# NASA F-106B AIRPLANE
RETIREMENT CEREMONY

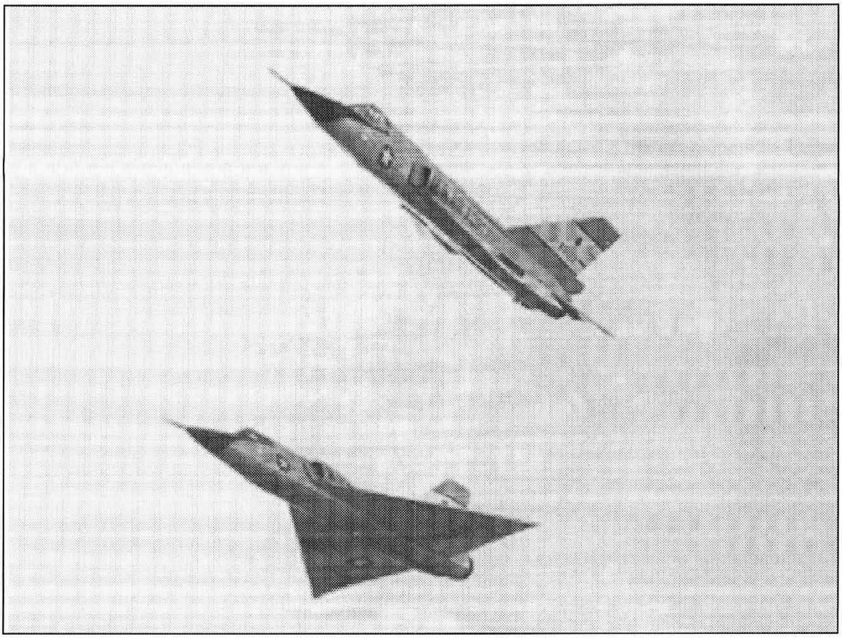
Langley Research Center
May 17, 1991

USAF 57-2516

NASA 616

NASA 816

*This souvenir booklet is issued by the NASA Langley Research Center in conjunction with the retirement of NASA 816.*



## AN INTRODUCTION TO THE F-106

*The F-106 Delta Dart is a supersonic, all-weather interceptor. Originally envisioned as an advanced derivative of the F-102A Delta Dagger and given the designation F-102B, the "Ultimate Interceptor", as it was known, entailed such extensive changes that in June, 1956, the designation was changed to F-106. The single-seat F-106A first flew on December 26, 1956, entered operational service in May, 1959, and achieved initial operational capability in October, 1959.*

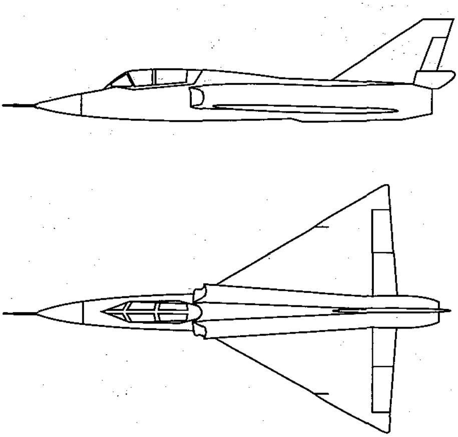
*The two-seat F-106B made its maiden flight on April 9, 1958, and achieved initial operational capability in July, 1960. It retained the full combat capability of the F-106A.*

*On December 15, 1959, Colonel Joe Rogers piloted an F-106A to a world speed record of 1,525.695 mph (Mach 2.41). The F-106 still holds the record as the fastest single-engine turbojet-powered airplane.*

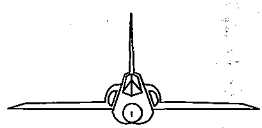
*The Delta Dart was manufactured by the Convair Division of General Dynamics. It was powered by a single Pratt and Whitney J75-P-17 turbojet engine of*

*16,100 lb thrust (24,500 lb thrust with afterburning). Developed as an interceptor, its mission was to shoot down other aircraft, bombers in particular. The F-106 served with the USAF Air Defense Command, Tactical Air Command, and Air National Guard. A total of 277 F-106A and 63 F-106B airplanes were built at a cost of about $5 million each.*

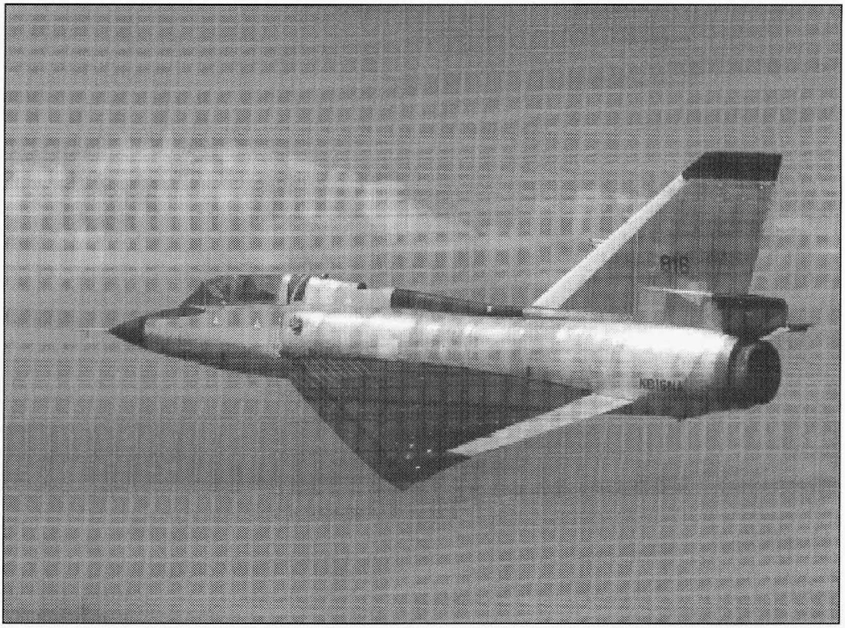
*The Air Force has retired the F-106 from active squadron service after a long and distinguished career. Currently, the aircraft are used as drone targets during air-to-air missile training for our current generation of fighter aircraft.*



| | |
|---|---|
| *Span* | *38′ 3.5″* |
| *Length* | *70′ 8″* |
| *Sweep* | *60°* |
| *Weight* | *35,000 lb* |
| *Max speed* | *1500+ mph* |
| *Ceiling* | *55,000 ft* |
| *Range* | *1100 mi* |



*Design of both the F-106 and its predecessor, the F-102A, is closely linked to Langley and the development of "area ruling" in the early 1950's. Area ruling, which reduces drag at transonic speeds, is reflected in the "coke bottle" or "wasp waist" shaped fuselage of the F-106. Area ruling enabled the YF-102A to easily exceed the speed of sound and subsequently led to the go-ahead for the advanced version which became the F-106. The significance of area ruling was recognized by the National Aeronautic Association which awarded the originator, Richard T. Whitcomb, its prestigious Collier Trophy for the greatest achievement in aeronautics in 1955.*

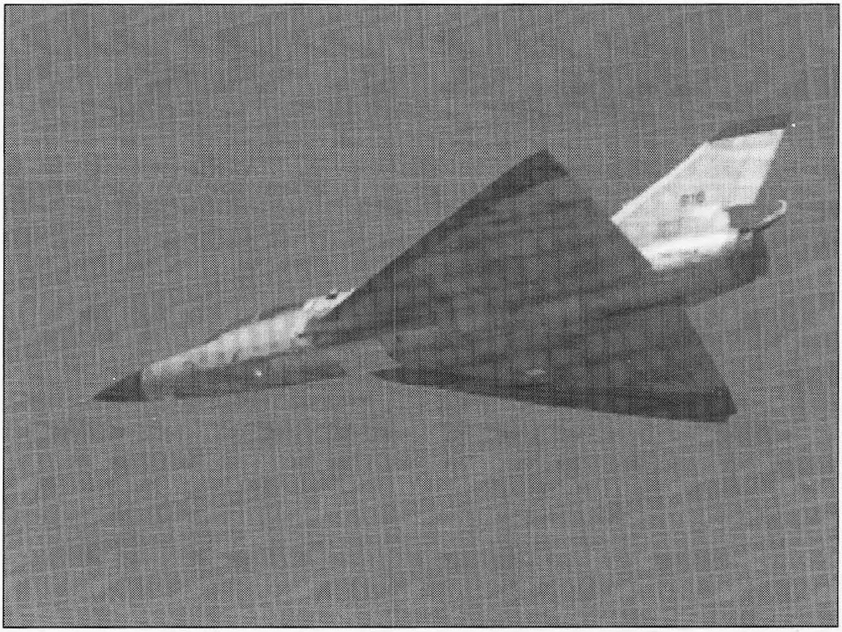


## OUR DISTINGUISHED RETIREE

The F-106B aircraft to be retired today is the last piloted aircraft of its type in the world. It has had an extremely unique history, having served as the test vehicle for a series of important USAF and NASA research projects.

During more than 30 years of service, from roll-out in 1958 to retirement in 1991, this particular F-106B has been utilized for:

- Research and development testing for the U. S. Air Force
- Research in support of the U. S. Supersonic Transport Program of the 1970's at the NASA Lewis Research Center
- Research in the Storm Hazards Program and the Vortex Flap Program at the NASA Langley Research Center.



F-106B 57-2516 in its Air Force markings

## THE AIR FORCE YEARS 1959 - 1966

Manufactured by Convair at San Diego, CA, F-106B serial number 57-2516 was completed on September 4, 1958, and was delivered to the Air Force on February 27, 1959. Initially, "516" was posted to the Air Research and Development Command, Air Force Flight Test Center, Edwards Air Force Base, CA. This was the first of many test and evaluation assignments, as "516" spent its Air Force years primarily as a Logistics Command test asset for evaluation of new modifications before they went to the fleet.

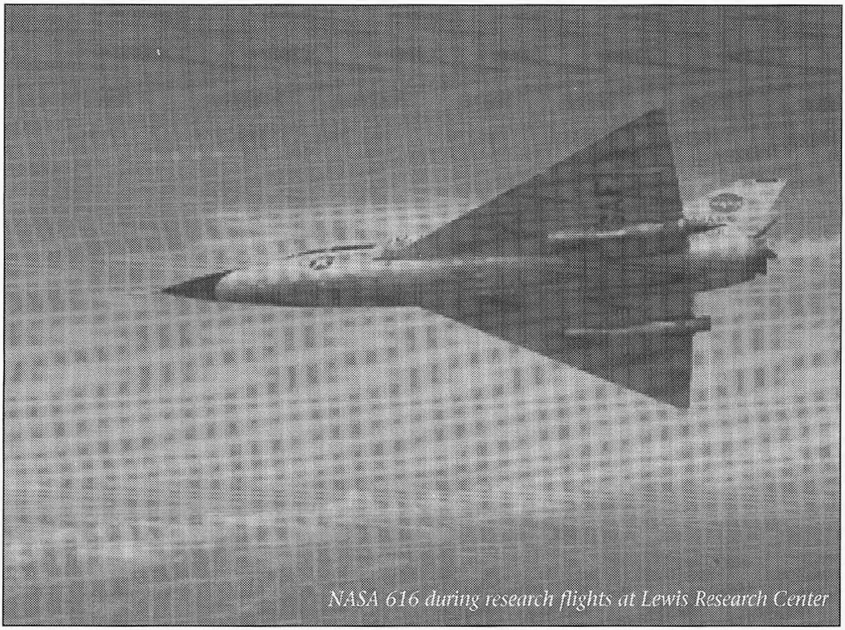
On May 18, 1959, "516" returned to Convair for work. Subsequently, on February 23, 1960, it was assigned to Air Materiel Command, Sacramento Air Materiel Area (SMAMA), McClellan AFB, CA. On June 1, 1960, "516" was assigned to Air Defense Command, 84th Fighter Group, Geiger Field, Spokane, WA, but was transferred back to SMAMA at McClellan AFB on June 4, 1960.

On March 3, 1963, "516" was assigned to Air Defense Command, 4756th Air Defense Wing, Tyndall AFB, FL, and on May 6, 1963, the airplane was transferred to Air Force Logistics Command, SMAMA at McClellan AFB. The airplane was sent to General Dynamics, Fort Worth, TX, on April 3, 1964, and remained there until sent to the 6583rd OMS, Holloman AFB, NM, on February 27, 1965.

The airplane returned to General Dynamics, Fort Worth, TX, on April 1, 1965, for test support and was redesignated JF-106B on April 29, 1965. Following this service, on December 22, 1965, "516" returned to SMAMA at McClellan AFB. On March 16, 1966, the airplane was redesignated F-106B, and on April 7, 1966, it returned to General Dynamics, Fort Worth, TX, for test support.

F-106B "516" was transferred on October 31, 1966, to the NASA Lewis Research Center, Cleveland, OH, and was assigned NASA tail number 616. On May 31, 1967, "516" was redesignated NF-106B. The Air Force dropped "516" from its inventory on February 27, 1970, due to transfer to a non-Air Force activity.

*F-106B 57-2516 on its arrival at NASA Lewis from Carswell AFB, TX, in 1966*



*NASA 616 during research flights at Lewis Research Center*

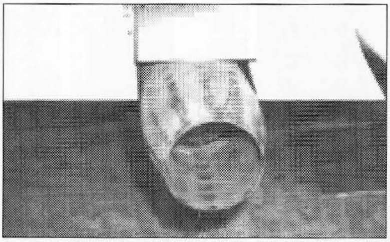
## THE LEWIS YEARS 1966 - 1979

As part of a broad program in airbreathing propulsion, the NASA Lewis Research Center investigated the effects of the airframe flow field on the performance of propulsion systems appropriate for use at supersonic speeds. One of the more desirable locations for the propulsion system of airplanes which must cruise efficiently at both subsonic and supersonic speeds is in aft-mounted underwing nacelles. To study installation effects in the high subsonic and transonic speed range, NASA 616 was modified to carry two 25 inch diameter underwing nacelles containing J85-GE-13 afterburning turbojet engines. This installation enabled investigation of complete propulsion systems using larger and more complex hardware with more complete instrumentation than was possible with wind-tunnel models. The F-106 was selected for the research program because its delta wing planform was representative of those proposed for supersonic transports and because of its good performance capability and high load-carrying capacity. The F-106B two-seat version was perfect for the task since it could carry a second crewmember to operate the research engines and record data.

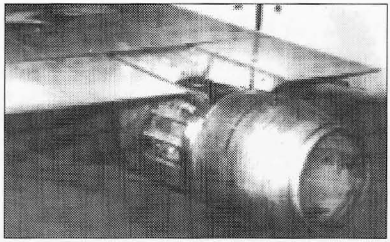
Modifications included addition of underwing nacelles with elevon cutouts to clear the nacelles, changes to the fuel system, installation of a fuel tank in the aft missile bay for A-1 fuel to power the J85 engines, removal of the MA-1 fire-control system, installation of communications and navigation equipment, installation of a research instrumentation system, and replacement of the standard pitot-static boom with a test boom incorporating pitch and yaw vanes. The nacelles included interfaces at both front and rear for various types of inlets and nozzles to be tested on the research (left) nacelle. The reference (right) nacelle was normally flown with a reference nozzle to provide a constant base for thrust comparisons with the research nacelle.


*NASA 616 with J85 engines under each wing panel*

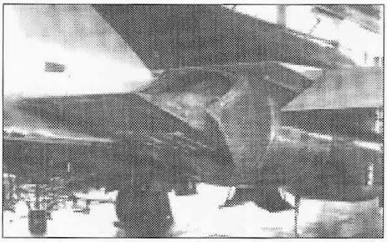
The first flight of "616" modified for propulsion system research was on June 3, 1968. The original objectives of the flight program were expanded to include investigations of scale effects on boattail drag, inlet variations, and forward speed effects on jet noise. The total program encompassed over 300 flights and addressed numerous inlet and nozzle configurations. Variable flap ejector, conical-plug, auxiliary inlet ejector, wedge, and noise suppression nozzles were tested.
Vertical wedge, horizontal wedge, and spike inlets were also tested.



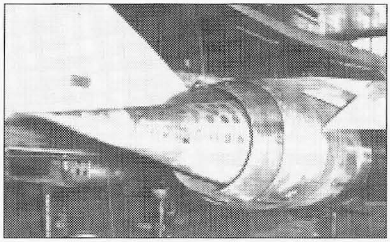
*Variable Flap Ejector Nozzle*



*Auxiliary Inlet Ejector Nozzle*



*Wedge Nozzle*

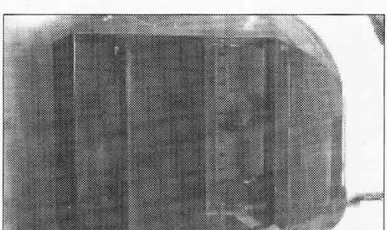


*Plug Nozzle*

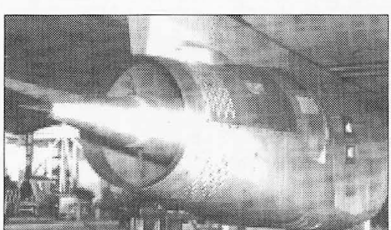
*Supersonic cruise nozzles flown on NASA 616*

Nozzles mounted in aft underwing nacelles were shown to have installation effects which decrease boattail drag at high subsonic speeds. Comparisons between flight and model tests showed a sizeable scale effect on the drag of some nozzle configurations, with drag being lower at flight conditions.

The noise program was initiated to study the effects of the external air flowing over the nozzles on the noise and thrust performance at take-off conditions. NASA 616 was found to be uniquely suited for flyover noise measurements.



*Vertical Wedge Inlet*

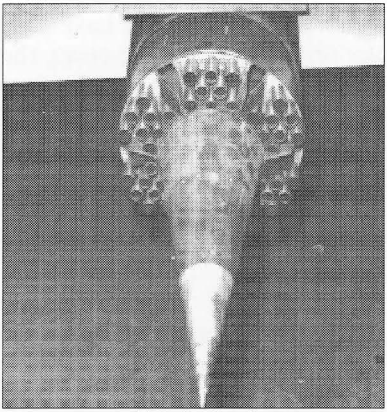


*Spike Inlet*

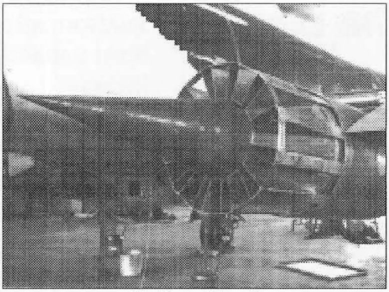
*Inlet configurations tested on NASA 616*

The external flow environment was typical of supersonic cruise aircraft and exhaust nozzles could be easily changed. For noise measurements, flyovers were made at a height of 200 ft. and a Mach number of 0.4 with the main engine at idle. One J85 engine was windmilled and the other was operated at a range of power settings up to maximum afterburning. In general, noise levels at take-off flight velocity were shown to be higher than predicted from static data.

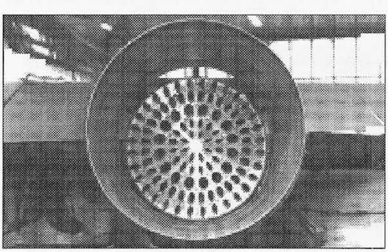
At the conclusion of the work at Lewis, NASA 616 was turned over to NASA's Dryden Flight Research Center and was redesignated NASA 816. Research needs, however, resulted in Dryden's airplane being transferred directly from Lewis to the NASA Langley Research Center in Hampton, VA. The transfer to Langley took place on January 29, 1979.



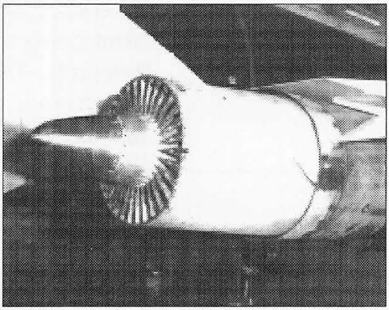
*48 Tube Nozzle*



*12 Chute Nozzle*



*104 Tube Nozzle with Acoustic Shroud*



*32 Spoke Nozzle*

*Noise suppression nozzles tested on NASA 616*


*NASA 816 during Storm Hazards Program at Langley in 1982.*
*Note paint "spots" that were applied to the aircraft to denote lightning attachment points*

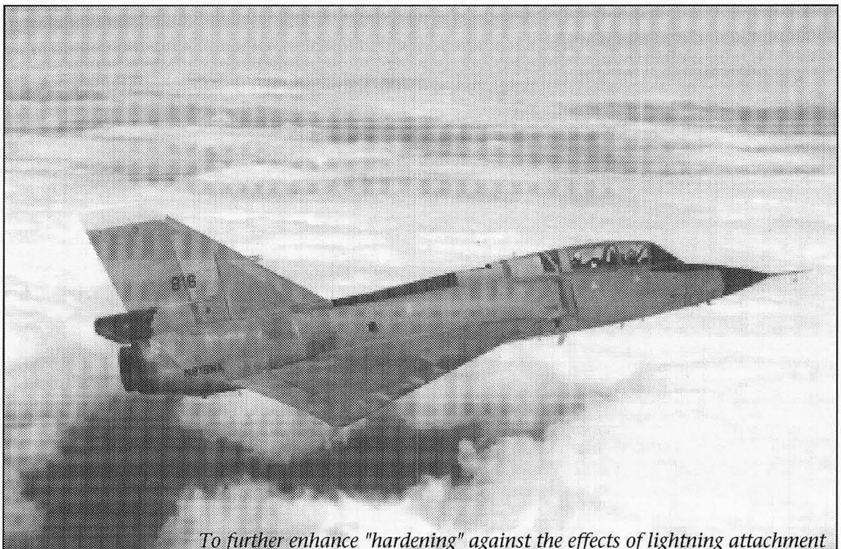
## THE LANGLEY YEARS 1979 - 1991

*Storm Hazards Research 1979 -1986*

Traditionally, aircraft lightning strikes have not been a major aviation safety issue. However, the increasing use of composite materials and the use of digital avionics for flight critical systems will require that more specific lightning protection measures be incorporated in the design of such aircraft in order to maintain the excellent lightning safety record presently enjoyed by transport aircraft.

To address these issues, NASA 816 was transferred from Lewis to Langley for use in Storm Hazards Research. This program was designed to provide data from in-flight measurements of direct-strike lightning characteristics to assess the direct-strike lightning threat to aircraft with digital systems and composite structures. The program also provided data for correlation of the relative location and strength of the various severe storm hazards of precipitation, wind, turbulence , and lightning during the life cycle of severe storms.

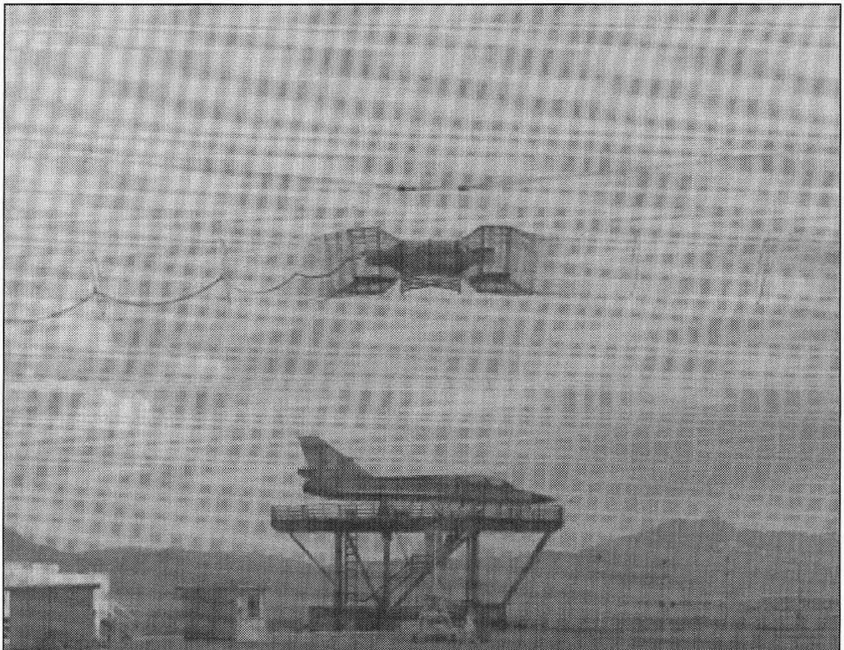
NASA 816 was "hardened" against the effects of lightning by installing surge protection devices and electromagnetic shielding of electrical power and avionic systems, and using JP-5 fuel in lieu of the more volatile JP-4. Electromagnetic sensors installed throughout the airplane and a shielded recording system in the weapons bay recorded the electromagnetic waveforms from direct lightning strikes and nearby flashes. Several video, movie, and still cameras captured the lightning attachment and subsequent swept-stroke attachment patterns along the airplane's exterior. An X-band color digital weather radar displayed both airborne and ground based images of the weather systems to the crew. A research instrumentation system recorded flight conditions. An air sampling system and composite fin cap also were flown.




*To further enhance "hardening" against the effects of lightning attachment to the airframe, the airplane exterior was stripped of paint in 1983*

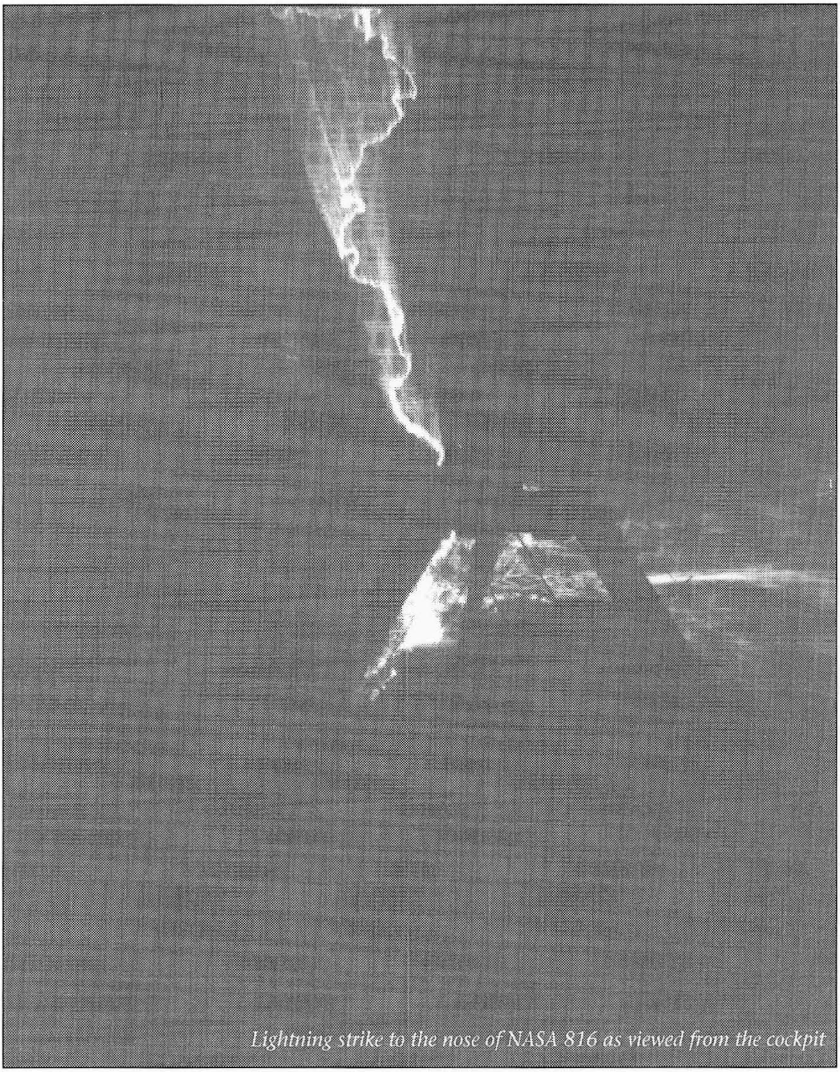
The majority of the thunderstorm research flights were conducted in the vicinity of NASA Langley and the NASA Wallops Flight Facility, Wallops Island, VA. Initial research flights in 1980 and 1981 were made in the vicinity of the NOAA National Severe Storms Laboratory, Norman, OK. Storm penetrations were flown at altitudes from 5000 to 50,000 ft.

In the course of the Storm Hazards Program, NASA and the USAF conducted joint tests to compare the electromagnetic effects of lightning with those from nuclear blasts. A simulated electromagnetic pulse test was conducted from January thru March, 1984, on the NASA F-106B at Kirtland Air Force Base, Albuquerque, NM, in conjunction with the Air Force Weapons Lab.



*NASA 816 mounted on dielectric test stand beneath nuclear electromagnetic pulse simulator at Kirtland AFB, NM*

During 195 Storm Hazards research flights, NASA 816 made 1496 thunderstorm penetrations during which 714 direct lightning strikes were experienced. The data gathered by the research program provided vital information for the designers of future advanced aircraft systems. Lightning certification testing of future aircraft will reflect more realistic and stringent criteria based upon the in-flight data from the F-106B. The program also provided valuable guidelines on the probability of lightning occurrences at various altitudes and environmental conditions.



*Lightning strike to the nose of NASA 816 as viewed from the cockpit*

The airborne data, in conjunction with ground-based data from the NASA Wallops Flight Facility, provided the first verification that aircraft frequently trigger their own lightning strikes. Additionally, atmospheric science benefitted from the capture of the first samples of air directly struck by lightning.

*NASA 816 during Vortex Flap Program. Note deflected leading-edge flap, pressure belts on wing, and flow visualization light system on fuselage behind cockpit*

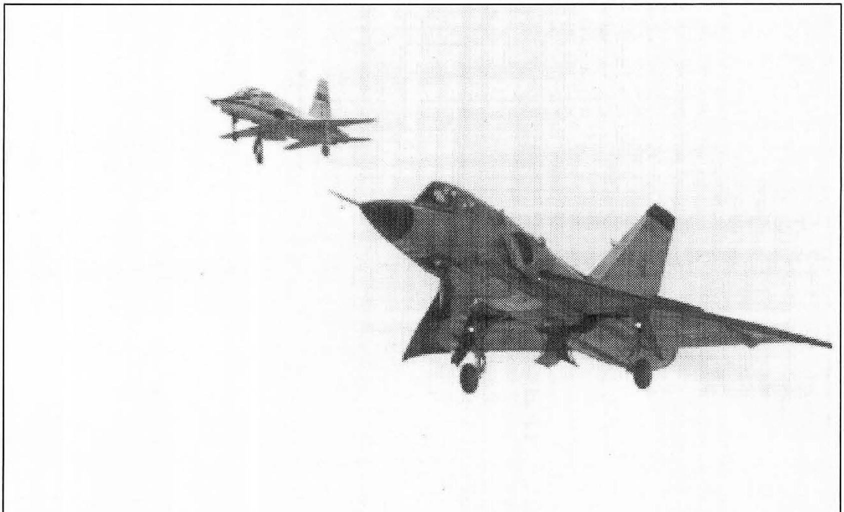
*Vortex Flap Flight Experiment 1986 -1991*

Civil and military aircraft designed to cruise efficiently at supersonic speeds usually employ highly swept wings with relatively sharp leading edges. Unfortunately, at off-design conditions (transonic and subsonic speeds) the air flow over the wing tends to separate and form strong vortices over the upper surface of the wing. Although the vortices increase lift, they are associated with a significant increase in drag. Through the use of computational fluid dynamics and wind-tunnel model tests, a specially shaped flap was developed at Langley to carefully "trap" a vortex spanwise along its leading edge, resulting in a significant improvement in lift-to-drag ratio. Verification of the performance improvements provided by this "vortex flap" and validation of the design methods required flight testing. Because of its highly swept wing representative of those that might employ a vortex flap, the F-106B was selected as the test article. NASA 816 was used in a flight experiment to evaluate the aerodynamic characteristics of a sharp, leading-edge vortex flap system by analysis of the wing surface pressure distributions and flow visualization data.

In preparation for the Vortex Flap Flight Experiment, the airplane was equipped with a vapor screen flow visualization system to view and record the features of the vortical flow over the leading edge. The airflow was seeded with heated propylene glycol vapor pumped from a missile bay pallet and expelled through a probe placed under the leading edge of the left wing. A light sheet, projected across the wing by a mercury arc lamp atop the fuselage, illuminated the vapor entrained in the vortex. The resultant sectional views of the wing vortex system were made available in the aft cockpit via video camera and were recorded for later analysis. Flow visualization flights of the unmodified wing began in February, 1985, and were conducted during moonless night conditions to optimize the images produced.

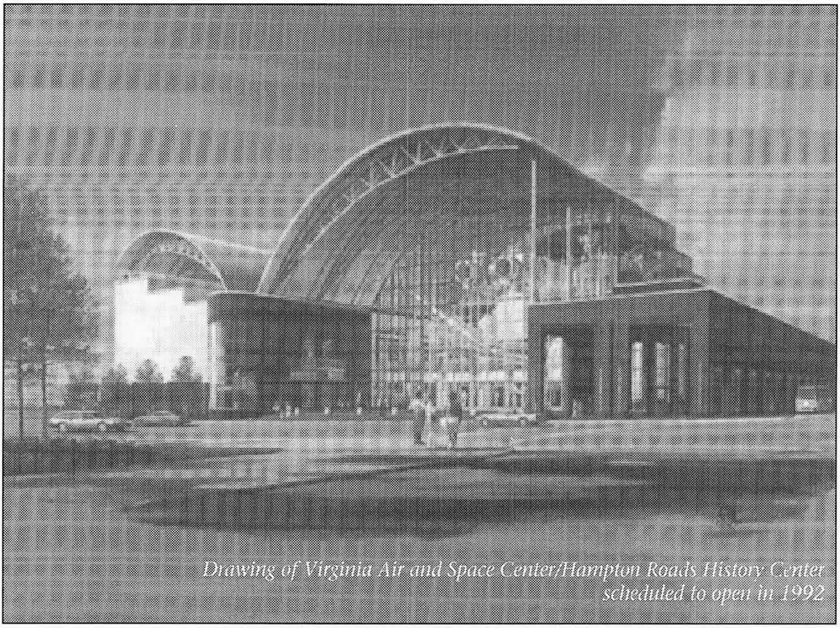

*NASA 816 during Vortex Flap research flight at Langley Research Center*

The vortex flap concept, developed computationally and refined by nearly 3000 hours of wind-tunnel model testing, was evaluated in flight on the F-106B beginning in 1987. Flight tests of the unmodified F-106B were conducted in August and September, 1987, to establish a performance baseline. Then, the production wing leading edges were removed and new leading edges incorporating ground-adjustable vortex flaps were installed. The right wing was instrumented to measure surface pressures; the left wing was instrumented with accelerometers and strain gauges to monitor structural loads and deformation.



*NASA 816 with Vortex Flap approaching to land at Langley*

The first flight with the vortex flap was on August 2, 1988. In 93 research flights over the next two-and-a-half years, aerodynamic performance of the flap and visualization of the flow over the flap were determined for different flap deflections. Potential for application of vortex flaps to improve takeoff and landing performance of future High Speed Civil Transports (HSCT) led to additional flight testing at conditions representative of HSCT takeoff and landing. The Vortex Flap flight research was extremely productive. The significant performance benefits of the concept were verified and questions regarding handling and flight characteristics were answered.



*Drawing of Virginia Air and Space Center/Hampton Roads History Center scheduled to open in 1992*

## THE FUTURE

*With the retirement of NASA 816 on May 17, 1991, the last known manned F-106 passes from active service. A handful of QF-106Bs continue to fly as drones to be used as air-to-air targets for our current fighters. Later in the year, NASA 816 will be placed on permanent display along with other historic NASA and U. S. Air Force aircraft in the new Virginia Air and Space Center / Hampton Roads History Center in Hampton, Virginia.*

# ACKNOWLEDGMENTS

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| | |
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