REVIEW OF HARDWARE PREPARATION AND FLIGHT TEST OPERATIONS TO ASSESS ACTUATED FOREBODY STRAKES

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ABSTRACT

Flight tests of actuated forebody strakes on an F-18 research airplane are to be conducted at the NASA Dryden Flight Research Center. The purpose of these tests is to provide flight validation of ground-based studies and to evaluate the use of such forebody strakes as a means to enhance fighter maneuverability at conditions where conventional aerodynamic controls become ineffective. This series of tests is collectively referred to as the Actuated Nose Strakes for Enhanced Rolling (ANSER) flight experiment, which is part of NASA's High-Angle-of-Attack Technology Program. Following extensive experimental studies, a new research radome, housing the strakes, actuators and attendant research hardware, was designed and fabricated at the Langley Research Center. The new radome was delivered to Dryden in late December 1993, where preparations for integrating the hardware with the F-18 and incorporating the strake control laws into the aircraft's research flight control system are underway. Flight tests are to begin later in the year and it is estimated that 60-70 flights will be required to complete the flight experiment. The purpose of this paper is to summarize the development, design, fabrication and ground testing of the flight article, and present the latest schedule regarding the planned flight test activities.

INTRODUCTION

The National Aeronautics and Space Administration (NASA) is presently conducting a High-Angle-of-Attack Technology Program (HATP) to develop technologies that can significantly improve control and maneuver effectiveness of fighter-type aircraft[1]. As part of this research effort, studies have been conducted to evaluate the effectiveness of actuated forebody strakes to provide increased levels of yaw control at flight conditions where conventional aerodynamic controls become ineffective[2]. A representation of the loss of conventional control and the amount required to coordinate a full roll control input, as angle of attack is increased, are shown in figure 1. This reduction in conventional rudder control is due to the blanketing effect of the stalled-wing wake on the vertical tail. However, the forebody or nose of the aircraft remains in undisturbed flow and sheds a powerful vortex flowfield at high angles of attack. Under such conditions, the use of forebody strakes to control the location of the vortices can produce side forces on the nose to generate the yaw control needed to coordinate the rolling maneuver.

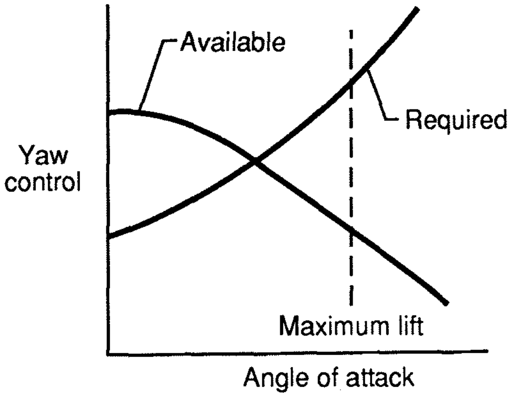

Figure 1. Yaw control characteristics and requirements for typical fighter-type aircraft.

One approach that has shown significant potential towards providing the desired control augmentation is designated as the Actuated Nose Strakes for Enhanced Rolling (ANSER) concept. This configuration has been fabricated at the Langley Research Center and is to be flight-tested on the NASA F-18 High Alpha Research Vehicle (HARV) at the Dryden Flight Research Center. The HARV is being used as part of a joint research effort to systematically assess thrust vectoring and forebody vortex control concepts. The objectives of

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the ANSER flight experiment are to (1) obtain flight validation of ground-based forebody controls design and analysis methods and (2) evaluate the use of forebody controls to enhance fighter aircraft maneuverability. Because of the ongoing nature of this program, the purpose of this paper is to summarize the activities that have been conducted to date and the status of those currently underway in preparation for the flight tests. Included will be a description of the development, design, fabrication and ground testing of the flight article, and the latest schedule regarding the planned flight test activities.

ACTUATED FOREBODY STRAKES DEVELOPMENT

Several considerations have led to the research on advanced control concepts designed to manipulate the forebody flowfield and provide the required yaw control at high angles of attack. Two of these considerations are that for present day fighter aircraft the moment arm from the forebody to the center of gravity is equal to or greater than the moment arm of the vertical tail, and that the flow on the forebody remains undisturbed at high angles of attack, which allows the forebody to produce a very powerful vortex flowfield. However, typical forebody flowfields can exhibit very nonlinear characteristics over small changes in flight condition and can be very highly coupled with downstream aircraft components. Therefore, the designer of a forebody controller has the technical challenge to provide the desired control characteristics by harnessing such a powerful, though often unpredictable, flowfield. In general, it is highly desirable that the control device be effective over a wide range of flight conditions, have minimal control coupling with other axes, exhibit minimum time lags in the development of control forces, and provide well-behaved control linearity characteristics (no control reversals). The actuated forebody strake concept has been developed to provide these desired characteristics to ease implementation in a flight control system and provide a predictable response to the pilot.

Flight configuration

The process for developing the actuated nose strakes consisted of a series of experimental studies that included initial concept exploration to full-scale wind-tunnel validation. Using a generic model, initial tests showed that the actuated nose strake could provide a high level of yaw control over a wide range of angle of attack and sideslip and that the yawing moment could be controlled by varying the strake deflection. The concept was refined through a series of continued aerodynamic and simulation studies to determine the suitability of the strakes for flight testing. A sketch of the conformal actuated forebody strake design that was accepted for flight testing on the F-18 HARV is shown in figure 2. This ANSER strake design includes a pair of conformal actuated strakes, each capable of being deflected 90° and located at the 120° radial position from the bottom of the forebody. The term "conformal" refers to the configuration shape when both strakes are retracted; thus, the normal F-18 forebody contour is retained. To minimize cost and difficulty of modifying the research airplane, the strakes were designed to remain within the length of the full-scale F-18 radome[2]. A photograph of the final flight strake design applied to a full-scale F-18 forebody wind-tunnel model is shown in figure 3. The results of ground-based studies utilizing the flight strakes are given in reference 3.

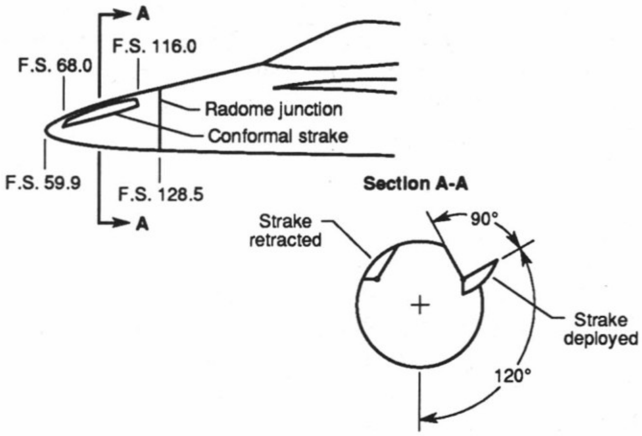

Fig. 2. Comformal strake design.

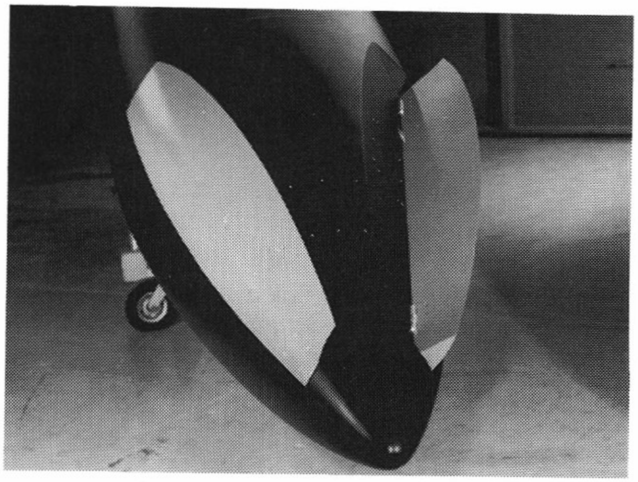

Fig. 3. Full-scale forebody strakes on wind-tunnel model.

Structural analysis

Because the strake concept involves a significant alteration of the basic flowfield around the forebody, there is an accompanying change in the aerodynamic load imposed on the forward fuselage. In addition, the resultant improved aircraft agility could impose large inertial loads on the overall structure. The effect of these aerodynamic and inertial loads imposed by the actuated nose strakes on the radome and forward fuselage was analyzed by the McDonnell Douglas Corporation, the manufacturer of the F-18 airframe, based on critical flight conditions provided by Langley. The scope of the analysis was limited to the nose barrel section of the F-18 hardware used for ground testing and the forward fuselage section of the HARV. The flight conditions selected by Langley were determined through real-time flight simulation of the HARV configuration with forebody strakes. A mathematical model of the aerodynamic and inertial point loads at two locations on the forebody was incorporated into this simulation. Approximately twenty flight conditions, where the total loads were considered critical, were identified. Langley also provided wind-tunnel based isolated forebody surface pressure data from which the distributed aerodynamic load imposed on the nose barrel section was determined. McDonnell Douglas used this data to develop information needed to perform a finite element analysis which established the internal structural loads at the critical loading conditions. The results were used to identify critical structural load paths and compared to the allowable forward fuselage loads to determine structural margins of safety. As reported in reference 4, the analysis verified the structural adequacy of the HARV's forward fuselage with the loads anticipated with the ANSER modification. All margins of safety were positive and no structural strengthening or flight limitations were recommended for flight within the current HARV flight envelope.

RESEARCH CONFIGURATION

The approach being taken to accomplish the ANSER flight experiment is to replace the basic radome of the F-18 HARV with a newly fabricated research radome that incorporates the strakes and servo actuators. A replacement metal forebody was necessary to accommodate the research hardware and maintain rigid configuration control for correlation of the flight data with model test results. The new components, designed at NASA Langley, consist of a flight radome, two flight control surfaces (strakes), associated attachment hardware, aerodynamic fairings, and instrumentation and actuator mounting hardware. The hydraulic actuators are versions of those used for the F-18 ailerons, modified by the manufacturer to meet the requirements for the strake application.

Structural components

The flight radome is a semi-monocoque structure consisting of seven ring frames, eight stringers, and a sheet metal skin. The general arrangement of the frames and stringers is given in figure 4. These items were manufactured by several contractors and NASA. The radome attaches

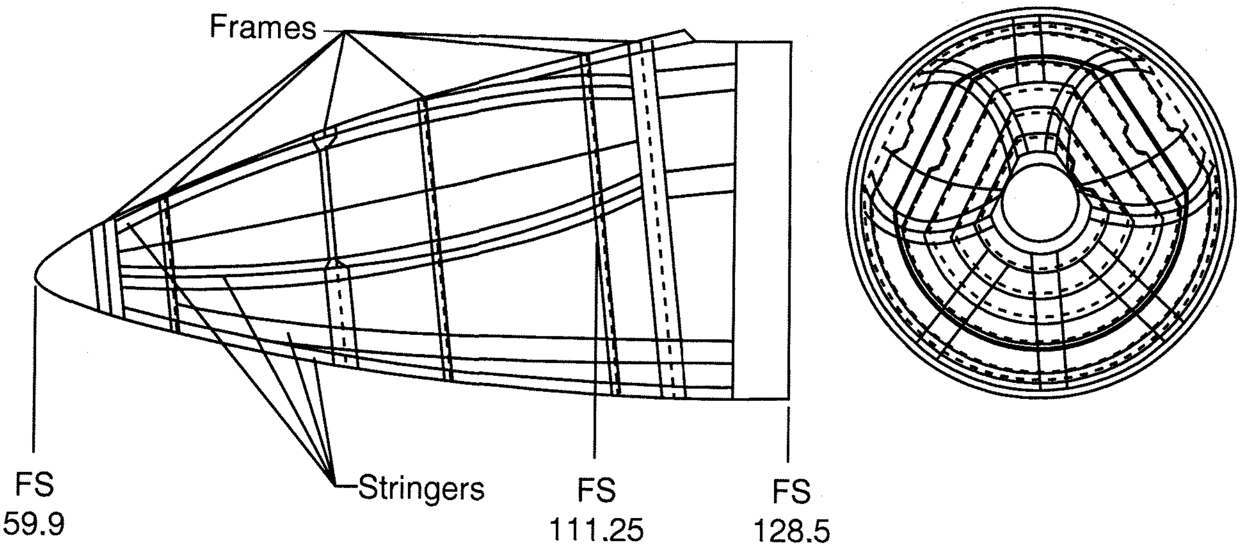

Fig. 4. Layout of frames and stringers for research radome.

to the aircraft at fuselage station (FS) 128.5 and extends forward to FS 59.9 as a body of revolution with an external contour that matches current, production F-18 radomes. The frame at FS 128.5 is a production F-18 manufacturing ring frame assembly which transfers aerodynamic and inertial loads from the radome to the aircraft nose barrel section. The remaining six frames, machined from 7075-T7351 aluminum, were designed to distribute vertical and horizontal loads to the skin panels, which react the loads as shear forces. The frames additionally serve as hard point mounting locations for equipment and ballast. Three frames have channel cross sections and provide attachment locations for the strake control surfaces. The other three frames provide skin panel attachment at skin butt joints and bound the regions that encompass the strakes. These regions are referred to as the "cove" regions which receive the strakes, when in their retracted position, to permit the exterior contour of the radome to match that of the production radome. Figure 5 shows the manufactured frame designed to be located approximately at FS 111.25. As noted in the photograph, the frame consists of the outer machined segment only, which is attached to alignment hardware used during the initial phase of the radome assembly.

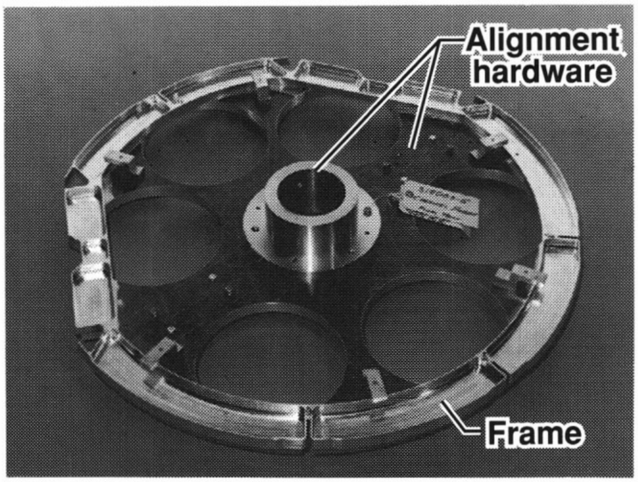

Fig. 5. Photograph of frame located approximately at FS 111.25.

Eight longitudinal stringers, made of 7075-T73 aluminum, provide structural strength to react bending loads. One upper and three lower stringers are extrusions that have a T cross section. Two stringers on each side define the upper and lower boundary between the radome exterior shell and the inner flat surface in the strake cove region. These four side stringers were stretch formed and each transition from a channel to an angle cross section. Figure 6 shows one of the angle stringers being formed.

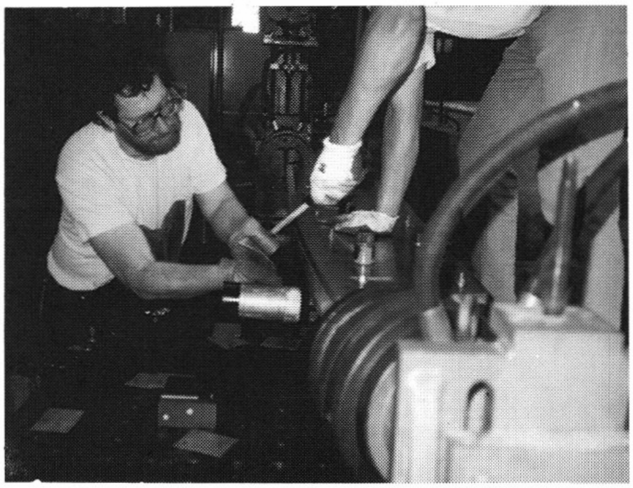

Fig. 6. Forming of an angle stringer at the contractor's plant.

The radome skin panels were stretch formed from 0.08 inch thick aluminum sheets. These panels react the vertical and horizontal shearing forces and carry some of the bending loads. Three separate molds were used to form a set of skin panels that represented the complete radome surface. Forming one of these aluminum sheets is shown in figure 7. Flat aluminum skin panels were also made to complete the cove region behind the strakes.

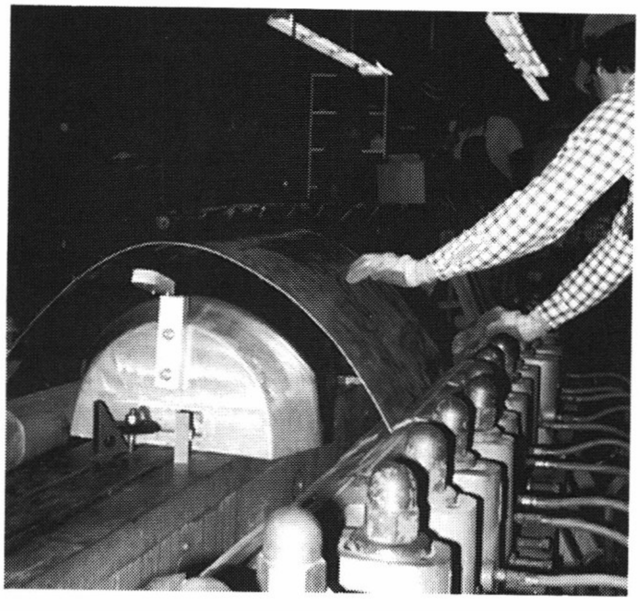

Fig. 7. Forming one of the radome skins over a section mold.

Radome assembly

As the major structural components were being manufactured at the contractor sites, the Langley Fabrication Division produced the remaining subcomponents and support hardware needed for the final assembly of the new research radome. The initial phase of this assembly was the design and fabrication of an assembly fixture. This structure formed the precision backbone required to properly align and join the frames and stringers, thus assuring the final contours of the metal radome would be produced with a high degree of accuracy. Figure 8 illustrates the fitting and alignment of the frames and stringers using the fixture.

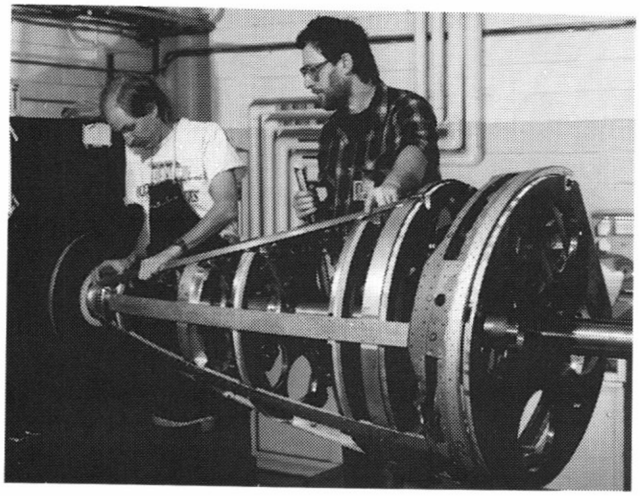

Fig. 8. Fitting and aligning frames and stringers using the assembly fixture.

Following the assembly of the basic skeletal framework, the skin panel sections were cut and fitted to this support structure. These panels were then fastened to the structure by first applying a bonding agent to all the contact surfaces. Once a skin panel was in place, it was secured using several types of fasteners, most of which were rivets. In figure 9, technicians are shown applying a line of rivets to a skin panel on the bottom side of the radome. When completed, the basic radome structural assembly, without the actuators, strakes or instrumentation and equipment mounts, weighed approximately 121 lb, about the same as the production F-18 radome.

Strake assembly

While the radome structure was being assembled, the Fabrication Division was also manufacturing a set of flight strakes and a set of ground-test strakes. Assembly of one of the flight strakes is shown in figure 10. The structure of each flight strake consists of a leading edge, trailing edge, forward end cap, and aft end cap machined from 7075-T7351 aluminum plate. Three internal rib assemblies, manufactured from 7075-T73 aluminum, provide structural support for the rear and base skins and the contoured outer skin panel. In addition, a combination control horn/rib section (figure 10) distributes and disperses actuation loads to the strake structure. The contoured outer skin panel was stretch formed in conjunction with the radome skin panels. The end caps and the aftmost rib assembly serve as lug mounting locations along the hinge line of the strake. Each strake assembly, which weighs about 19 lb, is approximately 51 inches long with an average chord of 7.65 inches and a thickness varying from 0.75 inches at the ends to 2.38 inches near the center. Subsequent fitting for installation of one of the strakes, during assembly of the research radome, is shown in figure 11.

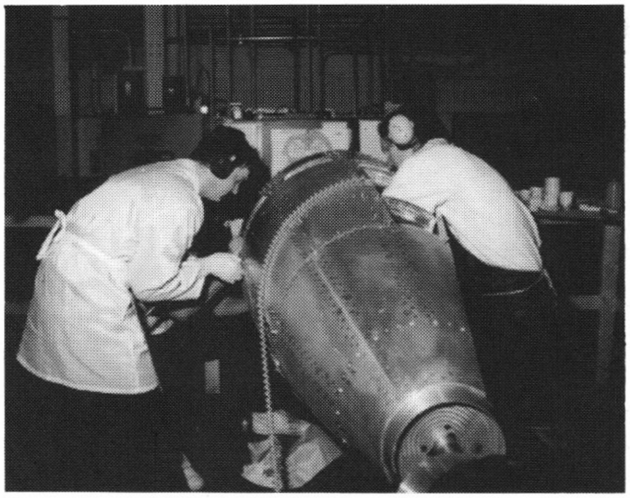

Fig. 9. Skin panel being fastened to radome.

Instrumentation

Most of the flight data requirements for this experiment will be provided by the basic instrumentation system being flown on the F-18 HARV. The newly fabricated radome will incorporate additional instrumentation specifically required for the ANSER flight experiment. A total of 225 flush-mounted pressure orifices have been installed to provide surface pressure distributions around the radome, on the strakes, and on the nose cap. Figure 12 depicts the installation of the strake pressure transducer modules and associated hardware. The pressure orifices duplicate the locations existing on the test aircraft radome, which include those in the nose cap that comprise the Flush Airdata Sensing

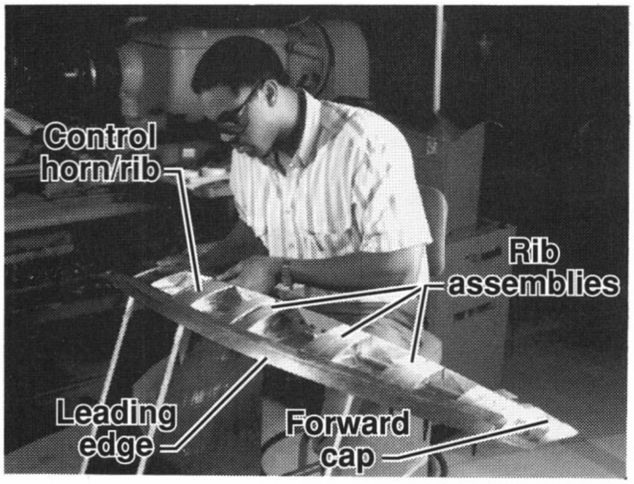

Fig. 10. Assembly of a flight strake.

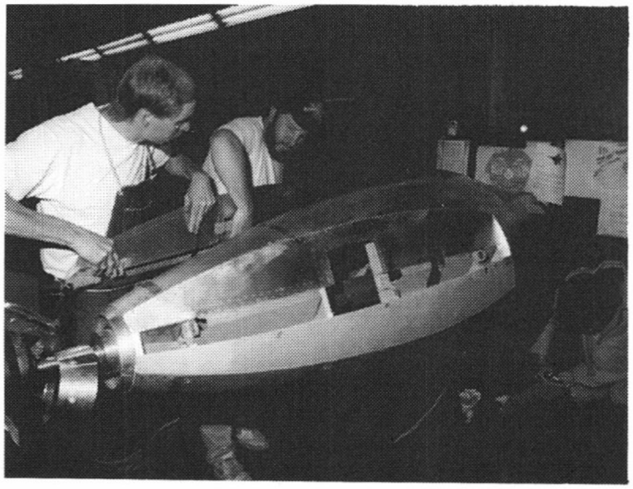

Fig. 11. Fitting strake to radome during assembly of the hardware.

Fig. 12. Installing the pressure transducers in the strakes.

(FADS) System. The FADS is an experimental data system to provide such flight parameters as airspeed, altitude, and angles of attack and sideslip without having to resort to a nose boom that would interfere with the flow on the forebody. Information on radome structural loads and strake hinge moments will be provided by strain gage measurements, while vibration information associated with the strakes will be obtained using accelerometers. Smoke ports will also be incorporated on each side of the radome and connected to the existing HARV smoke generating system to allow visualization of the forebody and strake vortex flowfields.

Servo actuators

The hydraulic actuators used to drive the strakes are a version of the F-18 aileron actuator, modified to meet the requirements for a longer stroke, higher rate, and less force capability. The strake actuators have a stroke of ±2.84 inches that provides each strake with a deflection of 0° to 90°. Based on hinge moment results and control law development, the strake actuators were designed to provide a minimum control surface rate capability of 180 deg/sec under the highest expected strake loads. This rate allows the strake to be fully deployed in approximately 1/2 sec, which is the same time required for a maximum rudder deflection for this airplane (30° deflection at 60 deg/sec).

Static loads testing

The ANSER flight hardware underwent comprehensive mechanical and structural testing to verify the strength and operational integrity of the new structure. NASA Langley performed all structural testing with the exception of the actuator qualification and acceptance testing performed by its vendor. Structural strength verification, specifically static loads tests, comprised the bulk of the test program. An aircraft nose barrel, the ANSER flight test radome, and the flight test strakes, shown in figure 13, were load-tested during the program. Included were ultimate load tests of the strake configuration and the prototype randome-strake attachment hardware. Documentation of the test results included tension and shear strain gage measurements, and deflection measurements.

The strength testing of the nose barrel had several objectives: first, to demonstrate the up-bending and lateral-bending capability for the fuselage frame at station 128.5; second, to load qualify the ANSER radome shear attachment modification to the FS 128.5 frame; third, to validate structural load paths resulting from the application of

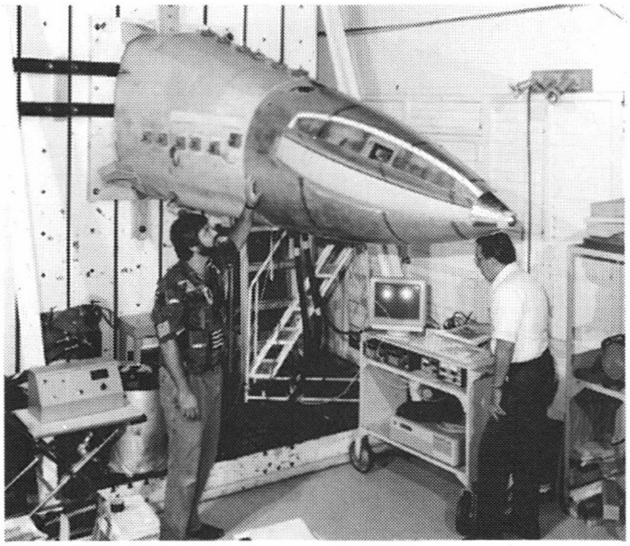

Figure 13.- Static loads test set-up.

a (one-g) distributed load to the nose barrel in both the up and side directions. It should be noted that loads in the down direction were not an issue for these tests, since the anticipated levels with the ANSER modification produced shear loads and bending moments below the aircraft allowables. Further, the loads applied to the frame and shear attachment hardware were conservatively assumed to be aerodynamic loads only. The test load levels were in excess of 1.5 times the anticipated loading of the ANSER structure during flight. Throughout the tests, strain gage outputs remained linear and no damage to or yielding of the structure was observed.

The ANSER radome strength verification program involved static loads testing of the flight radome and strake assembly. The nose barrel section, cited above, provided the support structure and mounting interface for the radome during these tests. Radome attachment to the nose barrel duplicated the actual aircraft interface and permitted testing of the flight hardware in the actual flight configuration. Simulator studies of numerous flight conditions and maneuvers yielded critical load cases with time-correlated aerodynamic and inertial loads. These conditions corresponded to the loads at the boundaries of the anticipated flight test envelope, with actual test values that ranged up to 125% of the expected flight loads. The resultant strain gage measurements on the lower three stringers corroborated the stress levels from the finite element analyses for the test cases. Also, inspection of the hardware by quality assurance personnel indicated no discrepencies with any of the structure.

An independent strength verification of the strake design was also conducted by testing the final configuration to 125% of the expected maximum aerodynamic load. Specifically, this corresponded to a 1250 lb normal load applied to a fully deployed strake. Strain measurements on the control horn and at two attachment locations validated the analytical stress analysis and demonstrated that the resultant structural loads remained within acceptable levels. In addition to the strain measurements, angular deflection measurements recorded the position of the deployed strake under load. A test strake and attachment hardware also underwent ultimate loads testing. The results of these tests matched predicted load levels and substantiated the prediction that strake attachment failure occurs well above expected flight loads.

Following the flight hardware strength tests, final assembly and preparation for shipment of the research radome to Dryden was completed. This included installation of brackets, equipment trays, instrumentation, and the system interface hardware produced at NASA Langley. A view of the internal configuration of the research radome, near completion, is shown in figure 14. The exterior of the completed radome was then painted with a black, white, and gold color scheme, shown in figure 15, to match the F-18 HARV. The final configuration, with spare parts, drawings, and quality assurance inspection reports was delivered to the Dryden Flight Research Center in late December 1993.

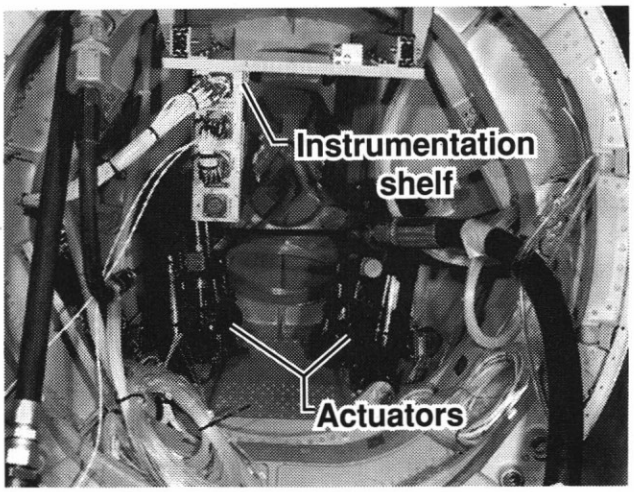

Fig. 14. Features of internal hardware during assembly.

FLIGHT TEST PLANS

The main objectives of the ANSER flight experiment are to provide flight validation of a ground-test database for a forebody control device and to evaluate the use of this type of control to enhance fighter aircraft maneuverability. Accordingly, one emphasis of the flight tests will be

Fig. 15. Completed research radome prior to shipment to Dryden.

to obtain aerodynamic measurements associated with the use of the forebody strakes. These measurements include surface pressures, strake control effectiveness, and hinge moments, along with the documentation of the flow field emanating from the radome, for comparisons with ground-test results. A second focus of the flight tests will be on evaluating the overall payoffs in agility and controllability obtainable with this type of control. Other important issues regarding the integration of forebody control concepts in future applications are also being addressed. Some of these issues include control law design implications, hydraulic/actuator requirements, structural loads, aircraft systems integration and pilot acceptance of the unique response characteristics of the strakes.

Control modes

In order to accomplish the flight test objectives, advanced control law concepts are being developed to provide various control capabilities for the research airplane. The thrust vectoring control system[1], currently being flown on the F-18 HARV, will be retained during the ANSER flight experiment. As a result, the control laws will integrate the actuated forebody strakes and the multi-axis thrust vectoring systems to provide unprecedented levels of yaw control and allow the strakes and thrust vectoring to be operated independently or simultaneously. These flight control laws will be implemented using the existing research flight control system[1] on the HARV and include four research modes: (1) control augmentation using strakes (including pitch thrust vectoring); (2) control augmentation using multi-axis thrust vectoring; (3) control augmentation using strakes and multi-axis thrust vectoring; and (4) a programmed strake mode.

The first control law mode is designed to evaluate yaw-control augmentation using strakes only. Pitch thrust vectoring is used in this mode to allow the aircraft to be trimmed to higher angles of attack than possible with aerodynamic controls alone. The second mode (with strakes deactivated) is the same set of advanced thrust vectoring control laws currently being evaluated on the F-18 HARV. This control law mode will be retained during the ANSER fight experiment to allow a direct comparison between strake augmentation and thrust vectoring augmentation. The third mode combines strake and multi-axis thrust vectoring to provide the maximum potential agility. The fourth control mode is designed primarily to obtain aerodynamic data for various strake positions and test conditions. This mode will allow pre-programmed deflections of the strakes and will use the thrust vectoring system to maintain a stabilized aircraft flight condition.

Approach and technique

The flight tests will be conducted using different approaches depending on the type of data desired. For aerodynamic, control power, and flow visualization measurements, the HARV's on-board excitation system (OBES)[1] will be used to command pre-programmed strake deflections. During these pre-programmed strake deflections, the pilot will maintain a stabilized flight condition by commanding rudder and yaw thrust vectoring controls to offset the yawing moments generated by the strakes. The aerodynamic measurements (pressures, hinge moments, etc.) will be obtained directly, while the strake control power characteristics will be calculated from the levels of rudder and yaw thrust vectoring required to offset the strake-generated control moments. For selected test points, the flowfield associated with the use of the strakes will be documented using the existing HARV smoke generator system. This system permits flow visualization by ejecting smoke from ports on each side of the forebody. The results are recorded through the use of the on-board video system. The strake control effectiveness will also be examined through the use of the OBES to provide optimal inputs for parameter identification (PID) maneuvers. These maneuvers will consist of pre-programmed simultaneous and/or sequential deflection of various control surfaces on the aircraft that require a certain time of free aircraft response before the pilot takes control to terminate the test point. The results will provide assessment of such design parameters as system natural frequencies and damping ratios.

An example of part of the flight test matrix, the portion concerning aerodynamic measurements, is illustrated in table 1. The test points require that the airplane is stabilized for several seconds at some combination of angle of attack, angle of sideslip, and strake deflection. For the desired angles of attack, the flight tests will essentially be comprised of constant airspeed (or Mach number) runs, conducted for each of the altitudes noted. At the high angles of attack and Mach numbers, however, insufficient thrust will be available to maintain level flight and/or constant airspeed. For these conditions, the tests will be initiated at higher altitudes and/or Mach numbers and data will be obtained in descending and/or decelerating flight at conditions that bracket the desired flight condition.

Table 1. Proposed flight test matrix for the aerodynamic studies.

Altitude, feet	Angle of attack (α), degree	Strake position L/R, degree	Initial thrust	Maneuver
25,000	20, 25, 30, 35, 40, 45, 50, 55, 60, 70	0/0, 90/0, 0/90	PLF*	Maintain α, strake deflection and β**=0 for 10 seconds.
25,000	30, 40, 50, 60	60/0, 30/0, 20/0, 10/0, 0/10, 0/20, 0/30, 0/60	PLF	"
25,000	40	15/5, 10/10, 5/15,	PLF	"
25,000	50	35/5, 30/10, 25/15, 20/20, 15/25, 10/30, 5/35	PLF	"
25,000	60	45/15, 40/20, 35/25, 30/30, 25/35, 20/40, 15/45	PLF	"
35,000	30, 40, 50	0/0, 90/0, 0/90	PLF	"
35,000	50	60/0, 30/0, 20/0, 10/0, 0/10, 0/20, 0/30, 0/60	PLF	"
35,000	50	35/5, 30/10, 25/15, 20/20,15/25, 10/30, 5/35	PLF	"
25,000	30	90/0, 30/0, 0/0, 0/30, 0/90	PLF	Maintain α, strake deflection and β for max. left pedal, for 10 sec. Repeat at β for max. right pedal.
25,000	40	90/0, 30/0, 10/10, 0/0, 0/30, 0/90	PLF	"
25,000	50	90/0, 35/5, 20/20, 0/0, 5/35, 0/90	PLF	"
25,000	60	90/0, 45/15, 30/30, 0/0, 15/45, 0/90	PLF	"
25,000	30, 40, 50	0/0, 90/0, 0/90	PLF	Maintain α and β=0 for 10 sec in wind-up turn. At higher Mach and α, as needed, bleed through Mach while maintaining α.

*PLF denotes Power for Level Flight

**β is the angle of sideslip

As opposed to the OBES-commanded maneuvers, a different approach will be utilized when evaluating the control law design process and the agility characteristics. In these cases, the strakes will provide active yaw control augmentation and will respond to pilot commands through the research flight control system. The evaluation of the control law design process will use techniques similar to those used during piloted simulation studies, with aircraft performance and pilot comments forming the basis for comparisons. The maneuvers are designed to evaluate the following characteristics: departure resistance, closed-loop control system response, target acquisition and tracking, basic fighter maneuvers, and air combat maneuvering. Handling qualities ratings will be assigned for pilot-in-the-loop tasks using the Cooper-Harper rating scale.

Finally, a portion of the experimental testing will be directed toward determining the enhancements in agility provided by the strakes. Again, the approach for these tests will be to utilize techniques similar to those used during piloted simulation evaluations. The focus will be on lateral/directional maneuvers to evaluate high-angle-of-attack roll agility and handling qualities associated with the various control modes. Many of the agility maneuvers are the same as those to be used for the control law evaluations. Overall, it is estimated that 60 to 70 flights (about 100 hours) will be required to conduct the systems check-out, envelope expansion, and research flights associated with the ANSER experiment.

PROJECT SCHEDULE

The schedule of activities remaining to accomplish the ANSER flight experiment is shown in figure 16. The research radome, as assembled at Langley, was delivered at the end of 1993 to Dryden, where preparations for integration with the F-18 HARV are underway. Included are the verification and validation procedures associated with the control law development and provisions for the added instrumentation, electrical and hydraulic items, and support hardware needed to interface the ANSER systems with the test airplane. Once the current flight test phase is completed, the research vehicle will be available for the remaining instrumentation and test components to be transferred from the existing HARV radome to the ANSER radome. As noted on the schedule, this hardware integration is expected to begin by the latter part of June and continue through October 1994. Following this integration, initial test flights will be directed toward expanding the operational envelope of the F-18 HARV with the ANSER control system. The 60 to 70 flights anticipated to complete the ANSER flight experiment are expected to run through March 1995.

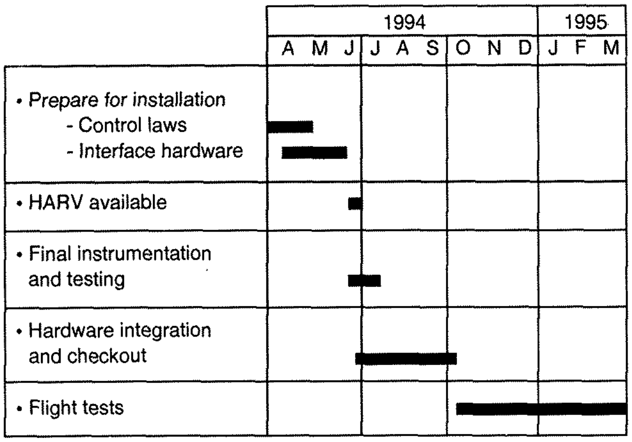

Fig. 16. ANSER flight experiment schedule.

CONCLUDING REMARKS

A wide range of coordinated activities have been used to develop the actuated forebody strake concept. Although directed towards a specific strake concept, these studies are providing an overall understanding of forebody control characteristics and the required design and analysis methods. To date, the favorable results from these efforts have provided confidence that the ANSER strake design will be a very effective yaw control device at high angles of attack. The flight tests using the F-18 HARV will emphasize the validation of the ground-based experimental design and analysis methods and will demonstrate the enhancements in maneuverability provided by forebody controls. The research radome was fabricated by the Langley Research Center and has been delivered to the Dryden Flight Research Center, where it is being prepared for installation on the flight test vehicle. It is expected the flight test activities will commence during the latter part of this year and be completed in early 1995.

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