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before the
Permanent Subcommittee on Investigations
Committee on Government Operations
United States Senate

Mr. Chairman and Members of the Committee:

I have been asked by the Senate Permanent Subcommittee
on Investigations to briefly summarize the NASA research which
led to the F-111 concept, the overall NASA program in support
of the F-111 development, the aerodynamic test results
accumulated by NASA during the 1963 portion of the development
program and any aerodynamic problems exposed by these test
results. My remarks will deal primarily with the research
and development activities of NASA's Langley Research Center.

With regard to the development of military aircraft,
the role of the Langley Research Center as well as other
NASA Centers can generally be divided into three areas:
1. Basic and applied research directed towards advancements in the state-of-the-art. The results of these research efforts are disseminated throughout the industry and other government agencies for use in the designs of new and advanced aircraft.

2. Direct support of the military services, at their request, during the development phase of a new aircraft by providing wind-tunnel tests and technical interpretation of test data required to establish aerodynamic characteristics of new aircraft, to identify problem areas and to suggest appropriate changes to correct or alleviate these problems.

3. Provide specialists to serve on review panels, consulting groups, various ad hoc committees and as advisors to source selection boards and system project offices.

This type of support has, in various degrees, been provided for nearly every military aircraft during the past 40 years.

**NASA VARIABLE-SWEEP RESEARCH**

The F-111 is the first production aircraft to employ the variable-sweep wing concept. Much of the research and development relative to variable sweep was accomplished at NASA's Langley Research Center beginning in 1947. By 1958 Langley was engaged
in research on a modified concept of the variable-sweep wing in which the pivots were located outboard of the fuselage. This approach offered a practical means of avoiding some of the problems encountered in earlier variable-sweep concepts. From 1958 to 1962 Langley was engaged in basic and applied research programs directed towards the development of design information for variable-sweep aircraft configurations. The basic research, which included both analytical and wind-tunnel studies, dealt with a wide range of aerodynamic aspects such as stability, control, and performance at subsonic, transonic, and supersonic speeds. In the applied research effort, Langley studied ways of combining the emerging variable-sweep technology with the well-known area rule concepts in order to provide good subsonic and supersonic performance in a single aircraft. Langley worked closely with the Tactical Air Command and the Bureau of Naval Weapons in order to provide information pertinent to their particular requirements and periodically reviewed new NASA research findings with the military services and industry. The results of this research was documented in 45 technical reports and distributed throughout the industry and the military services for use in preliminary design studies related to the TFX concept.
TFX SOURCE SELECTION

In November 1961, Col. Charles A. Gayle, System Program Director, requested NASA assistance in evaluating proposals from industry for the Tactical Fighter -X (TFX) beginning December 4, 1961, at Wright-Patterson Air Force Base. A number of Langley research scientists served as advisors in various technical areas during the TFX evaluations. The technical advisors' participation was completed on September 28, 1962, and the award of the contract to the General Dynamics Corporation was made on November 24, 1962.

SUMMARY OF OVERALL NASA SUPPORT OF F-111 DEVELOPMENT

After the award of the contract, the F-111 program entered the development phase, during which NASA provided a substantial test support effort at the request of the USAF. This support was primarily in the form of wind-tunnel testing directed towards two important functions: first, to establish, in detail, the aerodynamic characteristics of the aircraft over a wide range of operating conditions, and second, to evaluate configuration changes designed to alleviate any aerodynamic problems uncovered during the development testing. An indication of the level of NASA support effort can be seen
in the fact that during the first three years of development, from December 1962 until December 1965, a total of 19,933 hours of wind-tunnel occupancy time was devoted to the F-111 development support at the Langley, Ames, and Lewis Research Centers. By the end of 1968, the effort at the Langley Research Center alone had reached 22,000 hours and the total NASA wind-tunnel support had reached over 30,000 hours. This support was conducted in 18 different NASA wind-tunnel facilities and represented the most extensive wind-tunnel support every provided by the NASA or NACA, its predecessor agency, during the development of a military aircraft. By way of comparison, the Langley Research Center provided approximately 5,000 hours of wind-tunnel occupancy for the F-105.

There were several reasons for the large support effort on the F-111. First, a large amount of the testing had to be done for both Air Force and the Navy versions of the aircraft since there were appreciable differences in the fuselage nose and the outer wing panel. Second, for a sizable portion of the speed range, tunnel tests had to include various wing sweep positions which further multiplied the number of test runs required. Third, the multimission requirements made it
mandatory, in many cases, to evaluate proposed aerodynamic “fixes” designed to alleviate a problem in one area over the entire spectrum of flight requirements. Finally, some of the problems identified with the proposed design required substantial testing in order to indicate avenues for possible improvement.

In addition to the wind-tunnel tests, NASA engineers provided support in several critical design areas through independent analyses of the results and through proposals for alleviating aerodynamic problems. The NASA also provided specialists to serve on various review groups such as the F-111 Aerodynamic Consulting Group and the F-111 Nozzle Review Committee.

At this point I would like to make it clear that Langley's experience lies primarily in the area of aerodynamics rather than detailed aircraft design. While Langley specialists are well qualified to analyze aerodynamic problems and to recommend solutions, the impact of proposed aerodynamic changes must be evaluated in conjunction with other factors such as weight, cost, and operational implications. In the final analysis, the tradeoff decisions must be made by the designer and user.
1963 DEVELOPMENT SUPPORT

Having briefly summarized the breadth and magnitude of the NASA support, I would now like to describe more specifically the Langley Research Center test support during the first year of the F-111 development. The first year of the development phase of a new aircraft is usually a critical period since requirements for any major design changes must be discovered early if the contractor is to meet both the aircraft performance and delivery schedule guarantees. Problems discovered late in an aircraft development program will almost certainly result in costly retooling and retrofitting.

During an aircraft proposal stage, it is not generally possible for the various proposing contractors to conduct the extensive wind-tunnel programs required to validate every aspect of the design. Consequently, analytical and empirical methods, based on past experience, must be utilized in some areas. During the critical first year of a development, the contractor and the government work as a team to identify and correct, as soon as possible, any problems. This procedure is a well established practice and is used on every new aircraft development. Naturally, it is not unusual to discover problems requiring configuration changes once a thorough test program is underway. NASA, because of its extensive wind-tunnel facilities and the experience of its engineers, is usually an active partner with the military
services and the contractor during this important development phase.

Early Langley Support

The Langley Research Center's direct support of the F-111 development began in mid December 1962. On December 19, 1962, General Dynamics and Grumman representatives visited Langley to discuss ways of improving the F-111 wing design relative to supersonic performance, and Langley engineers made several suggestions with regard to the camber design, and wing and pivot location.

Also during December 1962, the contractor visited Langley to discuss the extent to which Langley could support the development program. After an internal assessment, Langley informed the Air Force on January 4, 1963, that the following could be conducted effectively in Langley wind-tunnel facilities.

1. Nacelle-fuselage base tests
2. High-speed (supersonic) force tests
3. Transonic speed force tests
4. Aeroelastic loads tests
5. Spin tests
6. Dynamic-stability tests
7. Free-flight model tests
8. Component flutter tests
9. Complete model flutter tests
Because of the critical effect of the transonic drag on the primary Air Force F-111 mission requirements, it was extremely important that accurate transonic drag data be obtained at an early date. Transonic testing, it should be noted, is particularly difficult and requires very careful attention to test techniques, including model size relative to the tunnel, and the minimization of model support interference. Since the contractors 1/15-scale model was too large to provide valid transonic drag data in either the Cornell Aeronautical Laboratory or the Langley 8-foot transonic pressure tunnels, or supersonic data in the Langley Unitary Plan wind tunnel, Langley recommended that a 1/24-scale model be constructed for transonic and supersonic testing. The recommended 1/24-scale model was constructed and used extensively at Langley. The contractor, however, did use the 1/15-scale model, and obtained some (invalid and optimistic) transonic drag values from tests run at the Cornell Aeronautical Laboratory which some months later was proved to be invalid and optimistic.

Wind-tunnel testing began at Langley on January 21, 1963, with some preliminary flutter trend tests of the isolated wing and tail surfaces. By May 13, 1963, over 1,100 hours of
tunnel occupancy time had been devoted to the F-111 at Langley and the 1/24-scale complete airplane force test model had been tested over a Mach number range from 0.6 to 2.5 in the Langley 8-foot transonic pressure and Unitary Plan supersonic wind tunnels.

These early Langley tests of the 1/24-scale complete model revealed major supersonic problems in the form of high drag, low maneuverability, low directional stability, and a serious transonic drag problem. Langley engineers concluded, on the basis of their tunnel data, that the high drag at transonic speeds would severely degrade the F-111's primary mission dash range and that significant design changes would be required to meet the Air Force requirement.

The low maneuver capability identified in the supersonic tunnel tests would be expected to reduce the airplane's capability to make tight, fighter-type turns and was associated primarily with wing design features, such as pivot location, and with control power. For some conditions, the maneuver capability (in terms of normal acceleration) was nearly 50 percent less than that indicated in the contractor's proposal.

The low level of directional stability at supersonic speeds is not an unusual problem to find at an early stage of aircraft development, and had it not been for the weight and drag problems on the aircraft, the solution to this problem would have been
fairly straightforward.

Following these initial studies, there was a period from late April through July 1963, during which time Langley briefed General Dynamics officials and Air Force representatives on several occasions relative to the problems, made additional studies of the problems, and explored possible methods of alleviating them. For example, on April 26, 1963, a meeting was held at Langley for the purpose of briefing high level General Dynamics representatives on the serious problems uncovered by the supersonic wind-tunnel tests. Although Langley had not, as yet, tested the inlet some concern was expressed during this meeting regarding the performance of the inlet. In this time period, an additional 1,348 hours of tunnel occupancy time was provided at Langley. During this period the 8-foot transonic pressure tunnel staff demonstrated that some transonic drag reduction could be obtained through local contour modifications, but it was apparent that major design changes would be required to correct the design problems identified through wind-tunnel tests. As an initial step, Langley recommended to the contractor that the severe afterbody closure and large base area be radically reduced. The contractor, however, insisted that the aircraft would actually exceed the primary mission requirement and did little in the way of airframe modification.

In connection with the transonic drag problem, tests of a large model were made in the Langley 16-foot transonic tunnel.
This model provided for simulation of jet effects and provided a true representation of the aircraft details in the area of the fuselage base and engine exits. Although this model experienced mechanical problems, the results did indicate the possibility of additional transonic performance problems due to adverse fuselage interference causing an increase in shroud drag and a decrease in the engine nozzle performance. These additional problems were substantiated by further tests made at Langley in 1964.

During this period, Langley suggested some wing design changes to improve F-111 maneuverability and demonstrated large improvements during tests in the Unitary Plan wind tunnel in June 1963. On June 24, 1963, Langley briefed the Air Force and the contractor on the drag, maneuverability, and directional stability problems and described the proposed wing design changes.

F-111 Aerodynamic Consulting Group

On June 20, 1963, the Langley Research Center received a letter from Col. Charles A. Gayle, F-111 System Program Director, requesting Langley participation in the newly formed F-111 Aerodynamics Consulting Group. The purpose of this group was "to review the current aircraft configuration from the aerodynamic viewpoint, and to make recommendations for necessary
corrections to the Deputy for Engineering, F-111 Engineering Office." I served as a Langley member of this group as did Mr. M. L. Spearman and, on occasion, Mr. R. P. Bielat. The group was chaired by Mr. E. V. Argabright of the F-111 System Program Office and consisted of engineers from the Air Force and the Navy in addition to the NASA members.

Two meetings of the consulting group were held during 1963 at the General Dynamics Plant at Fort Worth, Texas. The first meeting was held July 30 through August 2, 1963, and the second, September 30 through October 2, 1963. The minutes of the meetings containing the group's findings are contained in Air Force documents which have recently been declassified. The F-111 Aerodynamics Consulting Group shared Langley's concern in the problem areas discussed above and concluded that the contractor's performance figures were optimistic and that Langley tunnel tests and roughness drag analysis clearly indicated that actual aircraft performance would be well below specified contractual requirements.
August-December 1963 Test Period

The Langley wind-tunnel support from August through December 1963 brought the total for 1963 to 4,839 occupancy hours. This additional testing extended the development support into the areas of dynamic stability, tail flutter, and inlet, as well as additional transonic drag and supersonic stability tests. The dynamic-stability testing during this period included tests in subsonic, transonic, and supersonic tunnels. No obvious problems were encountered. The tail flutter tests covered the subsonic and transonic speed ranges and were for the purpose of establishing the extent to which the horizontal-tail flutter speed might be affected by the presence of the fully sweptback wing. The results indicated only minor effects.

During this period, some inlet tests were made in the Langley 16-foot transonic tunnel. The results indicated relatively high flow distortions, but no quantitative evaluation could be made at Langley since a quantitative evaluation of distortion effects would require special studies by the engine manufacturer with regard to engine sensitivity to flow distortion. The data were, of course, transmitted to the contractor and the Air Force.

There were several additional developments with regard to the transonic drag problem. Langley engineers did demonstrate
modifications which would provide some modest improvements. However, some fuselage changes made by the contractor to improve the flow field at the inlets caused an additional increase in transonic drag. Finally, some special tests at Langley demonstrated conclusively that the low drag measured in contractor tests runs at the Cornell Aeronautical Laboratory was invalid due to various combinations of excessive model sizes and a serious support interference effect. Further tests at Cornell and Ames also confirmed the F-111 drag problem.

SUMMARY

In summary, therefore, during the first year of the F-111 development program, extensive wind-tunnel tests in support of the aircraft were conducted at the Langley Research Center. During the course of this extensive development support effort provided by Langley, many of the normally expected problems in military aircraft development were discovered and solved. However, by June of 1963 it had become apparent to the Langley engineers that:

1. The F-111 design would not meet the Air Force specification for the primary mission dash requirement.
2. The airplane would not develop the maneuver capability at supersonic speeds specified by the contractor.
3. Its directional stability was extremely low at supersonic speeds. Moreover, the primary mission shortcoming was associated with a high drag level which required significant design changes to solve.