Flight Testing the F-12 Series Aircraft

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The airplanes were tested largely within the framework of military specifications applicable in the 1965-1966 time period and did extremely well in meeting the published requirements. The wide range of speeds and altitudes made the normal design flight profile the most logical performance testing area, with limited excursions for off-design checks. Stability and control tests included enough without stability augmentation operative to assure adequate definition of basic aerodynamic coefficients. Structural flight tests were at critical design speeds and weights. Safety chase aircraft information at high supersonic Mach numbers provided interesting results.

I. Introduction

THE flight testing of Mach 3.0+ aircraft is impressively different from slower vehicles, principally due to the test environment. The low density of the atmosphere, high speed and high stagnation temperatures in the primary flight regime result in stringent demands on flying qualities and temperature tolerance and conditioning. However, the published requirements to be met were not greatly different from those of slower speed aircraft, nor were test techniques. Performance, stability and control, and structural tests were flown within the rules framework of military specifications and related documents, just the same as any new aircraft entering the inventory. Although the aircraft was optimized for the very-high very-fast range of operation and not to meet specification requirements, it did extremely well in meeting these standard requirements. For example, there was little difficulty encountered in the cold weather tests in the big hangar at Eglin AFB. It turned out that, although the airplane was built to withstand very high temperatures, it withstood very low temperatures almost equally well, with only minor procedural changes.

Three aircraft were used in the Category I tests for a given model, one highly instrumented for aircraft parameters and two largely for payload systems test. The flying rate for one model is shown in Fig. 1. It is typical of those aircraft which advance the frontiers of aviation, that during the initial phase the flying rate is low while early problems are found and fixed, then picks up and remains at a much higher rate for the program duration. One model flew to 1.5 Mach number on its first flight. A not-to-scale altitude-speed envelope is shown in Fig. 2. This is to show envelope clearance in Category I, sometimes to a greater degree than intended.

As a step preparatory to flight, the ejection system was qualified. Both ground and inflight tests were made, using a two-seated F-106 for the flight phase. The "skunk works" philosophy has been to use pressurized clothing for individual protection instead of capsules. There has been an excellent success rate with such protection, including one ejection at high Mach. The pressure suit also provided excellent protection in cases of cockpit depressurization at high altitude. There is substantial cockpit depressurization when both inlets are unstarted, resulting in virtually full inflation of the suit. With only one inlet unstarted the pressurization is much less severe.

II. Performance

In the area of performance testing, as is standard procedure, airspeed was calibrated early in the program. The high Mach points were checked using ground radar tracking and atmospheric surveys as outlined in some earlier NACA reports.[1,2]

In general, the climb schedule calls for climbing and accelerating simultaneously until cruise conditions are attained. This best method was determined using test climbs, verified by check climbs. Level accelerations were not practical for our large ranges of speeds, high acceleration, and other aircraft characteristics. We also found that high equivalent airspeeds (EAS) were best for climbs. (Equivalent airspeed is defined as the product of true airspeed and the square root of the density ratio.)

The wide range of speeds and altitudes and the dynamic nature of vehicle performance influenced all other normal performance tests. We stayed near the normal design flight profile as the most logical performance testing area, and modified the profile if test results showed advantages could be

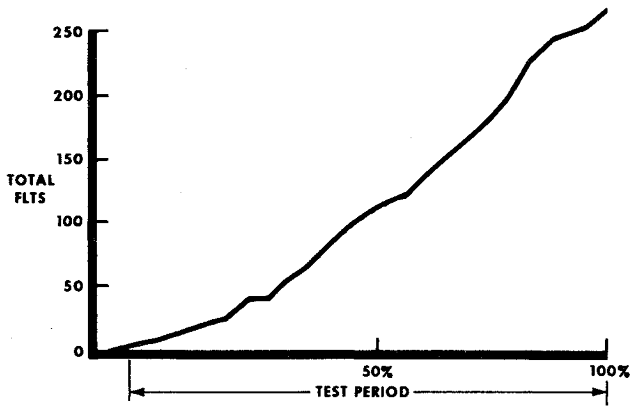

Fig. 1 Category 1 flights.

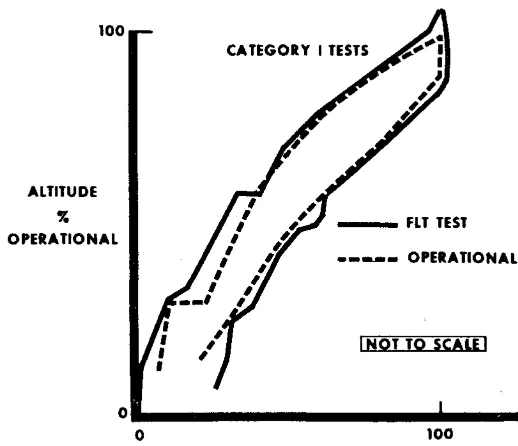

Fig. 2 Test envelope.

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Index category: Aircraft Testing.

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Table 1 Speed record[a]

EVENT		RECORD
SUSTAINED ALTITUDE	80,258 FT.	WORLD
	SAME	CLASS
SPEED:		
15/25 Km CLOSED COURSE	2,070 MPH.	WORLD
	SAME	CLASS
* 500 Km CLOSED COURSE	1,643 MPH.	CLASS
* 1000 Km CLOSED COURSE 2000 Kg PAYLOAD	1,689 MPH.	WORLD
	SAME	CLASS
1000 Kg PAYLOAD	1,689 MPH.	WORLD
	SAME	CLASS

[a]Established 4 world and 5 international class records in one day on May 1, 1965. These records have since been captured by the E-266 in Oct. 1967.

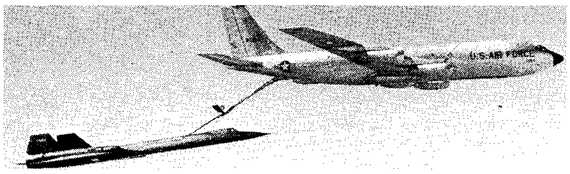

Fig. 3 Refuel picture.

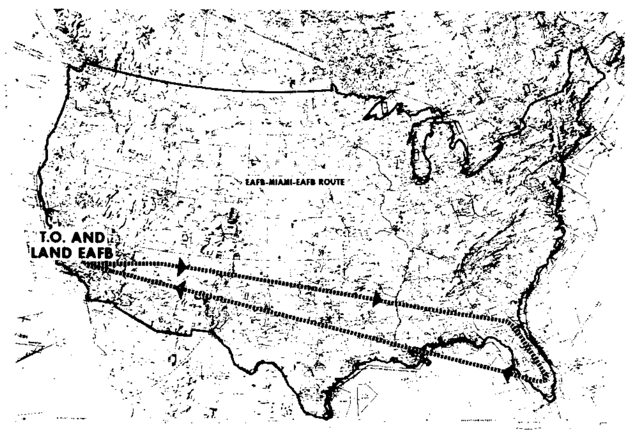

Fig. 4 Map of the United States.

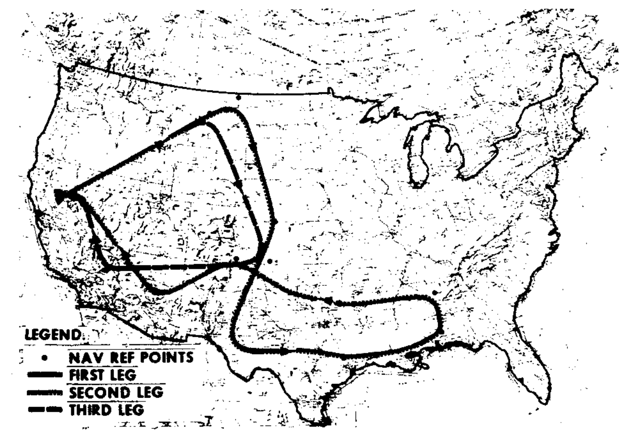

Fig. 5 Mackay trophy route.

obtained by such action. A limited number of excursions away from the profile were made to check off-design performance for training and emergency condition simulations. Under typical mission conditions there is no reason to vary excessively from the standard profile as determined by design and flight test.

While in this performance discussion, it should be mentioned that during the test period Colonel R. Stephens of the Air Force flew an F-12 to new world records for speed and altitude and Major W. Daniel obtained new records for the 500 and 100 km closed course (Table 1). This occurred on May 1, 1965 and the speed and altitude records still stand, although the Russian Foxbat has beaten and now holds closed course records for 500 and 100 km.

Range of the aircraft cannot be told here. However, it does have a refueling capability (Fig. 3). Aerial refueling is easy and routine and thousands have since been accomplished. During the test program we simulated an emergency case where no locking to the tanker was possible. The probe was held in place by the receiver pushing against it. Many thousand pounds of fuel were transferred in this test.

Figure 4 shows a local flight from Edwards AFB on one of the standard routes for aircraft and systems tests. Range missions should verify results. Whether this mission was refueled is not specified, but the route was under three hours. A crew of the 9th SRW, Lt. Colonels Estes and Vick, was awarded the Mackay trophy for 1971 for a demonstration flight which covered over 15,000 miles in 10½ hr. (Fig. 5). This was equivalent to a nonstop flight from San Francisco to Paris and return.

Another performance test which differed from the ordinary was in determining stopping distances after landing on grooved runways, with and without drag chute, in addition to the standard wet and dry runway tests. Figure 6 shows a closeup of a grooved runway. The F-12-type aircraft uses smooth tires. Tests found that grooving reduces appreciably the landing distance in event of wet runways. Our findings added impetus to runway grooving to the extent that such treatment has spread to include many other airports as well as those used by F-12 aircraft. This chart (Fig. 7) shows the relative improvement obtained.

III. Stability and Control

Stability and control testing was as much in accord with Specification MIL-F-8785 as possible. Figure 8 is a conventional plot of static longitudinal stability. What is not con-

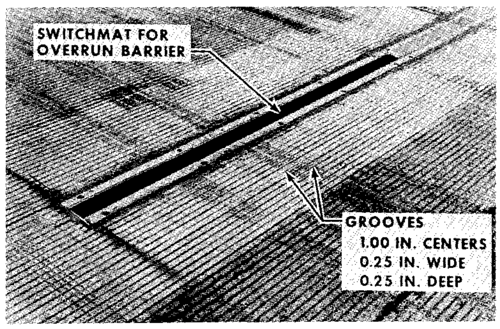

Fig. 6 Grooved runway.

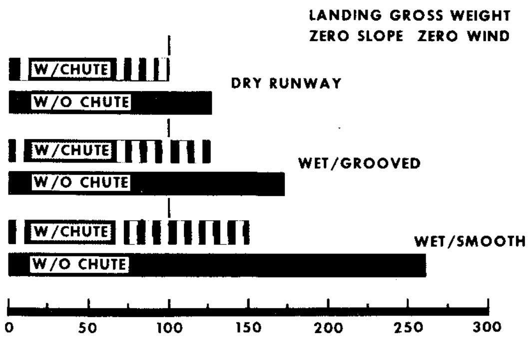

Fig. 7 Stopping distance.

ventional is that this test required about 400 miles distance over the ground to get the speed change for the measurements. The same smooth techniques used at lower speeds are essential and require time to accomplish. Minimum control speeds were found to be below final approach speed.

The stability augmentation system (SAS) in this aircraft design for full-time augmentation in flight required an increased number of tests, since we had to check characteristics with and without augmentation and with partial engagement. All SAS-on tests were well damped. All basic aerodynamic parameters were defined without the dampers operating as well as safety of flight verification for critical conditions. In one safety demonstration, the pilot turned off the SAS at full speed and decelerated to subsonic conditions in that condition despite having inlet unstarts in the vicinity of Mach 2.

To do the SAS-off tests as safely as possible, there was a cutout switch on the stick similar to a deadman throttle: depress and hold the spring loaded switch down for SAS-off maneuvers, and release for recall.

The next two illustrations are used together to demonstrate an unpredicted result. The first (Fig. 9) shows adequate directional control power at a representative angle of attack for positive directional control throughout the envelope. This was verified during the test program, as shown by the test points plotted and also usually is accompanied by good damping at lower altitudes. Figure 10 shows a dynamic directional test early in the program at approximately Mach 3. This was SAS-off. The apparent divergence was not a lack of airframe stability or damping, but the small directional damping at the high altitude was overcome by stronger spike pumping effects at that intermediate Mach (slide off) and low density. With the spikes manually fixed, normal convergence resulted.

Since the discussion has come to spike effects on aircraft control, it is time to describe unstarts (Fig. 11). The aircraft primary motion when these occur is sudden yaw about the vertical axis. And the motion is quite violent, with violence directly commensurate with dynamic pressure. Helmets have hit the canopy hard at times. The higher the dynamic pressure, the greater the violence. We can fly over a substantial range of dynamic pressure at any given Mach number, with dynamic pressure inversely proportional to altitude at the selected Mach. The onset of an unstart is not predictable unless they are intentionally excited. They are quite impressive physically. They result from an equipment malfunction or failure and the incidence was greatly reduced during the test program as component thermal reliability was improved. They still occur occasionally and, although most restarts are automatically energized, the pilot training program still includes training in procedures for recovery and aircraft control.

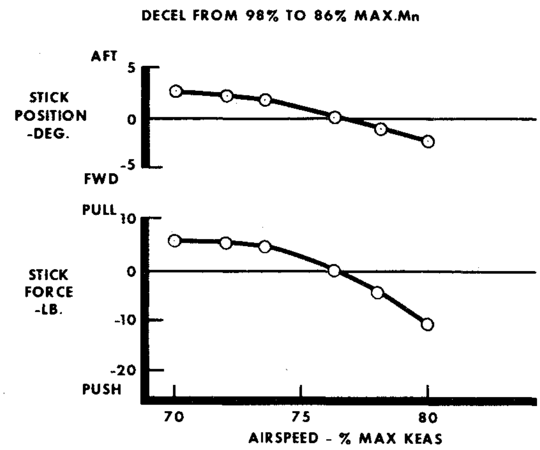

Fig. 8 Static longitudinal stability.

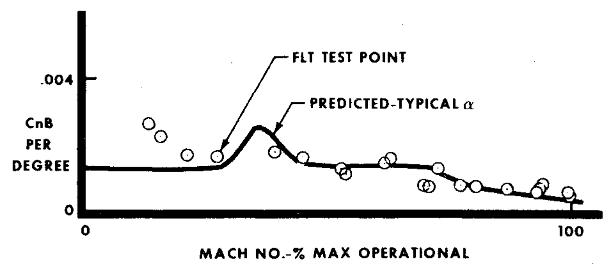

Fig. 9 Yawing moment due to sideslip.

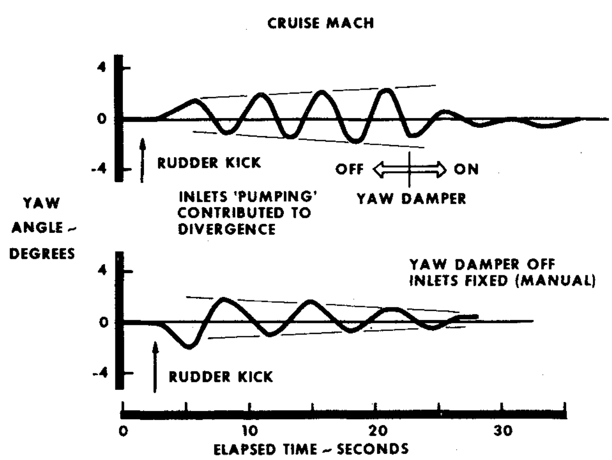

Fig. 10 Dynamic directional stability.

IV. Structural

Structural flight tests were done at critical structural design weights and speeds. Test points are shown in Fig. 12. Specifications MIL-S-5711 and MIL-A-8861 formed the basis of the required tests. Safety chase at high Mach number was used most of the time in normal formation except during test maneuvers. In Century Series Fighters, early tests measured up to 60% of limit vertical stabilizer load at normal formation separtion when passing through the shock wave of the lead aircraft, largely due to yawing moment created. Such was not the case in our flying. Instrumentation measurements could detect no forces when flying through the shock, nor could the passage be positively felt in the control system except during crossover when directly behind and below there was a nose-up tendency which required countering. The formation itself was just the same as formation at lower speeds with normal aircraft visibility at short to medium ranges. If separation became extended it was slightly more difficult to see.

V. Test Instrumentation

Instrumentation transducers used for the various tests required careful selection due to the elevated temperature environment. The recording mediums were conventional oscillograph and photographic methods. Both were thoroughly proven, lowest cost methods.

The transducers were often employed with water or ice jackets and shielding, or remotely located if parameters and accuracy permitted. Principally, devices used were synchro transmitters for angular rotation, and linear voltage differential transducers for linear positions and pressure measurements. These devices performed satisfactorily at temperatures exceeding 750° F. The largest problem was structural loads measurement due to bonding, temperature drift tendencies, hysteresis, and calibration of the strain gages. The bonding was cured by flying at increasingly hot Mach numbers until uniform curing was assured.

VI. Other Tests

As a system development item, high drag chute reliability is desirable, to help stop in event of a refused takeoff at high weight. The drag chute is also used routinely for all landings.

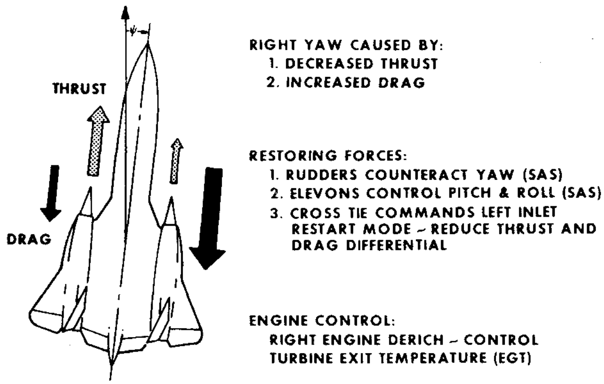

Fig. 11 Unstart.

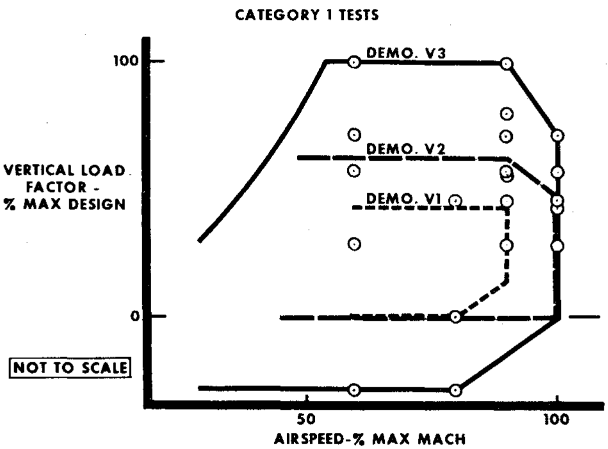

Fig. 12 V-N diagram.

Since takeoff speeds are around 200 knots, this requirement became stringent at the maximum gross-weight conditions. To provide a source of test information, we would accomplish landings at high speeds to stimulate conditions for the refused takeoff. If the chute held we would taxi in; if it failed, go around. We went around quite a few times. Our stress analysis people would take each failure and examine the failure mode, add strength where needed, and retest. We achieved extremely reliable operation, well above 99%, which has now been demonstrated thousands of times.

Engine failure at high Mach was found to give a very rough ride down to subsonic speeds using the normal method of moving the spikes forward and opening the bypass doors. So a decel was made from cruise Mach with engine off and the spike moved full aft. This provided a smooth ride, and became an accepted procedure for such an occasion. One of the related capabilities is shown in this supersonic missile firing. A sizeable program was conducted in this area with a high success rate, over both land and water.

In all the performance, stability and control, structural, and payload testing performed, the aircraft met operational requirements and demonstrated that the capabilities could be used routinely on a sustained basis. This has been subsequently verified by the Air Force air and ground crews in normal service.

VII. Conclusion

The difference between testing this type airplane and its predecessors, as stated earlier, is principally due to the test environment. Heat effects required specialized instrumentation mounted to reduce heat effects or artifically cooled. The range of the instrumentation is also larger. The large range of speed and atmospheric densities, together with aircraft characteristics, resulting in flight control augmentation for flying qualities on all axes at all times, a more severe and sophisticated requirement than previous aircraft had experienced. The tests of flying qualities therefore covered a broader spectrum, not only of speeds and altitudes, but of modes of augmentation. Structural testing for this airplane was conventional, flown according to specification requirements within the limits of the structural design and the control system authority.

It would be inappropriate to talk so much about supersonic activities without some words about sonic booms and the impressions they make on the public. First, as is evident, the fineness ratio of the F-12 type aircraft is high, giving a mild shock wave to the ground from normal cruise altitudes. At low altitudes, the shock to the ground is much stronger. Urban areas with uneven terrain are more susceptible to stronger concentrations of shock waves. We flew over San Francisco twice and got many strong complaints. Cities like Phoenix, Fort Worth and Chicago resulted in far fewer and less severe complaints, even with a high incidence of flyovers. Second, individuals have different attitudes toward sonic booms. Some people don't mind and some do. A strong public antiboom sentiment can develop if they are hit frequently with strong booms.

References

[1]Huston, W. B., "Accuracy of Airspeed Measurements and Flight Calibration Procedures," NACA Rept. 919, 1948.

[2]Gracey, W., "Measurement of Static Pressure on Aircraft," NACA Rept. 1364, 1958.