Quieting the Boom

Eight Decades of NASA’s Supersonic Flight Research

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Special thanks to the many contributors to this historical overview

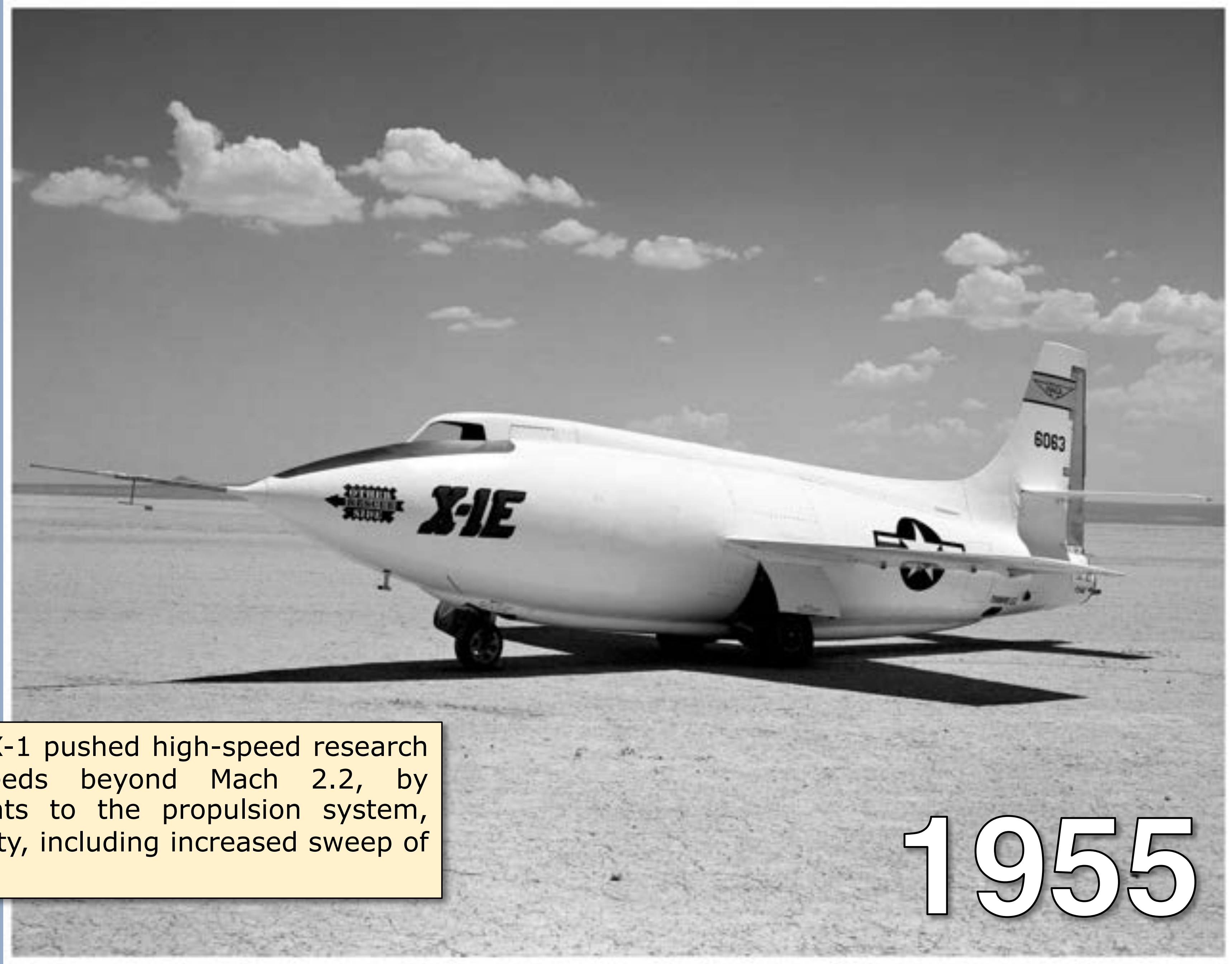
X-1


Credit: USAF

1946

The X-1 aircraft flew as a joint research endeavor between NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), and the U.S. Army Air Force. The X-1 established the concept of a research aircraft built solely for experimental purposes – an "X-plane" – and will always be remembered as the first inhabited aircraft to fly faster than the speed of sound. The primary roles of the X-1 were to conduct high-speed flight research, conquer the "sound barrier" and prove the aerodynamic viability of thin wing sections.

X-1E



The larger variant of the X-1 pushed high-speed research to new limits, at speeds beyond Mach 2.2, by incorporating improvements to the propulsion system, fuel, and directional stability, including increased sweep of the ultra-thin wings.

1955

X-1E

The X-1E aircraft is prominently displayed in front of NASA Armstrong's building 4800.

F-104

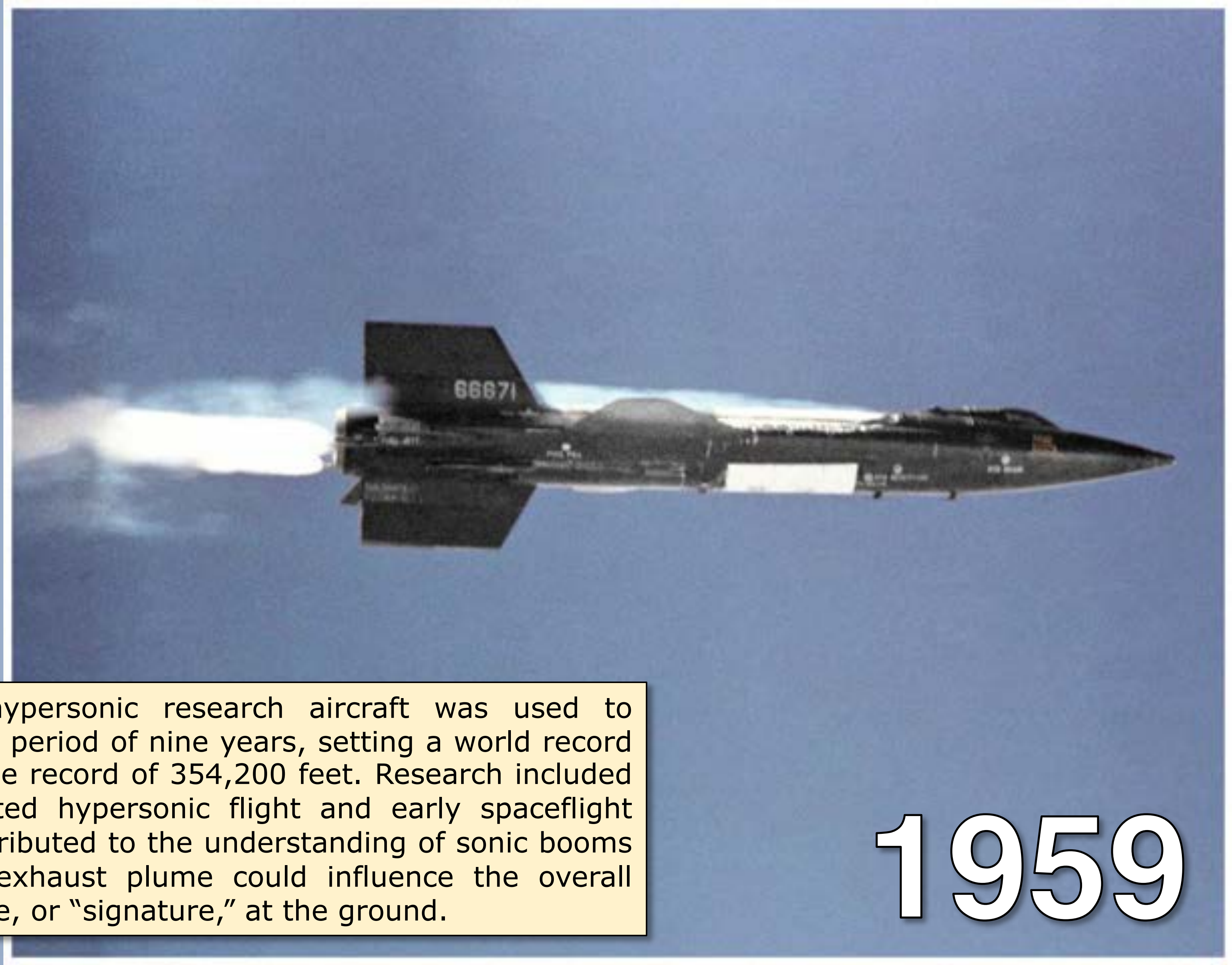
NASA's F-104s were in operation from 1956 to 1994 and considered the most versatile workhorses in its stable of research and support aircraft. NASA's fleet of 11 F-104s accumulated 18,000 flight hours over a 38-year period. F-104 research aircraft supported a wide variety of research missions including some early investigations into the sonic boom phenomenon. An F-104 was the first aircraft to probe and measure the near-field flow of another aircraft during supersonic flight.

1956

F-104

One critical research mission included rain erosion studies of space shuttle tiles.

X-15



The rocket-powered X-15 hypersonic research aircraft was used to conduct flight research over a period of nine years, setting a world record speed of Mach 6.7 and altitude record of 354,200 feet. Research included investigating aspects of piloted hypersonic flight and early spaceflight programs. The X-15 also contributed to the understanding of sonic booms including how the engine's exhaust plume could influence the overall character of the pressure wave, or "signature," at the ground.

1959

X-15

Neil Armstrong

F-100

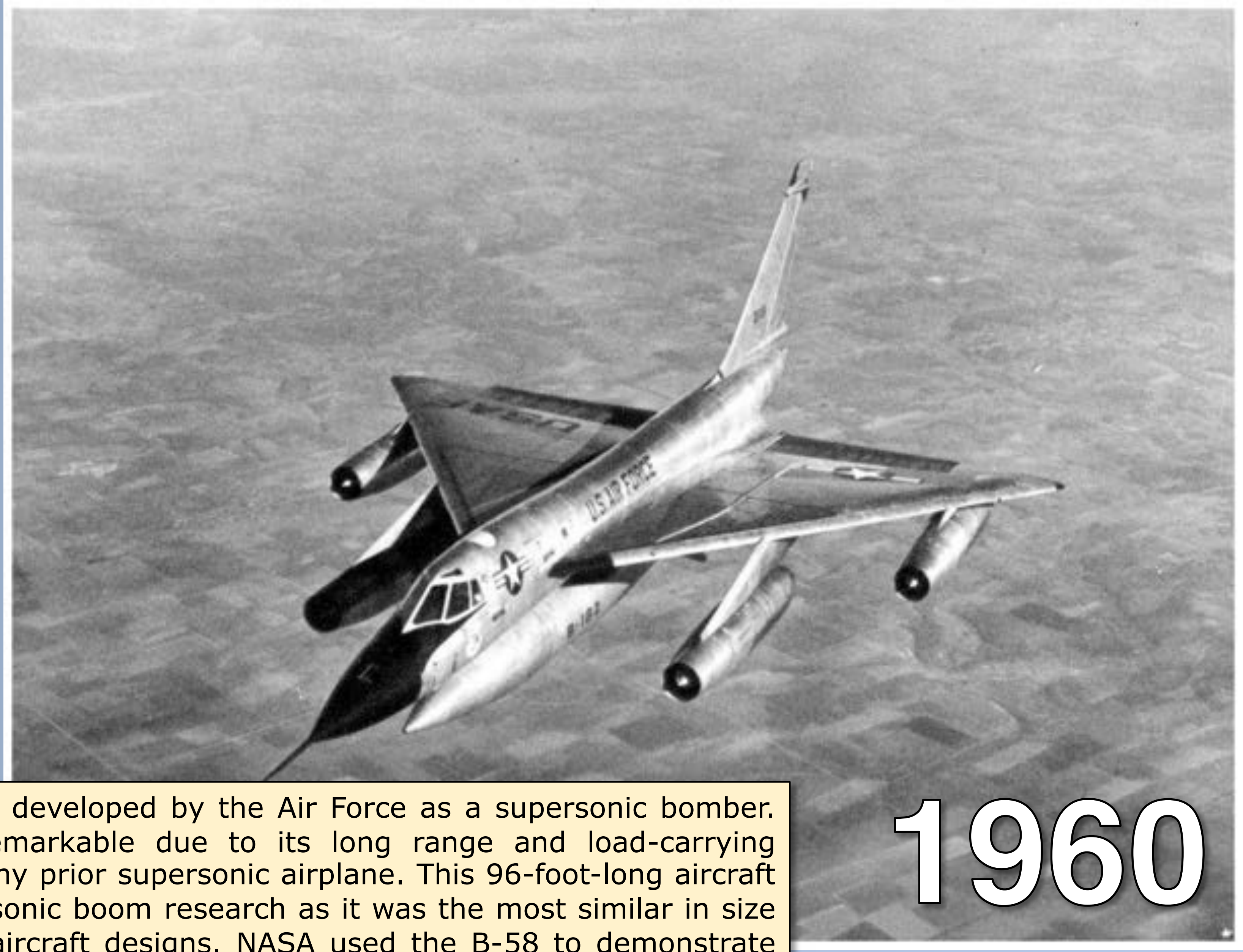
F-100 in formation with F-101 (top), YF-102A (fwd), F-104 (aft)

1960

Credit: USAF

The F-100 Super Sabre was the first of a new series of Air Force fighter aircraft that were capable of sustained supersonic flight. The development of these “Century Series” fighters revealed many unique challenges related to the supersonic speed regime. The NACA initially flew the F-100 to investigate supersonic stability and control and later used a modified F-100 for a number of sonic boom research activities in support of the X-15 and the U.S. SuperSonic Transport (SST) program.

B-58



1960

The B-58 Hustler was initially developed by the Air Force as a supersonic bomber. The delta-wing B-58 was remarkable due to its long range and load-carrying capability that far exceeded any prior supersonic airplane. This 96-foot-long aircraft was ideally suited to expand sonic boom research as it was the most similar in size and speed to proposed SST aircraft designs. NASA used the B-58 to demonstrate the contribution of aircraft lift on the near-field shock wave and resulting sonic boom signature on the ground.

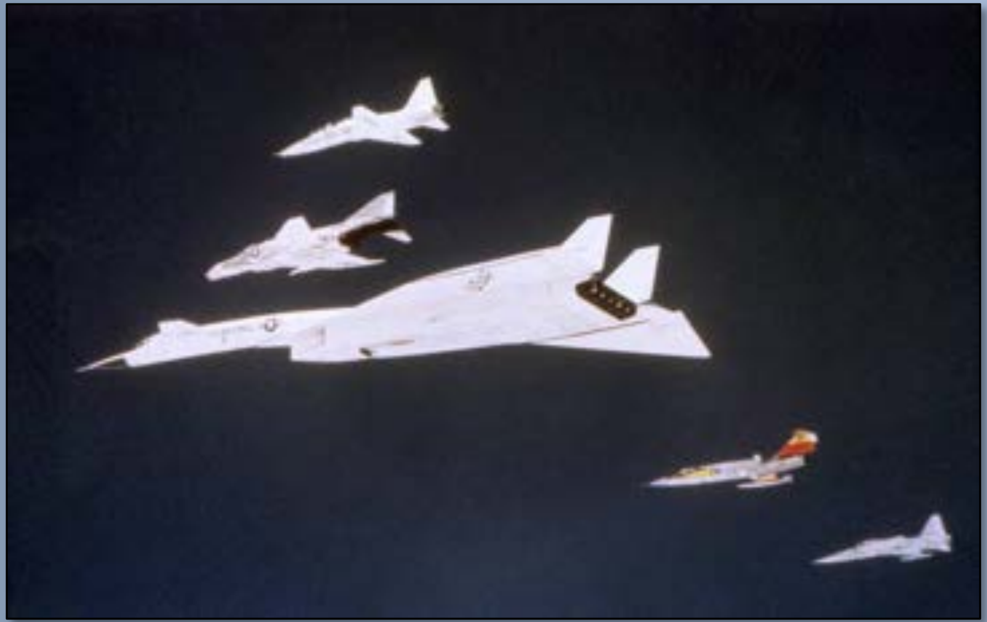
Credit: USAF

XB-70

The XB-70 Valkyrie was originally a prototype Mach 3 bomber. Its large size closely represented that of proposed SST aircraft designs and was ideal for SST research. Early flights provided data on several issues facing SST designers, ranging from aircraft noise to control system design. Sonic boom research using the XB-70 included a study on the near-field signature of the XB-70 aircraft using a F-104 as the probing aircraft.

1964

XB-70



The XB-70 #2 flight formation with a T-38, F-4, YF-5 and F-104N (orange tail) moments before mid-collision that occurred June 8, 1966.

The XB-70 was 185 feet long with a wingspan of 105 feet.

The final XB-70 research flight was piloted by Fitz Fulton (NASA) and Ted Sturmthall (AF) on Feb. 4, 1969 and flew to Wright-Patterson Air Force Base, OH, where the aircraft is on display at the National Museum of the U.S. Air Force.

F-16 XL

NASA's two F-16 XL aircraft were prototypes of an improved version of the F-16 that did not go into production. The F-16 XL had a unique delta wing design that was representative of a wing shape with potential for use in future supersonic cruise aircraft. The F-16 XL-1 provided aerodynamic data for NASA's High-Speed Research (HSR) program and eventually shifted to the role of the probing aircraft for the SR-71. The F-16 XL-2 was modified for flight research in active laminar flow control to reduce aircraft drag and fuel consumption at supersonic speeds.

SR-71

Two SR-71 aircraft (A and B model) were used by NASA as testbeds for high-speed, high-altitude aeronautical and reusable launch vehicle research. Retired in 1999, the SR-71 is still the world's fastest (Mach 3+), highest-flying (85,000 feet) piloted aircraft with airbreathing engines. NASA proposed modifying an SR-71 to demonstrate technology for reducing sonic boom noise. Extensive near-field probing with the F-16 XL-1 was conducted to gather baseline shock pressure data for the validation of prediction codes.

SR-71

NASA flight crew from left to right: Rogers Smith, Robert Meyer, Marta Bohn-Meyer, and Steve Ishmael. Edward Schneider not shown.

F-15B

For more than 25 years, NASA's F-15B Research Testbed has been a highly effective testbed aircraft that continues to fly a wide variety of research experiments and missions as supersonic chase and probing aircraft. Some of these experiments have utilized test fixtures mounted under the aircraft to investigate supersonic laminar flow and other aerodynamic and propulsion phenomena. The F-15B was used as the probing aircraft for the Shaped Sonic Boom Demonstration (SSBD). An improved shock measurement probe is being added to the F-15B to support X-59 acoustic validation flight testing.

1993

Tu-144LL

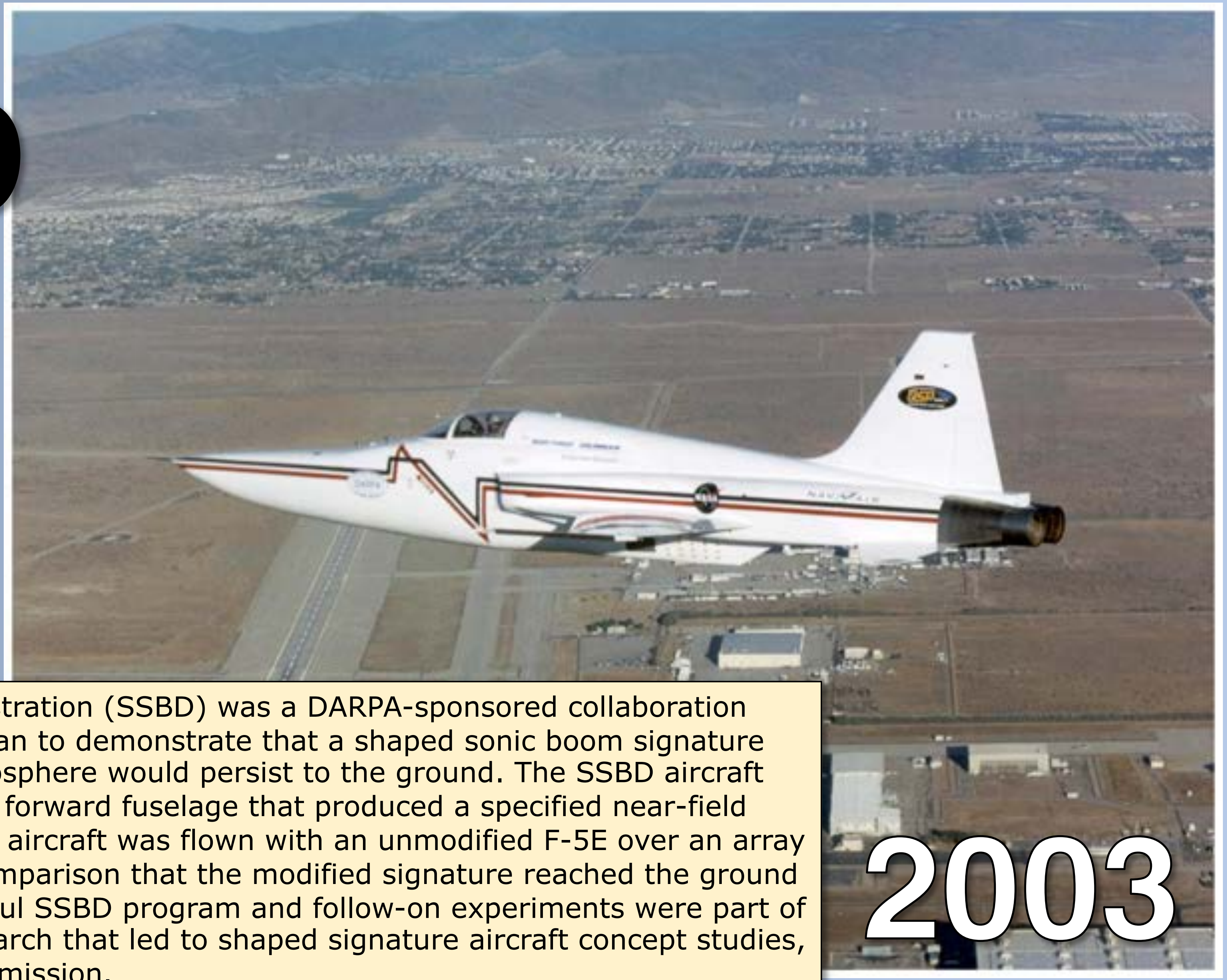
The end of the Cold War gave rise to an opportunity for international collaboration on an element of the HSR program. NASA engineers worked with their counterparts at Tupelov to restore a Tu-144 to flight status. Twenty-seven research flights of the Tu-144LL were conducted over a two-year period, greatly enhancing supersonic flight databases in propulsion, aerodynamics, structural heating, structural acoustics, ground effects, and handling qualities. In 1998, three evaluation flights were accomplished by NASA test pilots.

1996

Tu-144LL

NASA pilots Gordon Fullerton and Rob Rivers.

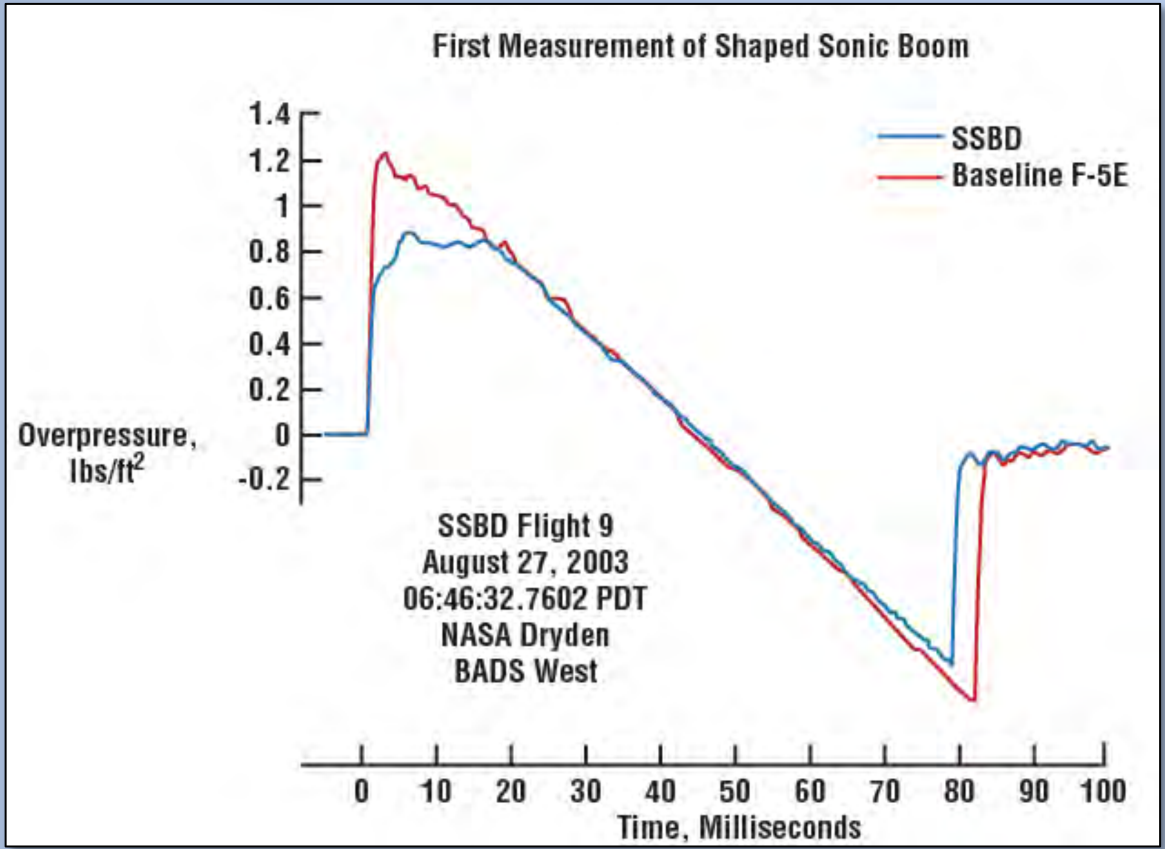
SSBD



The Shaped Sonic Boom Demonstration (SSBD) was a DARPA-sponsored collaboration with NASA and Northrop Grumman to demonstrate that a shaped sonic boom signature from aircraft flying in a real atmosphere would persist to the ground. The SSBD aircraft was a Navy F-5E with a modified forward fuselage that produced a specified near-field shock wave signature. The SSBD aircraft was flown with an unmodified F-5E over an array of ground sensors to show by comparison that the modified signature reached the ground as predicted. The highly successful SSBD program and follow-on experiments were part of a resurgence of sonic boom research that led to shaped signature aircraft concept studies, and ultimately to NASA's Quesst mission.

2003

SSBD



Northrup Grumman pilot Roy Martin / Joe Pawlowski quote (2003):
"In 1947, Chuck Yeager broke the sound barrier, we just fixed it."

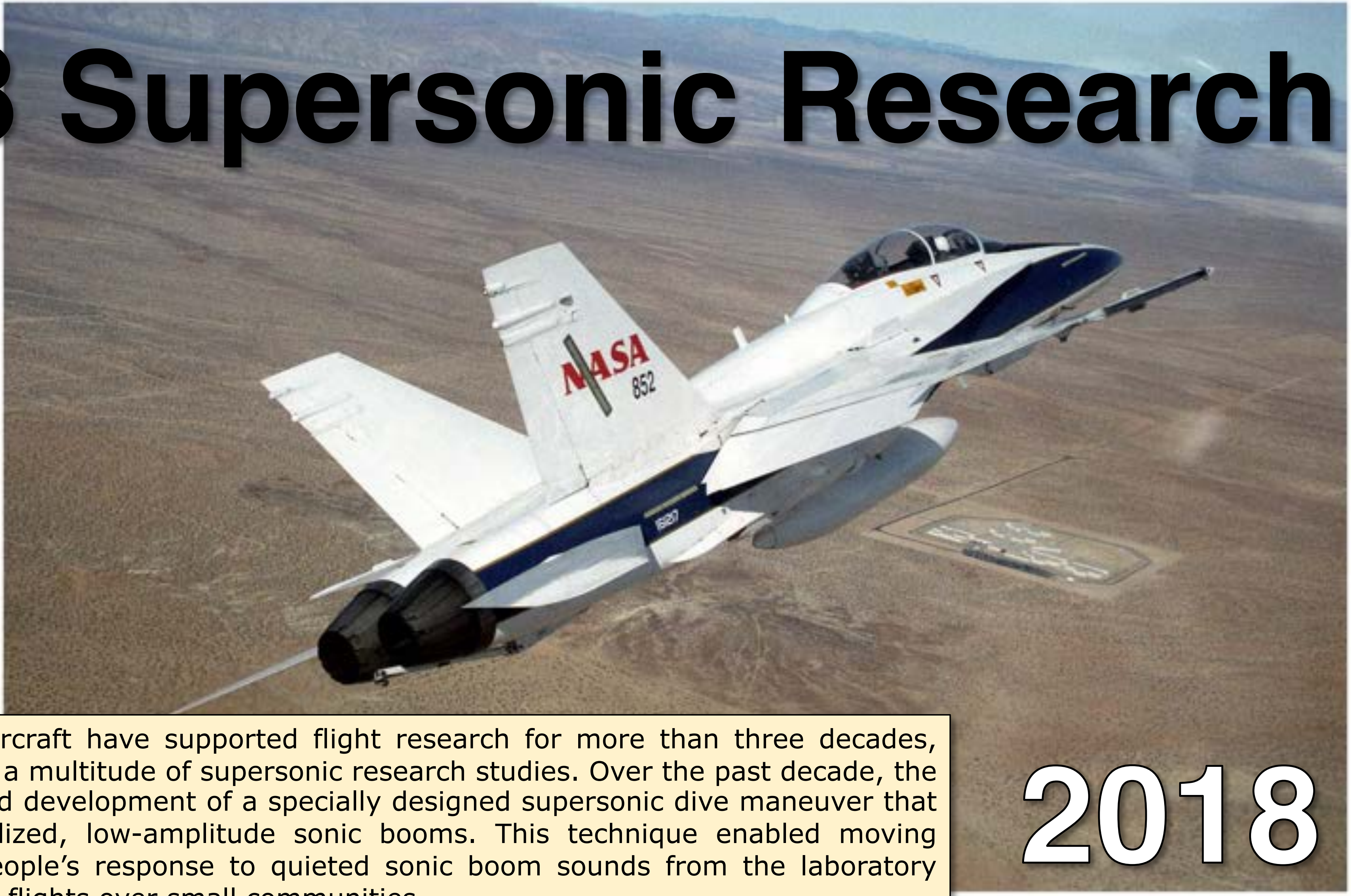
Might have been a bit overstated, but it was a critical step to "fixing" or reduction of sonic boom noise.

Quiet Spike

In 2006, NASA and Gulfstream Aerospace Corporation collaborated on a flight test of the company’s Quiet Spike concept. The idea behind Quiet Spike was to use a large telescoping nose section to control the strength and position of the forward shock waves and thereby reduce the sonic boom noise. A prototype, extending from 14 feet in subsonic flight to 24 feet in supersonic flight, was designed and installed on NASA’s F-15B. Although the flight test focused on understanding the structural and operational characteristics of the concept, data from probing flights did show that the sonic boom signature modification technique was feasible.

2006

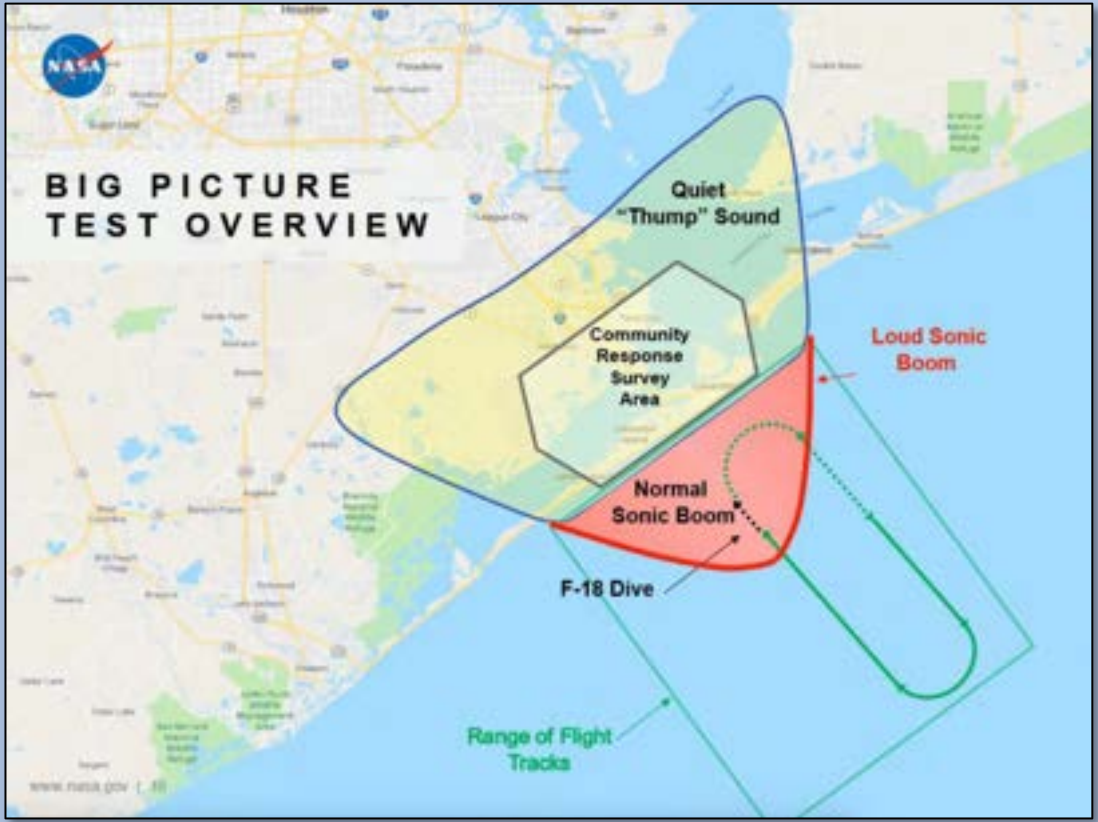
F-18 Supersonic Research



NASA's F-18 aircraft have supported flight research for more than three decades, participating in a multitude of supersonic research studies. Over the past decade, the F-18s supported development of a specially designed supersonic dive maneuver that generates localized, low-amplitude sonic booms. This technique enabled moving research on people's response to quieted sonic boom sounds from the laboratory environment to flights over small communities.

2018

F-18 Supersonic Research



During the Quiet Supersonic Flight 2018 (QSF18) campaign, the dive maneuver was used to expose the community of Galveston, Texas, to low-amplitude sonic booms enabling researchers to develop techniques that will be used during the Quesst mission's community overflight studies.

X-59

The X-59 aircraft, the culmination of 75 years of extraordinary X-planes and supersonic research, is the centerpiece of NASA's Quesst mission. The vast amount of data collected over the years has given designers the tools they needed to craft the shape of the X-59. This shape enables the X-59 to fly at supersonic speeds and reduce the loud sonic boom to a quiet "sonic thump" sound. The Quesst mission will use data from X-59 community overflight studies to provide regulators the data needed to support new standards for quiet supersonic flight that will open the future to commercial supersonic air transportation over land.

Credit: Lockheed Martin

Quesst Timeline

Credit: *Lockheed Martin*

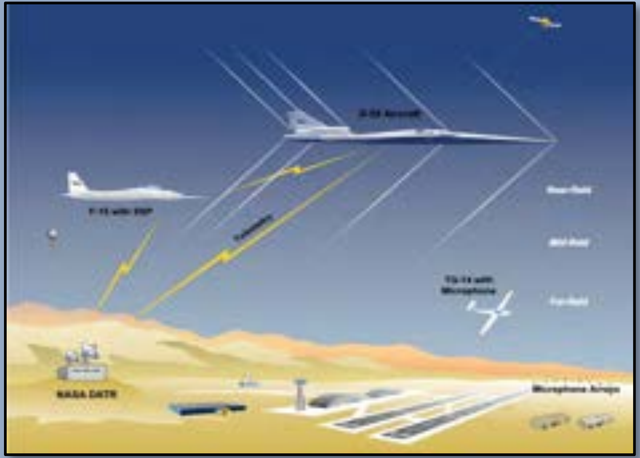
First Flight 2024

<u>Phase 1 – X-59 Aircraft Development</u>

Aircraft design, fabrication, and ground test

Checkout and envelope expansion

Systematic Approach Leading to Community Testing



2025

<u>Phase 2 – Acoustic Validation</u>

Detailed ground and flight measurements

Validation of sonic boom signature and prediction tools

2026

Credit: *Lockheed Martin*

<u>Phase 3 – Community Response</u>

Community response overflights, ground measurements, and surveys over representative communities across the U.S.

Overview of X-59 Aircraft Features

X-plane approach that meets key requirements in a cost-effective design

Design Parameters

- **Length: 99 ft**
- **Span: 29.5 ft**
- **Speed: Mach 1.4 (925 mph)**
- **Altitude: 55,000 ft**

Illustration Credit: Lockheed Martin

Integrated Testing Outdoors – August 2023

Photo Credit: Lockheed Martin

X-59 Aircraft Rollout – January 2024

Photo Credit: Lockheed Martin