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DEFINING THE FUTURE

Fixing the Sound Barrier

*The DARPA/NASA/Northrop-Grumman
Shaped Sonic Boom Flight Demonstration*

**Aerospace Testing Exposition
Hamburg, Germany**

April 2005

Roy Martin

Test Pilot

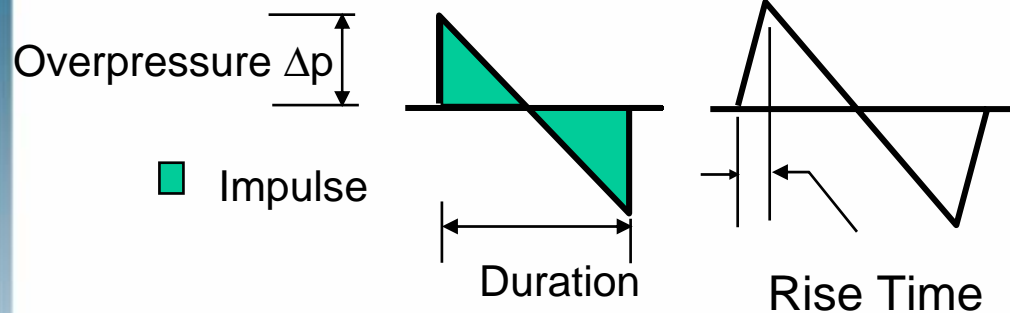
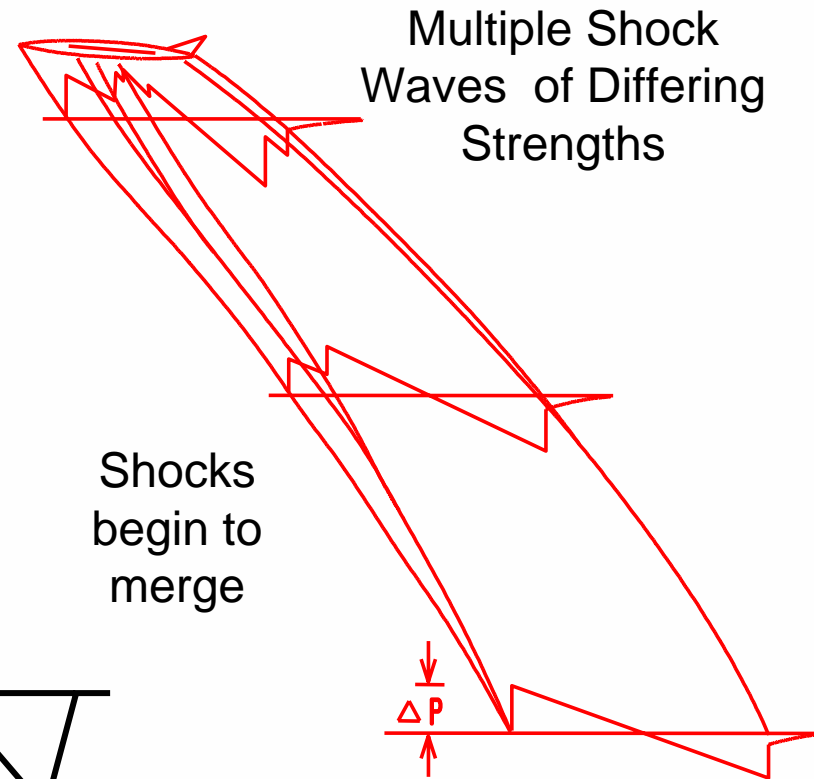
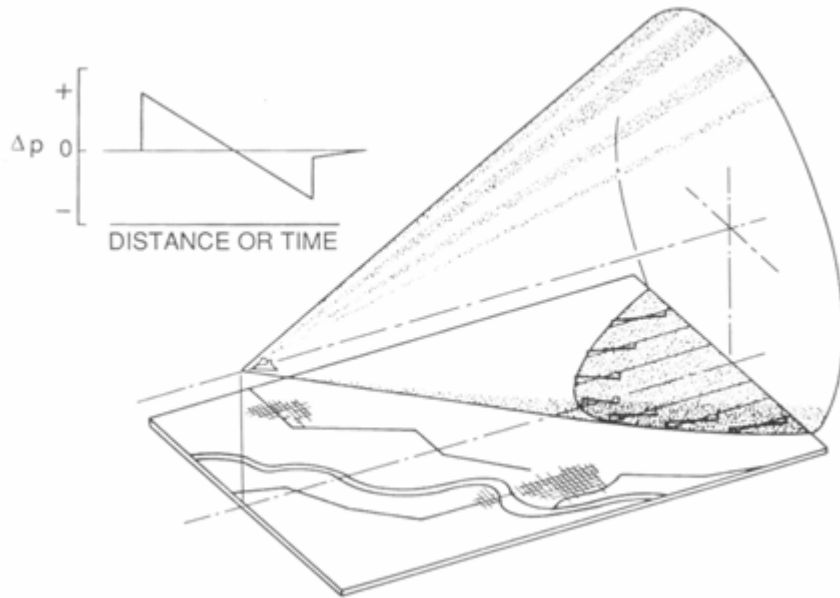
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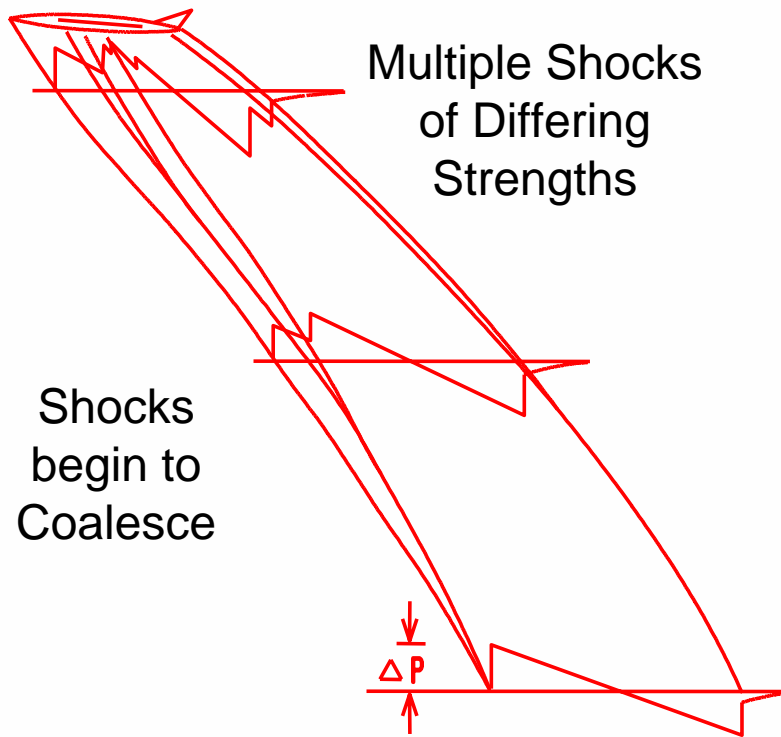
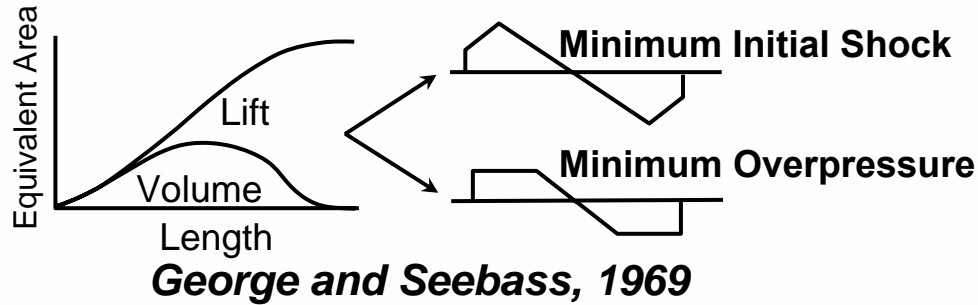
Shaped Sonic Boom Demonstration SSBD

- **First ever FLIGHT demonstration of sonic boom shaping**
- **Design, fabrication and test using a surrogate aircraft**
 - Nose modification of an F-5E fighter
- **Primarily funded by DARPA, Northrop Grumman and NASA**
- **Extremely successful government/industry collaboration**
 - 5 U.S. Government agencies
 - 8 U.S. Aerospace companies

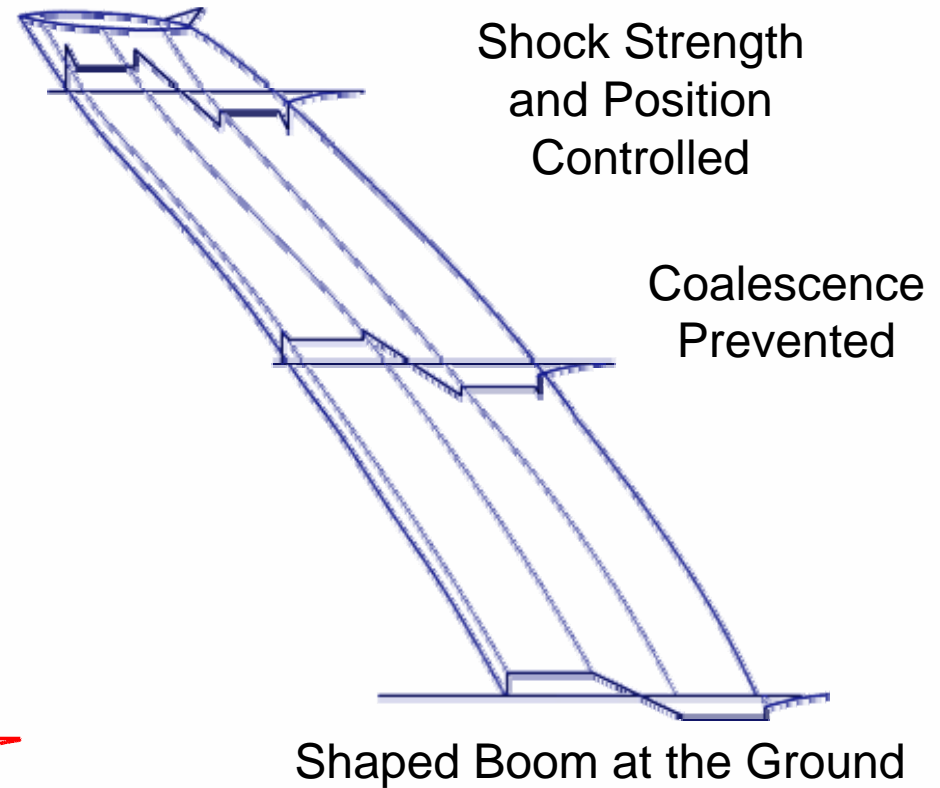
Sonic Boom Basics



Theory of Sonic Boom Minimization Through Aircraft Shaping



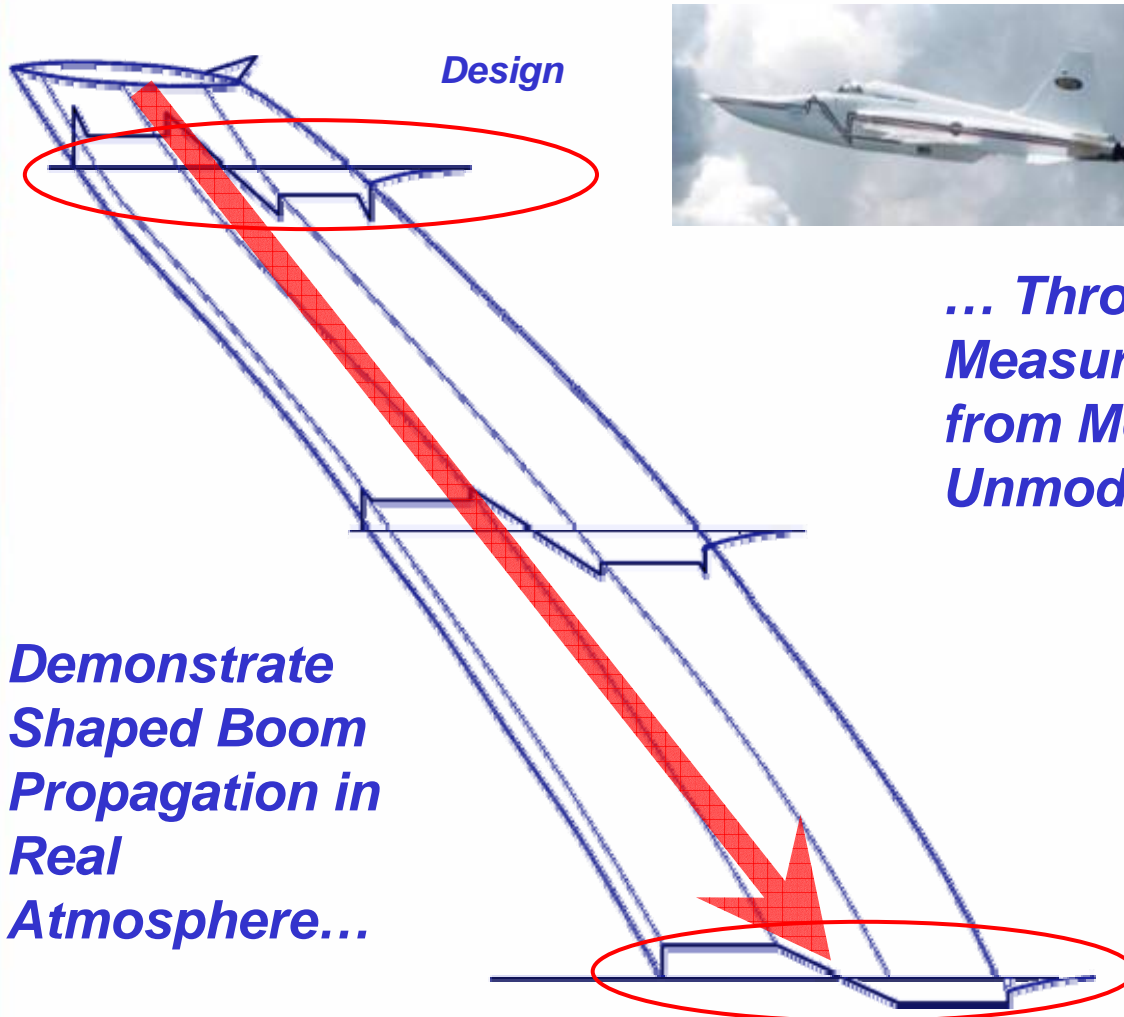
Shocks Coalesce into "N-wave"



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SSBD Provides a Missing Piece of the Puzzle



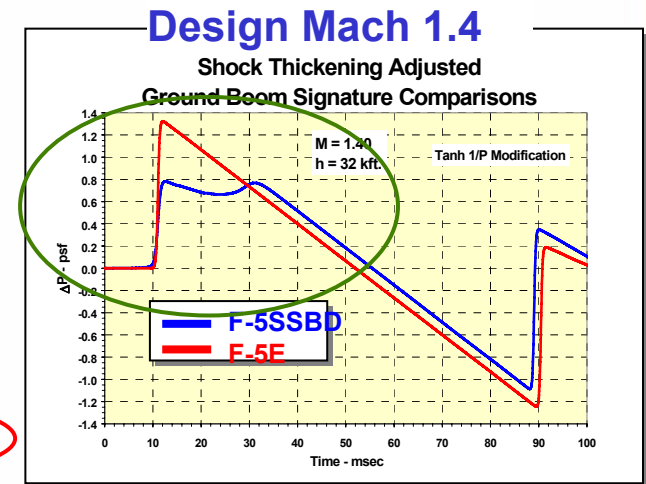
Design



... Through Ground Measurement of Booms from Modified and Unmodified F-5Es

Demonstrate Shaped Boom Propagation in Real Atmosphere...

Noise Acceptability

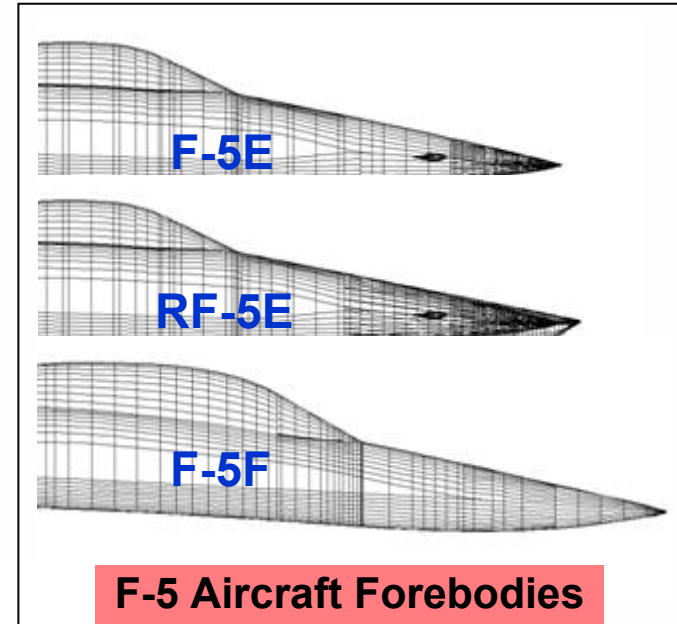


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Key to SSBD Success: F-5E

- **Aircraft Configuration Is Very Amenable to the Type of Forebody Modifications Required to Produce a Shaped Boom Signature**
 - Long Nose, Blended Canopy, and Inlets Relatively Far Back
 - Very High Overall Fineness Ratio
 - Lightweight
- **Modification Is Relatively Low Risk Due to Similarity with F-5 Family**
 - Extensive Database of Modified Forebodies with Comprehensive Wind Tunnel and Flight Testing
- **Cost-Effective Test Approach**
 - Limited Wind Tunnel Testing, Analysis Required for F-5 Mo
 - Low Aircraft Operating Cost
- **Supersonic Performance Capability with Margin**



Initial Design



Final Design

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Build-up Approach to Development & Validation

Extensive CFD



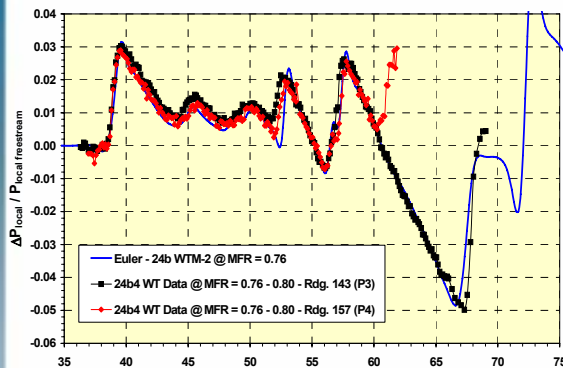
Inlet Shock Flight Test



Boom Tunnel Tests



Correlations Completed



S&C Tunnel Test



Force Tunnel Test



✓ IDRs - 12/01 & 2/02

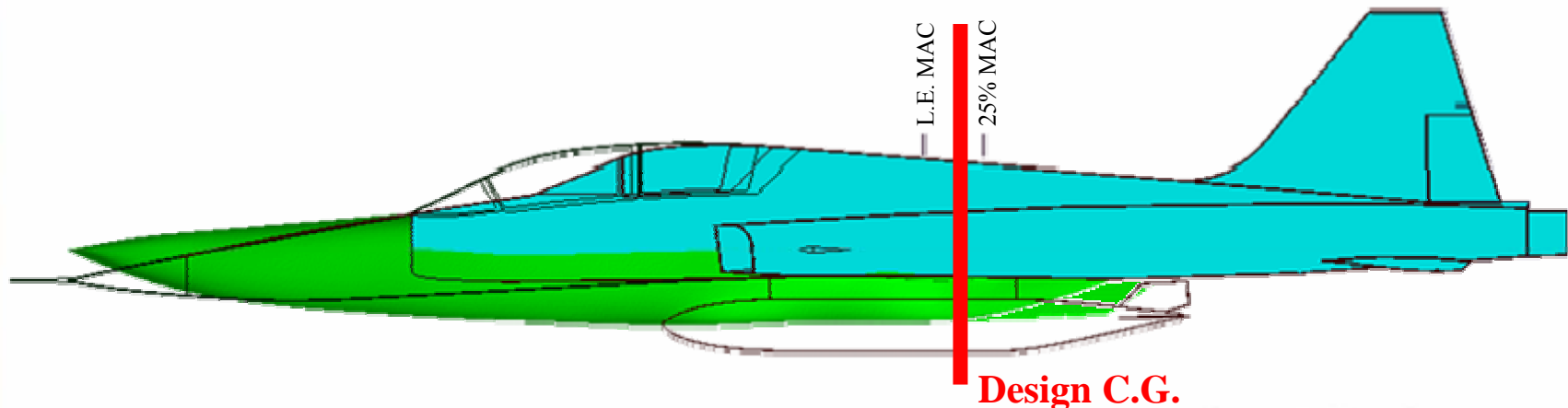
✓ PDR - 3/02

✓ CDR - 7/02

✓ Pre-FRR - 1/03

SSBD F-5E Handling Qualities Engineering Predictions

- Longitudinal stability comparable F-5F, minor reduction dynamic stability damping
- Directional stability of F-5SSBD is comparable to F-5F with 275 gallon centerline tank
- Directional stability is positive for AOA of planned flight envelope
- Subsonic and supersonic handling qualities satisfactory and comparable to other F-5 configurations (with stability augmentation engaged)
- Use aft CG limit of F-5F (more forward than F-5E)



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Fabrication & Flight Operations

USN F-5E Arrives NGS



Mod Nose Attached



Fairings Attached



Pre-Flight Prep



First Taxi



First Flight



**Envelope Expansion
& Ferry Flights**



**Back-to-Back &
Probe Flights**



**21 Flawless Flights
Over 1 Month!**

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SSBD F-5E Cockpit Modifications



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Preparation for First Flight

- **Test Plan Approved by NAVAIR**
- **Civil Landing Permits from USAF, USN, US Army**
- **F-5E Spare Parts from Marines at YUMA MCAS**
- **Flight Readiness Reviews: NAVAIR, DARPA, Northrop Grumman, NASA Dryden, NASA Langley**
- **Aircraft Prep, EMC, Low and High Speed Taxi**
- **Real Time Telemetry for First Flight and Envelope Expansion Flight Tests**
- **Pre-position T-38 Chase from Seattle to St. Augustine**
 - **Extremely Useful for Test Pilot Proficiency**

First Flight of SSBD F-5E

- Takeoff from St. Augustine (8000 Ft Rwy)
- Test Area Over the Atlantic (W-158)
- Boeing T-38 Chase (Mike Bryan)
- Landing at Cecil Field (12,500 Ft Rwy)

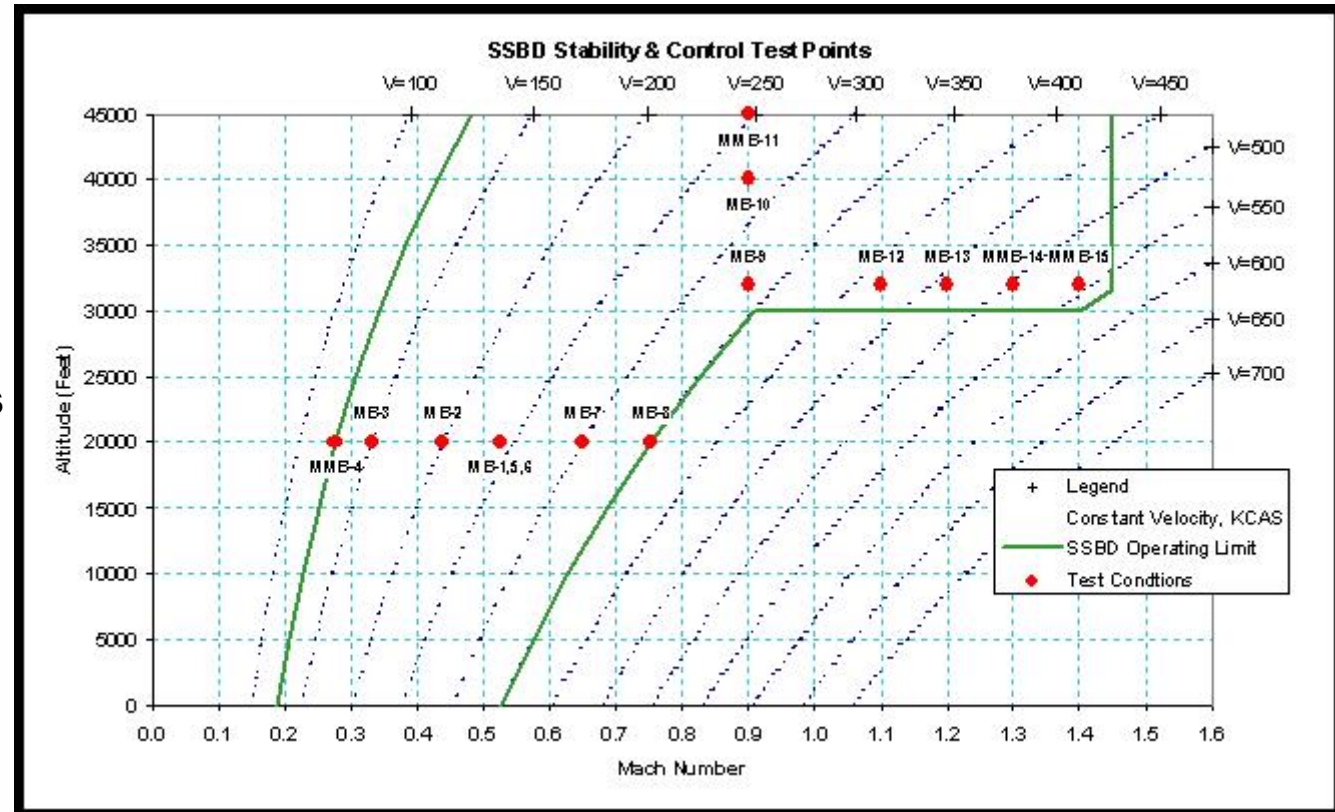


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Envelope Expansion Flights

Maneuver Block:

- Pitch Doublet
- Yaw Doublet
- Steady Sideslips
- 30 Bank to Bank
- Windup Turn (Augs-On then Off)



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Back-to-Back Data Flight 27 August 2003

(45 Second Separation Between Aircraft During Supersonic Run)



*NAS Fallon VFC-13 F-5E and
F-5 SSBD at Palmdale, CA*

*F-5 SSBD Takes Off
at Dawn Enroute to
EAFB Supersonic Corridor*



F-5 Pilots

Roy Martin

CDR Darryl "Spike" Long

LCDR Dwight "Tricky" Dick

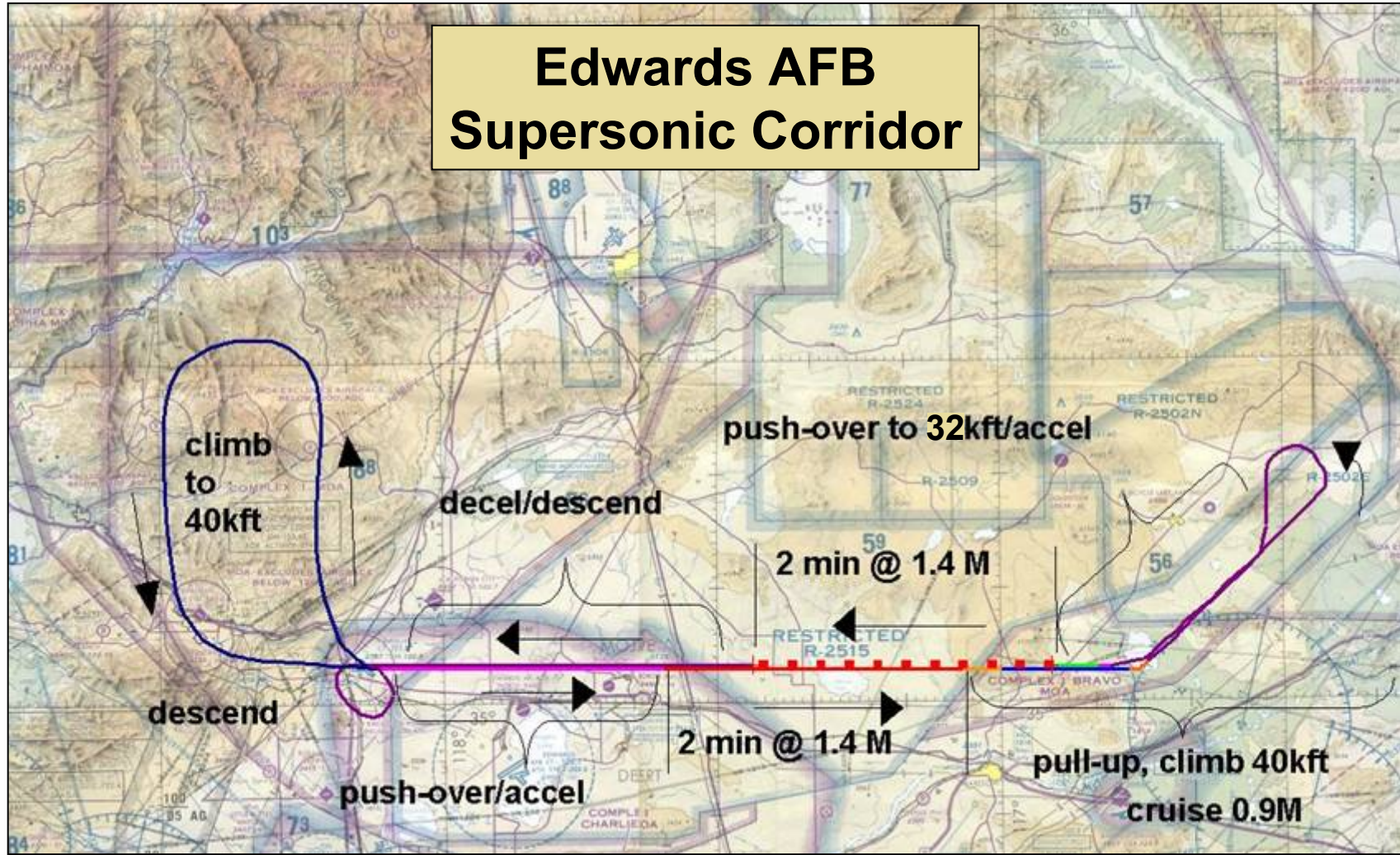


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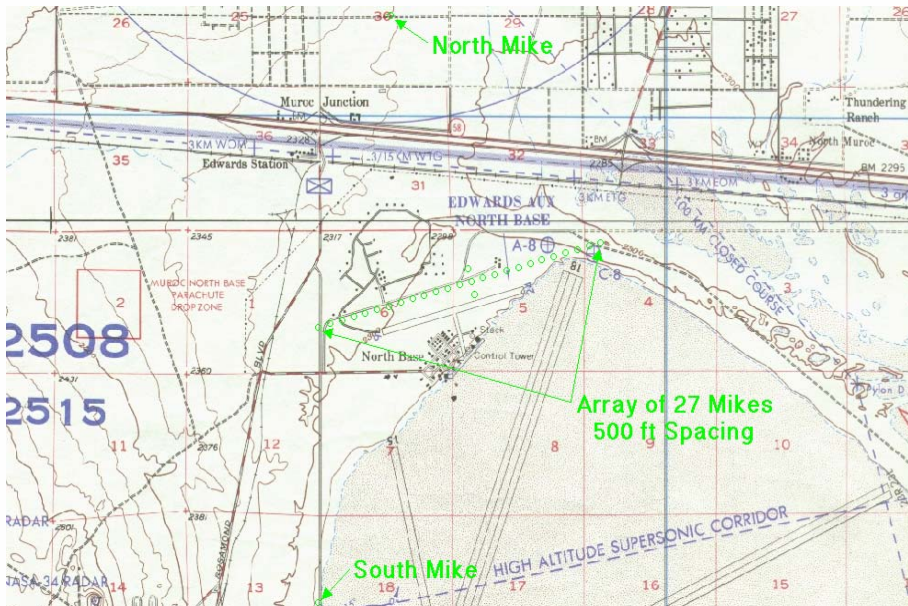
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SSBD Flight Path



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Ground Recording Array Setup



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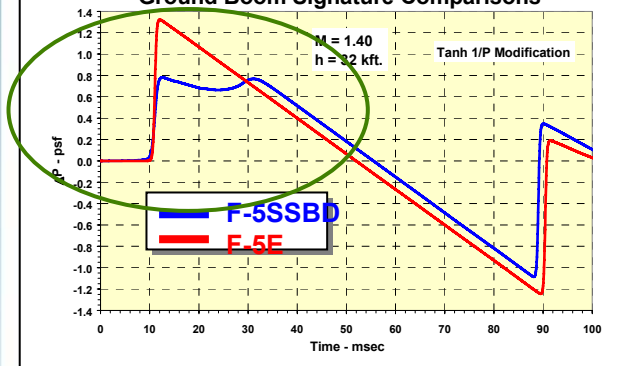
First-Ever Shaped Sonic Boom Recorded 27 August 2003

Signatures recorded during SSBD back-to-back data flights in the Edwards AFB supersonic flight corridor early morning

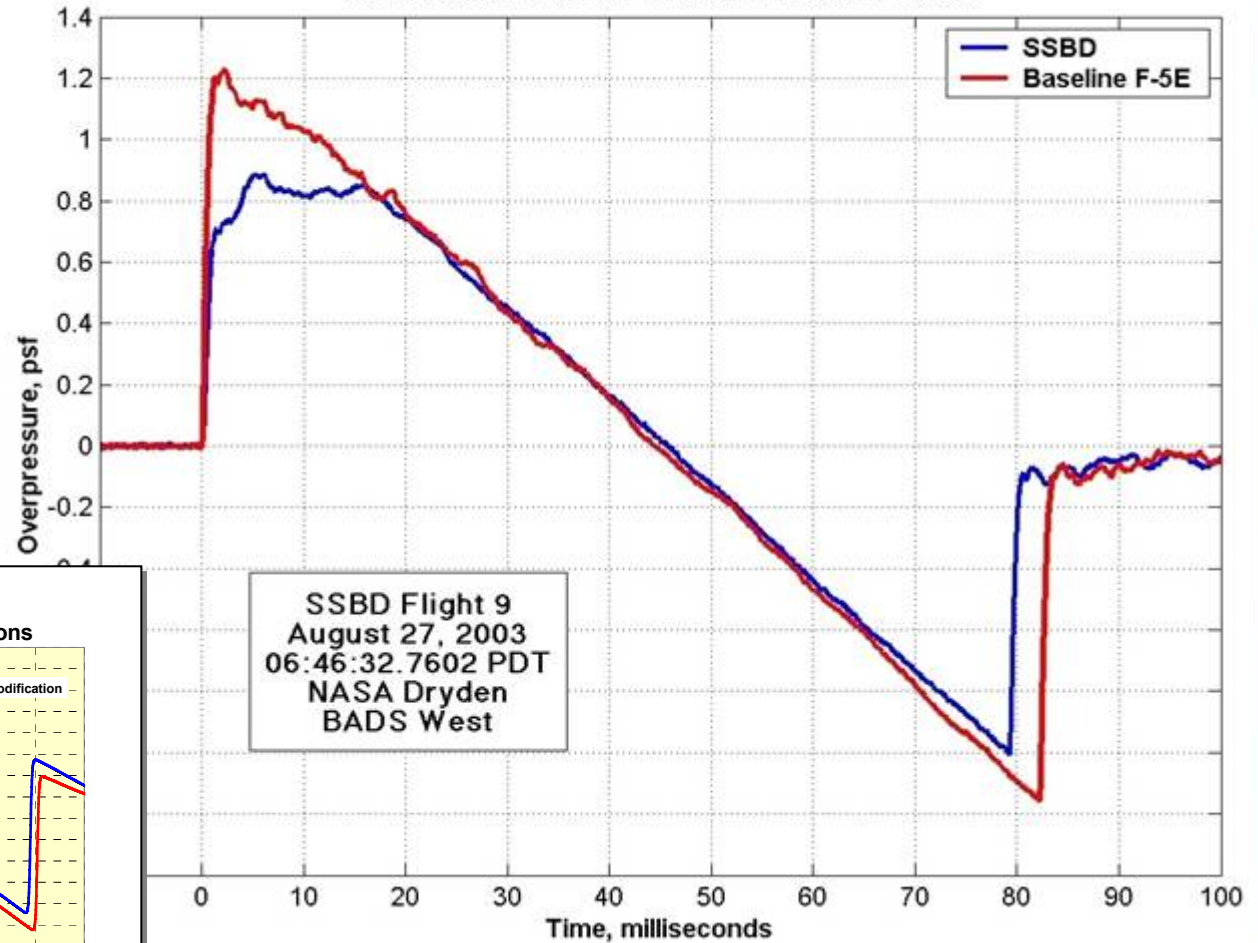
Flight conditions:
Mach 1.36+,
Altitude 32,000 ft

Design Mach 1.4

Shock Thickening Adjusted
Ground Boom Signature Comparisons



FIRST MEASUREMENT OF SHAPED SONIC BOOM



Shaped Sonic Boom Experiment

SSBE Experiment Designed to Collect Quality Data from Many Sources

Test Summary

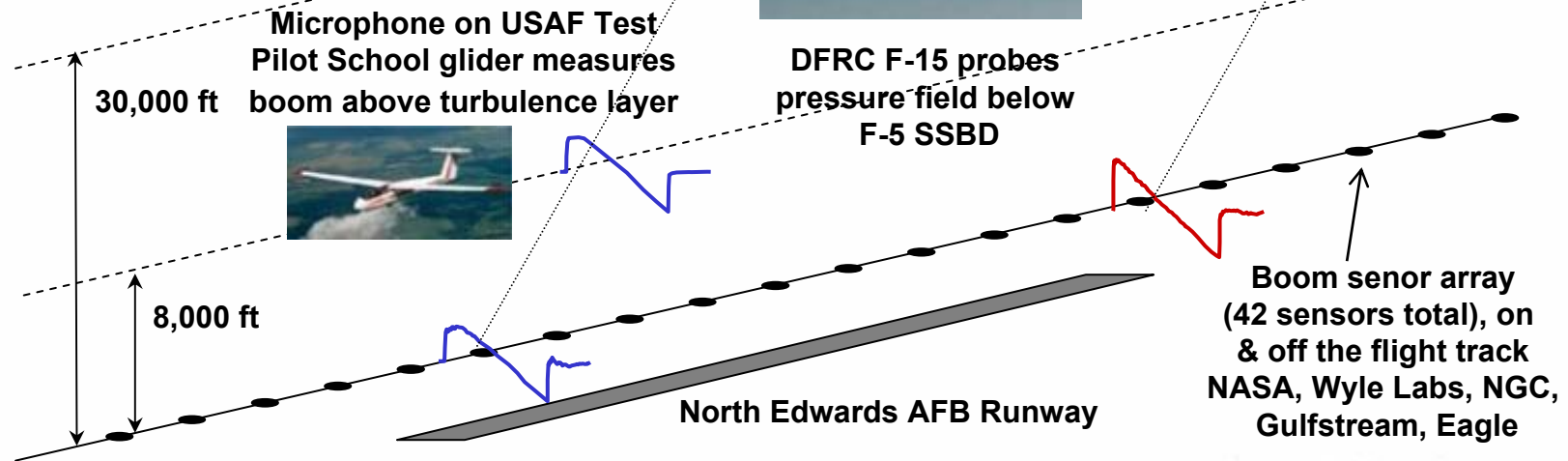
- 21 flights in 9 days
- 8 flights back to back with baseline F- 5E
- 4 flights with F-15 probe aircraft
- 45 probe data sets
- 13 flights with glider
- 1300 boom recordings
- 2 focus booms recorded

Test Schematic

F-5 SSBD operated by Northrop Grumman generates shaped boom over sensor array



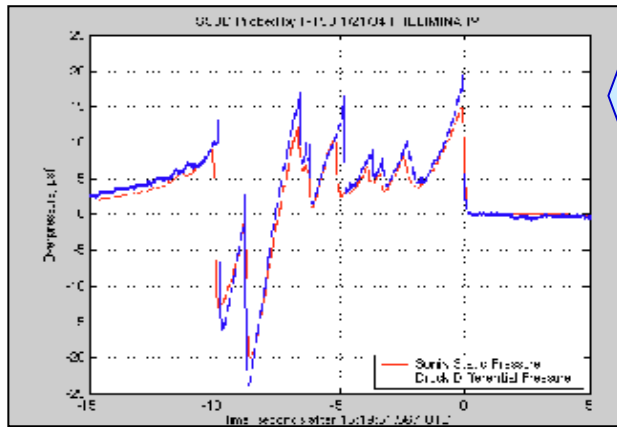
Unmodified F-5E from USN VFC-13 used to generate baseline boom signature



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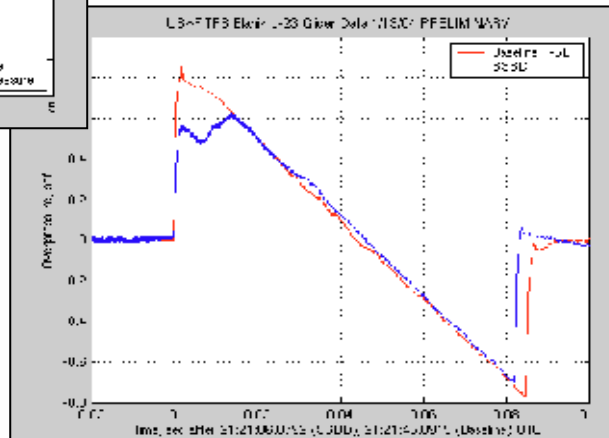
Initial SSBE Flight Test Results



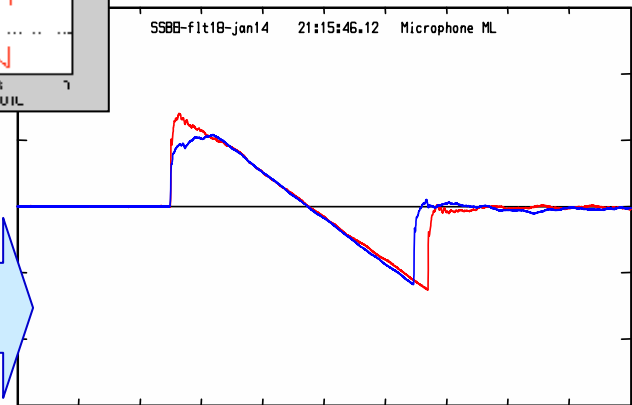
F-15B Probe Data



Glider Data



Ground Data





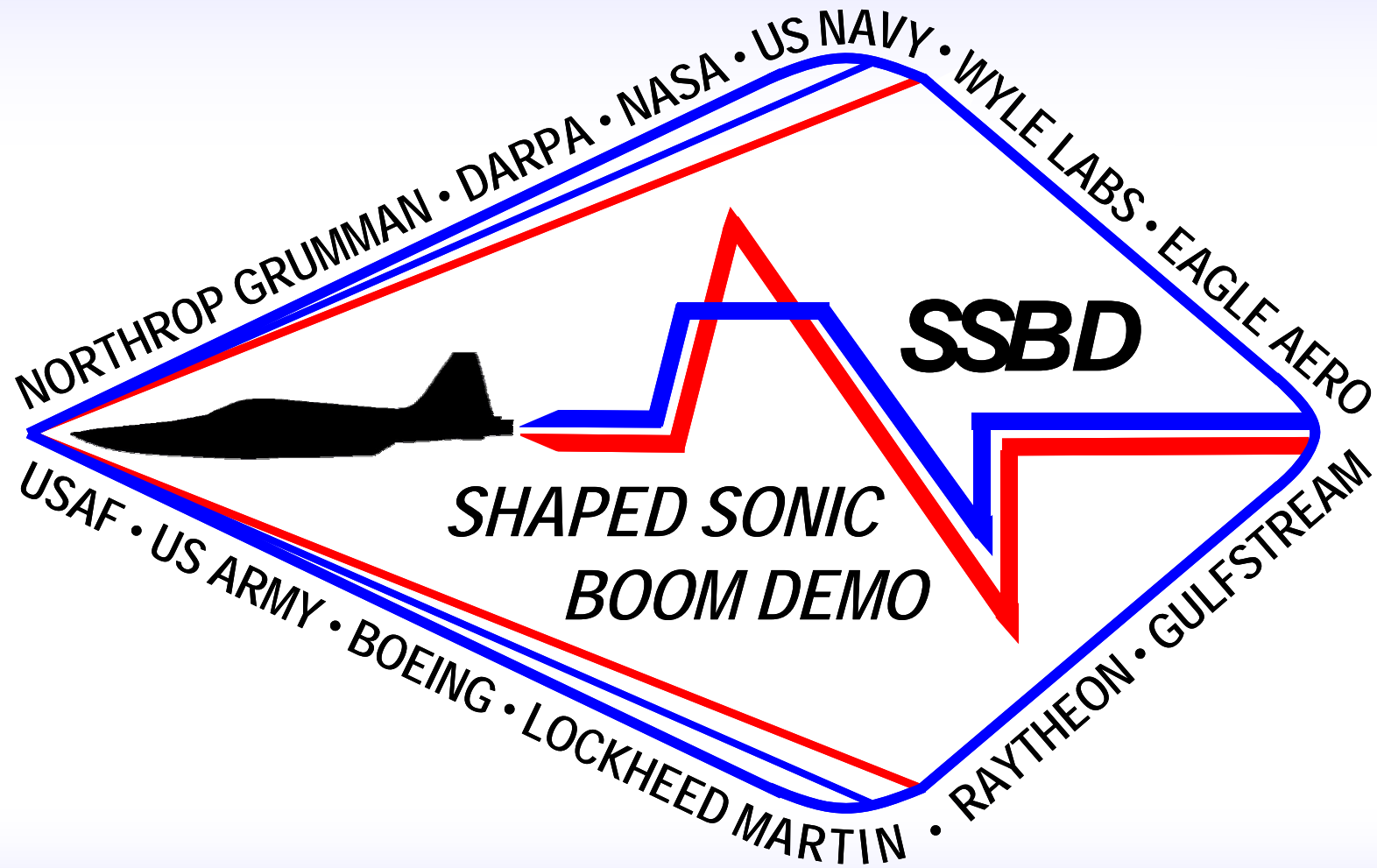
SSBD/SSBE Program Summary

- **Shaped Sonic Boom Persistence Theory was Proven in Actual Flight Conditions**
 - Sonic Boom Intensity Can Be Reduced Through Aircraft Shaping
 - Shaped Ground Boom Signature for a Supersonic Aircraft Can Be Predicted

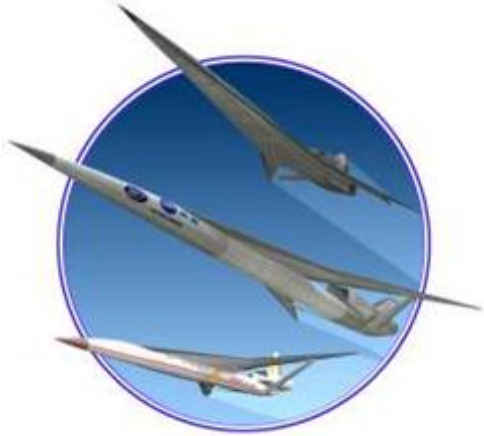
- **DARPA and NASA Were Delighted with the Quantity and Quality of the Supersonic Data**
 - Mapped Shockwave Propagation Around the Near-Field of SSBD Aircraft, at the Mid-Field Using a Glider, and at the Ground Level in Various Atmospheric Conditions
 - Recorded Boom Focus Data Using ¼ G Pushover

- **Program Data Will be Invaluable to Future Supersonic Aircraft Designs – Allows Designers to Go Forward with Confidence in Ability to Predict Boom Signatures**

SSBD/SSBE Test and Support Team



What's Next for QSP?



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