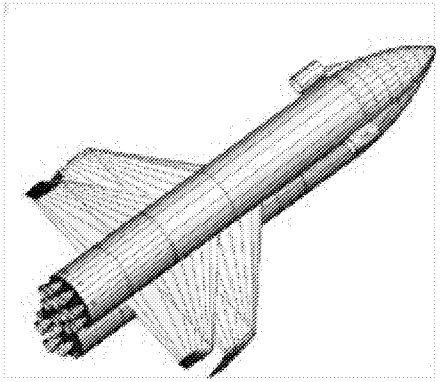
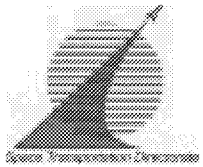
Launch Vehicle Ascent Stage Separation Wind Tunnel Test



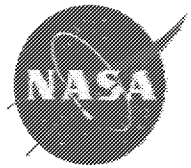
Wayne Bordelon/MSFC
Alonzo Frost/MSFC
Victor Pritchett/MSFC

12th Thermal and Fluids Analysis Workshop

September 10 – 14, 2001



Presentation Overview



- Background
- Objectives
- LGBB Configuration
- Approach
  - Test Facility
  - Instrumentation
  - Tests Conducted
- Preliminary Results
  - Pressure Sensitive Paint
  - Schlieren Video
  - Force and Moment
- Observations
- Summary
- Acknowledgements

Background

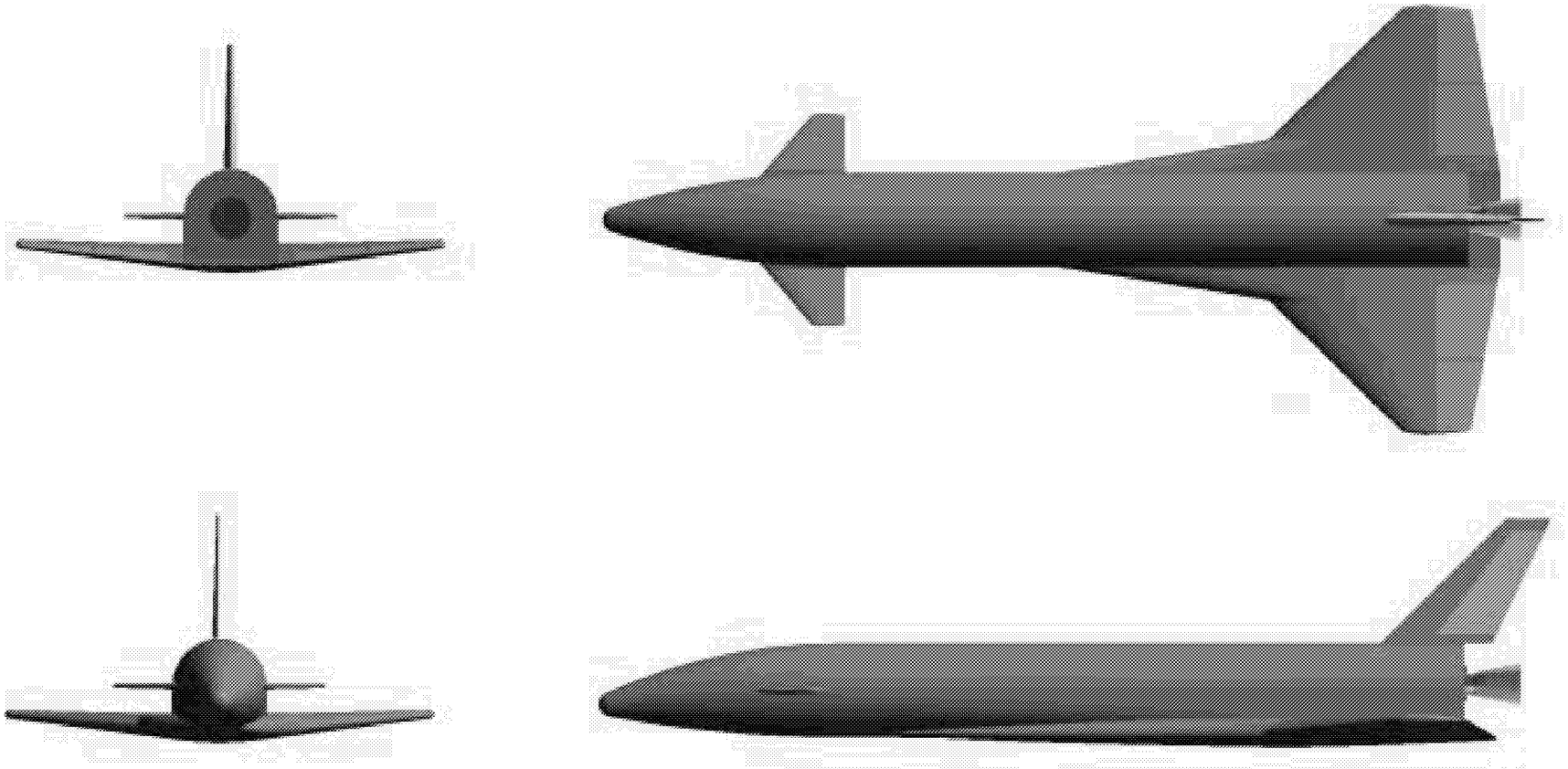
- 2nd Gen NASA Led Risk Mitigation Activities Call:
  - 1st round call – June, 2000
  - Goal: advance technologies, mitigate risks, and conduct advanced development activities to enable RLV decision/development

- Stage Separation and Ascent Aerothermodynamics Task Selected as part of the Airframe Project
  - Develop tools and databases to address TSTO stage sep
  - Multi-center team (JSC, LaRC, MSFC)
  - Wind tunnel testing and CFD development and application
  - LGBB bimese was selected as initial reference configuration
  - FY01 testing at MSFC and LaRC

MSFC Aero Research Facility Test Objectives

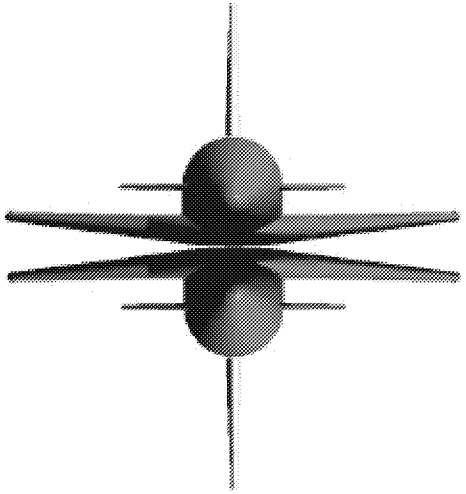
- Measure Force and Moment Data for Isolated and Bimese Configurations
- Record Schlieren Data for Aerodynamic Analysis
- Develop Pressure Sensitive Paint Test Methodology and Determine Feasibility
- Develop and Test Stage Separation Envelope using Manual Stage Separation Sting
- Develop Reference Databases to Validate Tools and Support Preliminary Design
- Develop NASA In-House Expertise and Capability to Support 2nd Gen Insight

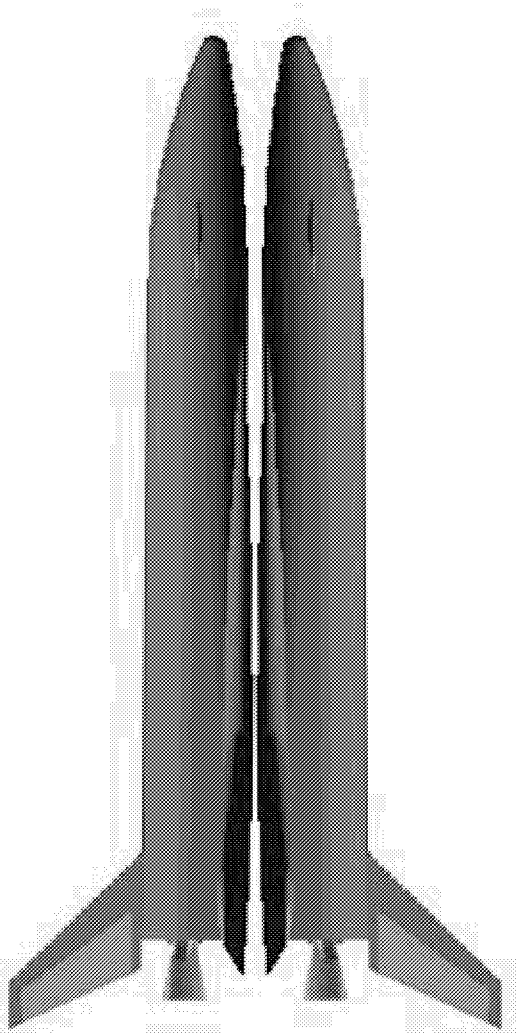
LGBB Configuration



LGBB Configuration

BIMESE ARRANGEMENT

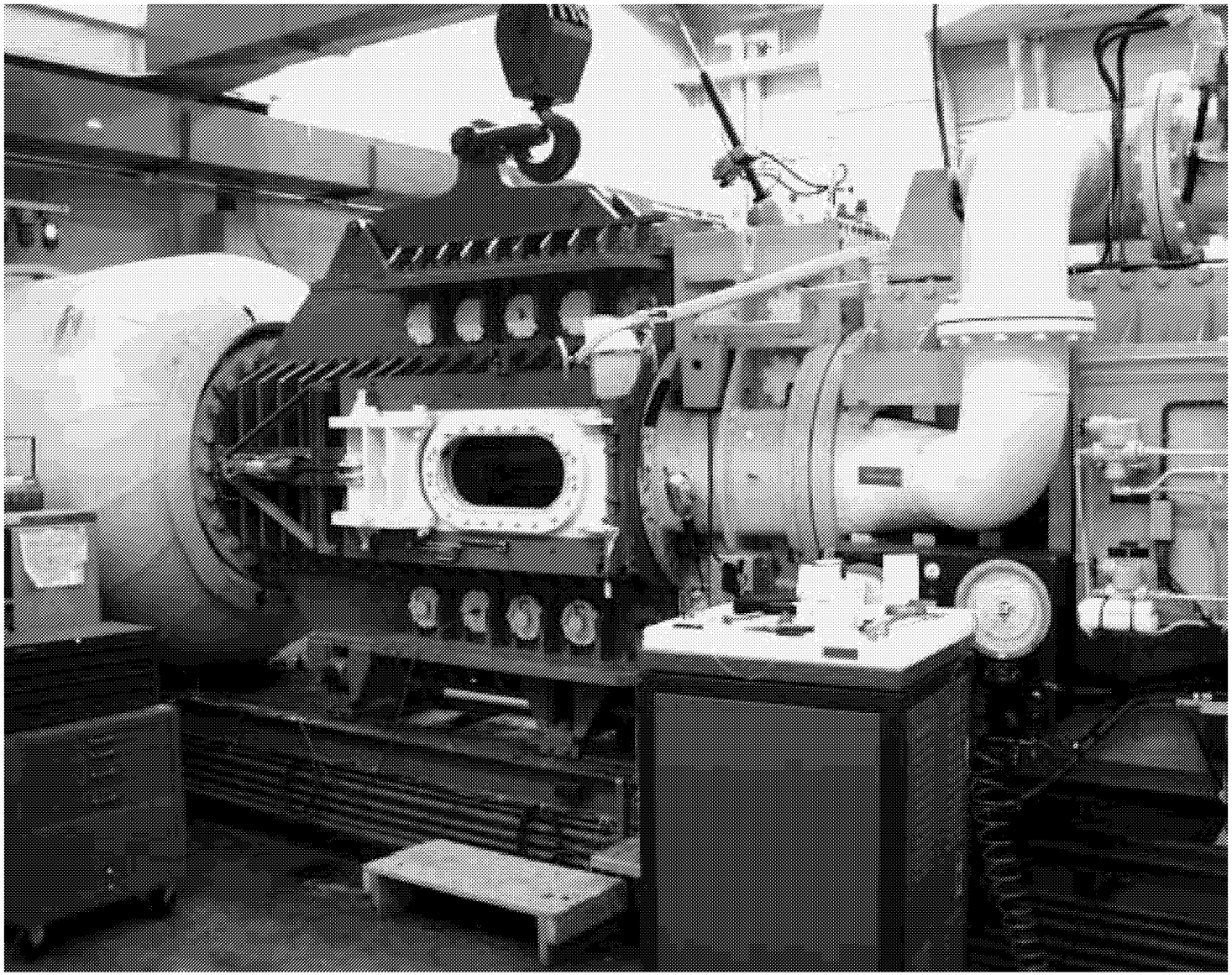




Aerodynamic Research Facility Test Approach

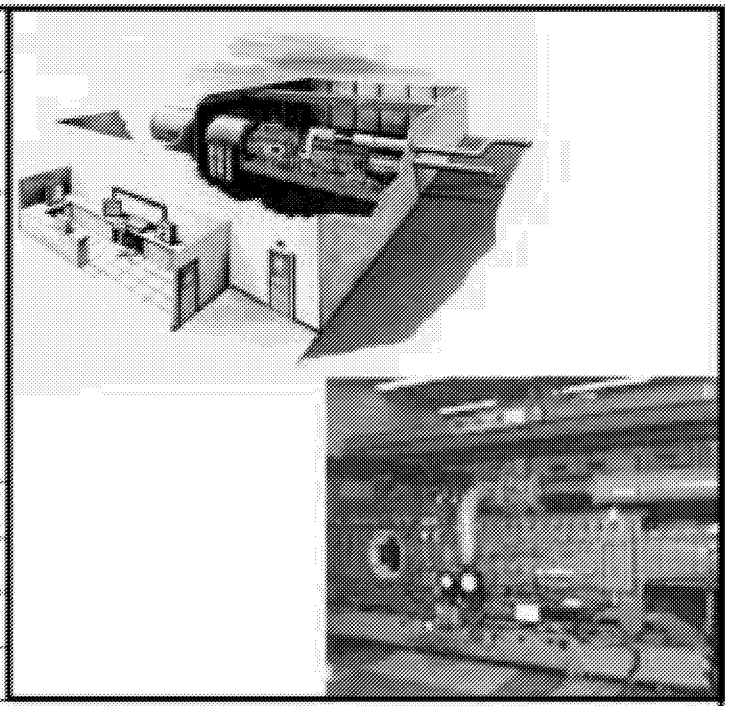
- Test Conducted at MSFC's 14" Aerodynamic Research Facility
- Design and Fabricate 0.0121 Scale LGBB Model
- Pressure Sensitive Paint Feasibility Test
- Isolated Orbiter Force and Moment Data
- Develop Stage Separation Test Envelope
- Bimese Configuration Force and Moment Data using Manual Stage Separation Test Rig
- Schlieren Video to Analyze Aerodynamic Environment

MSFC Aerodynamic Research Facility



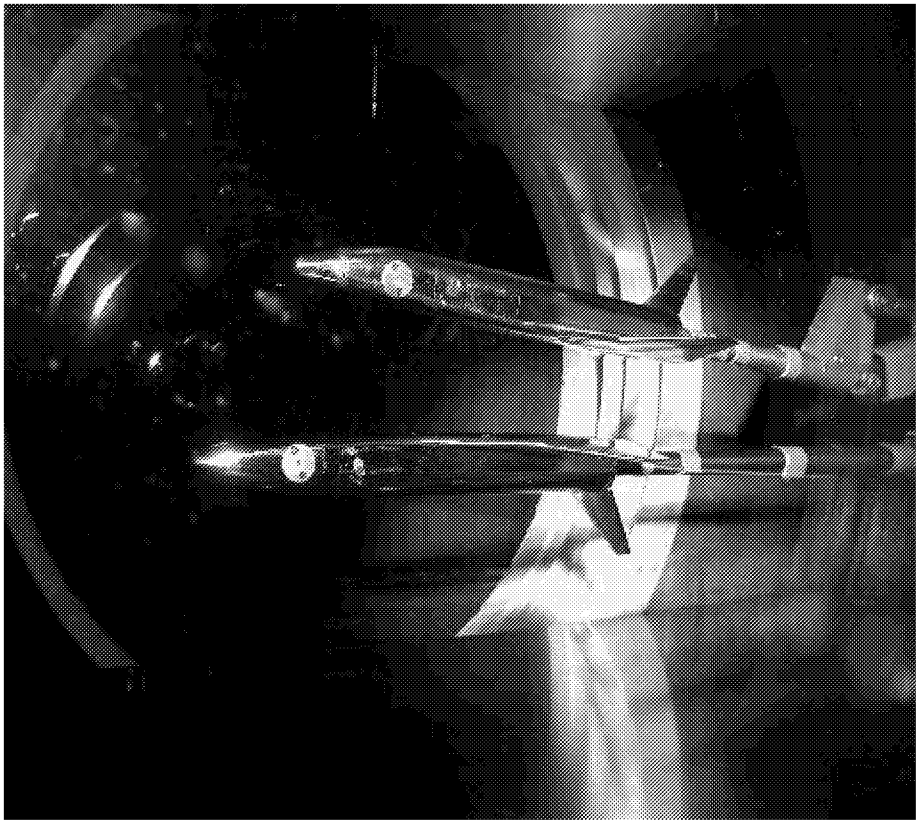
MSFC Aerodynamic Research Facility

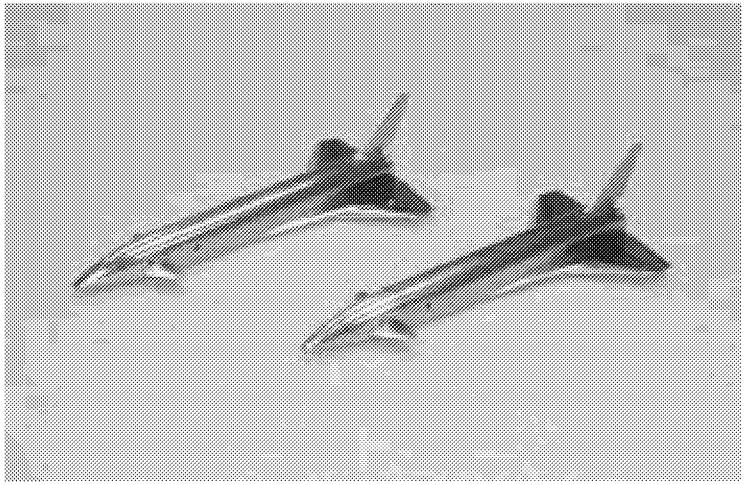
Type of Tunnel	Blowdown to atmosphere or vacuum
Test Section Size	Height 14 inches Width 14 inches Length 24 inches
Mach Number	Transonic test section with controllable diffuser, perforated walls, and interchangeable nozzle blocks. Mach 0.25 to 1.3, 1.46, 1.96 Supersonic test section with movable fixed contour nozzle blocks. Mach 2.74 to 4.96
Reynolds Number	1 to 18 million per foot
Stagnation Pressure	22 to 105 psia
Dynamic Pressure	2 to 20 psia
Stagnation Temperature	Ambient to 200 F; normally 100 F
Air Storage	6000 cubic feet at 515 psia and 100 F
Vacuum Storage	42,000 cubic feet at 0.1 psia
Run Time	60 to 90 seconds (transonic) 45 to 50 seconds (supersonic)
Recharge Time	10-20 minutes nominally for transonic and 15-20 minutes nominally for supersonic. Supplemental charging may be done with 3500 psi plant air when needed.
Run Rate	20 to 30 runs per 8-hour shift
Angle of Attack	-10 to +10 degrees with added range provided by offset stings up to 90 degrees

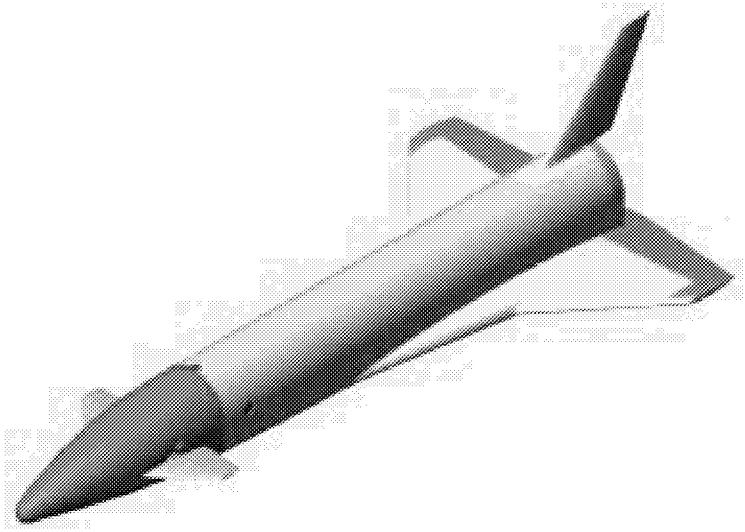


Courtesy of MSFC's Web Site

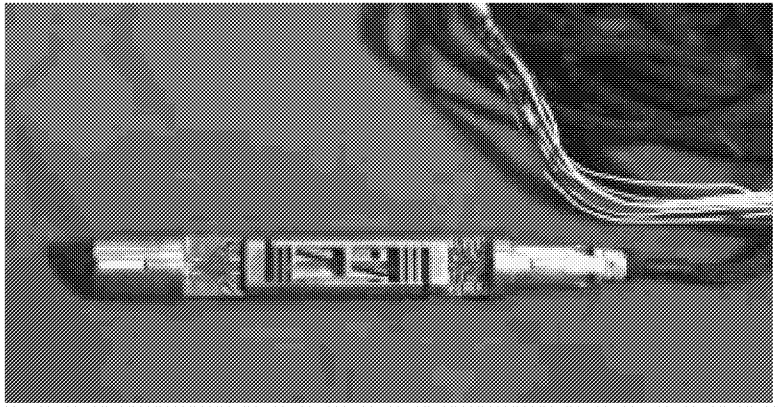
LGBB - 0.0121 Scale Model

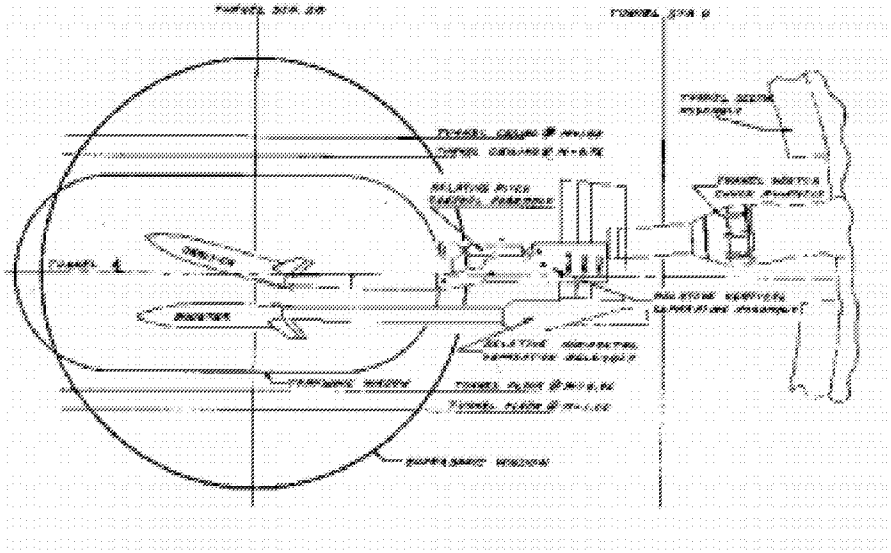


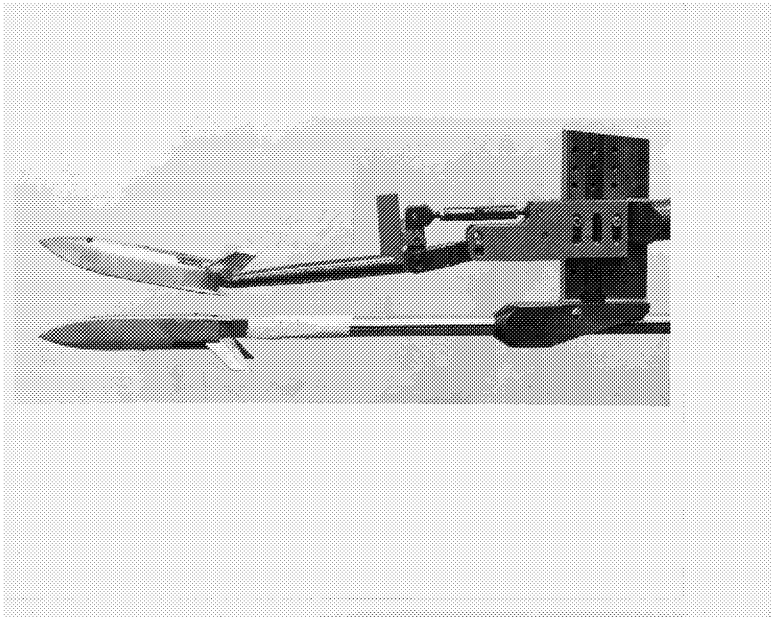




Stage Separation Test Instrumentation

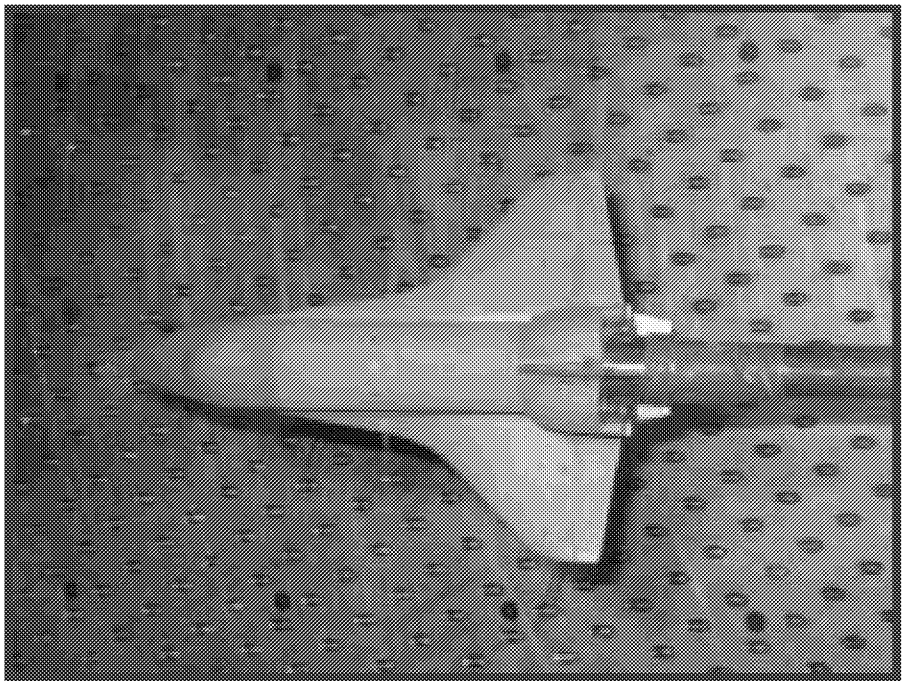




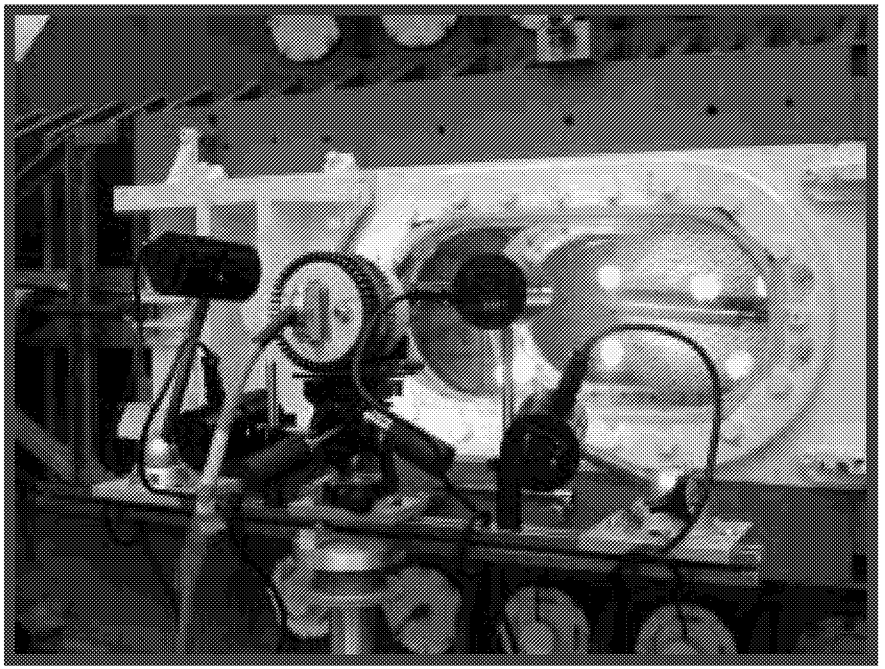


Wind Tunnel Separation Testing
(Phase A Shuttle Concept)

Pressure Sensitive Paint Test



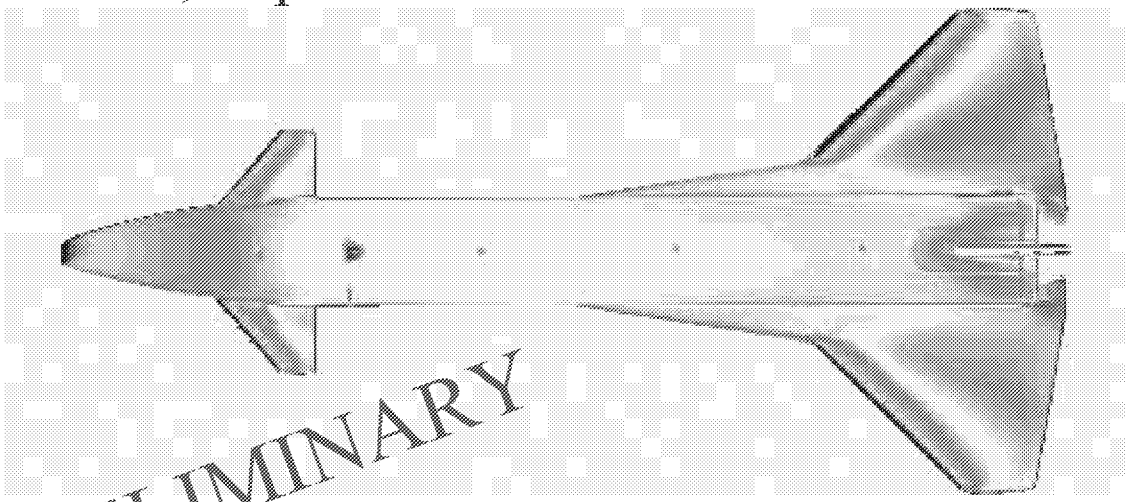
STS Orbiter Inside TST and
PSP Imager Outside Tunnel



Isolated LGBB PSP Sample Results

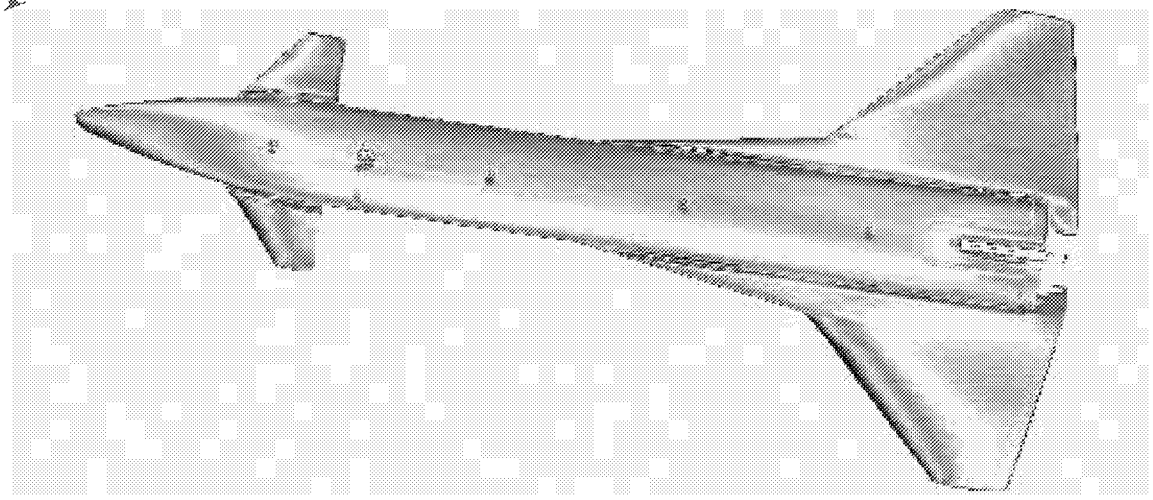
Mach 3.48, Alpha = 0°

$\beta = 0$ deg



PRELIMINARY

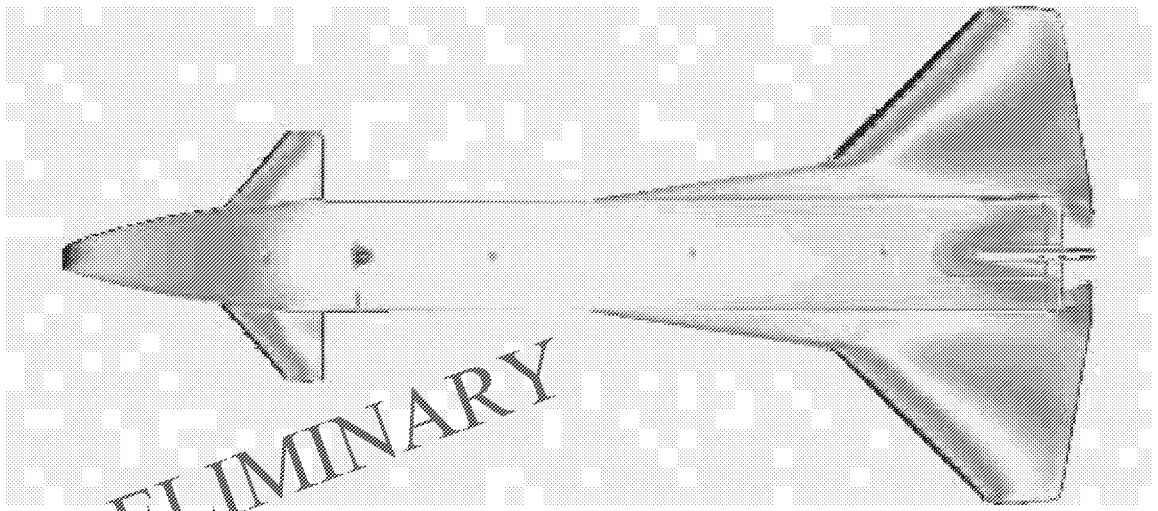
$\beta = 8$ deg



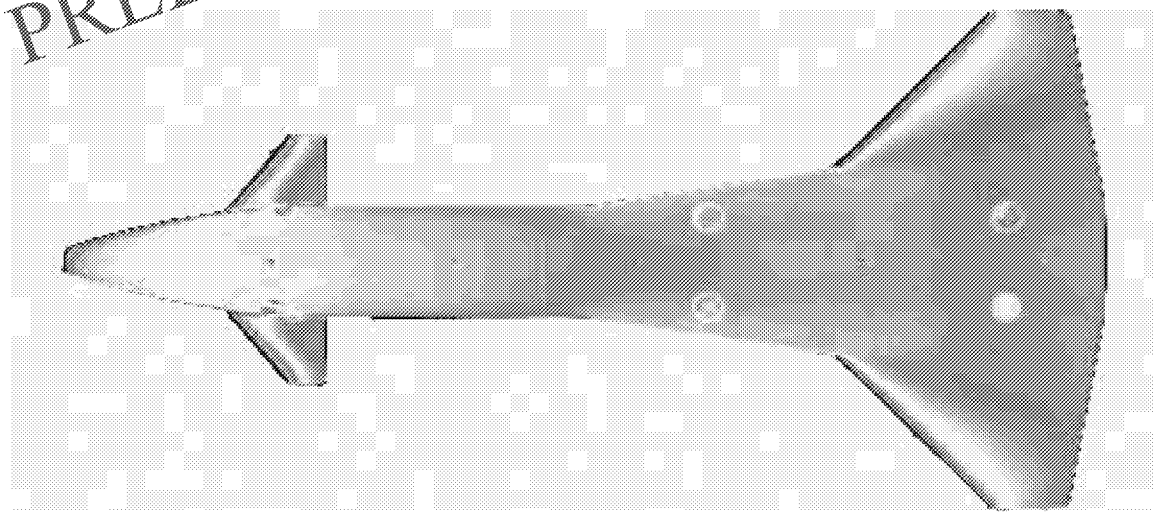
Isolated LGBB PSP Sample Results

Mach 3.48, Alpha = 0°

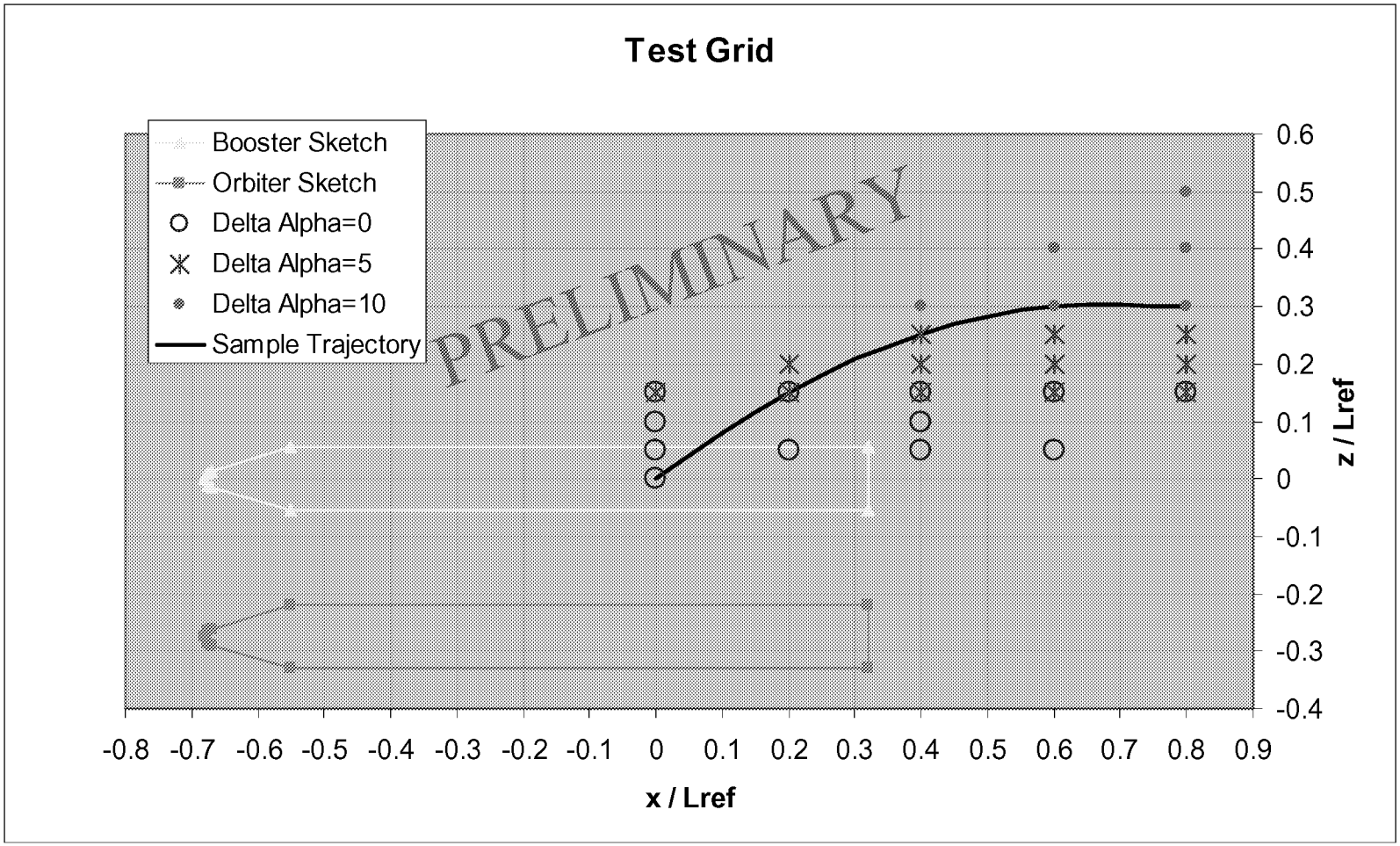
Top View



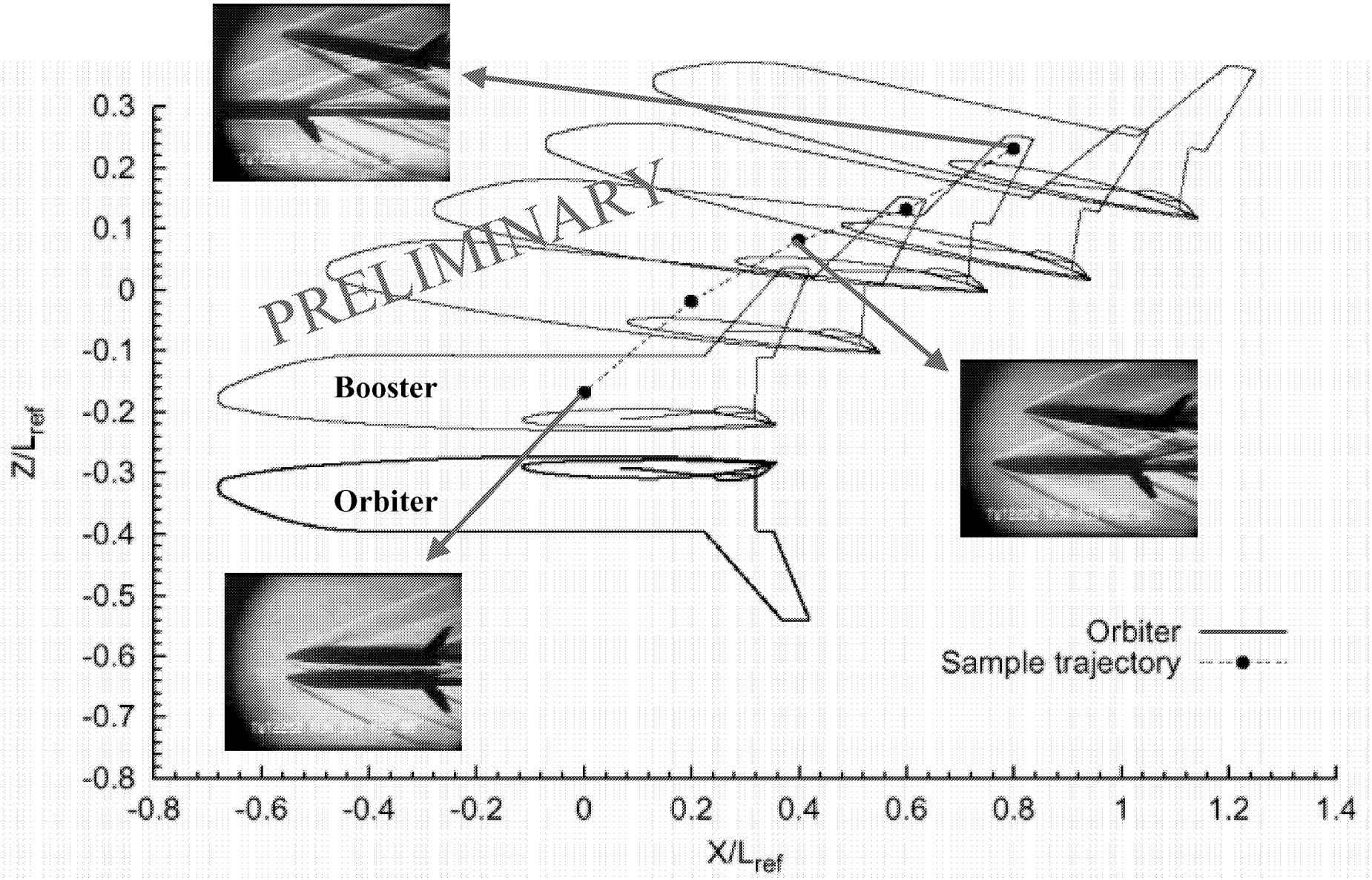
Bottom View



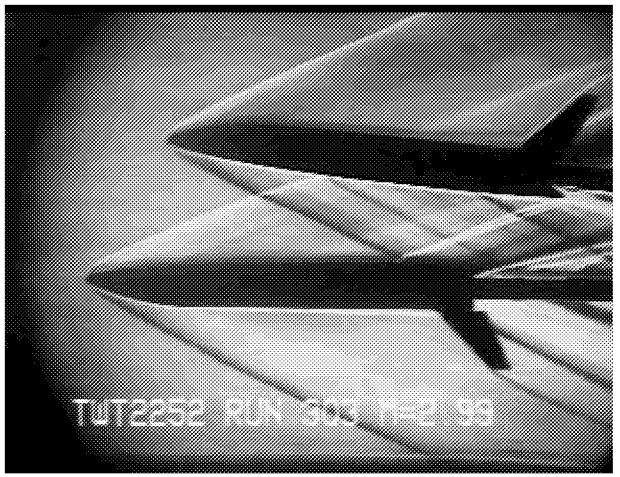
Stage Separation LGBB Test Envelope

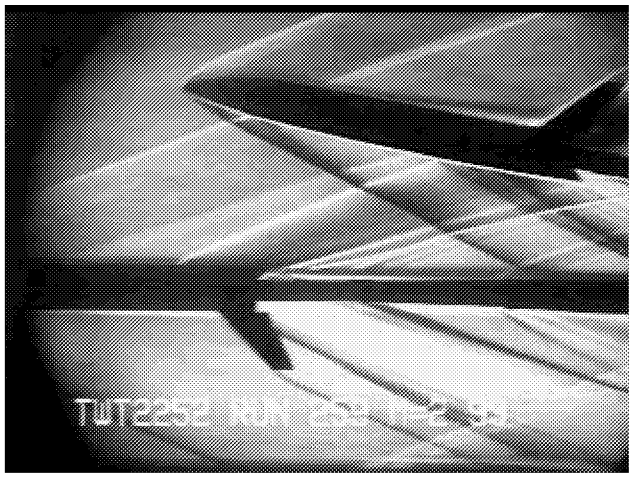


Sample Stage Separation Trajectory



Schlieren Photos of Sample Trajectory





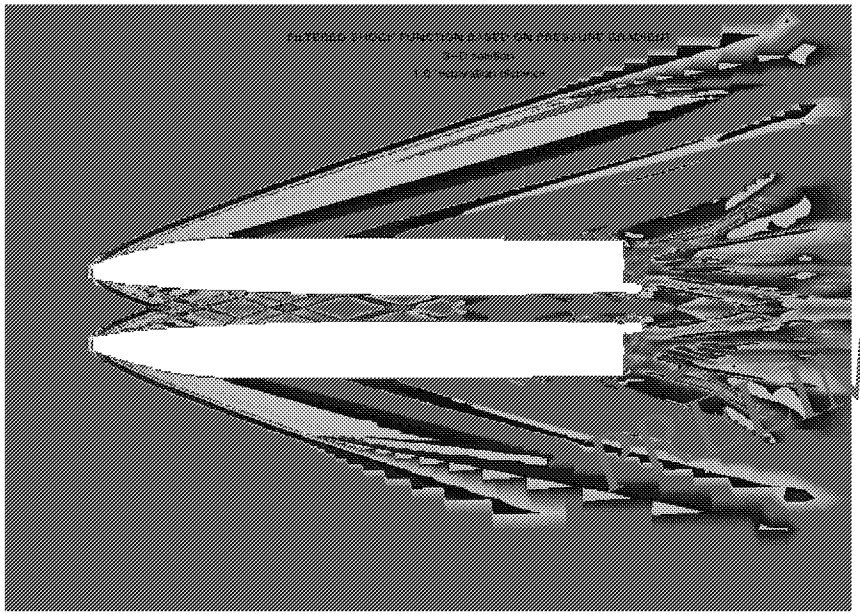
ARF 0.0121 Scale LGBB Test (Frost – MSFC)

-- Schlieren Video, Stack Proximity Location

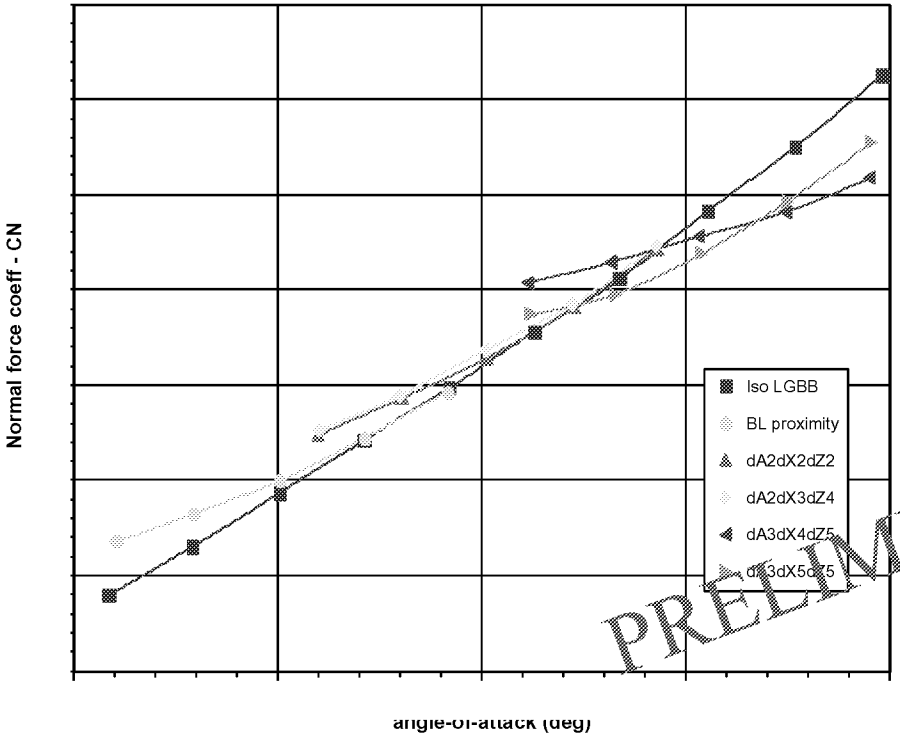
ARF 0.0121 Scale LGBB Test (Frost – MSFC)

-- Schlieren Video, Separated Location

Schlieren Results to OVERFLOW Comparison

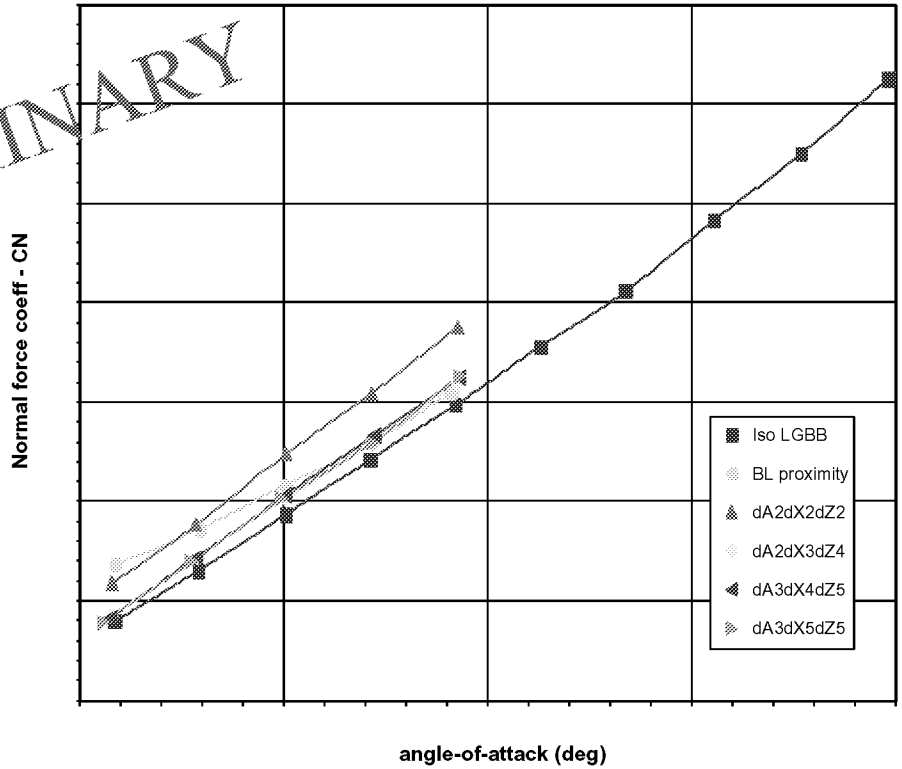


Preliminary Results – Normal Force vs AOA



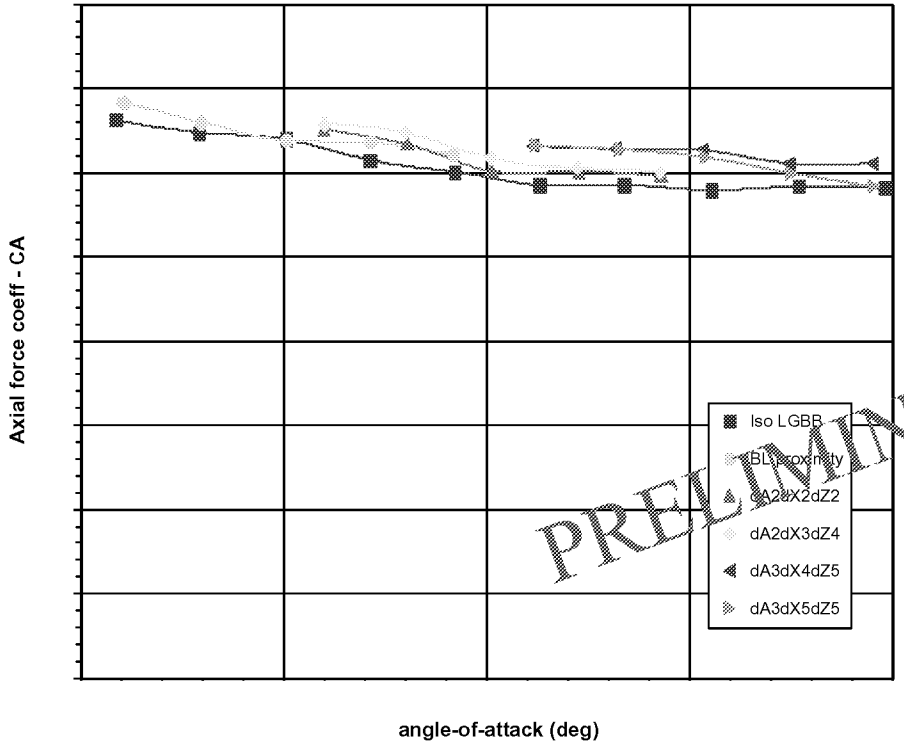
Booster

Orbiter



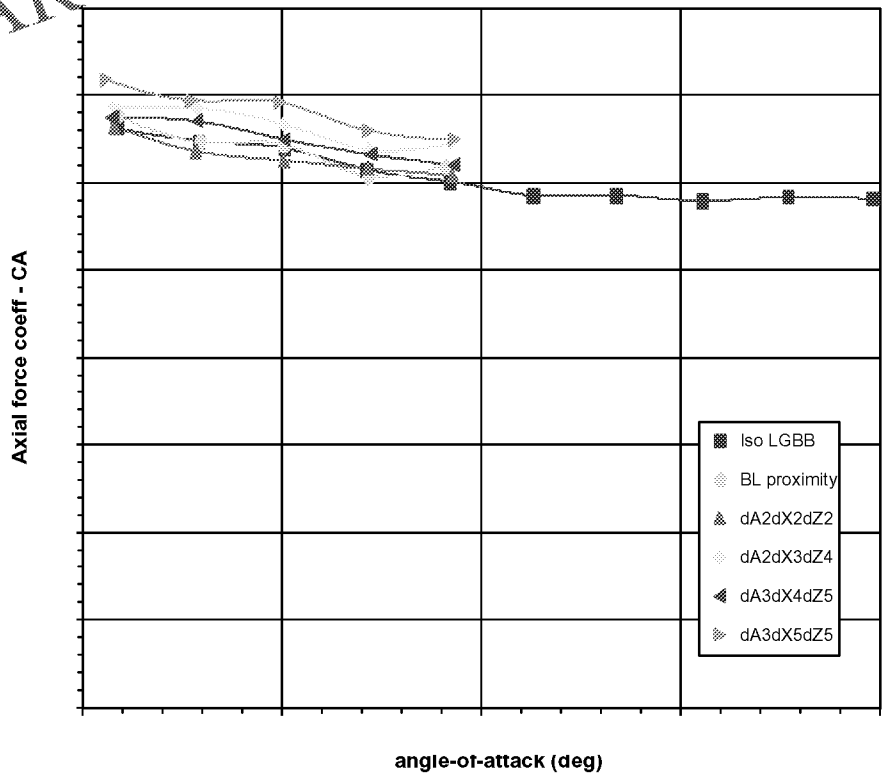
PRELIMINARY

Preliminary Results – Axial Force vs AOA

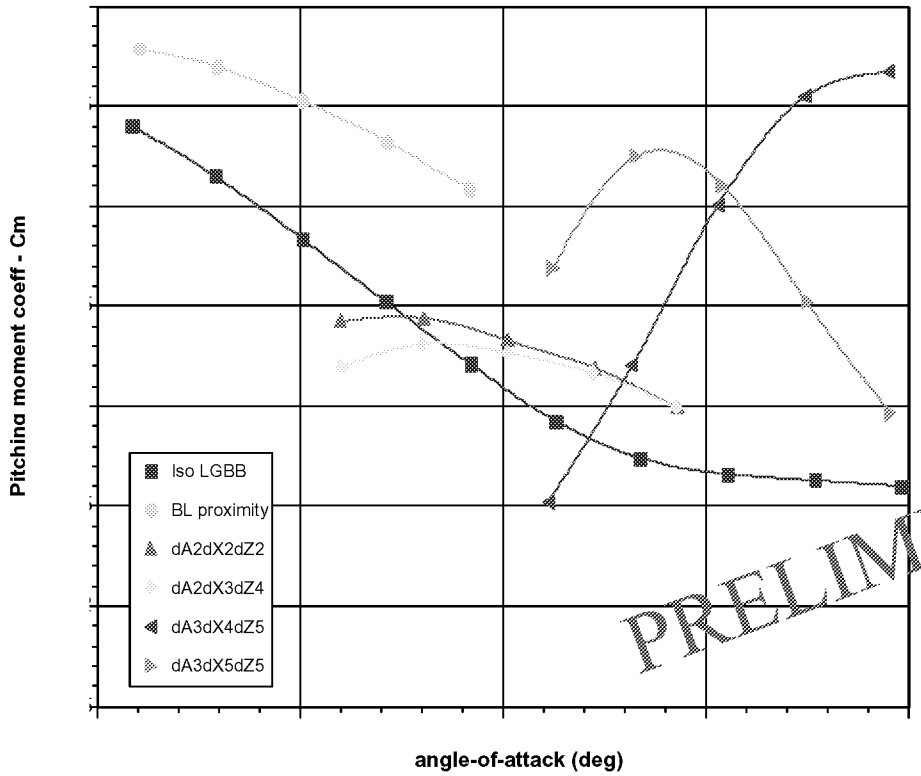


Booster

Orbiter

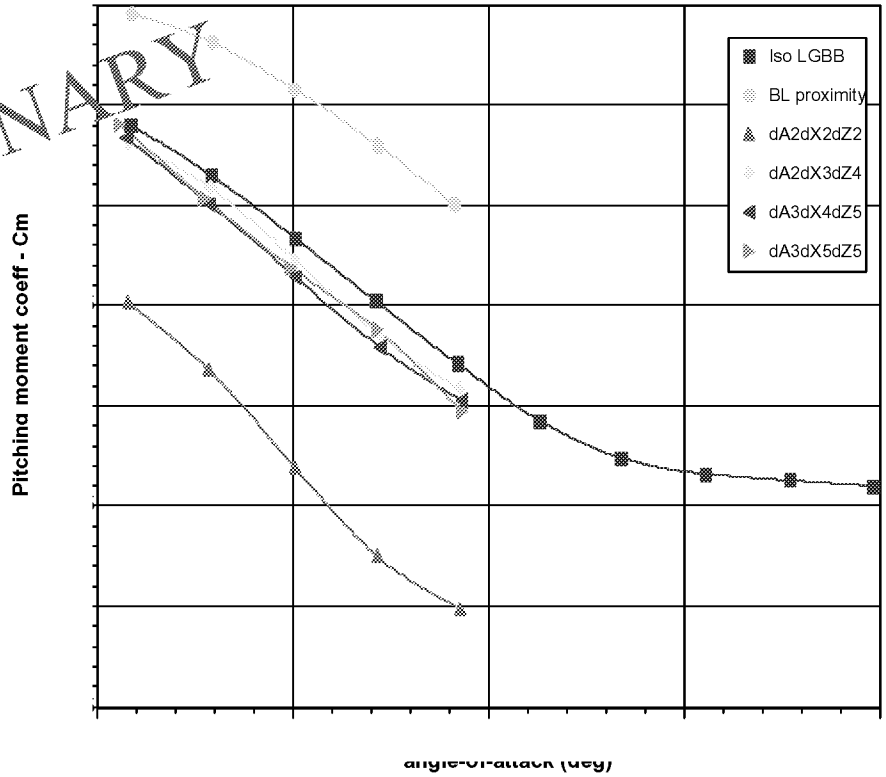


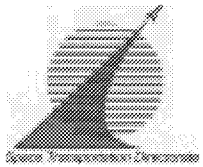
Preliminary Results – Pitching Moment vs AOA



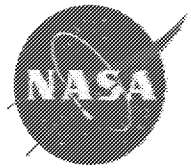
Booster

Orbiter

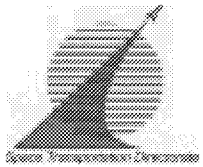




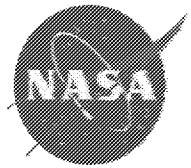
Observations



- Pressure Sensitive Paint Test
  - Preliminary Results Promising
  - Methodology Understood
  - Verification of Results
- Isolated Orbiter Force/Moment Data
  - Baseline Data
  - Interference Effects
- Stage Separation Force/Moment Data
  - Experience Using Stage Separation Sting
  - Shock Impingement Effects on Aerodynamic Forces
- Schlieren Video Data
  - Shock Reflections Between Bodies in Proximity Location – “Shock Train”
  - Separate Nose Bow Shocks for Bimese LGBB Configuration at Mach 3
  - Qualitative Agreement with CFD Results



Summary



- Aerodynamic Research Facility LGBB Stage Separation Test part of Multi-Center 2nd Gen In-House Tool Development Task
- ARF LGBB Stage Separation Test Completed at MSFC
  - PSP Feasibility Test
  - Isolated Force/Moment Data
  - Bimese Configuration Force/Moment Data
  - Schlieren Video
- LGBB Bimese Reference Configuration Analyses and Test Results In-Work to Develop Tools and Database
- Preliminary Results Showed Qualitative Agreement with CFD Aerodynamic Predictions
- Preliminary Results Exhibiting Complex Nature of Stage Separation Aerothermal Problem

Acknowledgements

- Stage Separation Test Team:
  - Wayne Bordelon -- MSFC/TD63
  - Alonzo Frost -- MSFC/TD63
  - Victor Pritchett -- MSFC/TD63
  - Alan Droege -- MSFC/TD64
  - Tara Polsgrove -- MSFC/TD30

- Aerodynamic Research Facility (ARF) Test Team:
  - Henry Brewster -- MSFC/TD74
  - John Galloway -- MSFC/TD74
  - Richard Norman -- MSFC/TD74
  - Herb Bush -- MSFC/TD74
  - Holly Walker -- MSFC/TD74