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SUMMARY OF NACA/NASA VARIABLE-SWEEP RESEARCH AND DEVELOPMENT LEADING TO THE F-111 (TFX)

By Staff of Langley Research Center

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SUMMARY OF NACA/NASA VARIABLE-SWEEP RESEARCH AND DEVELOPMENT LEADING TO THE F-111 (TFX)

Prepared by

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LANGLEY RESEARCH CENTER

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Working Paper No. 285

SUMMARY OF NACA/NASA VARIABLE-SWEEP RESEARCH AND DEVELOPMENT LEADING TO THE F-111 (TFX)

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INTRODUCTION

On November 24, 1962, the United States ushered in a new era of aircraft development when the Department of Defense placed an initial development contract for the world's first supersonic variable-sweep aircraft - the F-111 or so-called TFX (tactical fighter-experimental). The multimission performance potential of this concept is made possible by virtue of the variable-sweep wing - a research development of the NASA and its predecessor, the NACA. With the wing swept forward into the maximum span position, the aircraft configuration is ideal for efficient subsonic flight. This provides long-range combat and ferry mission capability, short-field landing and take-off characteristics, and compatibility with naval aircraft carrier operation. With the wing swept back to about 65° of sweep, the aircraft has optimum supersonic performance to accomplish high-altitude supersonic bombing or interceptor missions. With the wing folded still further back, the aircraft provides low drag and low gust loads during supersonic flight "on the deck" (altitudes under 1000 feet).

The concept of wing variable sweep, of course, is not new. Initial studies were conducted at Langley as early as 1945, and two subsonic variable-sweep prototypes (Bell X-5 and Grumman XF-10F) were flown as early as 1951/52. These were subsonic aircraft, however, and the great advantage of variable sweep in improving supersonic flight efficiency could not be realized. Further, the structures of these early aircraft were complicated by the necessity for translating the wing fore and aft to achieve satisfactory longitudinal stability as the wing sweep was varied.

Late in 1958 a research breakthrough at Langley provided the technology for designing a variable-sweep wing having satisfactory stability through a wide sweep angle range without the necessity for fore and aft translation of the wing. In this same period there evolved within the military services an urgent requirement for a versatile fighter-bomber that could fly efficiently at subsonic and supersonic speeds at high altitude and "on the deck". The application of variable sweep to this mission requirement then became obvious.

Further, in one of those rare instances of timing, the aerodynamic advantage of the variable-sweep wing was further enhanced by the development of a versatile new propulsion system - the afterburning turbofan - which was already in the final stages of experimental testing. This new engine concept, which has outstanding potential for subsonic as well as supersonic performance, effectively complements the versatility of the variable-sweep wings.

The NACA/NASA participation in the variable-sweep research programs culminating in the TFX contract is unique. Not only was the variable-sweep concept born at NACA/NASA (Langley) and the aerodynamic problems solved in its wind tunnels, but this Center took the initiative in transforming a research concept into a practicable vehicle. Wind-tunnel studies of advanced research configurations employing the variable-sweep concept were conducted and the results interpreted in terms of performance potential of complete aircraft. Through the medium of technical briefings as well as formal reports, the performance potential inherent in the variable-sweep concept was made known to the military services and the Department of Defense.

Once the military potential of this new concept was recognized and became the basis for the new weapon system requirements, the NASA instituted a major technical effort in direct support of the military services and their programs. Technical teams from Langley were detailed as advisers to the military services during their in-house studies, and Langley wind tunnels and shop facilities often worked around the clock to provide supporting data during critical phases of the evaluation of the variable-sweep concept as an advanced weapon system. Once the formal military procurement procedures were initiated, key Langley staff members upon the request of the military services were again detailed to assist in the technical evaluation of the contractor's proposals.

The purpose of this paper is to describe in chronological order the NACA/NASA research and development which led to the F-111. This chronology ends with the award of the F-111 contract and does not include the extensive development support provided since the contract award.

CHRONOLOGY

This chronology is divided into the following phases:

Phase I - Period prior to June 1951.- NACA research prior to first flight of the X-5.

Phase II - June 1951 to November 1958.- X-5 flight tests and early technical support of variable sweep.

Phase III - November 1958 to July 15, 1959.- Development of new variable-sweep concept and application to aircraft configuration and performance studies.

Phase IV - July 1959 to February 12, 1960.- Period of technical briefing of military and civilian staffs prior to revised USAF Tactical Air Command, Qualitative Operational Requirement.

Phase V - February 1960 to September 1961.- Issuance of TAC QOR incorporating variable-sweep potential. Subsequent technical assistance and research support of military and civilian staffs.

Phase VI - September 1961 to December 31, 1962.- TFX proposal to industry. NASA support of military services during evaluation period.

PHASE I - Period Prior to June 1951

NACA Research Prior to First Flight of the X-5

Early thoughts on variable sweep.- It is not possible to say what individual first conceived the idea of variable-wing sweep for aircraft, nor is it important. Like so many other radical ideas, the concept is of little importance unless it arrives at a time when there is a strong need for it. When the advantage of high sweep angles for reducing supersonic wave drag was pointed out by Messrs. A. Busemann, R. T. Jones, and others, the thought certainly occurred to many engineers that attractive low-speed and supersonic aerodynamic characteristics could best be achieved if it were possible to vary the sweep angle from essentially zero sweep at low speeds to the optimum angle for supersonic flight.

1945.- Mr. John Campbell initiated work in the Langley free-flight tunnel on a concept of the variable skew/yawed wing to improve high-speed flight efficiency. In order to establish the feasibility of the concept a simplified research model was built for flight testing in the free-flight tunnel. (See Ref. 1) The wing skew angle was varied from zero to 60°. The model exhibited surprisingly good flight characteristics up to skew angles of about 40°. Reference report, TN 1208 by Campbell and Drake.

Semispan wing models tested in the Langley 7- by 10-foot tunnel at various fixed-wing sweeps relative to variable-sweep aircraft. Maximum sweep, 60°.

1947.- A research program on variable sweep using a modified X-1 model (Figure 1) was conducted in the Langley 7- by 10-foot tunnel under the direction of Mr. Charles J. Donlan. The results (See Ref.2) indicated that variable sweep afforded a solution to low-speed problems of high-speed aircraft, and some success was realized in

controlling the longitudinal stability with sweep angle; however, wing translation would probably be required to obtain satisfactory stability characteristics. Mr. Donlan also proposed X-2 be converted to a variable-sweep aircraft.

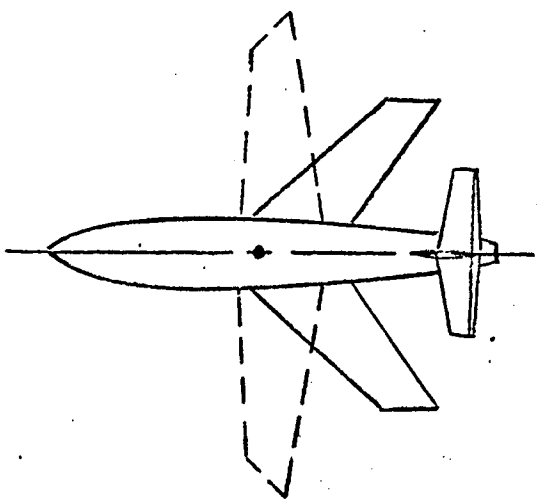

Figure 1.- Early Langley wind-tunnel model.

July 1948.- Based on the Langley 7- by 10-foot tunnel experiments during 1945 - 1947 on the application of variable sweep to the X-1 research aircraft, Bell Aircraft Corporation submitted a proposal to USAF for a variable-sweep aircraft with wing sweep variable in flight. USAF approaches NACA regarding possible support of program as USAF-NACA research aircraft. NACA team composed of Messrs. Soulé, Donlan, and Wetmore of Langley and Mr. A.Silverstein of Lewis, visited Wright Field to review project and strongly endorsed program. Airplane became X-5 research aircraft (See Figure 2).

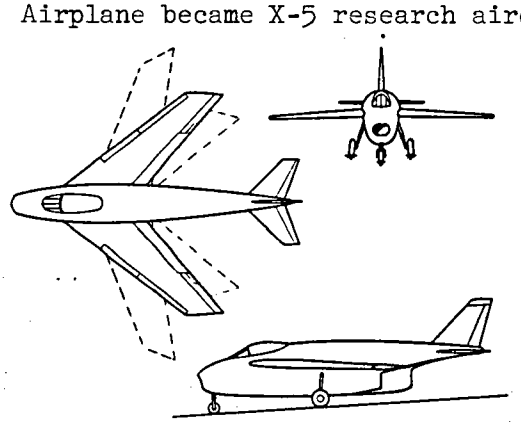

Figure 2.- The X-5 variable-sweep research airplane.

PHASE II - June 1951 to November 1958

X-5 Flight Tests and Early Technical Support of Variable Sweep

June 20, 1951.- FIRST FLIGHT OF THE X-5 VARIABLE-SWEEP RESEARCH AIRCRAFT

An extensive flight program was conducted at the High-Speed Flight Station on the X-5 airplane with Mr. Thomas Finch as project engineer. Mr. H. A. Soule was Research Airplane Projects Leader and Mr. Walter Williams was Chief of the Flight Research Center. Performance and handling qualities information was obtained at various fixed-sweep angles. The sweep angle was varied in flight repeatedly with essentially no mechanical problems.

The X-5 was a remarkable aircraft in that it performed all of the expected research and experimental flights envisaged in the planned programs. The structural and configuration design of the X-5 was undoubtedly compromised, however, by the complicating difficulty that the wing had to be translated fore and aft as the wing was swept and unswept to maintain adequate stability and control. Consequently, the performance potential of the X-5 as a purely subsonic aircraft did not appear attractive in its time period. Nevertheless, the airplane exhibited excellent short-field landing and take-off characteristics and a high rate of climb. As a result of these features, the X-5 proved very useful as a chase airplane in connection with flight operations of other research aircraft.

Mr. Donlan recognized the possible significance from a military standpoint of the unique characteristics of the airplane. Although he argued strongly to the effect that the operational characteristics of the X-5 should be analyzed with reference to military applications, such an analysis was never formally accomplished at the Flight Station because of manpower requirements of other programs.

A comprehensive wind-tunnel and flight correlation program was carried out with the resulting publications in references 3 to 20.

May 1952.- First flight of Grumman XF-10F (See Figure 3) variable-sweep fighter was made in May of 1952. The potential advantages of variable sweep with reference to naval carrier operations were recognized by the Navy with the result that the F-10F airplane reached the prototype stage. Many unfortunate design decisions were made on this aircraft. Consequently, it provided no significant assessment of variable sweep, except that variable sweep presented no serious mechanical problems. After a flight-test evaluation which indicated many problems not associated with variable sweep, the F-10F was discontinued. A wind-tunnel program was conducted by the NACA in support of the F-10F program and is documented in references 21 to 26.

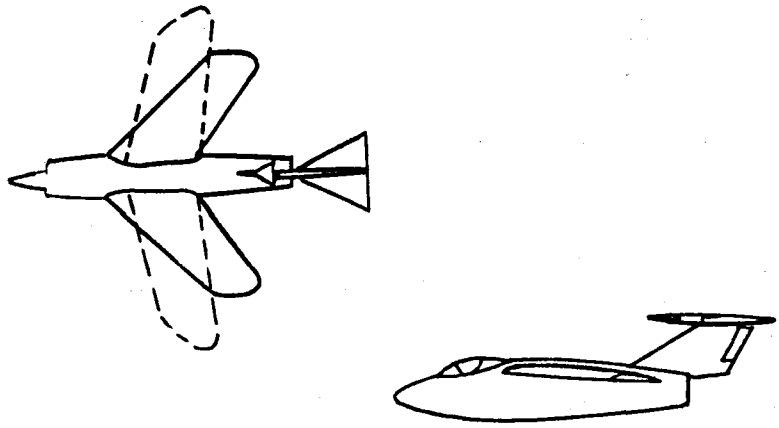

Figure 3.- The XF-10F variable-sweep fighter.

1953. - A Langley proposal to convert the X-5 airplane to a supersonic airplane was presented to the Research Airplane Panel in 1953. The proposal was rejected in favor of proceeding with an airplane of much higher speed potential (X-15). Members: H. A. Soule, Chairman; C. J. Donlan (Langley); W. Williams (High-Speed Flight Station); J. Sloop (Lewis); W. Harper (Ames); C. Wood (NACA Headquarters).

November 1953. - A report issued by Donely and Gillis (reference 17) showed that for high-speed, low-altitude flight of 1 to 2 hours duration, the aircraft motion and acceleration due to rough air must be reduced to one-third current levels. Large wing sweep angles or high wing loadings were recommended as the best solutions. This report was especially significant, for it pointed out that aircraft must be specially designed for low-altitude flight if pilot performance is to be maintained.

March 2, 1955. - NACA Conference on Aircraft Loads, Flutter, and Structures held at Langley Aeronautical Laboratory. In a paper by Funk, Mickelboro, and Rhyne, some recent flight-test results relating to gust loads were reported. Flight-test comparisons of the F-80, F-86, and X-5 in the fully swept mode (59° sweep), showed about a 40-percent reduction in gust loads due to wing sweep (59°) compared to unswept configurations.

1953 to 1957. - Interim activities.

During the early portion of this period several factors led to the lack of enthusiasm for the potential of variable sweep:

(a) It was not clear yet that sustained supersonic cruise could be achieved efficiently. With the military requirement

limited to supersonic dash, a fixed-wing configuration that was less than optimum supersonically and still acceptable subsonically seemed to be a satisfactory compromise.

(b) The designers were faced with the mechanical complexity of variable-sweep systems which, because of stability considerations, had to provide for fore and aft wing translation.

(c) The necessity for on-the-deck operation to minimize radar detection was not yet reflected in a primary military mission requirement.

February 1955: A Langley design study of variable-sweep configurations was made by Mr. Mark R. Nichols at the request of Mr. Donlan. The subject design was of a 160,000-pound attack aircraft with supersonic capability. This was an aft-tail configuration utilizing four external engine pods. The wing-sweep range varied from 15° to 63°.

Later in this period the picture began to change in that a requirement for sustained supersonic cruise was reflected in the WS-110 program. Further, mission requirements called for radar penetration at low altitudes and high speeds. In another area V/STOL activity resulting from new airframe and propulsion-system concepts highlighted the potential of short-field capability. All this began to create a new atmosphere where multimission capability was evolving as a military requirement. From a budgetary standpoint one aircraft that could do many missions and thereby replace several different aircraft appeared to be a necessity for the military service.

June 7, 1957. - United Kingdom representatives from Saunders-Roe visited Langley relative to the F.177D tubojet plus rocket interceptor. U. K. representatives were as follows: Maurice J. Brennan, Chief Designer, Saunders-Roe; Cmdr. Peter S. Wilson, Ministry of Supply; Cmdr. Roy H. Weber, British Joint Services Mission. NASA representatives: Messrs. Stack, Donlan, Toll, and Nichols. Mr. Donlan discussed the use of variable sweep as a possible solution to the low-level attack mission. The visitors were shown data from the 1953 NACA conference on High-Speed Aircraft and referred to reference 17 on high-speed low-altitude gust problems and their means for alleviation.

July 1957. - Mr. Stack visited the Navy Department cognizant desk (Captain Ray Ours) to point out Navy requirement TS149 was not sufficiently advanced relative to the NA-39 and current research status. Mr. Stack specifically suggested variable sweep as the solution to the Navy requirement.

January 1958. - Mr. Stack was appointed Chairman of a DOD Ad Hoc Group on Compatibility of Long-Range Air-to-Air Guided Missiles. The study group considered the use of variable-sweep aircraft for the Navy combat air patrol (CAP) mission.

May 1958. - Langley was requested to comment on the Swallow variable-sweep proposals of Dr. Barnes Wallis of Vickers Aircraft, England.

The Swallow concept involved application of variable sweep to an aircraft design capable of sustained supersonic cruise above Mach 2. Four swiveling engines were mounted on pylons far out on the wing tips. It was hoped to maintain satisfactory stability characteristics during wing sweep without the requirement for wing translation. The shifting center of gravity of the engine weight with wing sweep was intended to alleviate this problem. Dr. Wallis suggested applications as a bomber and as a transport and recommended early construction of a small research airplane under U. S. Mutual Weapons Development Program (MWDP) funds. The reviews of the proposal brought out many technical misgivings, particularly with regard to drag estimates, structural weight fractions, and stability and control. No MWDP funds were allotted to construction. (At the time of the Langley review, it was indicated that the U. K. had discontinued active support of the Swallow program.)

Because of the continuing interest at Langley in the variable-sweep concept, the decision was made to initiate an active research program with the objective of developing a practicable variable-sweep arrangement compatible with supersonic cruise configuration requirements and to coordinate our initial efforts with the U. K. It was felt that there was an immediate need for an aircraft of the tactical fighter size. Accordingly a new proposal of a Swallow configuration was requested by the U. S. through MWDP. Arrangements were made with the British for a joint meeting at Langley in November 1958 to discuss their proposal and to outline a joint research program.

November 3, 1958. - Visit of BuAer representatives to Langley to discuss Navy thinking relative to variable sweep. Navy representatives were: Gerald Desmond, Mr. Brockway, and Commander Haverstein.

November 13-18, 1958. - Joint meeting at Langley Research Center with representatives of the U. K. to discuss Swallow proposal and outline joint variable-sweep research program. Members in attendance: United Kingdom - Mr. John R. Christie, Asst. Secretary, Ministry of Supply; Dr. Philip A. Hufton, RAE, Bedford; and Dr. Barnes N. Wallis, Norman W. Boorer, Cecil W. Hayes, Mrs. Elsa Hoare, Herbert Jefree, Maj. Philip L. Teed from Vickers-Armstrong. Langley Research Center - Messrs. J. Stack, L. I. Turner, Jr., H. A. Wilson, Jr., E. M. Gregory, A. R. Heath, Jr., A. T. Mattson, F. E. McLean, O. G. Morris, M. R. Nichols, T. A. Toll, D. D. Baals, and B. W. Corson, Jr. A joint program was agreed upon which provided for elaborate jet-exit tests of the Swallow in the 16-foot transonic tunnel and Langley configuration wind-tunnel tests with engine in fuselage as recommended by Mr. Nichols. The Langley Research Center accepted the major share of model construction and wind-tunnel programs because of the unique nature of its facilities and research background.

PHASE III - November 1958 to July 15, 1959

Development of New Variable-Sweep Concept and Application to Aircraft Configuration and Performance Studies

November 1958 to February 1959. - Studies of variable-sweep initiated in the Langley 7- by 10-foot tunnels under the direction of Mr. T. A. Toll provided the major breakthrough needed to eliminate the undesirable wing translation of previous variable-sweep aircraft.

Tests of the research models began in the high-speed 7- by 10-foot tunnel, with Mr. W. J. Alford, Jr., as project engineer assisted by Mr. W. P. Henderson. The 7- by 10-foot tunnel program lasted about 2 months, during which time four basic configurations including many minor variations were studies. One of the four configurations was a simplified model of the Swallow (configuration I) and the results confirmed the anticipated stability and control deficiencies. The work on the Swallow was therefore discontinued, with the effort being concentrated on engine-in-fuselage configurations employing both canard (configuration II) and folding aft tail (configuration III) arrangements. Early results from these configurations were disappointing in view of inadequate control characteristics and excessive longitudinal stability variations with wing sweep.

Concurrent analytical span-loading studies conducted by Messrs. W. J. Alford and E. C. Polhamus indicated that by use of an outboard-pivot location the stability variation with sweep could be reduced considerably. By careful selection of the pivot location the desired wing span and sweep variations could be maintained with reduced variation of the rotating panel center of pressure. In addition this pivot location also provides a relatively large fixed area ahead of the rotating panel such that the aerodynamic loads of the fixed and rotating panels combine in a manner as to further reduce the center-of-pressure travel of the total lifting surface. On the basis of the results obtained on configurations I to III and the analytical studies, a fourth research model (configuration IV) was constructed (see figure 4). Experimental studies on this configuration by Messrs. Alford and Henderson in the 7- by 10-foot tunnel substantiated the importance of the pivot location and an outboard-pivot wing, aft-tail configuration having essentially the same stability at 25° and 75° of sweep with only moderate variation of stability level at intermediate sweep angles was developed. A technical paper by Messrs. Alford and Henderson (see reference 27) reported the detailed results of this study.

This attractive arrangement provided for large wing-sweep angle variation without the need for fore and aft wing translation and was the beginning of a rather extensive variable-sweep development program that ultimately resulted in the F-111 airplane (TFX).

A patent on this variable-sweep wing concept was eventually awarded to Messrs. Alford and Polhamus on September 11, 1962. (Patent No. 3,053,484)

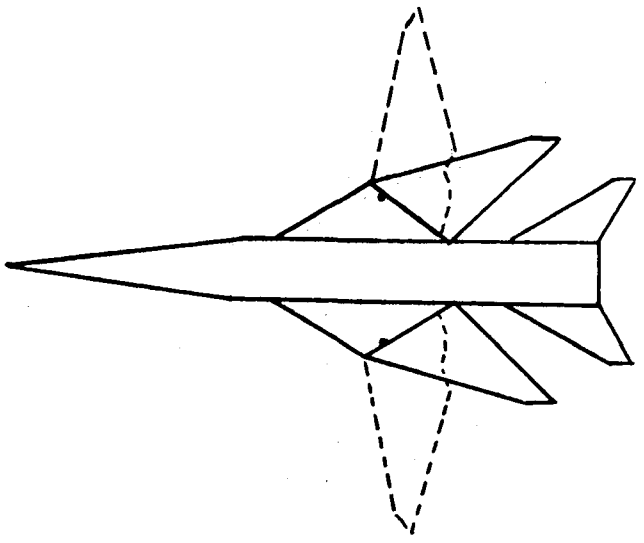

Figure 4.- Outboard pivot research model (Conf. IV).

January 12, 1959. - Headquarters USAF letter to NASA by Major General Swafford requested NASA research support of British "Swallow" variable-sweep proposal.

February 1959. - Mr. Gerald Desmond of Navy Bureau of Aeronautics visited Langley to review new variable-sweep concept relative to air-to-air weapons compatibility study. At Navy request NASA supplied available variable-sweep data. Mr. Desmond was also shown British "Swallow" concept and informed that sweep mechanism had been laboratory tested in England and was under British patent.

March 1959. - Tests of configuration IV in the 4-foot supersonic pressure tunnel supervised by Mr. M. L. Spearman indicated that supersonic performance potential compared favorably with best design point supersonic cruise configurations developed previously (see reference 28).

March 1959. - Mr. E. M. Gregory began layouts of wing-pivot structural designs.

March 1959. - Mr. A. R. Heath applied outboard-pivot concept to an actual aircraft designed to meet long-range interceptor mission of interest to the Air Force. This eventually evolved into a configuration proposed by Langley for the Navy combat air patrol mission.

March 25, 1959. - Langley transmits data on configurations I through IV and drawing of Mr. Heath's configuration to the Bureau of Naval Weapons.

April 1959. - Research on the outboard-pivot concept continued as Mr. A. A. Luoma made transonic tests of configuration IV in the 8-foot transonic pressure tunnel. A technical paper summarizing subsonic, transonic, and supersonic studies was written by Messrs. Alford, Luoma, and Henderson (see reference 29). Other tests of configuration IV are summarized in references 30 to 32.

June 3, 1959. - Tests of Swallow configuration using hydrogen peroxide to simulate jet effects initiated in Langley 16-foot transonic tunnel by Messrs. Corson and Runckel. It should be noted that this was one of the most complex models ever constructed at Langley. Tests were completed August 11, 1959.

June 10, 1959. - Representatives of Navy BuAer visited Langley to discuss application of variable sweep to future fighter aircraft. Navy representatives were Messrs. G. T. Desmond, F. E. Ellis, H. G. Sheridan, W. H. Young, W. Koven, C. P. Smith, Commander W. C. Bryan, and R. M. Machell. NASA was represented by Messrs. Stack, Toll, Heath, and Turner.

June 13, 1959. - Mr. Morgan Blair of North American (Columbus) briefed on outboard-pivot results by Stack, Nichols, Polhamus, Corson, Heath, Baals, and Turner. It was suggested that North American consider application to A3J.

June 1959. - Messrs. Toll, Alford, and Henderson estimated the performance characteristics of an outboard-pivot variable-sweep aircraft for the Navy Combat Air Patrol Mission.

June 23, 1959. - Visit of Mr. Stack to Vickers Aircraft, Weybridge, England, to review Langley work on Swallow in accord with November 1959 agreement via MWDP. Mr. Stack noted that Langley research was essentially completed; and leads to engine-in-fuselage rather than engine-on-wing arrangement as in Swallow. Although the British research was not completed, the Vickers design team had also come to the engine-in-fuselage arrangement.

July 8, 1959. - During visit of Mr. Lawson of Vickers Aircraft (U.K.) to Langley, Mr. Stack summarized potential of variable sweep and results of Langley research programs.

July 10, 1959. - Official transmittal of final Langley 7- by 10-foot tunnel low-speed aerodynamic data to Vickers-Armstrong Aircraft Company on configurations I, II, III, and IV. Configuration I was similar to Swallow. Memorandum pointed out the deficiencies of the Swallow configuration. It also showed variable-sweep aircraft configuration development currently underway in the U. S. and presented layout studies of U. S. full-scale aircraft.

July 14, 1959. - Transmittal to Vickers-Armstrong Aircraft Company summary of recent Langley studies of twisted and cambered wings applicable to Swallow. Subject analysis prepared by Mr. McLean.

PHASE IV - July 1959 to February 12, 1960
Period of Technical Briefing of Military and Civilian Staffs
Prior to Revised TAC QOR

July 15, 1959. - Langley presentation at the Pentagon to Admiral Coates, Assistant Chief for R and D. Messrs. Stack and Polhamus summarized the aerodynamic results of configurations I through IV and presented a layout of a 50,000-pound Navy CAP aircraft embodying variable-sweep principle. Based on these results, a performance analysis was made for the Navy CAP mission, high-altitude attack, and low-altitude (M = 0.9) attack missions. Navy representatives: Admiral L. D. Coates, Capt. N. L. Leon, Capt. J. R. Brown, Capt. O. C. Dunkin, Capt. W. H. Keen, G. L. Desmond, plus a large staff. NASA representatives: Messrs. Stack, Evans, Nichols, Polhamus, and Baals. The Navy announced that they had initiated a proposal for industry study of variable sweep for the combat air patrol (CAP) mission.

July 15, 1959. - Same briefing by Langley team to officials of Office of Director of Research and Engineering at Pentagon. DOD representatives: Dr. E. W. Paxon, Col. Steadman, Col. Honeycutt, and Mr. Cal Muse. NASA: Messrs. Stack, Nichols, Polhamus, Baals. Dr. Paxon suggested: (a) staff of Tactical Air Command, Headquarters, be briefed on the potential of variable sweep; (b) the Navy feasibility program should be a joint Air Force-Navy sponsored study.

July 16, 1959. - Detailed performance characteristics of variable-sweep aircraft applied to Navy CAP mission summarized and documented in a memorandum by Messrs. Foss and Swihart. Subject material submitted in July 15th briefings to DOD. These preliminary calculations, based on limited wind-tunnel data and a paper engine, indicated an all-around performance for the variable-sweep airplane which exceeded the performance of any weapons system being built or planned. The very short acceleration time, the endurance time, and the all-supersonic cruise radius of about 900 miles represents a very high level of weapons system capability.

July 20, 1959. - Initial briefing of staff of TAC Headquarters at Langley on the potential of variable-sweep aircraft. TAC representatives: Col. Mitchell, Col. McGough, Maj. Whitmyer, Maj. Schneider, Capt. Nashold, and Mr. Reese Ivey. NASA: Messrs. Stack, Nichols, Polhamus, Foss, and Baals. The TAC representatives were impressed with the performance of variable-sweep aircraft and Colonel Mitchell requested an early briefing of the general staff of Tactical Air Command. A tentative date of July 22 was set.

July 22, 1959. - Briefing of general staff of Tactical Air Command, Langley, on the potential of variable-sweep aircraft. TAC representatives: General Momyer, General M. L. McNickle, Col. W. L. Mitchell, Col. W. A. Williams, Dr. C. W. Bryant, and Mr. George Stickle. NASA: Messrs. Stack, Nichols, Polhamus, and Baals. Variable-sweep aircraft appeared to be the immediate answer to the TAC requirements for high-altitude supersonic and on-the-deck strike capability combined with long-range ferry capability. Present TAC requirements call for VTO capability; however, in view of the outstanding performance of variable-sweep aircraft, TAC might reconsider STOL operation (that is, take-off and landing out of approximately 3000-foot runways).

July 23 to August 17, 1959. - The following briefings were made at Langley on industry studies of the potential of variable-sweep tactical aircraft: Boeing, July 23; Douglas, July 27; Republic, August 3; Bell, August 6; McDonnell, August 6; Chance Vought, August 7; North American, August 14; Martin, August 17.

July 28, 1959. - Langley briefing of Tactical Air Command Headquarters staff (Pentagon) on the potential of variable-sweep aircraft. USAF Headquarters staff: General J. S. Holtner, General Maris, Col. J. W. Howell, Col. W. Chapman, Col. B. E. Steadman, Col. R. Gates, Col. J. McNabb, Col. McDonald, and others for a total of about 27 Air Force members. NASA team: Messrs. E. O. Pearson, (NASA Headquarters), Stack, Nichols, Polhamus, Baals, Swihart, Foss, Heath, Hammond, Spearman, Toll, and Reeder. General Holtner expressed great interest in the potential of variable-sweep aircraft. The NASA representatives suggested an early industry feasibility study of variable-sweep capability.

August 10, 1959. - Receipt of letter from Colonel J. W. Howell, Chief of Aeronautics Division, Directorate of R and D, USAF Headquarters stating that the USAF is taking the following actions as a result of the July 28th briefing: "ARDC (Aeronautical Research and Development Command) is being asked to take a further more detailed look at your variable-sweep design concept as a possible solution to Air Force requirements for tactical strike-recce and long-range interceptor (LRI) aircraft."

September 1959. - Configuration layouts of Navy CAP II configuration initiated at Langley by Mr. Robins (see figure 5).

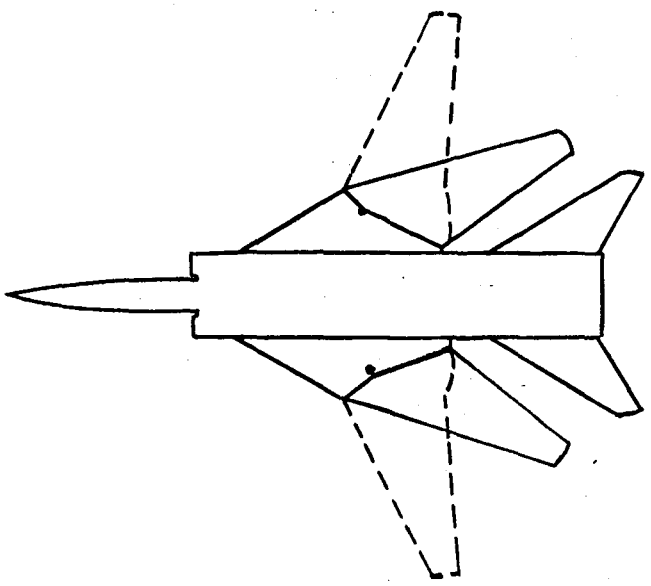

Figure 5.- CAP II research model.

September 9, 1959. - Visit of representatives from Chance Vought to Langley to discuss their variable-sweep design study. Chance Vought representatives were Messrs. Warren Trent and Harold Stahl. NASA representatives: Toll, Baals, Whitcomb, Polhamus, Swihart, Heath, Foss, Robins, McLean, and R. Kuhn. Chance Vought had completed preliminary design studies of variable-sweep aircraft and their analyses showed excellent agreement with performance potential indicated by NASA studies. This appeared to be the first independent check by industry of the NASA performance analyses.

October 13, 1959.- Visit of Mr. John Hay and Mr. Ernest Marshall of Vickers-Armstrong (England) to Langley 16-foot transonic tunnel to discuss Swallow results. NASA representatives: Messrs. Schmeer, Cassetti, and Riebe. The 16-foot transonic tunnel work pointed out the large aerodynamic losses due to nacelle toe-in and low control effecitveness.

September 11, 1959.- Visit of representatives of Wright Air Development Division (WADD) to Langley to discuss variable-sweep program. WADD representatives: Mr. John Chuprun, Mr. L. J. Tedeschi, Lt. J. P. Nenni, and Mr. F. H. O'Donnell. Langley representatives: Messrs. Stack, Nichols, Toll, Polhamus, Swihart, Heath, Spearman, and Foss. WADD emphasis was on LRI studies. All available technical data were turned over to WADD representatives for their independent analysis.

September 28, 1959. - Meeting held at Vickers Aircraft Company, Weybridge, England, relative to NASA results on variable-sweep studies. These included both the independent NASA research, and the NASA test results of the Swallow. NASA work was considered to be essentially complete fulfillment of obligations under November 1958 joint agreements. NASA representatives were Messrs. Stack, Nichols, and Toll. Representatives of the Ministry of Supply and the RAE were also in attendance.

October 1959. - Mr. B. Spencer of the Langley 7- by 10-foot tunnels staff develops rapid method of estimating lift-curve slope for the unusual planforms encountered with outboard pivot for variable-sweep wings (see reference 34).

November 1959. - Langley 7- by 10-foot wind-tunnel studies of two types of variable-sweep wings on A3J by Mr. Spencer further substantiates advantages of outboard pivot. (See reference 35). This was first wind-tunnel investigation of the new concept on an actual aircraft and it established aerodynamic feasibility of modifying an A3J. The outboard pivot version of the variable-sweep A3J designed by Langley is shown in figure 6.

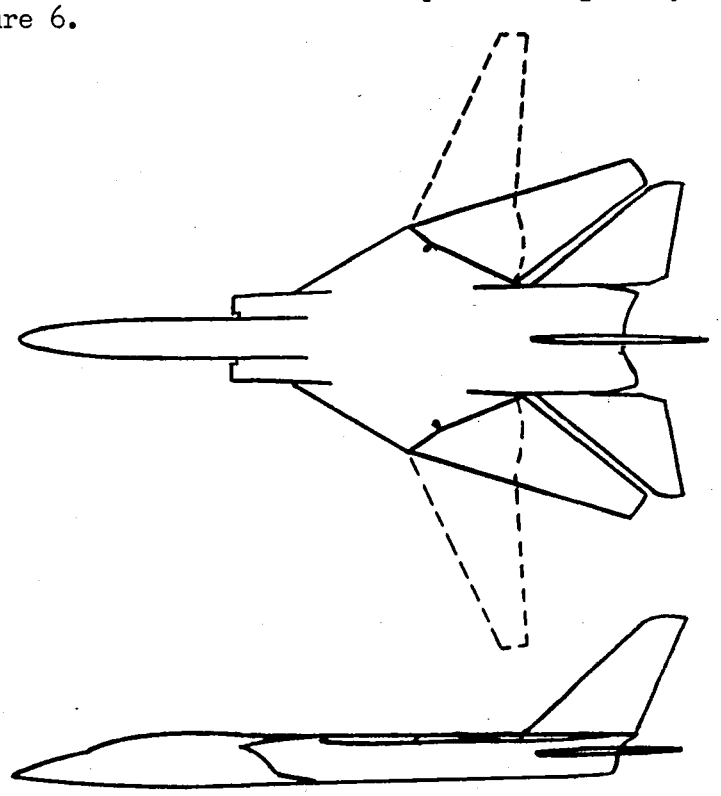

Figure 6.- A3J model with outboard pivot wing.

December 3, 1959. - Proposal by Navy for feasibility study of the application of variable sweep to the combat air patrol mission sent to industry on this date. Proposal return scheduled for January 18, 1960. Subsequent contracts let to Douglas (El Segundo) and North American (Columbus).

September 15, 1959 to January 5, 1960. - Second round of industry briefings at Langley. Boeing, September 15; Douglas, September 17; Grumman, September 22; Douglas, September 22; Grumman, October 14; General Electric, October 27; Republic, November 5; Lockheed, January 5.

January 11, 1960. - Information on Vickers Swallow publicly released by Dr. Barnes Wallis. Noted in Aviation Week of this date. The article stated that U. K. had once canceled the whole project but work was resumed about a year later with joint British and U. S. backing.

January 13, 1960. - Visit of representatives of BuWeps to Langley to discuss application of variable sweep to CAP mission now in the process of industry feasibility study. BuWeps representatives: Messrs. G. L. Desmond, J. Teplitz, C. P. Baum, H. G. Sheridan, C. P. Smith, and R. I. Norford. NASA: Messrs. Stack, Gregory, Brooks, Kruszewski, Griffith, Wood, Spencer, Polhamus, Baals, Hammond, Nichols, Toll, and Swihart. Langley stressed the importance of a new turbofan engine to match the variable-sweep airframe versatility.

January 1960. - Investigation run in transonic blowdown tunnel to determine effect of sweep angle on flutter boundary of a variable-sweep wing. Sweep-angle range from 25° to 75°. The analysis of Mr. R. W. Boswinkle showed the pronounced effect of increased sweep in improving flutter boundary.

January 1960. - Tests of A3J with variable-sweep wing made at supersonic speeds in 4-foot supersonic pressure tunnel.

January - May 1960. - Messrs. Hammond and Henderson of the 7- by 10-foot tunnel staff develop high-lift and lateral control systems for variable-sweep wings (ref. 33).

PHASE V - February 1960 to September 1961
Issuance of TAC QOR Incorporating Variable-Sweep Potential Subsequent Technical Assistance and Research Support of Military and Civilian Staffs

February 12, 1960. - Tactical Air Command Headquarters (Langley) briefing of NASA staff on revised TAC mission requirements. TAC representatives: General W. W. Momyer, Col. W. L. Mitchell, Col. E. A. McGough, Col. P.D. Green, Maj. Whitmyer, Capt. L. Fisher, Mr. W. S. Aiken, Mr. T. E. Eklof, Mr. G. W. Stickle, Mr. Roche. NASA: Messrs. Stack, Gregory, Nichols, Reeder, Polhamus, Alford, Spearman, Griffith, Schade, Corson, Boswinkle, Whitcomb, Baals. General Momyer informed Langley that TAC had changed their previous VTOL requirements to provide for STOL

operation out of 3000-foot fields. A QOR had been prepared for a tactical strike aircraft embodying the potential performance of variable-sweep aircraft. Requirements called for a ferry mission capability of 3500 nautical miles and a 400/400 mission at M = 1.2 on the deck. It should be noted that this was the first Langley had heard of the requirement for supersonic capability on the deck; previous Langley studies had been for Mach number 0.9.

February 12, 1960. - Mr. Nichols suggests that sweep angles greater than 90° may be needed to meet TAC low-level supersonic requirements. The resulting configuration becomes little more than a flying fuselage. Mr. Alford builds small working model of configuration having outboard pivot and sweep angles beyond 90° showing mechanical feasibility of this approach.

February 1960. - Invention disclosures submitted to NASA patent office on outboard-pivot variable-sweep wing concept by Messrs. Alford and Polhamus.

February 23, 1960. - Langley technical briefing at Pentagon for General Haugen, Director of Development Plans, plus staff members of ARDC. USAF representatives: General Haugen, Col. J. A. Ryan, Col. J. Pelligrini, Col. H. Davis, Col. J. W. Howell, Col. W. Chapman, Col. R. Moffatt, Mr. W. Summerfield, Mr. J. Ellis, plus an additional staff of about 15 civilian and military personnel. NASA: Mr. J. Brewer, NASA Headquarters, Langley - Messrs. Stack, Swihart, Spearman, Polhamus, Foss, Robins, Champine, Baals. General Haugen requested NASA assistance to ARDC during their variable-sweep evaluation program now underway at Wright Field.

February 24, 1960. - Messrs. Alford and Spencer initiated design modifications to the Langley version of the variable-sweep A3J to provide for 113° sweep. This modification was intended to explore the use of this concept to improve the on-the-deck operation at M = 1.2. Tests were scheduled in 8-foot transonic pressure tunnel within 2 weeks and tested later at supersonic speeds (see references 36 and 37).

February 1960. - Free-flight spin tests of A3J model modified to incorporate variable-sweep wings initiated. A total of about 30 (modified) A3J drop tests were made plus about 20 additional with a general research model.

March 1, 1960. - Visit of Langley technical team to Wright Field to brief them on the structural and aerodynamic aspects of variable-sweep aircraft. WADD personnel: Mr. S. Naughton, G. Poisal, H. Rohle, I. Hinders. NASA: Messrs. Baals, Gregory, Griffith.

March 3, 1960. - Members of the Aerodynamics Committee meeting at Langley were briefed on the research status of variable-sweep aircraft. Later, individual reviews were given to the following: Mr. R. Heppe (Lockheed), Charles Frick (Convair), and Larry Greene (North American).

March 14, 1960. - "Aviation Week" publishes article entitled "USAF Drops Mach 2 VTOL for STOL." Aviation Week reports SDR 12 covering Mach 2 VTOL fighter stopped and SDR 17 for 3000-foot STOL fighter initiated within matter of a few days after TAC Headquarters made position forcibly clear. The article further noted that NASA suggests variable sweep as solution to TAC requirements.

March 15 to 18, 1960. - Assignment of Langley technical team to WADD to assist STOL task group re SDR 17. Langley team members: Messrs. Baals, Gregory, Polhamus, Foss. The Langley members served as technical advisers to Colonel K. O. Chilstrom, Project Director during initial airframe and engine industry briefings.

March 22, 1960. - Visit of Convair, Ft. Worth, representatives to Langley Research Center re variable-sweep fighter aircraft now designated TFX.

March 1960. - Test program initiated in 8-foot transonic pressure tunnel to determine dynamic stability derivatives of variable-sweep aircraft. Project engineers: Messrs. Kemp and Wiley.

March 22, 1960. - Tests of A3J configuration with 113° sweep in 8-foot transonic pressure tunnel substantiate feasibility of extreme sweep concept. Reference: NASA TM X-342.

March 25, 1960. - Visit of General Demlar and staff to Langley Research Center to review variable-sweep program.

March 27, 1960. - Return of Langley technical team to WADD, Wright Field, to provide aerodynamic assistance on SDR 17. Langley team members were Messrs. Baals, Gregory, and Alford. Preliminary WADD studies showed a 63-square-foot cross-section 76,000-pound gross weight configuration that would not meet the basic mission. Langley left drawings of its 45-square-foot configuration. WADD presentation to ARDC scheduled to be made April 11, 1960. Langley team concluded that drastic research steps would have to be taken to provide improved performance potential of WADD configuration.

March 29, 1960. - Initiation of Project "Hurry Up" by Baals to provide aerodynamic data on transonic drag characteristics of practicable representative variable-sweep configurations prior to April 11 briefing of ARDC. Program consisted of three configurations designed by Langley and designated as TAC 7, 8, 9, and a configuration (TAC 10) based on a WADD design to be tested in 8-foot transonic pressure tunnel. These configurations combined minimum cross section, optimum area ruling, proper stability, advanced propulsion systems, and practicable internal arrangement required to meet the TFX mission. A design team was formed consisting of the following staff members: Messrs. Robins, Swihart, Nichols, Baals, Alford, Hammond, Polhamus, and Pierpont. Wind-tunnel test programs headed by Messrs. Bielat and Luoma. Design, shop

construction, and wind-tunnel tests were set on a 24-hour basis, 7 days a week. The TAC 8 design is shown in figure 7.

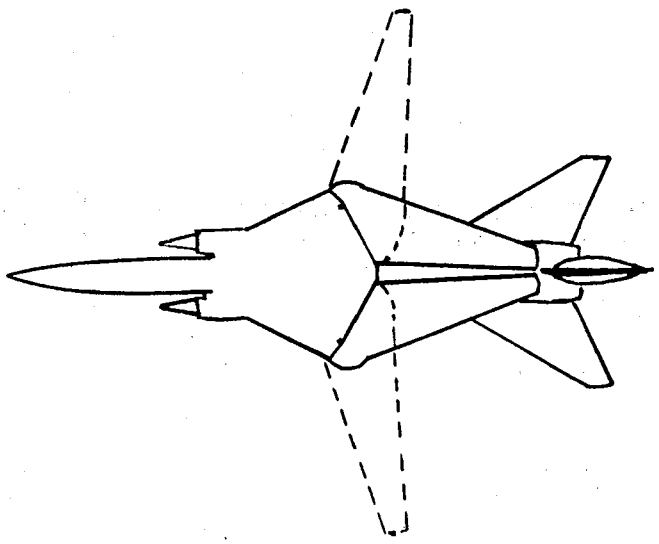

Figure 7.- TAC 8 "fully folded" wing concept.

April 4, 1960. - Aviation Week article by Sam Butts entitled "Industry Reviews Variable-Wing Potential." This article detailed the history of variable sweep and its application to the supersonic transport and the TAC fighter.

April 6, 1960. - Langley team visited WADD (Wright Field) relative to technical support of SDR 17. Langley team members were: Messrs. Stack, Gregory, Polhamus, Swihart, Robins, Champine, Reeder, and Baals. Major Whitmyer of TAC and Captain Bailey, Liaison Officer, were also in attendance. Langley submitted layouts of TAC 7, 8, 9, and 10 for WADD study, and promised the aerodynamic data by approximately April 11. It was pointed out that TAC 10 was based on the 63-square-foot WADD design. To allow more time for analysis of data, WADD agreed to delay presentation to ARDC until April 25. WADD initiated study of a light-weight vehicle having a 45-square-foot cross sectional area.

April 7, 1960. - Visit of Pratt and Whitney representatives to Langley Research Center relative to the propulsion system for TFX. Langley representatives were Messrs. Nichols, Keith, Hasel. The propulsion companies maintained a close liaison with Langley because of the recommendations of Mr. Nichols in the propulsion area, the fact that Langley had the basic airframe aerodynamics that sized the propulsion system, and the 16-foot tunnel had an effective research program on jet exits. The combination of tunnel size, transonic speed range, and hydrogen peroxide capability made this facility unique in the country.

April 11, 1960. - Project "Hurry Up" essentially completed. Data on TAC 7, 8, and 9 in hands of WADD 13 days after initiation of program. During this period of time, the four basic models were completely designed based on area-rule considerations and internal volume requirements. Scale models were built in the shops and tested at transonic speeds in the 8-foot transonic pressure tunnel and the data analyzed. The analyzed data were flown to Wright Field by Major Whitmyer of Tactical Air Command. Studies later extended to supersonic speeds. (See references 38 to 41).

April 18, 1960. - Langley five-man team visited WADD, Wright Field, to provide technical support of SDR 17. Langley team members were: Messrs. Baals, Alford, Foss, Robins, and Pierpont. Messrs. Swihart and Foss had previously computed performance of TAC 8 configuration relative to TAC mission requirements. These were submitted to WADD for their consideration. The new WADD configuration was down to 60,000 pounds and would negotiate 100-mile dash at M = 1.2 with no external fuel. Colonel Chilstrom's guess as to the schedule of TFX was as follows: May 15, proposal to industry, start evaluation in 75 days after submittal. He also indicated that NASA participation in the evaluation would be requested.

April 20, 1960. - (a) Messrs. Baals and Stack briefed Colonel Mitchell and Colonel McGough of TAC Headquarters on results of recent WADD trip; (b) McDonnell here re TAC QOR; (c) Northrop here re TAC QOR and CAP; (d) Douglas here re TAC QOR and CAP; (e) North American (Columbus) and Douglas (El Segundo) announced as winners of Navy variable-sweep study.

April 25, 1960. - Representatives of WADD (Wright Field) gave briefing to TAC Headquarters staff (General Everest) and ARDC Headquarters relative to results of their study program (SDR 17). NASA members in attendance: Messrs. Stack and Baals. Headquarters TAC members: General Everest, General Childre, General Momyer, General McNickle, Col. Green, Lt.Col. Hansen, Major Whitmyer, Dr. Bryant, and Mr. G. W. Stickle. Headquarters, USAF: General Haugen, Col. Laven. Headquarters, ARDC: General Ferguson, General Cooper, General Newton, General Kiesling, Col. Neunburg, Lt. Col. Davis, Major Curtis. Headquarters, WADD: General Holzapple, Col. Chilstrom, Major Miller, Mr. Boykin, Mr. Dillon. WADD members: Colonel Edwards, Colonel Robinson, Mr. Neil, Mr. Hodges, Mr. Chuprun. As a result of their study, WADD recommended variable sweep to meet the TAC mission requirements. This was a major recommendation for the subject SDR 17 did not specify variable sweep but the performance requirements were based on variable-sweep potential. WADD stated the requirements could be met, but at weights significantly greater than the desired 50,000-pound limit.

April 26, 1960. - Appointment of Langley project coordinators for variable-sweep military aircraft. Tactical Air Command TFX, Mr. Polhamus; Combat Air Patrol CAP, Mr. Spearman; SHAPE VTOL fighter, Mr. Alford.

April 1960 to mid-1962. - Messrs. Alford, Taylor, and Swihart develop and investigate SHAPE VTOL jet fighter series which paralleled TFX studies. Their work was a major input into NATO fighter configuration (AC/169). Mr. Alford served as Head of U. S. Design Analysis Area and U. S. Member to NATO Design Analysis Area. Messrs. R. E. Kuhn and W. B. Kemp were team members of above effort (references 42 to 46).

April 27, 1960. - Visit of BuWeps to Langley to discuss variable-sweep aircraft progress. The visitors were taken to TAC Headquarters (Colonel Green) to discuss their programs. BuWeps was impressed with TAC time schedule since TAC was jumping the paper study phase and going directly to hardware.

April 27, 1960. - Project "Hurry Up" Phase II initiated. This program provided for substantial aerodynamic refinement of the initial TAC series. Construction and tests of TAC 8a, 7b, 9a, and 10a were initiated. Model completion set for May 15 (18 days hence). Chief designer of the research layouts was Mr. A. W. Robins; Mr. Garland Wilson was responsible for the engineering design (see references 47 to 51).

April to May 1960. - Industry made 10 visits to Langley relative to variable-sweep research results.

May 1960. - Mr. W. B. Kemp made studies of pull-up response of variable-sweep aircraft which indicated that the high sweep angles desirable from the performance and gust response standpoint would not seriously limit the pull-up response during low-altitude terrain-following missions.

May 11, 1960. - Visit of Convair, Ft. Worth, representative to Langley to review variable-sweep research.

May 20, 1960. - Langley briefing of BuWeps personnel on the latest developments in variable-sweep aircraft. Subject briefing held in BuWeps Headquarters. Langley team members were Messrs. Stack, Spearman, Alford, Polhamus, Swihart, Baals, Weber, and Foss.

May 1960. - High Reynolds number wind-tunnel tests substantiate that low lift-drag ratio of early variable-sweep configuration was associated with low Reynolds number and not the broken planform (see reference 52).

June 1960. - Messrs. Hammond and Lowry develop flow control device for highly swept fixed portion of wing for use in combination with high-lift flaps. Device consisted of a leading-edge flap that was tapered in such a manner that a reduction in leading-edge sweep accompanied leading-edge flap deflection.

June 1 to 15, 1960. - Industry made nine visits to Langley to discuss latest findings in variable-sweep research.

June 18, 1960. - Mr. W. B. Kemp, Jr., presented paper on variable-sweep at AMAL (Johnsville) on low-altitude flight symposium.

June 21 to July 21, 1960. - Industry made seven visits to Langley Research Center to discuss variable-sweep research.

July 7, 1960. - Patent by Messrs. Alford and Polhamus on outboard-pivot variable-sweep concept filed in U. S. Patent Office.

July 1960. - Studies by Messrs. Kuhn and Alford clarify critical effects of horizontal-tail span relative to wing span on pitching-moment nonlinearities encountered with fully folded wings.

July 1960. - Spencer conducts systematic study in the 7- by 10-foot tunnels of the effects of geometry of the fixed portion of variable-sweep wings on the aerodynamic center shift and pitching-moment nonlinearities. The subject program provided valuable industry design information for variable-sweep configurations (see reference 53).

July 1960. - Experimental and theoretical studies of rolling derivatives under direction of Mr. Kemp provide inputs for TFX and other variable-sweep aircraft design studies. Results published in reference 54.

July 13, 1960. - Briefing by Langley technical team of Admiral Stroup, Admiral Hayward, and Captain Chambers of BuWeps at Navy Department building. Langley team consisted of Messrs. Stack, Polhamus, Spearman, Hammond, and Swihart.

August 1 to 3, 1960. - Langley team presented summary papers at IAS National Meeting on Future of Manned Military Aircraft. Papers summarized in reference 55. The following titles were pertinent:

"Aerodynamic Research Relative to Variable-Sweep Multimission Aircraft," by E. C. Polhamus and A. D. Hammond.

"Supersonic Cruise Aircraft," by D. D. Baals, C. Driver, and O. G. Morris.

"Air-Breathing Propulsion Systems for Supersonic Aircraft," by L. E. Hasel, W. E. Foss, Jr., and D. N. Bowditch.

These papers clearly delineated the attainable performance capabilities of high-performance aircraft and provided the first national forum for discussion of variable-sweep aircraft potential.

September 2 to October 12, 1960. - Industry made seven visits to Langley to discuss variable-sweep research.

September 1960. - Dynamic Loads Division and Engineering Division personnel conduct structural tests of quarter-scale model of Lockheed variable-sweep wing pivot. Results reported in reference 56.

October 13, 1960. - Invention disclosure on double-pivot variable-sweep wing submitted to U. S. Patent Office by Mr. Polhamus. This concept eliminates the leading-edge discontinuity, reduces pitch-up tendency and allows pivots to be located within fuselage while still minimizing the aerodynamic center shift.

October 1960. - Mr. Lockwood makes preliminary wind-tunnel study of application of boundary-layer control to variable-sweep wing.

October 1960. - TFX preliminary work statement sent to industry by Air Force. This was not a formal submittal but was sent in an attempt to keep industry informed of current Air Force thinking relative to potential requirements.

November 10 to 21, 1960. - Industry representatives made six visits to Langley to discuss variable-sweep research.

November 1960. - Major jet-exit program applicable to TFX initiated in the 16-foot transonic tunnel under direction of Messrs. Corson and Runckel. This program pointed out crucial importance of the jet-exit problem in the critical transonic speed range. Program coordinated with airframe and engine manufacturers (see reference 57).

November 22 to 23, 1960. - Langley team visits Pratt and Whitney Aircraft, Hartford, Conn., to discuss the propulsion systems for TFX and supersonic transport. Later, the team inspects Republic TFX mockup at Farmingdale.

December 1, 1960. - Initial meeting of Langley representatives in the Pentagon with members of the Weapons System Evaluation Group (WSEG) relative to variable-sweep aircraft. It should be noted that WSEG had been assigned the responsibility by DOD to coordinate the requirements of all military services into a Tri-Service variable-sweep aircraft. Messrs. Swihart and Foss played the key role on this rather long-drawn-out-mission analysis.

December 22, 1960. - Langley team visited WSEG relative to potential performance of variable-sweep aircraft.

December 27, 1960. - Free-flight tests of CAP II performed in the full-scale tunnel under the supervision of Messrs. Campbell and Paulson with Mr. J. Hassell as the project engineer. Initial flight tests covered the sweep-angle range from 25° to 75°. Later, the model was modified so that a maximum sweep angle of 110° could be obtained. Wing sweep was varied during flight and no special dynamic stability or control problems were encountered. This was a key experiment in the development of variable-sweep aircraft. A free-flight demonstration was made for General Everest and his staff on January 3, 1961.

January 1961. - Wind-tunnel tests substantiate the aerodynamic advantages of the double-pivot variable-sweep concept as applied to an attack-

type aircraft. Wind-tunnel tests demonstrated the same aircraft stability for the wing in the 25° sweep and 75° sweep position along with linear pitching moments.

January 30, 1961. - Visit was made to TAC Headquarters by Langley Representatives to provide a TAC STOL summary. Langley representatives were Messrs. Stack, Baals, Swihart, and Polhamus. TAC Headquarters: General Momyer, Col. Gregory, and Col. Green. The subject briefing was made at TAC Headquarters request to bring up to date with latest variable-sweep research findings. It was noted that the TFX was now known as WS-324A.

February 1961. - Secretary of Defense McNamara ordered that the requirements of USAF, Navy, and Army be combined into a Tri-Service tactical fighter.

January 9 to February 28, 1961. - Industry made 11 visits to Langley to discuss latest variable-sweep research results.

February 14, 1961. - Formal briefing by Langley team, headed by Mr. Stack, at WSEG relative to potential of variable-sweep aircraft.

March 1961. - Fixed-base simulator studies of handling qualities including roll coupling and terrain-following problems were conducted by Messrs. W. B. Kemp and L. W. McKinney. Also included in this study were piloting problems during sweep transition for typical variable-sweep fighter configuration.

April 11 to 14, 1961. - Langley technical team headed by Messrs. Swihart, Foss, Polhamus, and Robins worked with WSEG relative to evaluation and performance trade off for a tactical fighter bomber.

April 21, 1961. - Crash program initiated by Mr. Swihart to secure data on external stores for use in Big Boy/Little Boy study by WSEG. Langley technical team of Messrs. Robins, Alford, Taylor, Polhamus, G. Wilson, and Hilt performed the model layout and design studies. Mr. Bielat was project engineer on 8-foot transonic pressure tunnel programs.

March 27 to April 27, 1961. - Industry representatives made six visits to Langley relative to variable-sweep research.

April 31 to September 22, 1961. - Industry representatives made 18 visits to Langley relative to variable-sweep research.

PHASE VI - September 1961 to December 31, 1962
TFX Proposal to Industry
NASA Support of Military Services During Evaluation Period

September 1961. - Proposal sent to industry relative to design of TFX. Proposal return scheduled for December 6, 1961. Because of Navy requirements, the maximum aircraft length was set at 73 feet. TAC

modified their requirements to a 200-600 on-the-deck mission. These specification revisions had a major effect on the airframe design. The combination of restricted fuselage length and decreased distance of supersonic dash led to a low-fineness-ratio configuration of reduced supersonic performance.

November 1961. - NASA received telegram from USAF requesting six-man technical team to serve as advisers to Colonel Gayle, Project Officer in charge of TFX at Wright Field.

December 4, 1961. - First TFX evaluation started at Aeronautical Systems Division (ASD), Wright Field. NASA sent the following team of technical advisers to serve for approximately 3 weeks: Messrs. Polhamus (team captain), Robins, Foss, Keith, Hasel, and Gregory.

December 6, 1961. - TFX design proposals submitted to ASD. Contractors submitting were Boeing, General Dynamics plus Grumman, Republic plus Chance Vought, Lockheed, McDonnell plus Douglas, and North American.

December 15, 1961. - Mr. Roy Harris runs experimental wave-drag investigation in 4-foot SPT to establish low fineness ratio, minimum drag characteristics. Experimental results verified the validity of the characteristics system calculative method. The data and results phoned to Mr. Robins at Wright Field approximately December 18, 1961, to assist in TFX evaluation.

December 28, 1961. - Mr. Hammond to BuWeps Office to assist in evaluation of low-speed characteristics of TFX relative to Navy carrier compatibility.

January 10, 11, 1962. - Messrs. Polhamus and Foss returned to ASD to assist in completion of first evaluation.

January 17, 1962. - Langley team briefs British Air Marshall Hartley and staff at Langley Research Center. A complete review of variable-sweep work was presented along with discussions of the P.1127, the Swallow, and VTOL fighters.

January 31, 1962.- Boeing and General Dynamics selected as winners of Phase I evaluation. They are instructed to continue their TFX studies for approximately 60 days, to return April 1, 1962.

February 8, 1962. - Messrs. Polhamus and Robins return to Wright Field to aid in evaluation summary.

March 6, 1962. - CAP II free-flight tests made in full-scale tunnel with sweep range varied from 60° to 113°. Program directed by Mr. Hassell.

April 1 to 13, 1962. - NASA technical advisers return to ASD for second evaluation. Langley team consisted of Messrs. Polhamus, Hasel, Robins,

and Runckel. Mr. Kemp at ASD on May 11 to assist in analysis of buffet problems.

May 15, 1962 (Approximately). - Second technical evaluation submitted to Source Evaluation Board. The Navy noted deficiencies relative to the high-altitude maneuver buffet problems and carrier compatibility.

June 4, 1962. - Mr. Kemp at Wright Field to advise them relative to buffet problems. On hand for June 5 briefing.

June 5, 1962. - Contractors briefed by ASD relative to Navy deficiencies and given 10 days to indicate solutions thereto.

June 14 to 19, 1962. - NASA technical advisers returned to ASD for third evaluation. Technical team consisted of Messrs. Polhamus, Kemp, Robins, Runckel.

June 29, 1962. - NASA received letter of commendation from General Culbertson, USAF Vice Commander, ASD, to Messrs. Gregory, Robins, Polhamus, Runckel, Hasel, Foss, and Keith relative to their work on the technical evaluation of WS-324A (TFX).

July 2, 1962. - Boeing and General Dynamics sent back for 60 days' study of refinement of TFX.

August 1962. - High-lift and buffet studies using large-scale model by Mr. Hammond provide design information for TFX evaluation. Results indicate that lift coefficients in excess of three can be obtained with variable-sweep wings.

August 8, 1962. - Visit of representatives of General Dynamics and Grumman to Langley Research Center to discuss TFX inlet problems.

September 11, 1962. - A United States patent (3,053,484) on the outboard-pivot variable-sweep wing concept was issued to Messrs. W. J. Alford, Jr., and E. C. Polhamus. It is of interest to note that this patent was issued only 2 months prior to the awarding of the initial development contract leading to a possible multibillion dollar procurement program for biservice fighter aircraft which evolved from this concept. Rights for U. S. Government use of this patent have been assigned to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration.

September 10 to 14, 1962. - NASA advisers returned to ASD for technical evaluation. Team members: Messrs. Polhamus, Robins, Runckel, Hasel, Kemp.

September 24 to 28, 1962. - NASA advisers returned to ASD for final evaluation. Team members: Messrs. Polhamus, Robins, Runckel, Hasel, Kemp.

September 24, 1962. - Langley briefing of General Walter C. Sweeney, Commanding General, Tactical Air Command, at the Langley Research Center. Langley research work leading to TFX along with the future of manned aircraft reviewed by Mr. Baals.

November 24, 1962. - GENERAL DYNAMICS/GRUMMAN AWARDED CONTRACT TO DEVELOP TFX.

The following article from Air Force Magazine of January 1963 is descriptive of the contract:

"The F-111 development contract will be a multibillion dollar program and will surpass any fighter aircraft program since World War II in both numbers and dollars, the Defense Department reported in announcing award of the TFX contract to General Dynamics and its associate, Grumman, on November 24.

"The initial contract for the two-man tactical fighter, however, provides for only 22 test aircraft - 18 F111A's for the Air Force, 4 F-111B's for the Navy - at an estimated cost of $750 million. The Air Force version, at 70,000 pounds or more, will be the heaviest fighter ever built. The first plane is to be delivered within 2-1/2 years.

"Eventually, as many as 1500 F-111 may be built, at a total cost of $4 to $5 billion.

"A key feature of the F-111 will be its variable-sweep wing which will extend and retract during different phases of flight. This will make it possible for the plane to fly at Mach 2.5 speeds at altitude, yet land at only 80 knots. Its two Pratt and Whitney JTF-10A-20 turbofan engines will give the F-111 a ferry range of some 3600 nautical miles.

"DOD reported it 'will be able to fly anywhere in the world in one day.' Once there, it can operate from rough airstrips, taking off fully loaded in only 3000 feet, and required minimum ground-handling support. It will be capable of carrying all conventional and the latest nuclear weapons.

"Grumman's role in the program will be to build the Navy's F-111B version on basic airframes produced by GD's Ft. Worth Division."

December 3, 1962. - Aviation Week editorial by Robert Hotz credits NACA/NASA for the whole TFX concept. Excerpt follows:

"Underlying the whole TFX concept is one of the solid, basic technical explorations by the researchers of the old National Advisory Committee for Aeronautics (NACA) that did so much to keep this country the international leader in supersonic aircraft development. Without the fundamental research into the variable-sweep wing and the detailed development of this principle by the Langley research laboratory group headed by John Stack, the current TFX concepts of both final competitors

would have been impossible. Among Stack's able lieutenants in the Langley wind tunnels on this project were Thomas Toll, William Alford, Jr., and Edward Polhamus and later John Swihart, Donald Baals, and Mark Nichols. When Congress convenes again and begins carping over the Fiscal 1964 NASA budget for aeronautical research, the full story of the Langley contribution to the TFX program should be hammered home as an example of how these research and development investments eventually pay substantial dividends."

A three-view drawing of the F-111A (Air Force version) is presented as figure 8 and the influence of the NASA/LRC variable-sweep research is clearly evident.

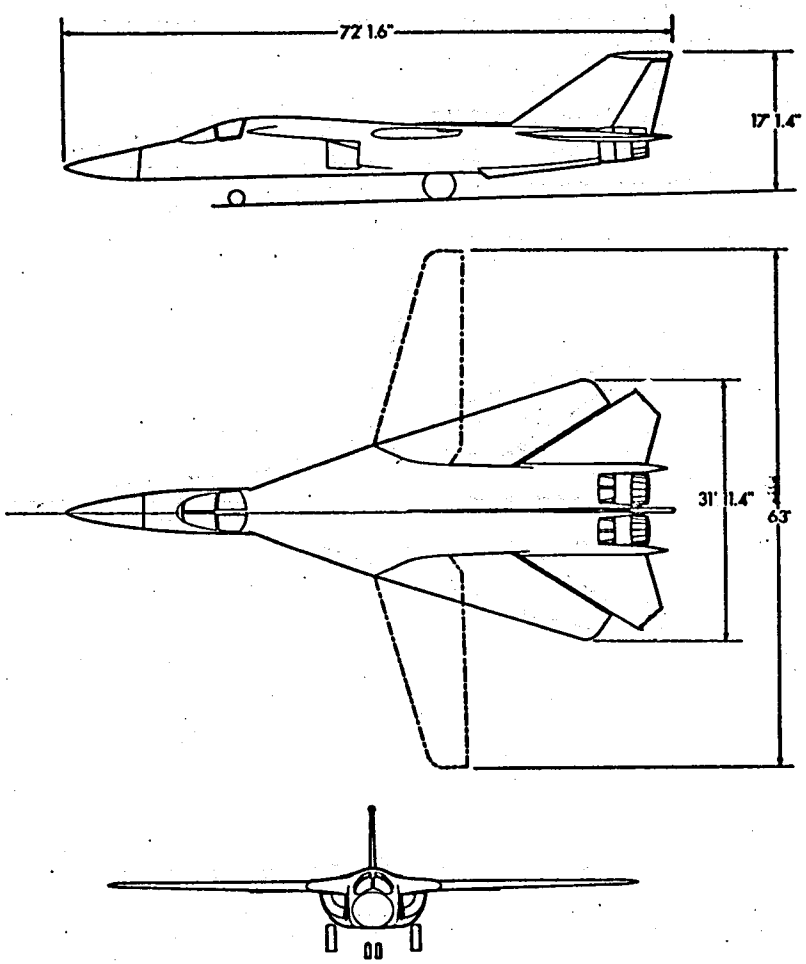

Figure 8.- Three-view drawing of F-111A.

C. SUMMARY OF LANGLEY TECHNICAL SUPPORT

1. LANGLEY RESEARCH CENTER SUMMARY OF WIND-TUNNEL SUPPORT OF VARIABLE-SWEEP FIGHTER (TFX)

Period: 1958 through 1962

	4' SPT	UPWT	7 x 10' T		8' TPT	16' TT	Total
			300 MPH	H.S.			
In-House Research	74/235	10/ 41	50/108	113/232	76/368	78/ 82	401/1066
Development:							
Republic	20/ 74			19/ 25	17/ 85	18/ 36	74/ 220
McDonnel	66/302	5/ 19				23/ 51	94/ 372
General Dynamics (Fort Worth)	19/ 70				7/ 48	14/ 32	40/ 150
North American (A3J)	13/ 43		25/ 40		8/ 49		46/ 132
General Electric						28/ 32	28/ 32
Allison						18/ 23	18/ 23
Pratt and Whitney						19/ 15	19/ 15
TOTAL	192/724	15/ 60	75/148	132/257	108/550	198/271	720/2010

NOTE: Key - Occupancy Days/Running Hours
Five occupancy days per workweek.

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14. Kolnick, Joseph J., and Kennedy, Robert M.: The Effects of Sweepback on Longitudinal Characteristics of a 1/30-Scale Semispan Model of the Bell X-5 Airplane as Determined From NACA Wing-Flow Tests at Transonic Speeds. NACA RM L52I23, November 14, 1952.

15. Silsby, Norman S., and Morris, Garland J.: Longitudinal-Control Effectiveness and Downwash Characteristics at Transonic Speeds of a 1/30-Scale Semispan Model of the Bell X-5 Airplane as Determined by the NACA Wing-Flow Method. NACA RM L52K12, January 1953.

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(b) Period from 1959 to date

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