Shaped Sonic Boom Experiment
Program Overview

Shaped Sonic Boom Experiment

INTRODUCTION

Based on the history-making results obtained during the DARPA Shaped Sonic Boom Demonstration (SSBD) Program August 2003 testing, NASA contracted Northrop Grumman to conduct additional flights with the F-5 SSBD aircraft in order to assess the characteristics and robustness of the shaped boom signature. The NASA-funded Shaped Sonic Boom Experiment (SSBE) Program commenced in November 2003 with a test planning/aircraft prep phase, followed by flight testing in January 2004. The Air Force Research Laboratory (AFRL) provided contractual assistance and an expedited funding path for the flight test activity.

PHASE I – EXPERIMENT DESIGN

The key tasks in the SSBE Design Program were the development of an expanded version of the data collection test plan that was used for SSBD and the performance of maintenance activities that were required to prepare the F-5 SSBD aircraft for additional flights. In addition, negotiations were conducted with NAVAIR, the owner of the aircraft, to get permission for additional testing, and to obtain a contract extension that would allow the aircraft to be returned at a later date than originally agreed to under the terms of the Cooperative Research and Development Agreement (CRADA).

On 12 November 2003, the SSBE Working Group, consisting of representatives from Northrop Grumman, NASA, Wyle Laboratories, Eagle Aeronautics, Gulfstream Aerospace, Raytheon Aircraft, Boeing and Lockheed Martin, met in Arlington, Virginia to establish requirements for the SSBE Test Plan. At the top of the list was the desire to conduct a test at the original design point flight condition of M1.4 at 32,000 ft MSL. This was not achievable during SSBD testing due to the high temperatures at altitude experienced during the month of August. Since SSBE testing was planned for the December/January timeframe, expected temperatures would allow for substantially increased performance, thereby providing the opportunity to collect data at the design point, as well as at higher and lower speeds and altitudes to evaluate shaped boom characteristics at off-design conditions. Back-to-back flights with a baseline F-5E, which proved to be extremely valuable during SSBD testing, were highly recommended. Near-field probing with the NASA F-15B was also considered to be a top priority. In addition, the team agreed to try and record at least one focused boom, and also to attempt a special close formation flight in order to better understand the effects of turbulence on the shaped signature. Weather go/no-go criteria were also discussed.

The SSBEWG developed a preliminary test plan that included a total of twenty data collection flights. These were prioritized in case unacceptable weather conditions, hardware problems or any other issues prevented the team from completing all flights before the deadline when the aircraft had to be returned to the Navy.

Based on lessons learned from the SSBD Program, it was recommended that the ground instrumentation array be moved to a less remote and more secure location at EAFB North Base as shown in Figure 1. The team also agreed to modify the array configuration since previous tests showed that flight tracks could be accurately targeted over a smaller area than what was

used during the SSBD testing. The quantity of monitors was increased, and NASA had plans to make a number of them operate autonomously, which would reduce manpower requirements.

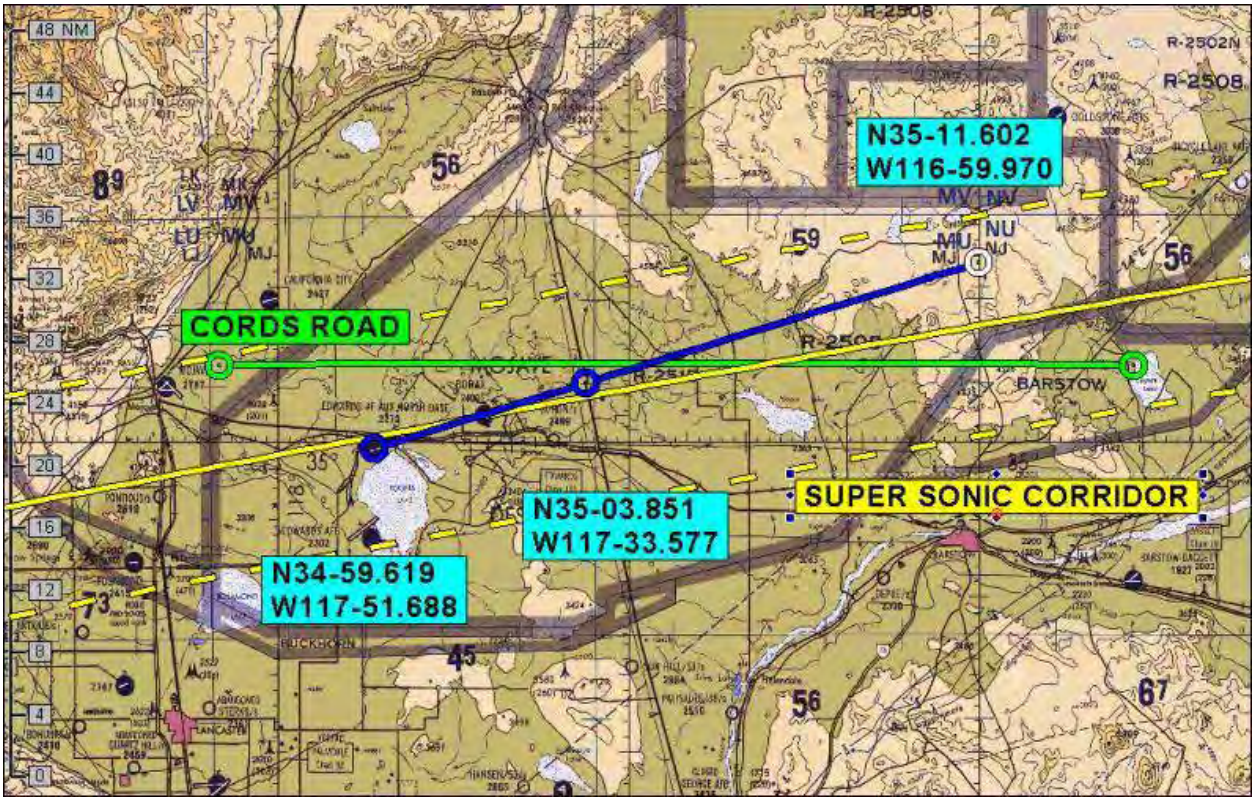

Figure 1. SSBE Flight Path Over EAFB North Base

In addition, NASA proposed outfitting a USAF Test Pilot School (TPS) Blanik L-23 glider with instrumentation (Figure 2) that would allow it to collect far-field boom signatures while flying above the turbulent boundary layer that normally exists near the ground. The use of a glider was suggested since earlier attempts to design instrumentation for airborne data collection with a Gulfstream V and a Raytheon Premier I encountered problems due to engine noise interference and instrumentation mounting issues. Rather than struggle with these issues, the simpler glider approach was recommended which had the added benefit of reduced operating costs.

Figure 2. Glider with Wingtip Sensor

Due to the fact that the F-5 SSBD aircraft had not flown since the SSBD testing in August 2003, multiple inspections were required and maintenance actions needed to be performed in accordance with standard accepted procedures in order to have the jet flight ready at the start of the Flight Test Phase.

NAVAIR personnel conducted an SSBE Test Plan review, which included a new 1/4g pushover maneuver for the focused boom attempt, and granted permission to proceed with the SSBE tests in accordance with the existing NAVAIR flight clearance.

Northrop Grumman contacted the commander of the VFC-13 Saint Adversary Squadron at NAS Fallon and received commitment that the baseline F-5E would again travel to Palmdale to support the flight test activity, assuming that the SSBE schedule did not conflict with planned fleet operations.

At the completion of the Design Phase on 9 January 2004, the F-5 SSBD aircraft was ready for flight, the glider instrumentation had been tested, the SSBE Test Plan was approved, the sensors were assembled and ready for deployment, the baseline F-5E was standing by, the Flight Readiness Review was complete, and the Navy had granted a contract extension to use the aircraft – but only until 31 January 2004.

PHASE II - FLIGHT TEST

Flight testing got underway on 12 January 2004, starting with a successful Functional Check Flight (FCF) that was necessary in order to ensure that the aircraft still met all performance and safety requirements. Upon its return to Palmdale, the aircraft was immediately refueled and sent out on the first of its planned data collection missions. Meanwhile, the go-ahead was given to ferry the baseline F-5E, shown in Figure 3, from Fallon to Palmdale, where a NAVAIR flight-certified GPS package was installed that evening.

Figure 3. Baseline F-5E Aircraft

Over a period of just eleven days, all 21 of the planned flights (Figure 4) were successfully conducted in the EAFB supersonic corridor, thanks to near-perfect weather conditions and a very reliable aircraft. In some instances, three flights were flown in a single day, even though historical weather data indicated that only one or two early morning flights would meet the stringent atmospheric criteria required for meaningful data collection for this type of testing. Eight back-to-back flights were flown with the F-5 SSBD and the Navy F-5E. In addition, focused booms were successfully recorded on two solo flights, and 45 near-field probings were accomplished during four flights with the NASA F-15. Over 1300 sonic boom signatures were recorded via the sensor array, including data collected on fourteen flights with the USAF glider.

Shaped Sonic Boom Experiment Flight Test Summary

Flt #	Test #	Date	Takeoff Time (PST)	Mission	Flight Condition	Fuel State (Pounds)	Test Support: F-5 SSBD	F-5E (Navy VFC-13)	F-15B (NASA)	Blanik L-23 (USAF TPS)	F-18 (NASA)	F-18 (Navy VX-31)	Citation XL (NGC)	Ground Data (NASA Wyle/ Gulfstream/NGC)
20	13	12 Jan 2004	1000	Functional Check	Up to M1.4, 32K	1900	X			X	X			X
21	14		1315	Probe/Solo	M1.40, 32K – Steady State	2100	X		F-15 Abort	X	X			X
22	15	13 Jan 2004	0700	Back-to-Back		2200	X	X		X				X
23	16		1000			2200	X	X		X				X
24	17		1300			2200	X	X		X				X
25	18	14 Jan 2004	1000		M1.43, 32K – Steady State	2200	X	X		X				X
26	19		1330		M1.35, 32K – Steady State	2100	X	X		X	X			X
27	20	15 Jan 2004	0700		M1.43, 32K – Steady State	2200	X	X		X				X
28	21		1000		M1.35, 32K – Steady State	2200	X	X		X				X
29	22		1300	Close Formation		2200	X	X		X				X
30	23	16 Jan 2004	1500	Solo	M1.375, 32K – Steady State	2200	X			X				X
31	24	17 Jan 2004	0700	Focused Boom	M1.375, 32K – Pushover Maneuver	2300	X							X
32	25		1000	Solo	M1.375, 36K – Steady State	2200	X							X
33	26		1140	Solo	M1.45, 36K – Steady State	2200	X							X
34	27	19 Jan 2004	0700	Focused Boom	M1.375, 32K – Pushover Maneuver	2300	X			X				X
35	28		1000	Solo	M1.375, 32K – Steady State M1.33, 31K – Steady State	2300 1500	X			X				X
36	29		1200	Solo	M1.40, 32K – Steady State M1.31, 32K – Steady State	2000 1200	X			X				X
37	30	21 Jan 2004	0700	Probe	M1.40, 32K – Steady State M1.35, 32K – Steady State	2300 1400	X		X					X
38	31	22 Jan 2004	1125	Probe	M1.375, 32K – Steady State M1.375, 32K – Steady State	2300 1600	X		X					X
39	32		1340	Probe	M1.40, 32K – Steady State M1.35, 32K – Steady State	2300 1400	X		X					X
40	33		1535	Probe	M1.375, 32K – Steady State M1.40, 32K – Steady State	2400 1500	X		X					X
41-42	Ferry 5-6	23 Jan 2004	n/a	Cross-Country Ferry Flights		n/a	X					X		
43	Ferry 7	24 Jan 2004					X					X		
44	Ferry 8	27 Jan 2004					X						X	

Figure 4. SSBE Flight Test Summary

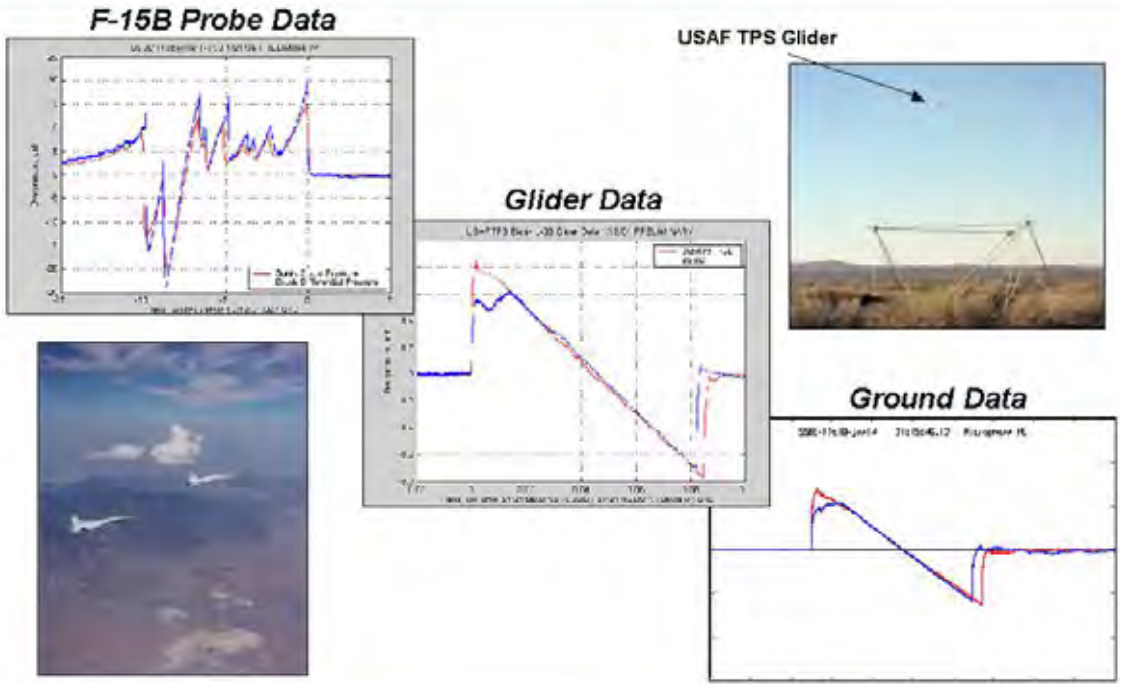

Figure 5. Typical Data Sample Shows Propagation Characteristics of Shaped Signature

Although valuable data was collected during the close formation flight, the separation distance between the two aircraft was greater than had been planned due to the fact that the F-5 SSBD out-accelerated the F-5E while attempting to reach the required steady-state condition. This can be partially explained by the fact that the F-5E arrived from Fallon with the centerline pylon installed. Unfortunately, due to the tight schedule constraints, there was not enough time to remove the pylon or repeat the flight before the aircraft had to return to the squadron.

The instrumentation that made up the ground-based array near EAFB North Base was provided by NASA Dryden, NASA Langley, Wyle Labs, Northrop Grumman and Gulfstream Aerospace. It was manned by personnel who braved the harsh early-morning desert elements and wildlife to set up the equipment before dawn. As part of their tasks, they were required to complete special Desert Tortoise training in order to ensure that they did not impact this endangered species while working in their habitat. The multi-company team consisted of representatives from NASA Dryden, NASA Langley, Wyle Laboratories, Northrop Grumman, Eagle Aeronautics, Gulfstream Aerospace, Boeing and the FAA (Figure 6).

Figure 6. Data Collection Team and Glider/Tow Plane Pilots

On 27 January 2004, four days before the Navy deadline, the F-5 SSBD aircraft was returned to the U.S. Navy at the Northrop Grumman facilities in St. Augustine, Florida -- even after being delayed for three days by inclement weather between Alabama and Florida. The aircraft was escorted to Alabama by an F-18 from NAS China Lake, and flew the last leg on the wing of a Northrop Grumman Citation XL.

SUMMARY

The vast amount of data collected during this test will be invaluable to future supersonic aircraft designs in that it will allow designers to go forward with confidence in the ability to predict, and thereby control, sonic booms. The successes and the significance of the SSBD and SSBE Programs have been featured on television, radio and the internet, and in numerous newspaper and magazine articles, including a cover story in the July 2004 issue of Popular Science. Team members have won multiple distinguished awards, including the 2004 NASA Turning Goals into Reality Partnership Award, Aviation Week & Space Technology Laurels – 2003 (Dr. Richard Wlezien, NASA HQ / Dr. Steven Walker, DARPA / Charles Boccadoro, NGC), Popular Science Best of What's New for 2003, and the Society of Flight Test Engineers (SFTE) Engineer of the Year – 2003 (Ed Haering, NASA Dryden). In addition, technical papers on the history-making program accomplishments have been presented to several national and international organizations, including the Society of Experimental Test Pilots (SETP), the Society of Automotive Engineers (SAE) - Aerospace, the American Institute of Aeronautics and Astronautics (AIAA), the Confederation of European Aerospace Societies (CEAS), and the Experimental Aircraft Association (EAA) at the Oshkosh AirVenture. Furthermore, an entire session has been set aside at the upcoming 2005 AIAA Aerospace Sciences Meeting in Reno, Nevada, for a series of SSBD/SSBE technical presentations.

As soon as space is available, the U.S. Navy plans to induct the F-5 SSBD aircraft into the National Museum of Naval Aviation in Pensacola, Florida. In the meantime, it will be on loan to the Valiant Air Command Warbird Museum in Titusville, Florida near the Kennedy Space Center.

Figure 7. F-5 SSBD Aircraft