

Hyper-X/ X-43A: Dryden's Role

Laurie Grindle

X-43A Flight 3 Chief Engineer

NASA Dryden Flight Research Center



Lockheed Martin Interchange
August 14, 2012

X-43A (Hyper-X) Project Overview

Project Start
1995

Flt 1
6/2001

Flt 2
3/2004

Flt 3
11/2004

Proj. End
12/2004

- First ever flight demonstration of an airframe-integrated scramjet powered hypersonic vehicle
- Primary objective was to validate the tools, test and analysis techniques, & design methods of scramjet powered, hypersonic vehicles
- Three flight project
 - Two flights at Mach 7
 - One flight at Mach 10

Hyper-X Research Vehicle (HXRV)

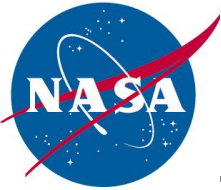
Research Vehicle Adapter

Hyper-X Launch Vehicle (HXLV)

- Hyper-X Research Vehicle (HXRV): ATK-GASL
- Hydrogen fueled scramjet engine
 - Scaled version of a Mach 10 "cruise" configuration

- Hyper-X Launch Vehicle (HXLV) - OSC
- Air launched from NASA's B-52
 - Boosts HXRV to test condition
 - Modified 1st Stage Pegasus booster

Hyper-X



Hyper-X Program Model



LaRC

Program Management

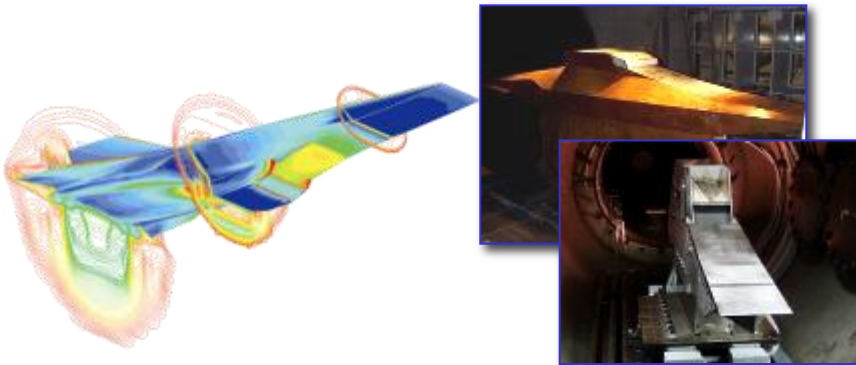
Shared Mission Success

LaRC

DFRC

Technology Development and Validation

Flight Research and Test



- Research and Technology Objectives
- Analytical and experimental performance verification (CFD, Wind Tunnel)
- Flight Validation of Design Predictions
- Improve Scramjet Design Tools

- Flight Research and Operations
- Vehicle Build, Integration and Validation
- Ground, Flight and Range Safety
- Flight Performance Assessment
- Responsiveness to Technology Objectives

Hyper-X



The Hyper-X Partnership

Drawing on Expertise from Coast-to-Coast

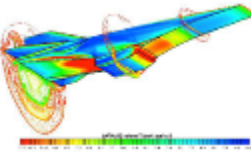
ATK - GASL
Ronkonkoma, NY



Engine & Fuel Systems

Research/Flight Operations
Airworthiness, Flight Safety, Range Safety

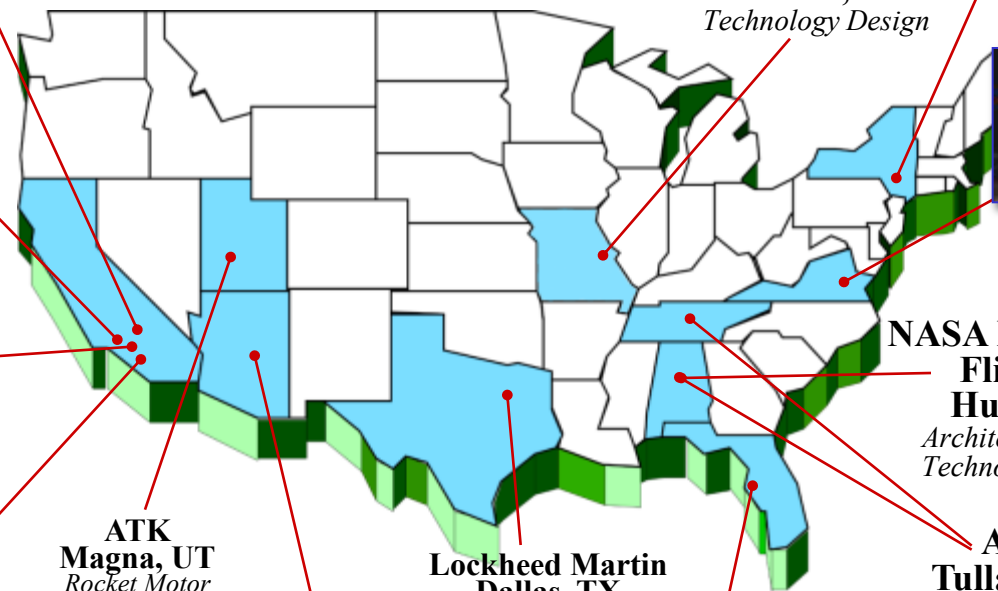
NASA Langley Research Center
Hampton, VA



Technology Design and Experimental Test

Air Force Flight Test Center, Vandenberg AFB
Naval Air Warfare Center, Pt. Mugu
Pacific Sea Range

Boeing
St Louis, MO
Technology Design



NASA Marshall Space Flight Center
Huntsville, AL
Architecture Studies and Technology Assessments

MicroCraft
Ontario, CA



Airframe Assembly

ATK - GASL
Tullahoma, TN and Huntsville, AL

ATK
Magna, UT
Rocket Motor

Lockheed Martin
Dallas, TX
Wind Tunnel Testing

Orbital Sciences Corp.
Chandler, AZ



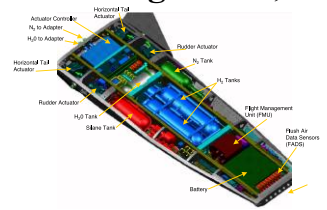
Launch Vehicle Development

Honeywell
Clearwater, FL
Research Vehicle Flight Computer



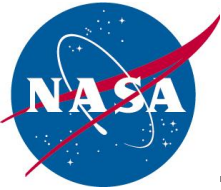
Research and Launch Vehicle Interface Stage Separation Testing

Boeing
Long Beach, CA



Systems/Software Design and Integration

Systems Installation



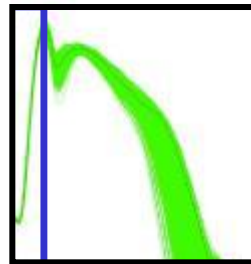
Highly Integrated Effort Required



Propulsion



Simulation



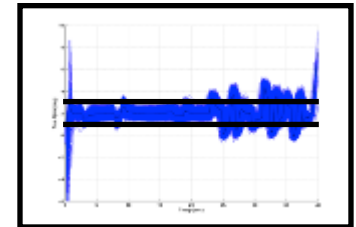
Stage Separation



Systems



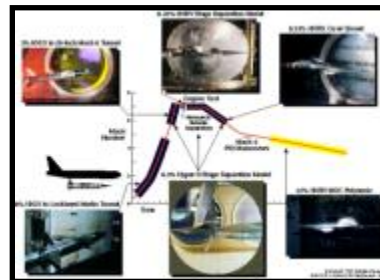
GNC



Structures



Aerodynamics



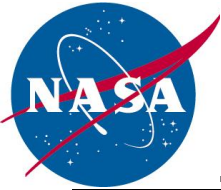
Flight Operations



Launch Vehicle



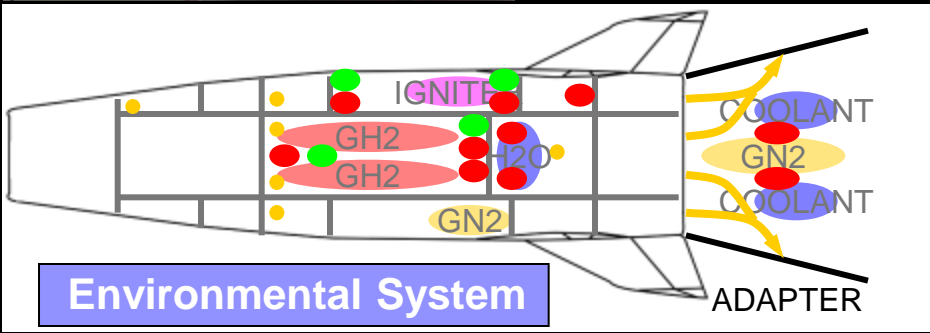
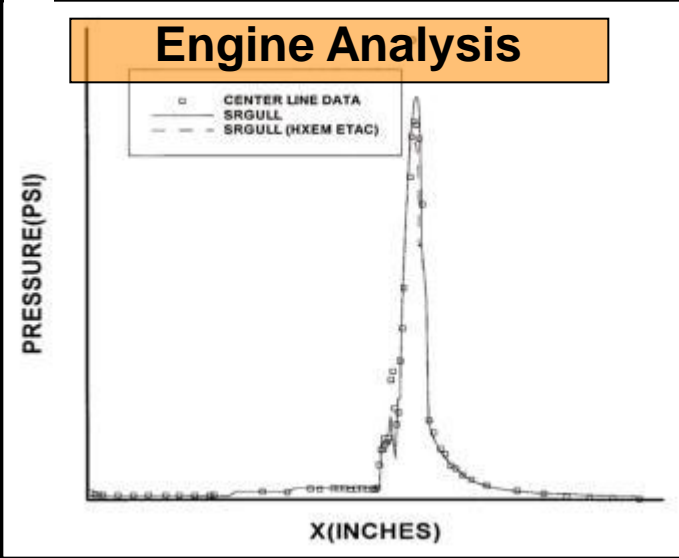
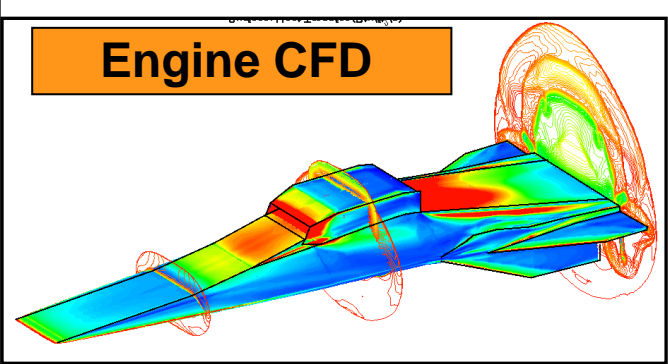
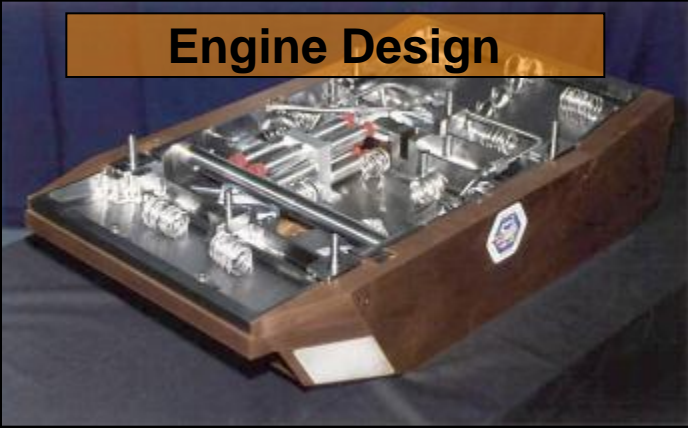
Hyper-X



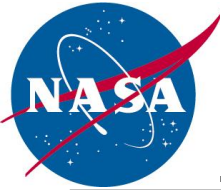
Propulsion

DFRC Role

Partner Role



Hyper-X



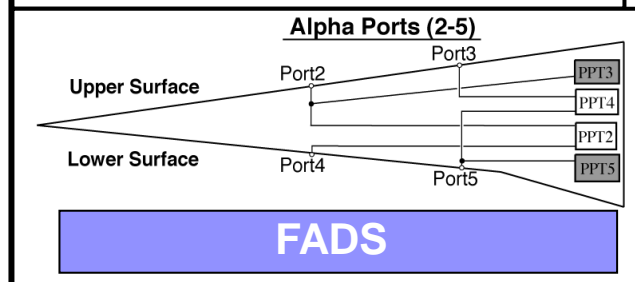
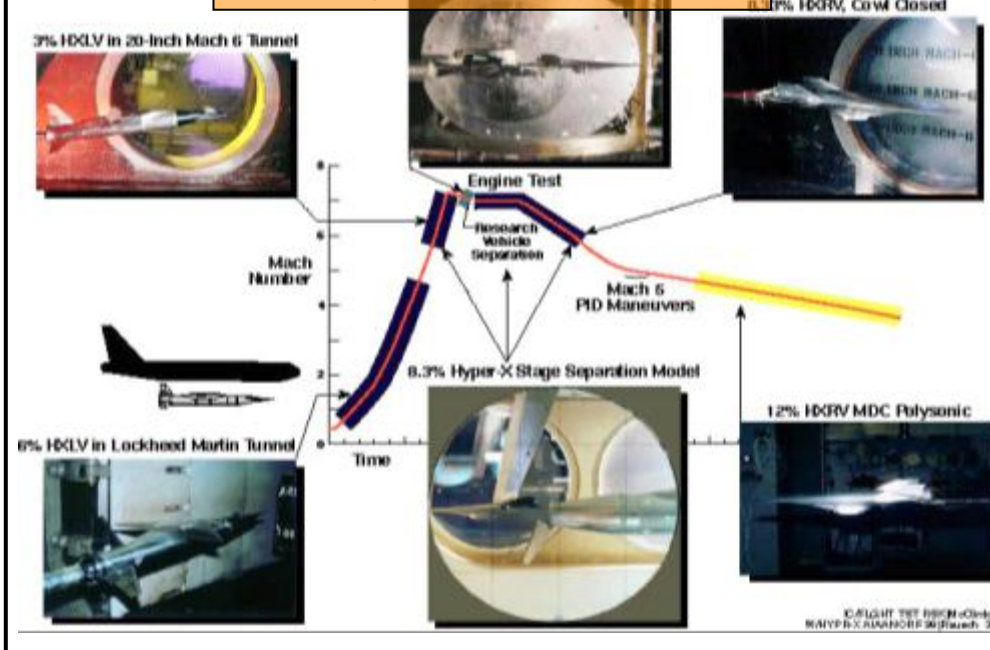
Aerodynamics

DFRC Role

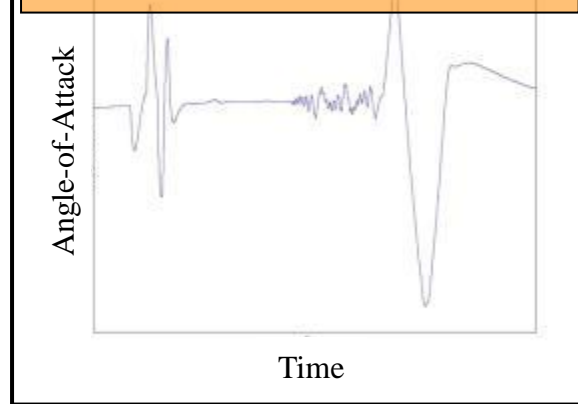
Partner Role



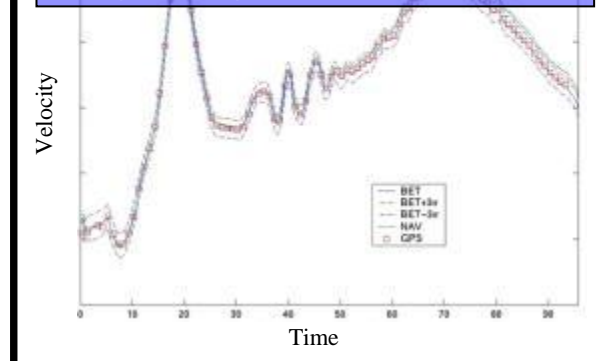
*Aerodynamic Databases



*Parameter Identification

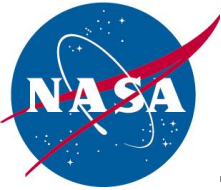


Atmospheric Definition & Trajectory Reconstruction



* DFRC Role:
X-43A Descent

Hyper-X



Systems

DFRC Role

Partner Role



Vehicle SW Testing



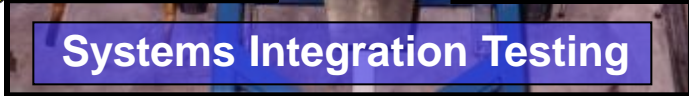
Instrumentation Systems Tests



Vehicle Integration



ASE

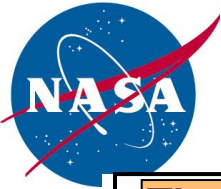


Systems Integration Testing



GSE

Hyper-X



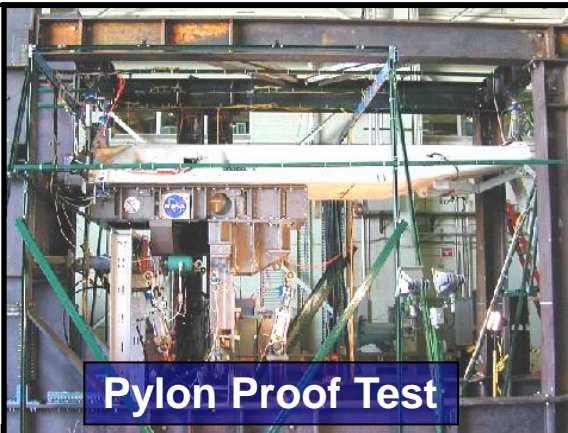
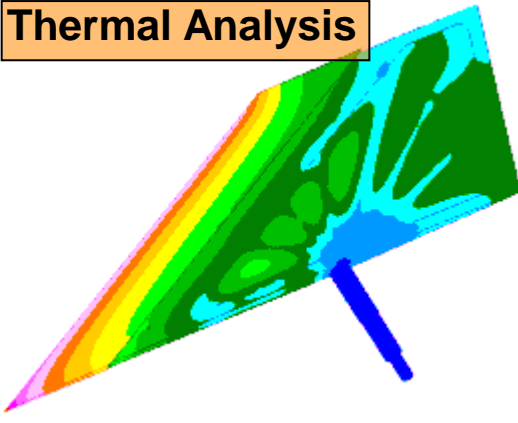
Structures

DFRC Role

Partner Role



Thermal Analysis



Pylon Proof Test

X-43A Mass Properties



Instrumentation Install



Ground Vibration Test



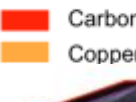








X-43A Inertias



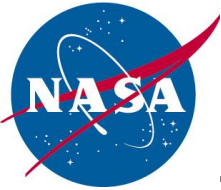
Loaded Actuator Test

X-43A Materials

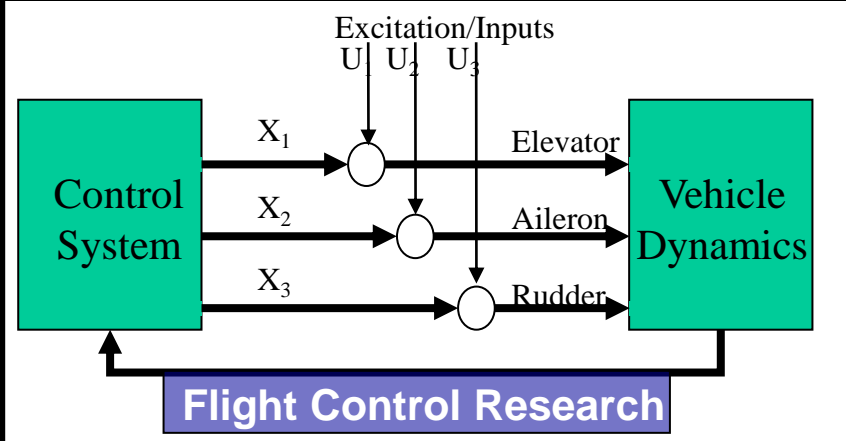
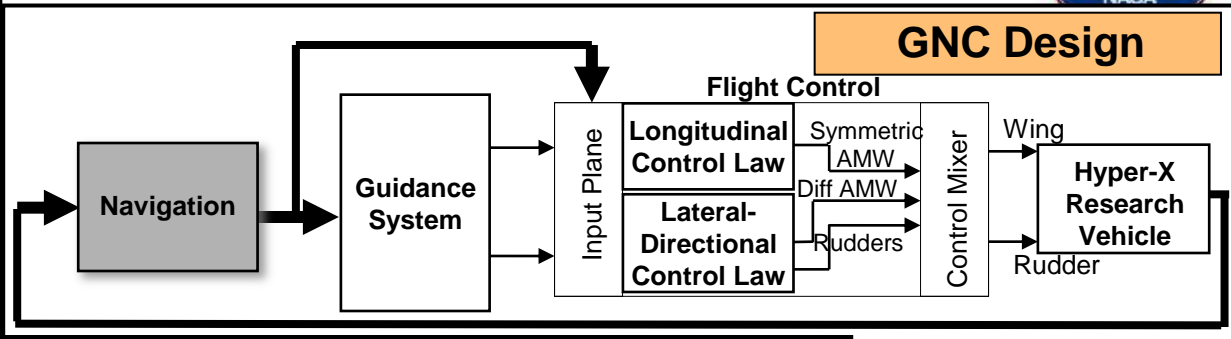
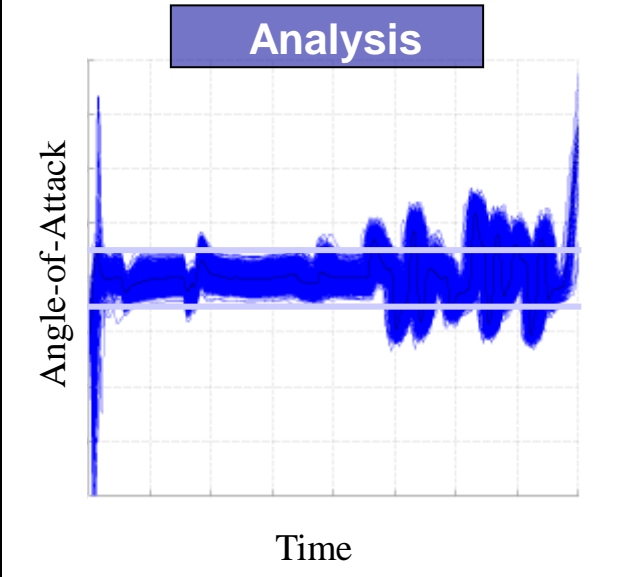
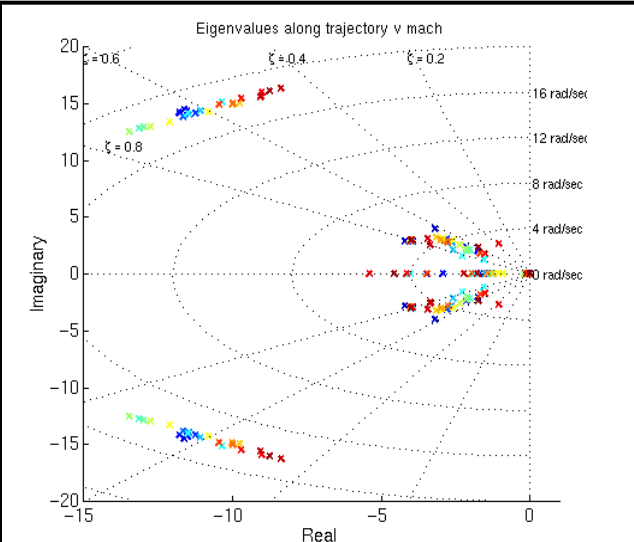
	 Tungsten		 Carbon-Carbon
	 TUFII/AETB		 Copper Alloy



Hyper-X

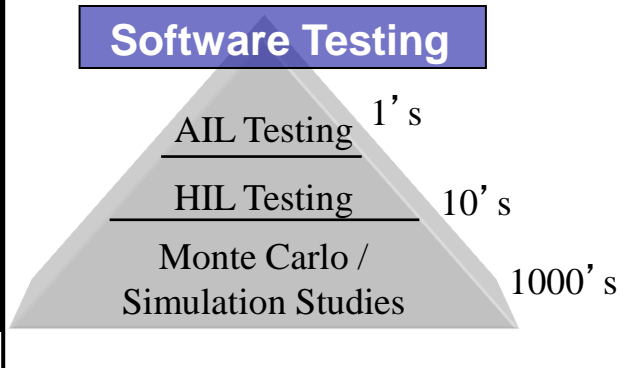


Guidance, Nav, & Flight Controls



DFRC Role

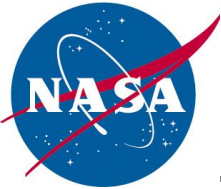
Partner Role



Additional Activities

- F2 & F3 SW Updates
- F3 Controller Design
- Performance & Stability Analysis

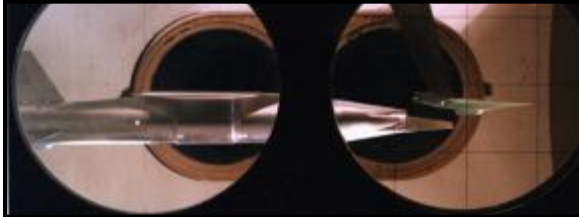
Hyper-X



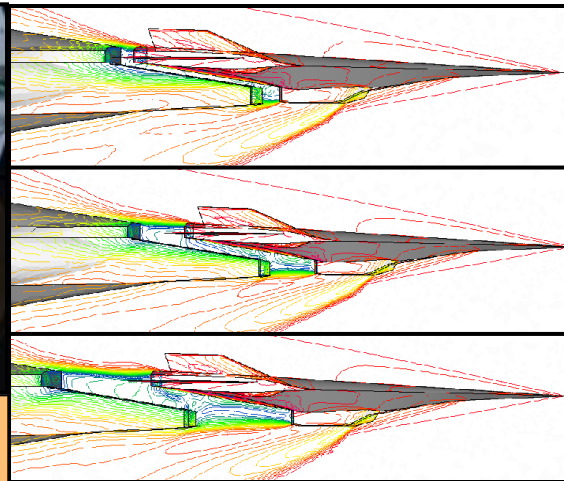
Stage Separation

DFRC Role

Partner Role



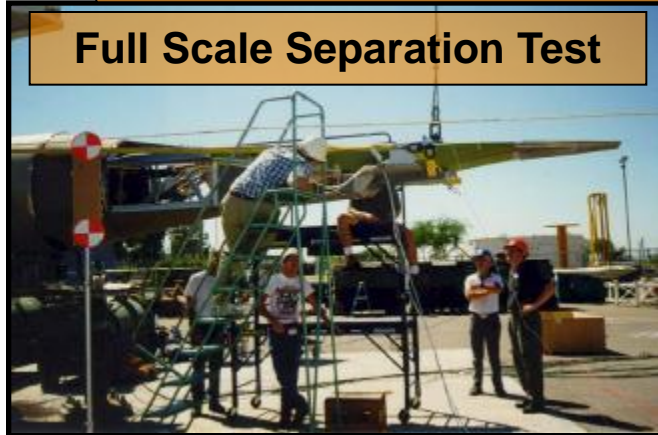
Separation Aerodynamic Database Development



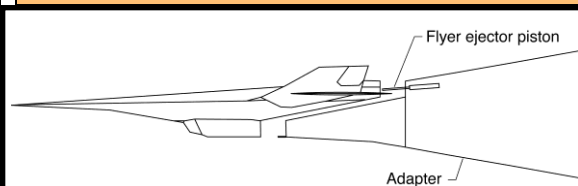
CFD Separation Analyses

0 msec	Start of Separation
	Mach = 7 $Q_{bar} = 1066\text{psf}$
100 msec	End of Piston push
	9 in. extension
250 msec	Beginning Transition to free aero
	$x_{sep} = -44\text{ in.}$
350 msec	Free aerodynamics
	$x_{sep} = -69\text{ in.}$
500 msec	All feedback control loops closed
2.5 sec	End of separation / Start of test
	$a = 2.5^\circ, b = 0^\circ$

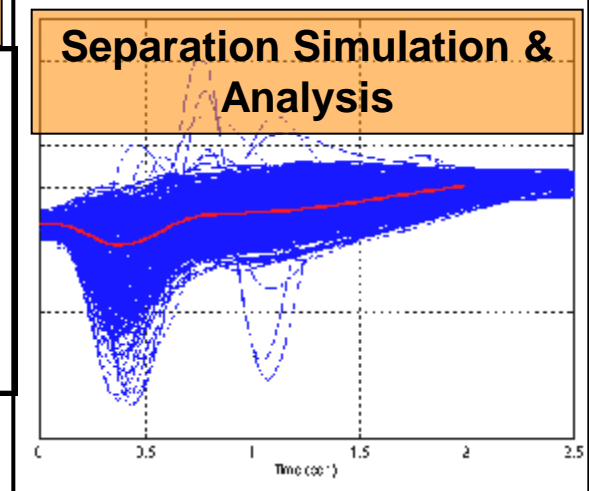
Separation Control Logic



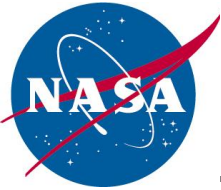
Full Scale Separation Test



Separation System



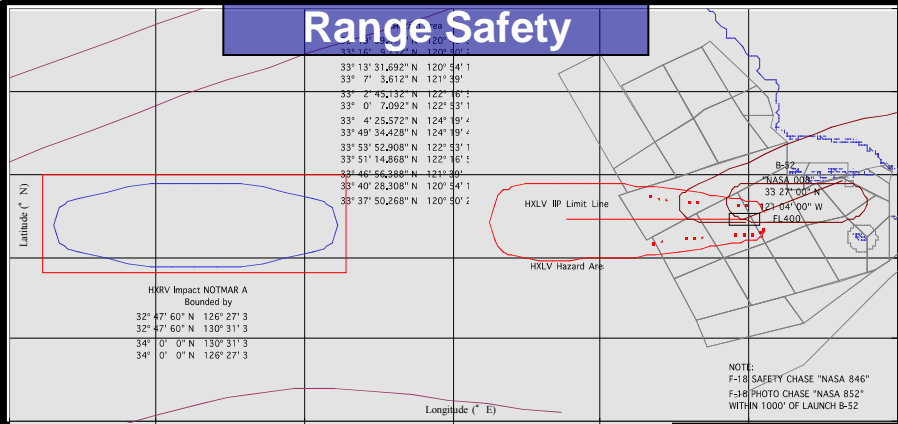
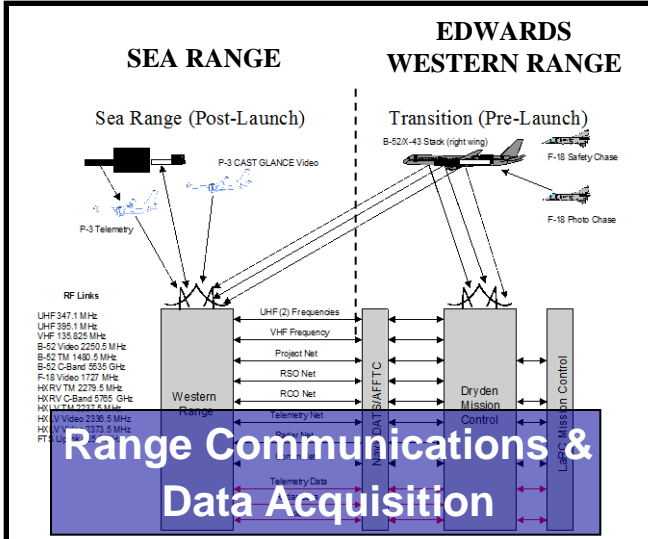
Hyper-X



Instrumentation & Range

DFRC Role

Partner Role



Range Communications & Data Acquisition

Instrumentation Systems Tests



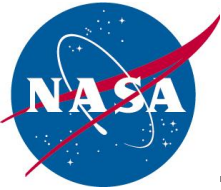
RV Instrumentation System

Pressures	175
Temperatures	113
Strain Gages	14
Misc Analog	9
1553 Bus	792
TOTAL	1103



RF System Validation Antenna Pattern Testing

Hyper-X



X-43A Simulation

DFRC Role

Partner Role



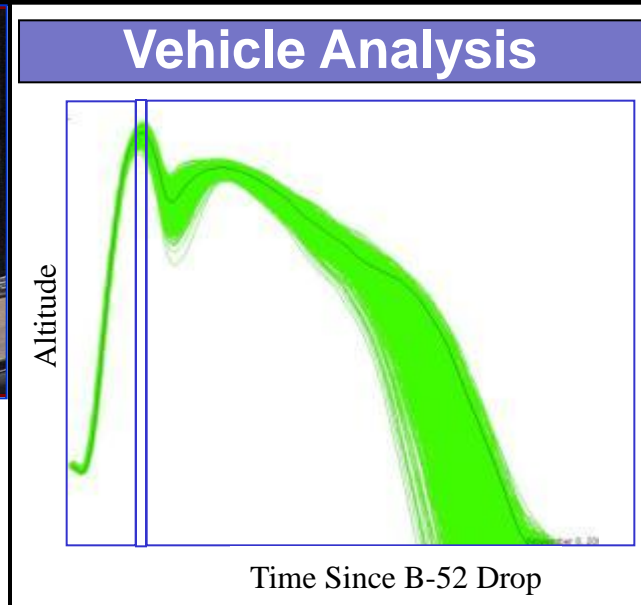
Hyper-X Sim Laboratory



Hardware-in-Loop Tests



Aircraft-in-Loop Testing

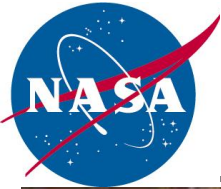


Control Room Training

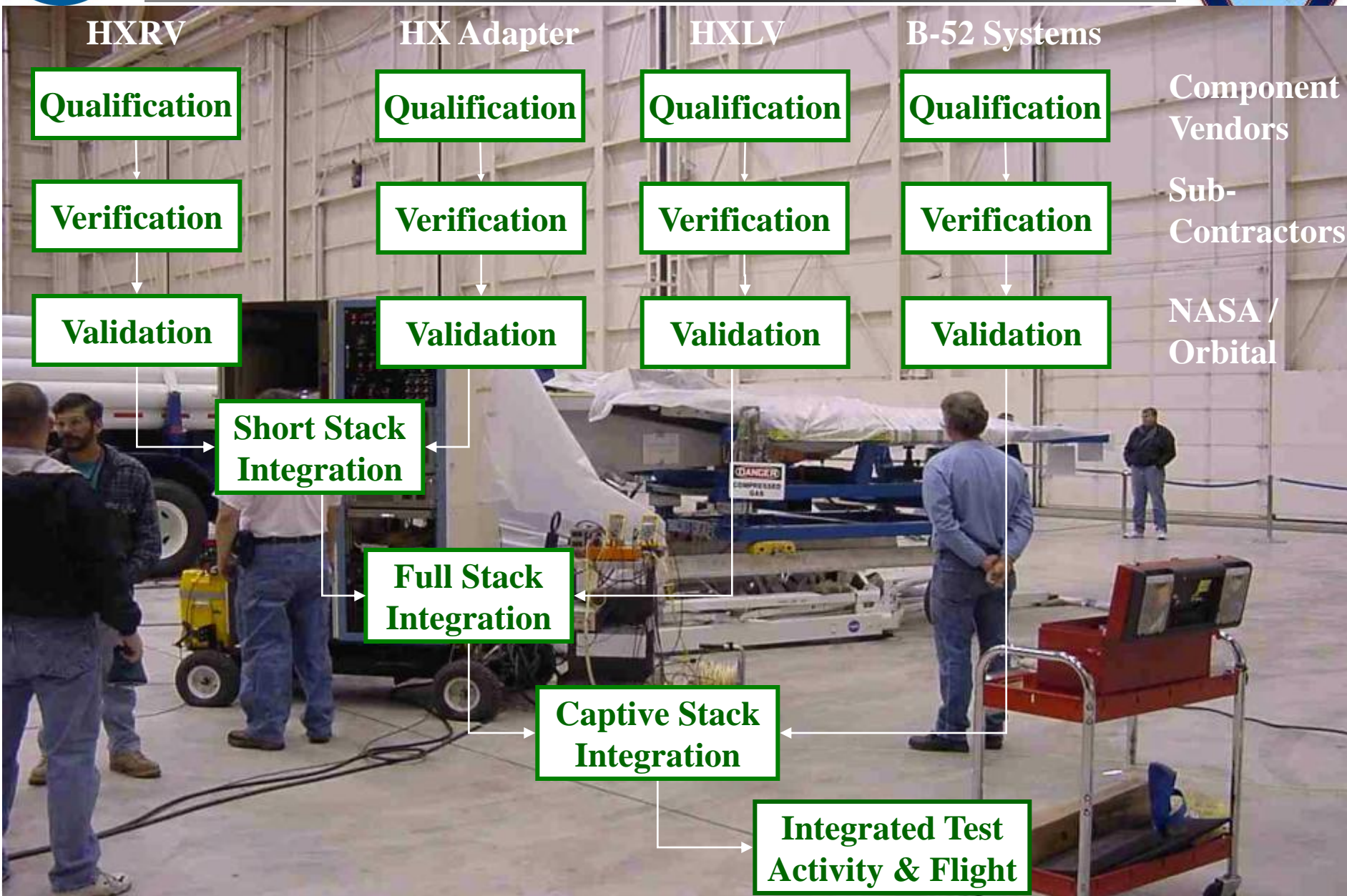
Additional Sim Activities

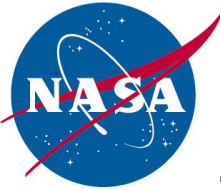
- Analytical End-to-End Mission Simulation
 - LVsim \rightleftarrows SepSim \rightleftarrows RVsim

Hyper-X



Test and Integration Activities





Flight Operations

DFRC Role

Partner Role



Vehicle Rollout



Pre-Flight Servicing



Control Room & Flight Ops



Pre-flight Tests



Emergency Training



Vehicle Testing



Vehicle Integration



Short Stack Mate



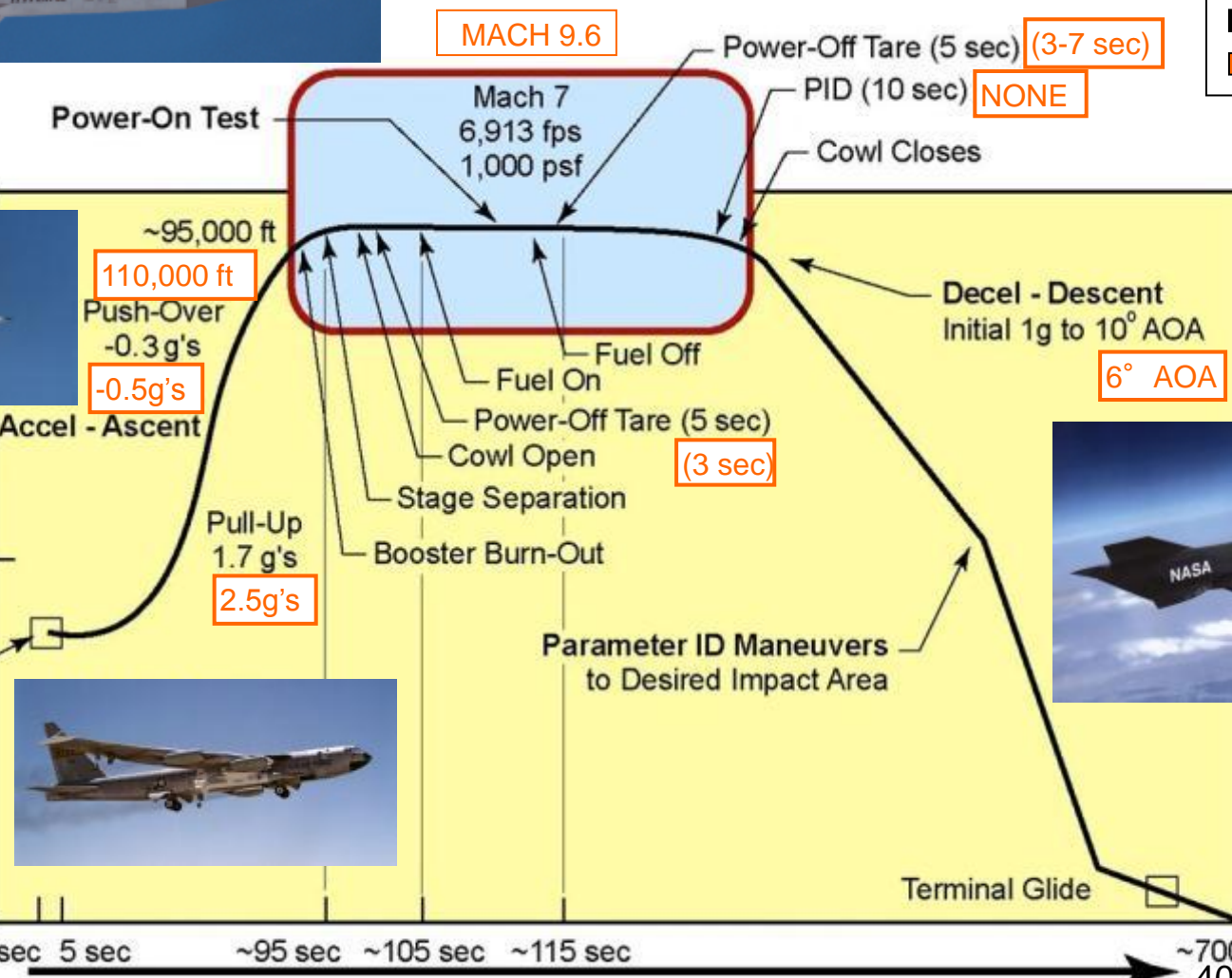
B-52 Operations



Hyper-X



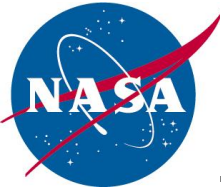
X-43A Mission Details



Flight 2
 Flight 3



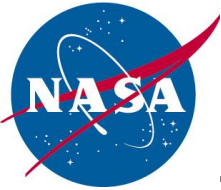
Hyper-X



Flight 2 – March 27, 2004

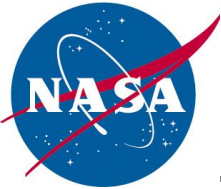


Hyper-X



Flight 3 – November 16, 2004

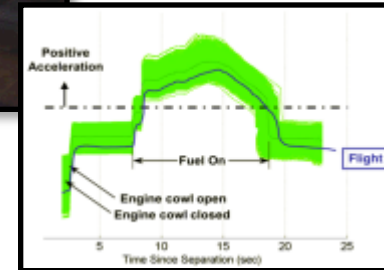




Concluding Remarks



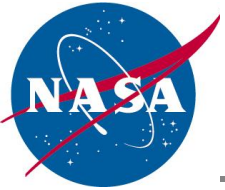
- Why were we successful?
 - Rigorous processes for design, development, testing, and validation
 - Strong technical expertise and team work between NASA, ATK GASL, Boeing & Orbital Sciences
 - A dedicated project team that worked for eight years to make these revolutionary flights a reality



Hyper-X

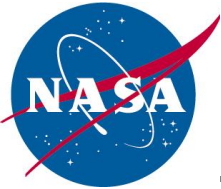
A clear blue sky with a large, white, curved contrail from a jet aircraft. In the bottom right corner, a smaller jet is visible, leaving two parallel white contrails.

Questions ???



Backup Charts

Hyper-X



Goals/Objectives of Hyper-X Program



GOALS: Demonstrate, validate and advance the technology, experimental techniques, and computational methods and tools for design and performance predictions of a hypersonic aircraft powered with an airframe-integrated, scramjet engine.

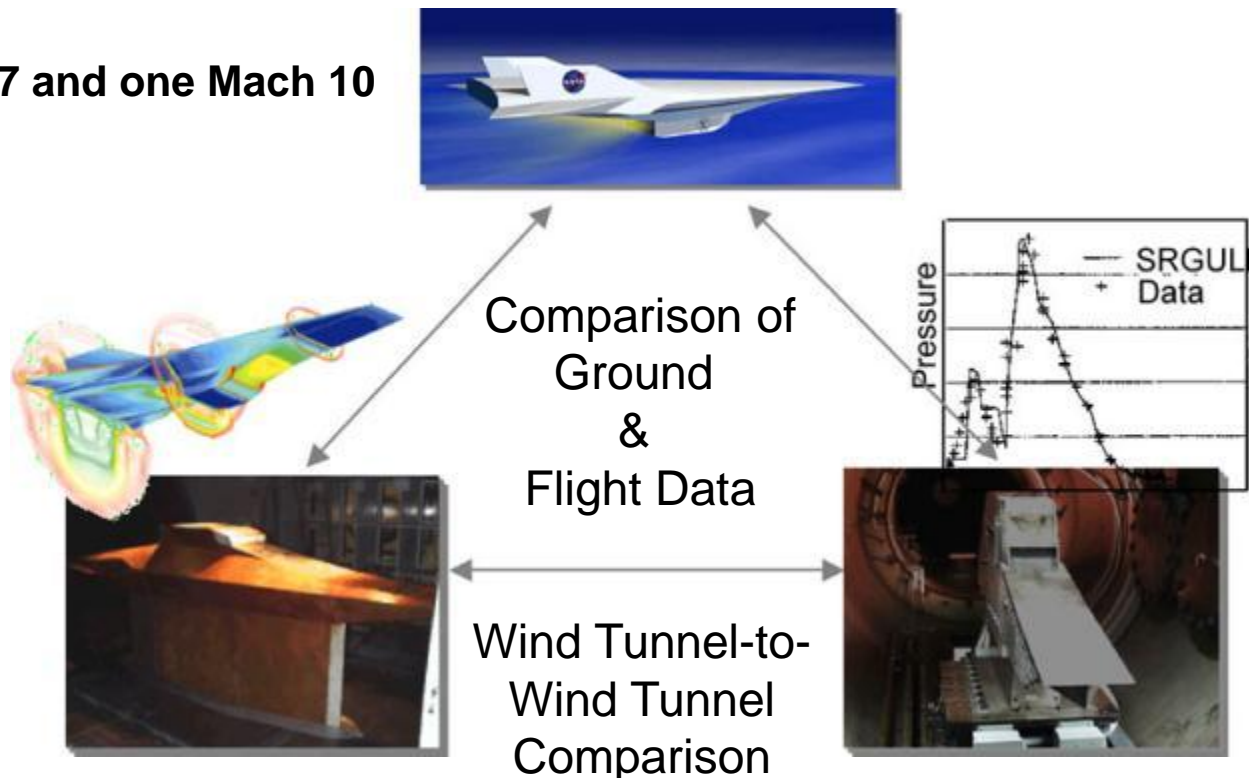
FLIGHT OBJECTIVES:

- Three flights: two @ Mach 7 and one Mach 10
- Methods verification
- Scaling confirmation

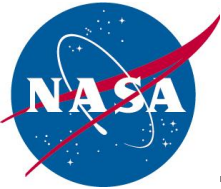
Primary Metric: Accelerate

TECHNOLOGY OBJECTIVES:

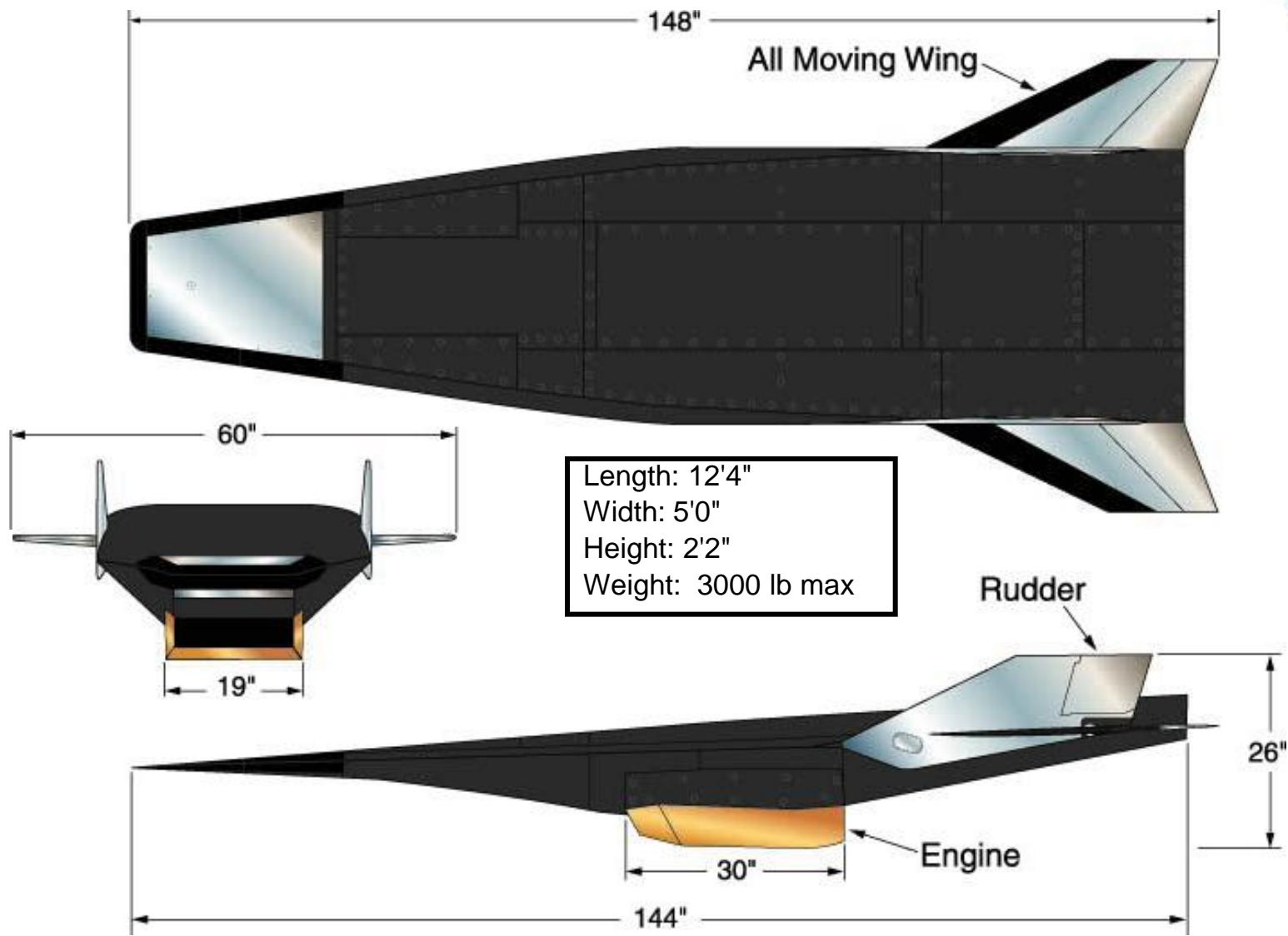
- Vehicle design & risk reduction
- Flight validation of design methods
- Design method enhancement
- Hyper-X Phase 2 and beyond



Hyper-X

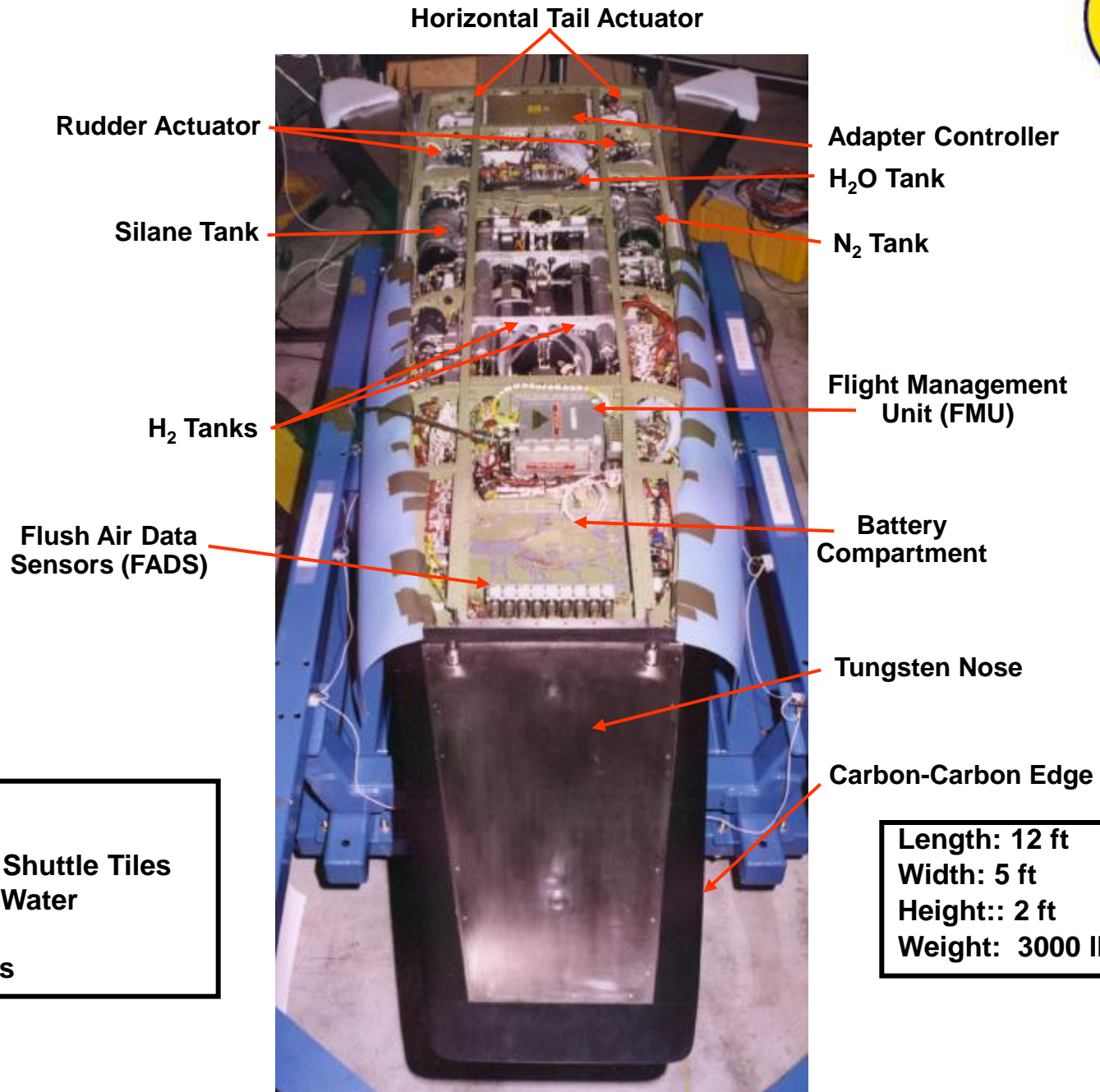


X-43A External Configuration





X-43A Internal Layout



Fuel: Hydrogen
Igniter: Silane
Thermal Barrier: Shuttle Tiles
Engine Coolant: Water
Nitrogen Purge
Electric Actuators

Length: 12 ft
Width: 5 ft
Height: 2 ft
Weight: 3000 lb



- ✓ Ground Vibration, Mode Interaction, Initial Mass Properties Testing
- ✓ Final Weight/Balance and Mass Properties Test



- ✓ VMS Hardware-In-Loop and Aircraft-In-Loop Tests
- ✓ RF Systems Tests
- ✓ Fuel Systems - High Pressure Bench Test
- ✓ Environmental Systems Test Installed
- ✓ Leak and Functional Test Full
- ✓ Mission Simulation With Inert Gas Test
- ✓ Full Mission Simulation With Real Gas Test



- ✓ HXRV-Adapter Systems Validation
- ✓ HXRV/Adapter Integration Tests

- ✓ Standalone HXLV Tests
- ✓ HXLV/HXRV Integration

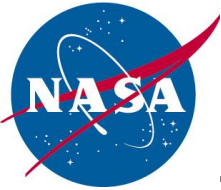


- ✓ Stack Hook Release
- ✓ B-52 Systems Test
- ✓ B-52/Stack Integration
- ✓ Combined System Test
- ✓ Captive Carry

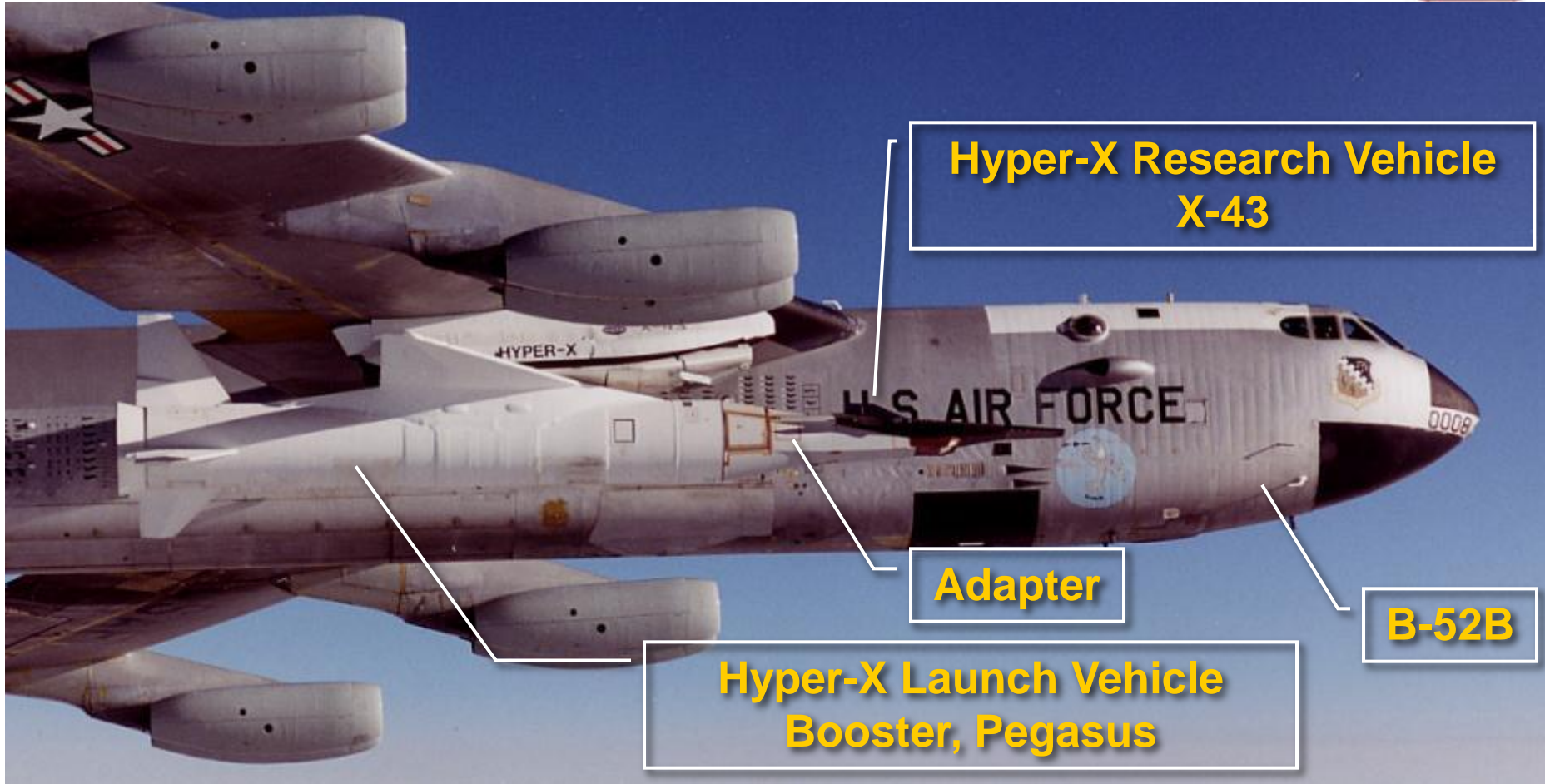


Hardware and Software Testing ...Preparing for Flight at DFRC





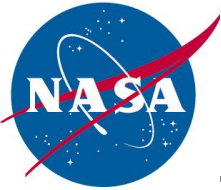
Hyper-X Components



Launch Stack = HXLV + Adapter + HXRV

Hyper-X is a complex system with multiple interfaces.

Hyper-X



Operations on Day of Flight



Day of Flight Ground Operations

- Control Room Staffing
- System power up and checkout
- B-52 engine start / power transfer
- Final X-43A closeout



B-52 Take-off

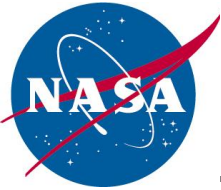


Flight Operations

- In flight systems / range checks
 - HXRV Built In Tests
 - FTS auto gain control
 - HXLV Fin Actuation System
- Launch and Free Flight



Hyper-X



Flight 3 Right Adapter Camera Image



- Time between images is 33.3 milliseconds - 1/30th of real-time.
- Right Adapter Camera Position

