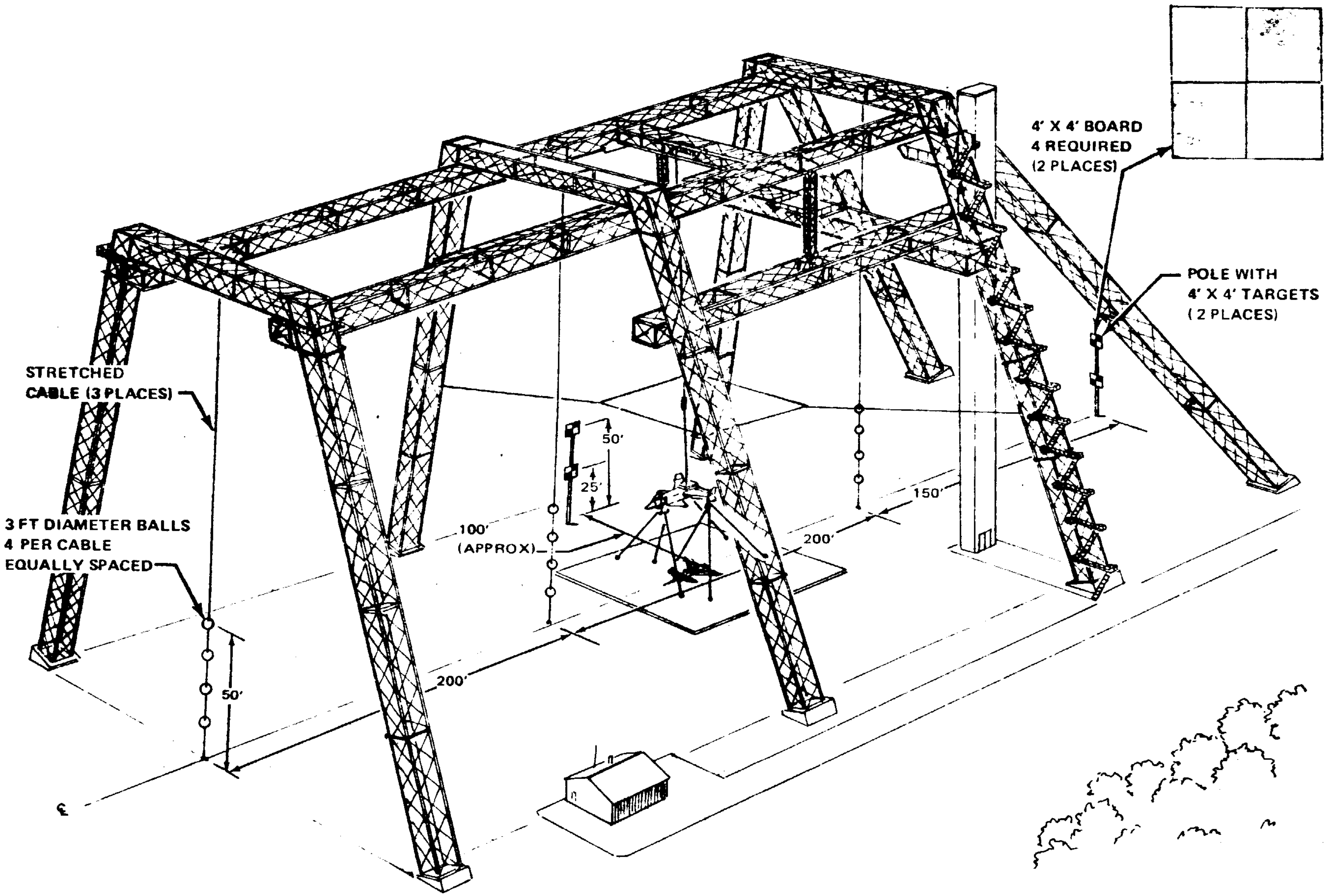

Figure 2.- NASA Langley test gantry.