Unified Data Visualization Using the Virtual Diagnostics Interface (ViDI)

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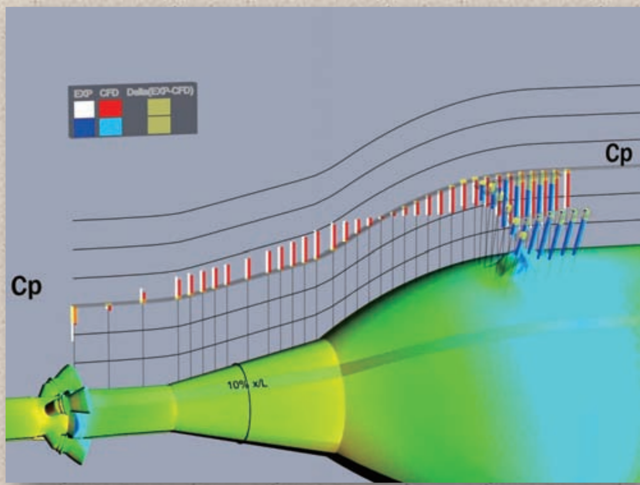

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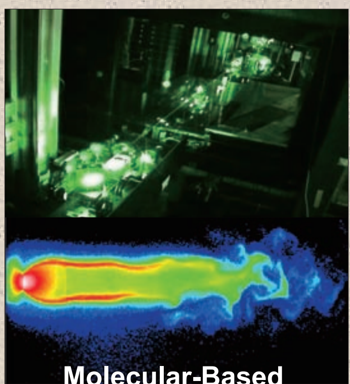
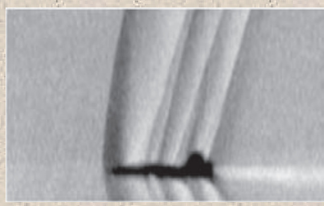


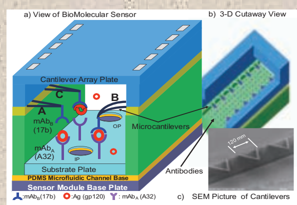
Molecular-Based Flow Diagnostics

Staff
- 20 Research scientists/engineers
- 12 Research technicians
- 6 Contractor personnel
- 3 Supervisory / Administrative

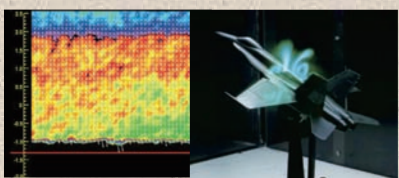
Research Efforts
- Development and deployment of aerodynamic measurement techniques to deliver critical knowledge in wind-tunnel investigations
- Nanoscale sensors/devices (structures/materials)
- MEMS (aero test/flight integration)



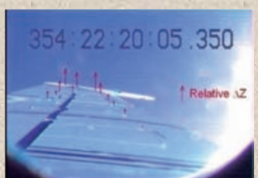
Innovative Concepts



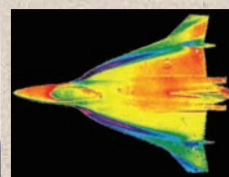
Nano-sensors



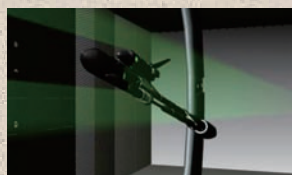
Advanced Particle-Based Flow Diagnostics



Structural Diagnostics



Surface Properties



Virtual Diagnostics

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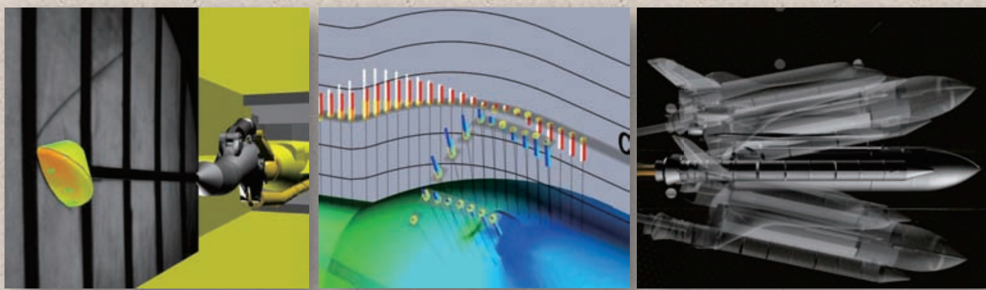
ViDI Background

The Virtual Diagnostics Interface (ViDI) is a methodology designed to solve a variety of aerospace testing problems through the use of visualization.

The primary tools of ViDI are:

- Three-dimensional computer modeling and visualization programs (primarily COTS).
- Two-dimensional image processing software (COTS and in-house developed).
- Customized user interfaces for easy and rapid data visualization manipulation (developed in-house).



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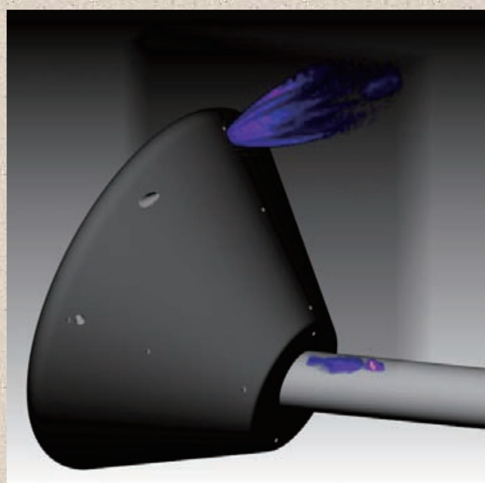
ViDI Data Visualization Introduction

- Applications of ViDI
- Early data visualization – different forms of experimental data displayed together
- Development of real-time data visualization
- Expansion of real time data visualization to include computational data
- Post – test experimental and computational data visualization work
- Future Directions



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Applications of ViDI

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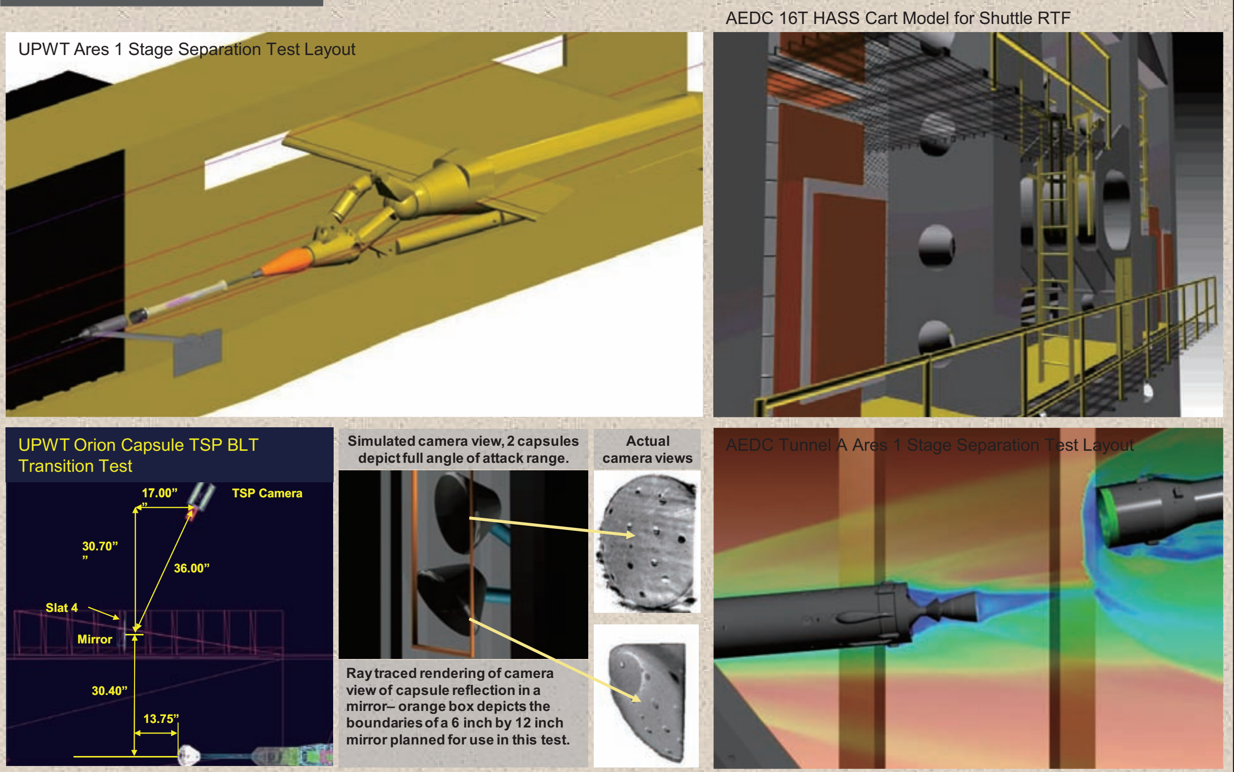
Pre-test Planning



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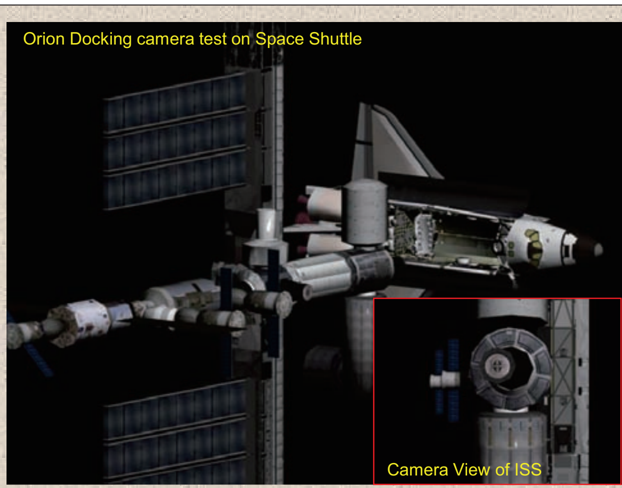
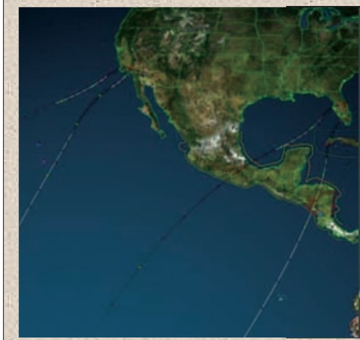
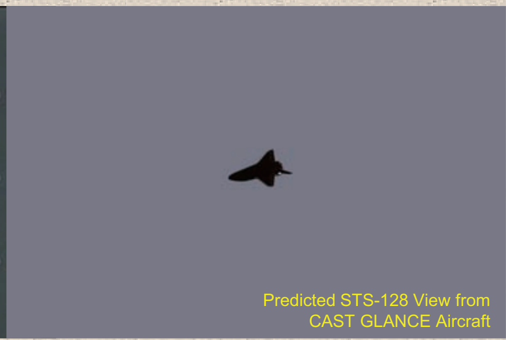
Flight Test Mission Planning







Early data Visualization with ViDI

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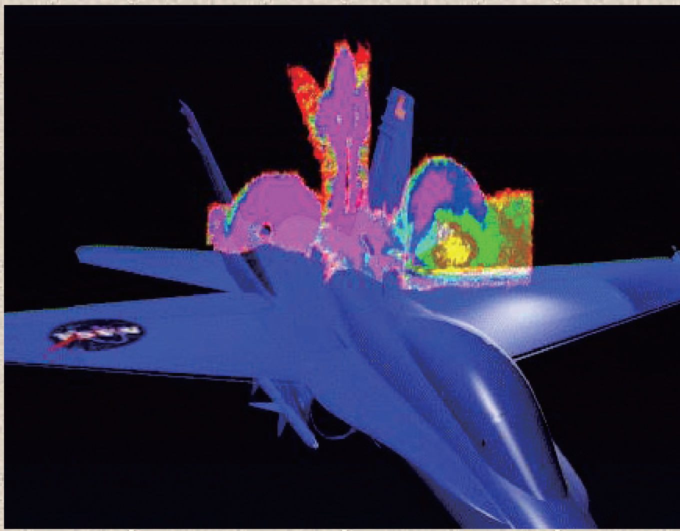
In the beginning…



Flow velocity contour map over F/A-18 wind tunnel model from Doppler Global Velocimetry (DGV).

Autodesk 3D Studio, DOS 6.2, Intel 486-25Mhz Processor, circa 1991

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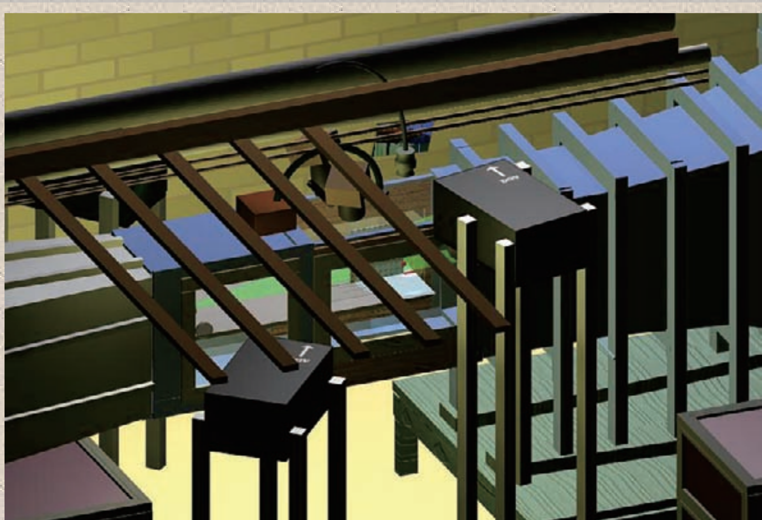
Multiple camera based instrument flow diagnostic test

The NASA Unified experiment included a number of different instruments. *ViDI* was used to determine where to locate the instruments in the limited space available, eliminating conflicts with both hardware and operation *prior to the wind tunnel entry.*

Instrumentation Used Simultaneously

Pressure Taps
Microphone Array
PMI
PSP
and
2D DPIV
or
Stereo DPIV
or
DGV



PMI - Projection Moiré Interferometer
PSP - Pressure Sensitive Paint
DGV - Doppler Global Velocimetry
DPIV - Digital Particle Image Velocimetry

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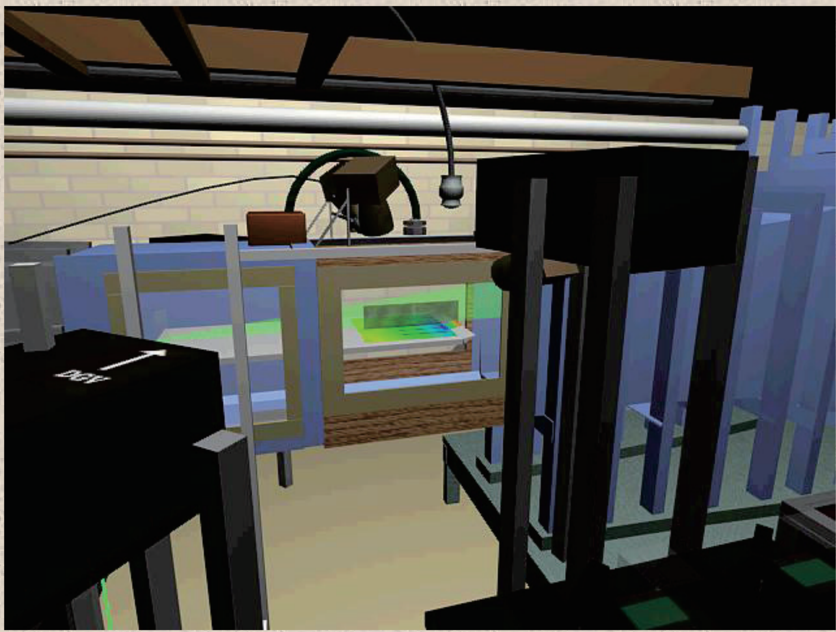
ViDI Data Visualization

Once the data was acquired and processed, it was imported back into the *ViDI*, providing a global, cause and effect understanding of the physical phenomena.



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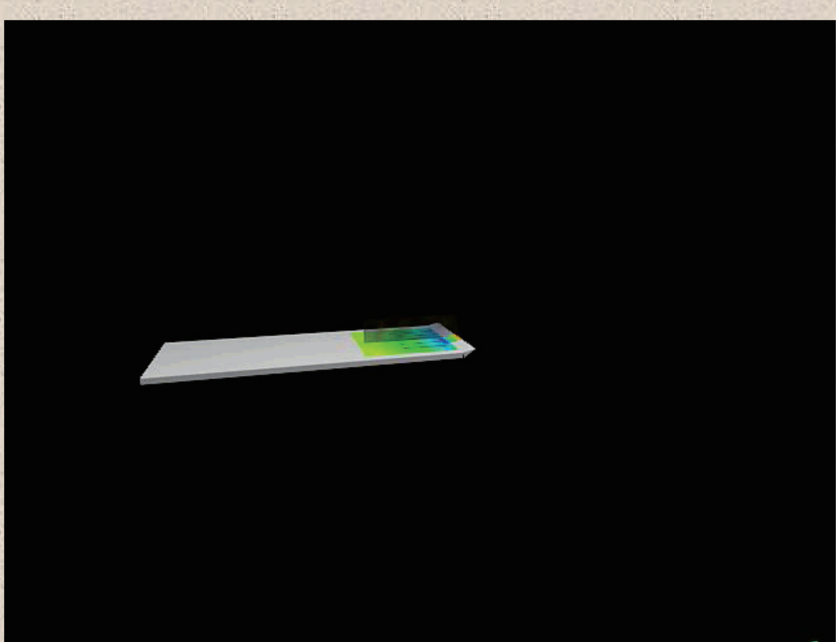
ViDI Data Visualization

Any data, be it computational or experimental, can be placed in this environment.



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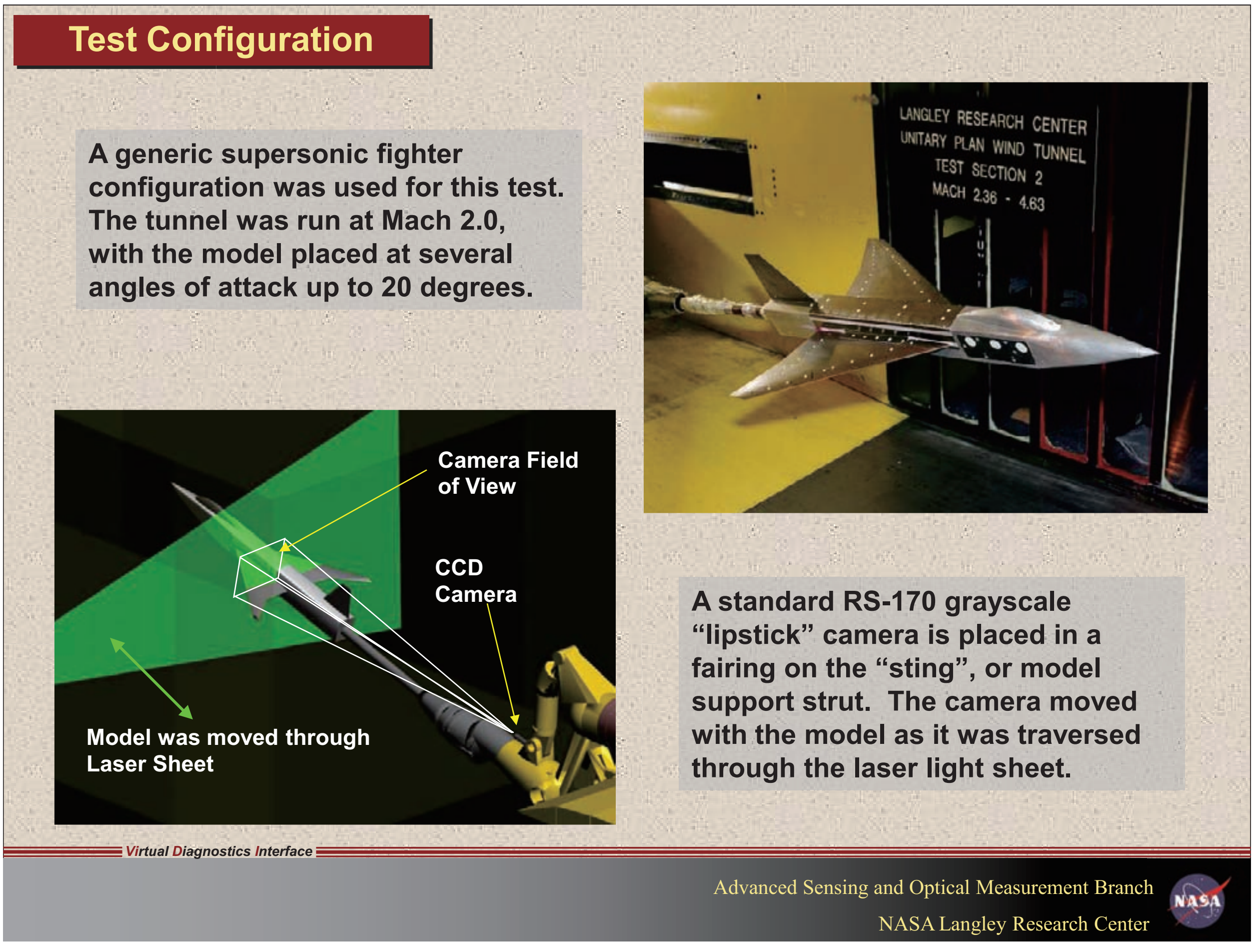
Real-Time Data Visualization with ViDI LiveView3D – Step 1

Flow Visualization in 3D

Real Time Data Visualization – LiveView3D

Goals

- *Develop the tools to enable researchers to have real-time situational awareness about the experiment being conducted.*
- *Achieve this using tools that are robust and easy enough to use to implement on a regular basis in support of a wide range of experimental facilities and test scenarios.*


Test Configuration
A generic supersonic fighter configuration was used for this test. The tunnel was run at Mach 2.0, with the model placed at several angles of attack up to 20 degrees.
LANGLEY RESEARCH CENTER
UNITARY PLAN WIND TUNNEL
TEST SECTION 2
MACH 2.36 - 4.63
Camera Field of View
CCD Camera
Model was moved through Laser Sheet
A standard RS-170 grayscale “lipstick” camera is placed in a fairing on the “sting”, or model support strut. The camera moved with the model as it was traversed through the laser light sheet.
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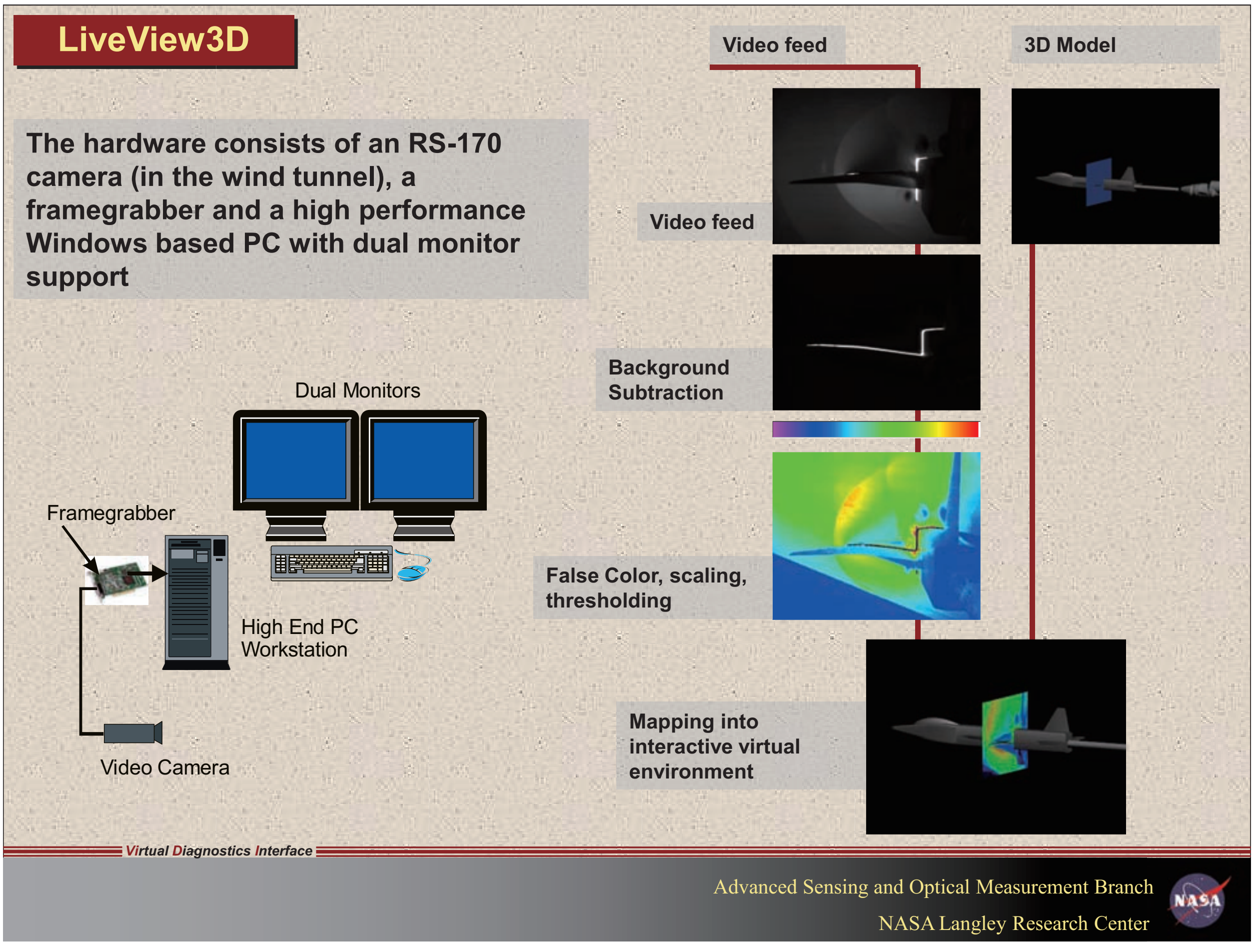
LiveView3D
The hardware consists of an RS-170 camera (in the wind tunnel), a framegrabber and a high performance Windows based PC with dual monitor support
Dual Monitors
Framegrabber
High End PC Workstation
Video Camera
Video feed
3D Model
Video feed
Background Subtraction
False Color, scaling, thresholding
Mapping into interactive virtual environment
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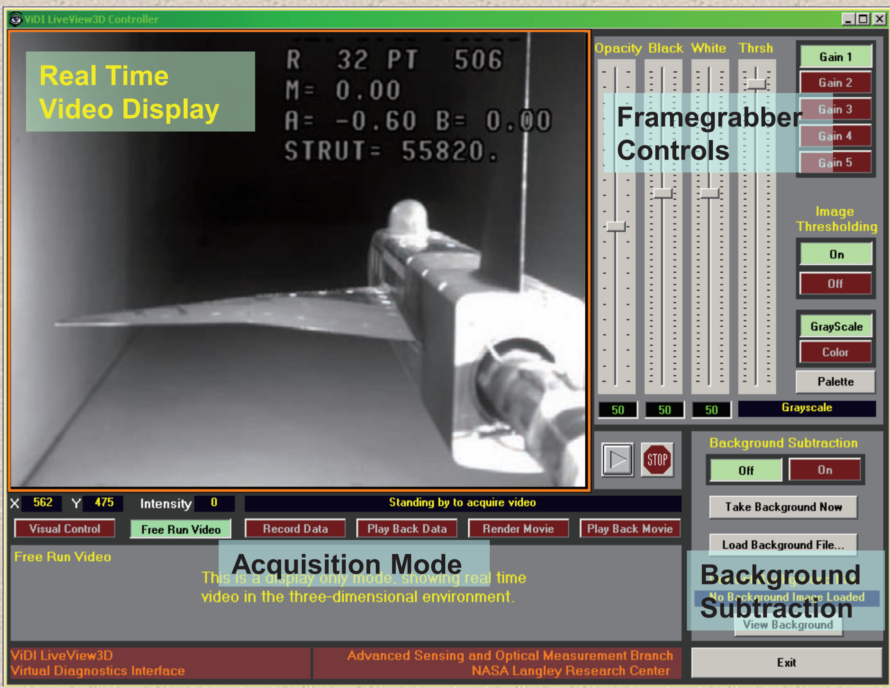
LiveView3D Controller Program



The goal was to create an easy to use interface that allowed the test engineer or wind tunnel facility personnel to control the visualization while keeping the need for training to a minimum.

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LiveView3D in Real Time Operation

The ability to work with the data in real time allows the researcher to investigate surprises and anomalies as they occur, enhancing the ability to make more detailed studies or fix problems

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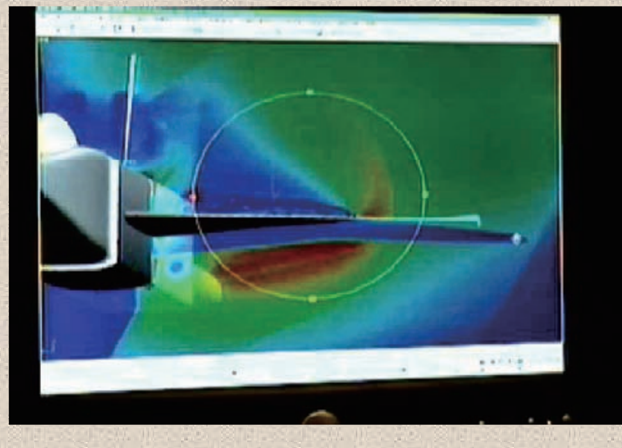
LiveView3D in Real Time Operation

Without LiveView3D

With LiveView3D



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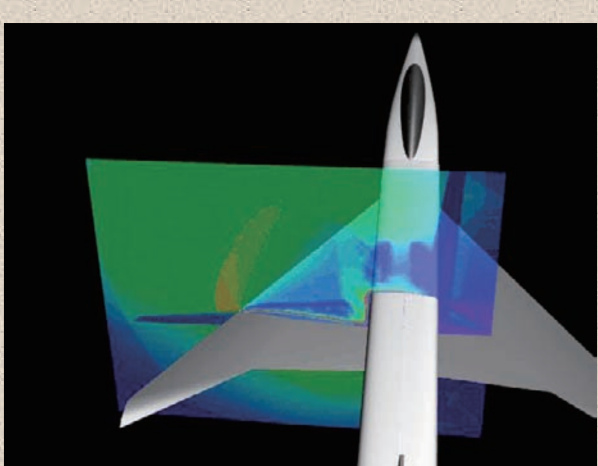
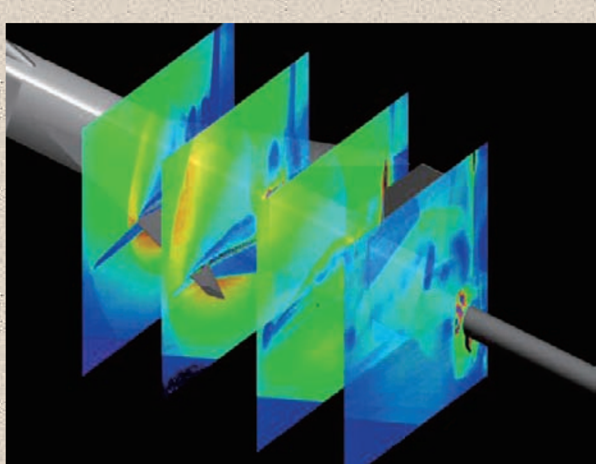
Post-Test Data Visualization

Single or multiple planes of data are displayed, and the animation is rendered to a standard movie format file that is compatible on a wide range of machines.





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Real-Time Data Visualization with ViDI LiveView3D – Step 2

Flow Visualization, DAS Data and CFD

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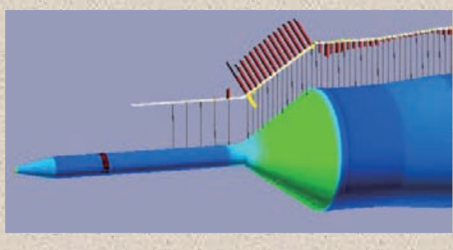
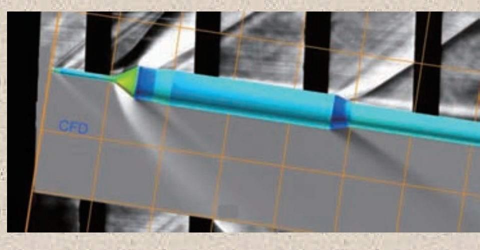
Example Application – Ares 1 – Like Configuration

ViDI *real-time* data visualization of the Supersonic Wind Tunnel Pressure Test on an Ares I-Like Configuration

- Ares 1 - Like Configuration
- Computations Predictions
- Experimental Setup
- Real-time visualization of experimental pressure data and computational predictions
- Schlieren data visualization compared to computational predictions





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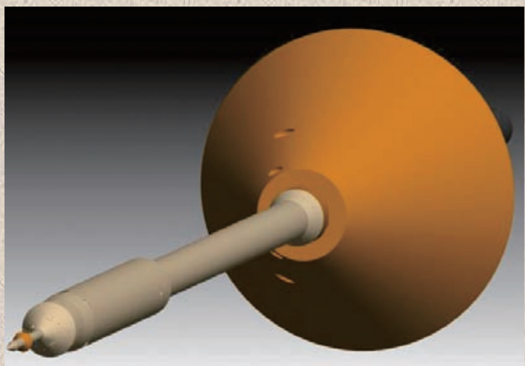
Ares Configuration

The Ares booster is a two stage rocket designed to loft the Orion Crew Exploration Vehicle (CEV) into orbit and trans-lunar space.

Wind tunnel model
- devoid of protrusions to match CFD
- nose flare and plume were removable, only used for a small portion of the test



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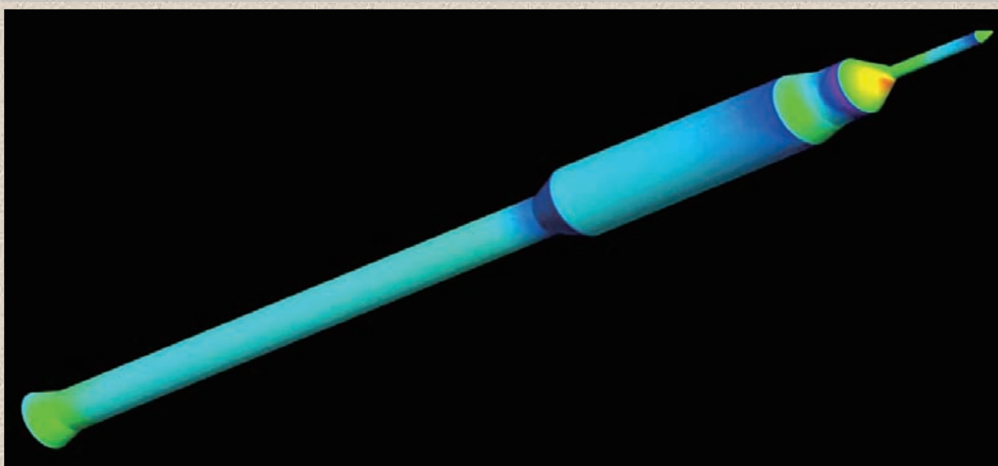
Computational Predictions

- Coefficient of Pressure Cp surface contour plot
- Exported from Tecplot, read into Autodesk 3ds max via a custom MaxScript program.
- A separate mesh was created for every Mach number, Reynolds number and angle of attack tested.



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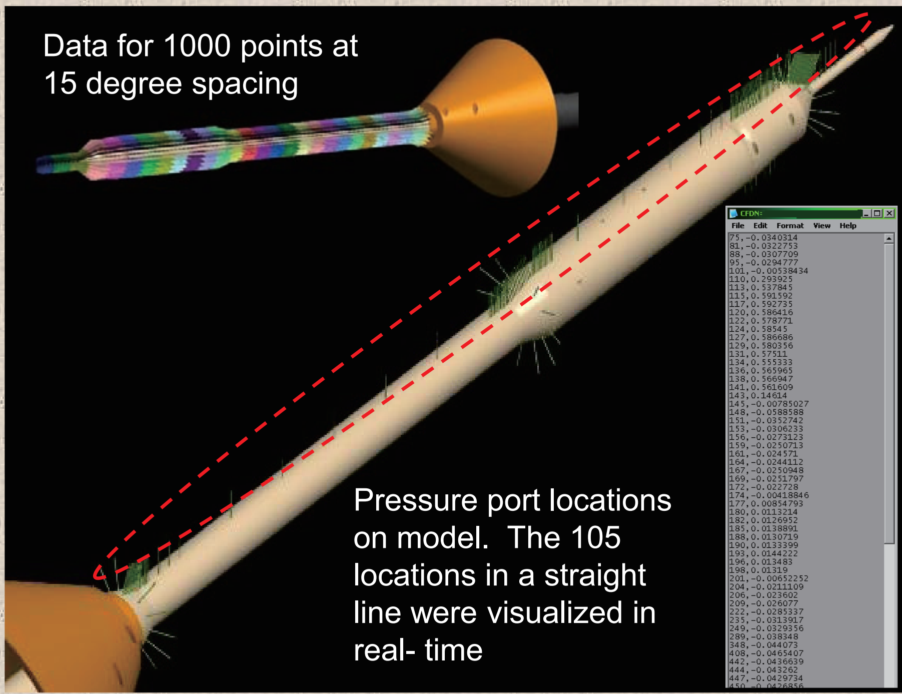
Computational Predictions

CFD Cp predictions also provided in a SIF file format.

The Cp's were given as 1000 points along a straight line running the length of the body. 105 Cp's were extracted to match pressure tap locations.



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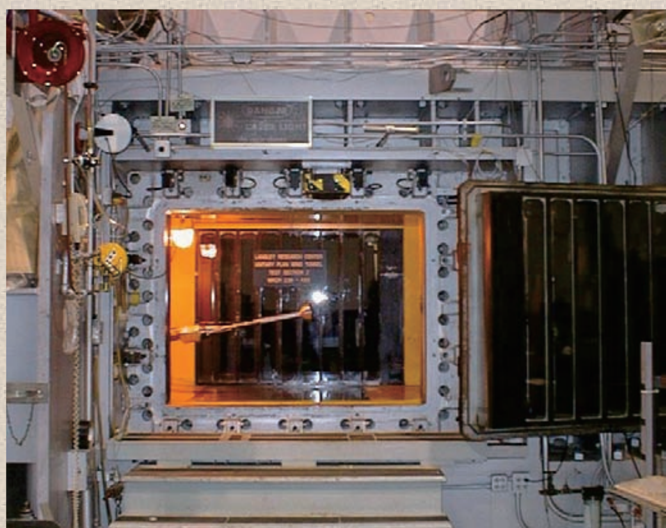
Unitary Plan Wind Tunnel

The Unitary Plan Wind Tunnel (UPWT) is a closed return supersonic facility capable of running from Mach 1.5 to Mach 4.6 continuously in either one of two test sections.



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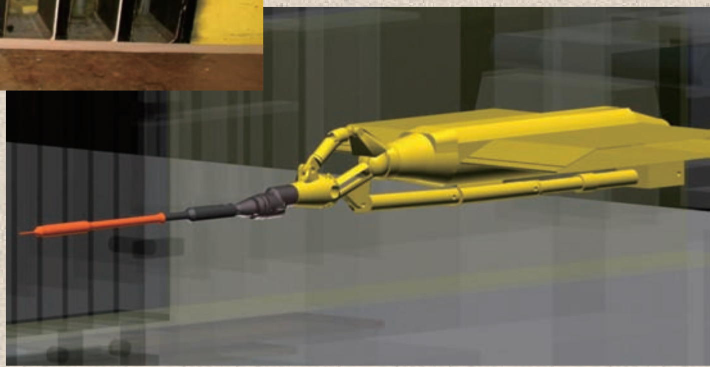
Experimental Setup

One-percent scale model of the Ares-like booster configuration in the NASA Langley Unitary Plan Wind Tunnel



Sting mechanism remotely controlled model translation, roll, pitch and yaw.

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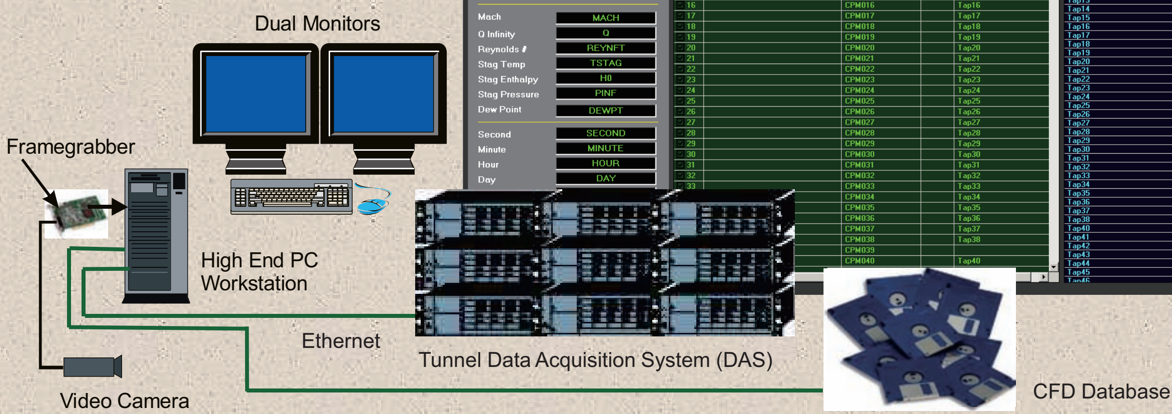
LiveView3D Real-Time Data Visualization

LiveView3D was expanded to incorporate data from the wind tunnel data acquisition system (DAS) via Ethernet. Current system is capable of accepting up to 500 channels of data from the DAS (DAS limitation).



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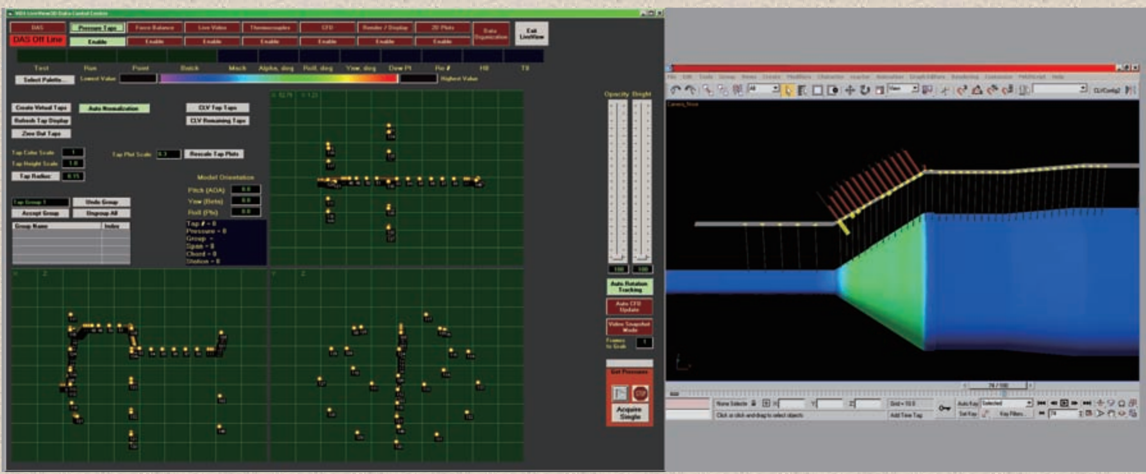
LiveView3D Real-Time Data Visualization

Surface pressure taps



LiveView3D Controller Program

Interactive 3-D Virtual Environment

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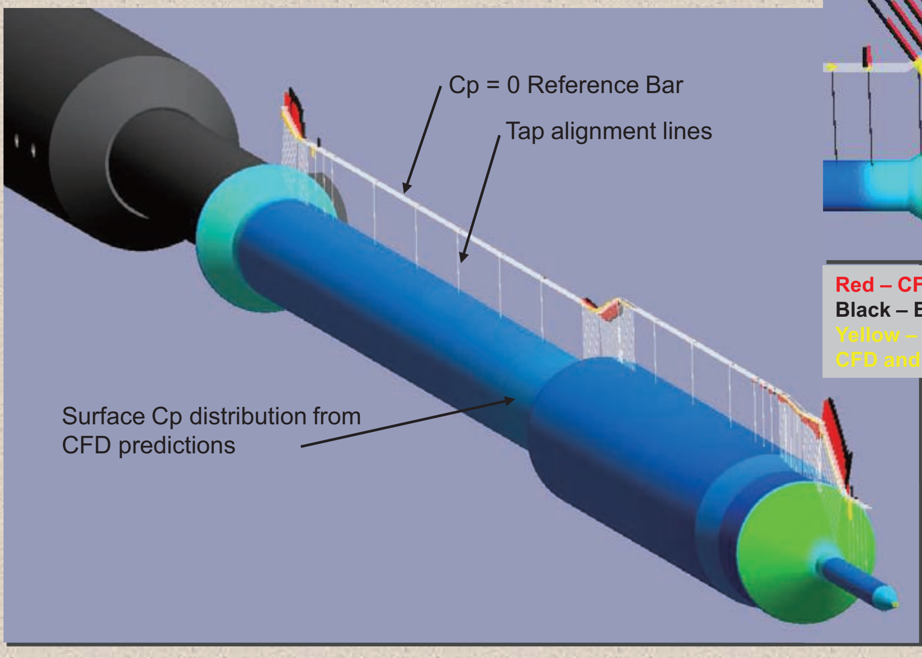
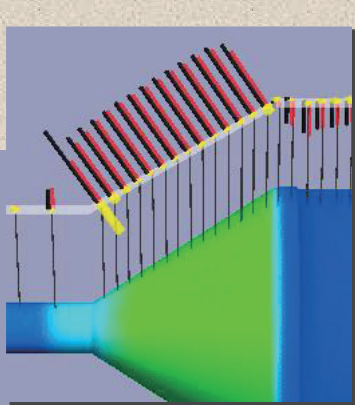
LiveView3D Real-Time Data Visualization

Surface pressure taps





Red – CFD
Black – Experimental data
Yellow – Difference between CFD and experiment

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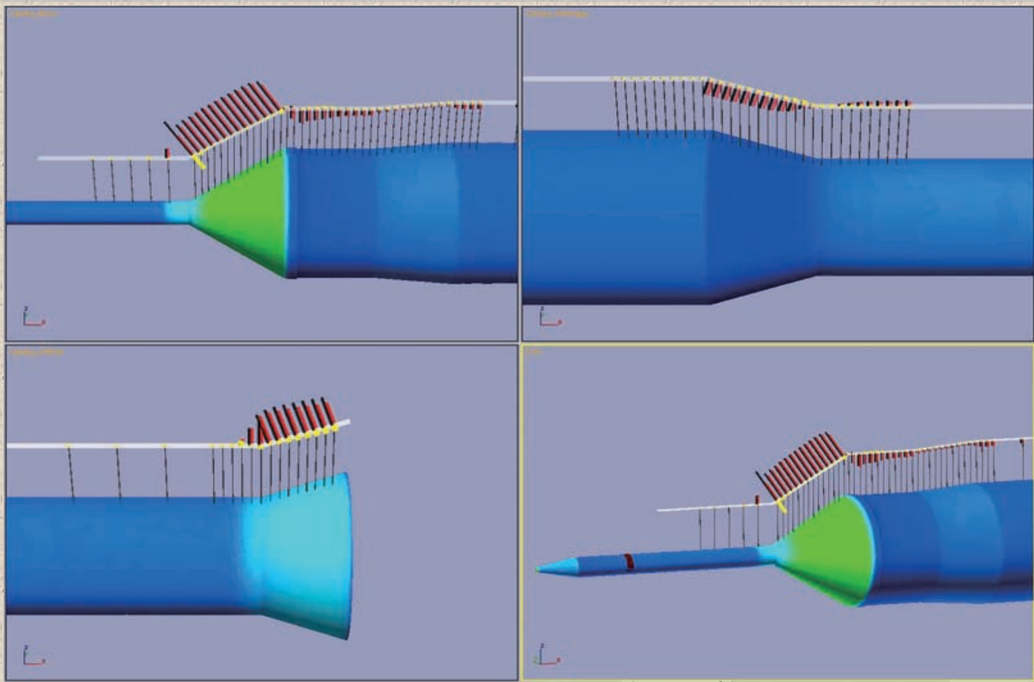
LiveView3D Real-Time Data Visualization

Three fixed camera views and a perspective view on the virtual environment



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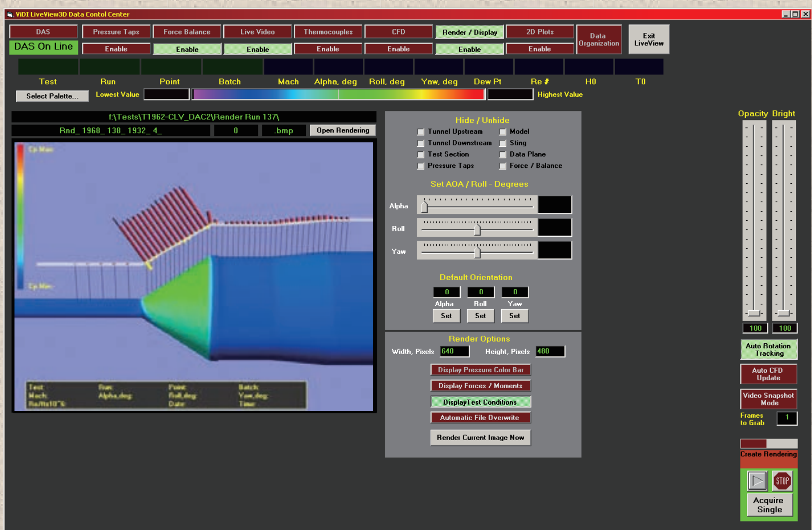
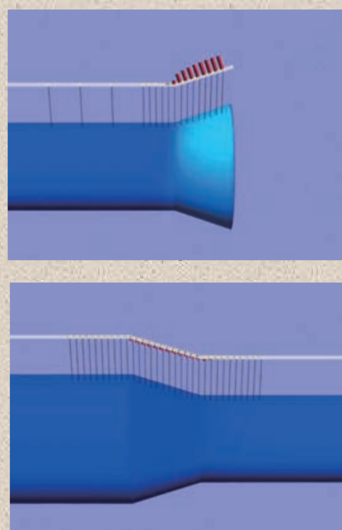
LiveView3D Real-Time Data Visualization

Rendering Control





The three fixed camera views were rendered and saved as separate bitmap images every time a data point was taken. The files were organized by filename based on test, run, and point numbers.

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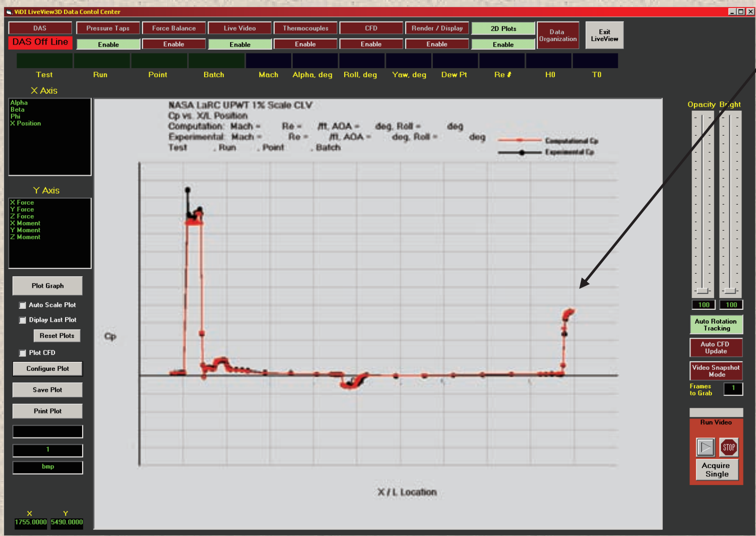
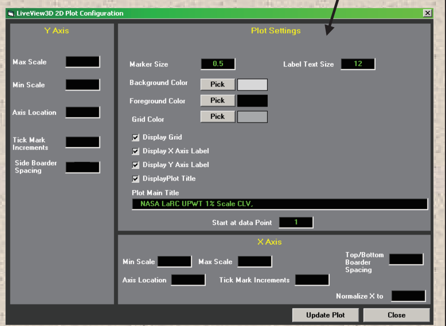
LiveView3D Real-Time Data Visualization

Plot Control



Red – CFD
Black – Experimental data

Configuration controls let the user customize the plot to best suit the data.

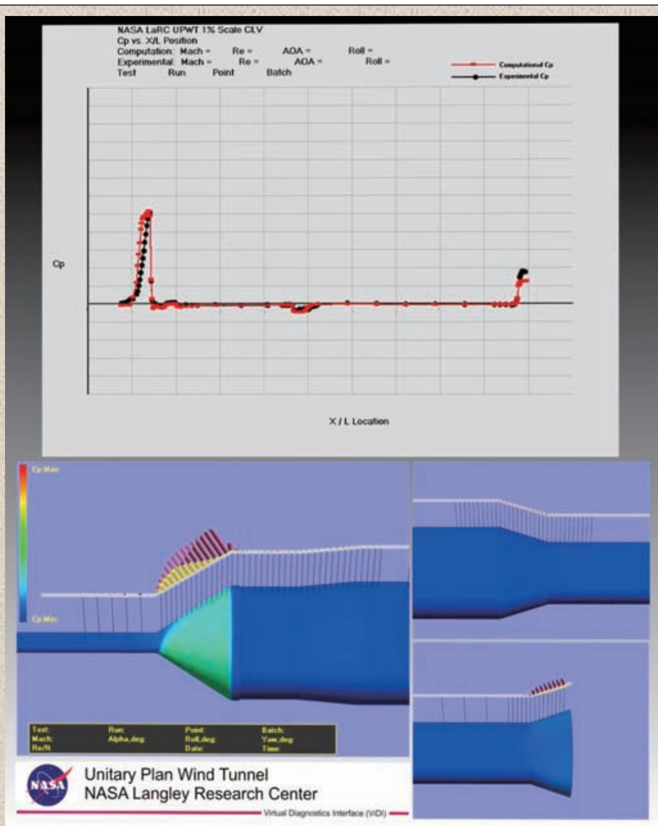


A 2-D plot of Cp vs. X/L for the line of 105 pressure taps was created for each data point. These plots were saved with filenames corresponding to the test, run and point.

LiveView3D

Final output –

The 2-D plots and 3-D renderings are combined into a single image depicting the Cp data and predictions for the selected pressure taps.



LiveView3D

Final output –

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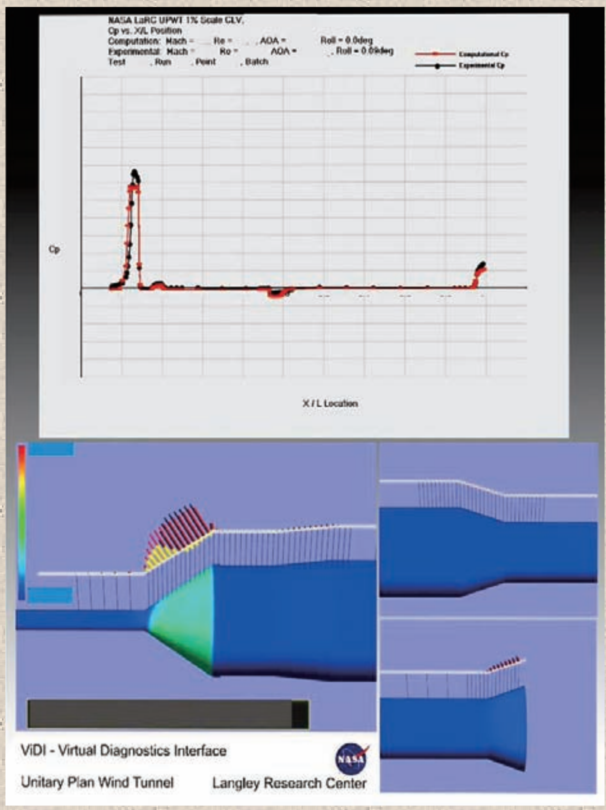

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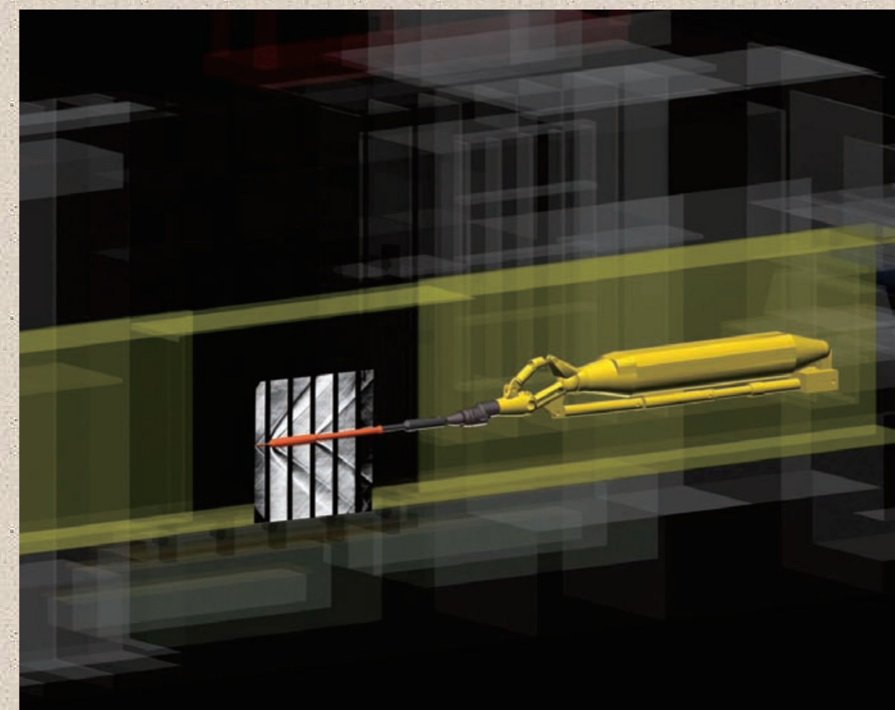
Schlieren Comparisons



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Schlieren Comparisons

High-resolution digital image of schlieren off-body flowfield density gradients

Contour map of CFD prediction of off-body flow density

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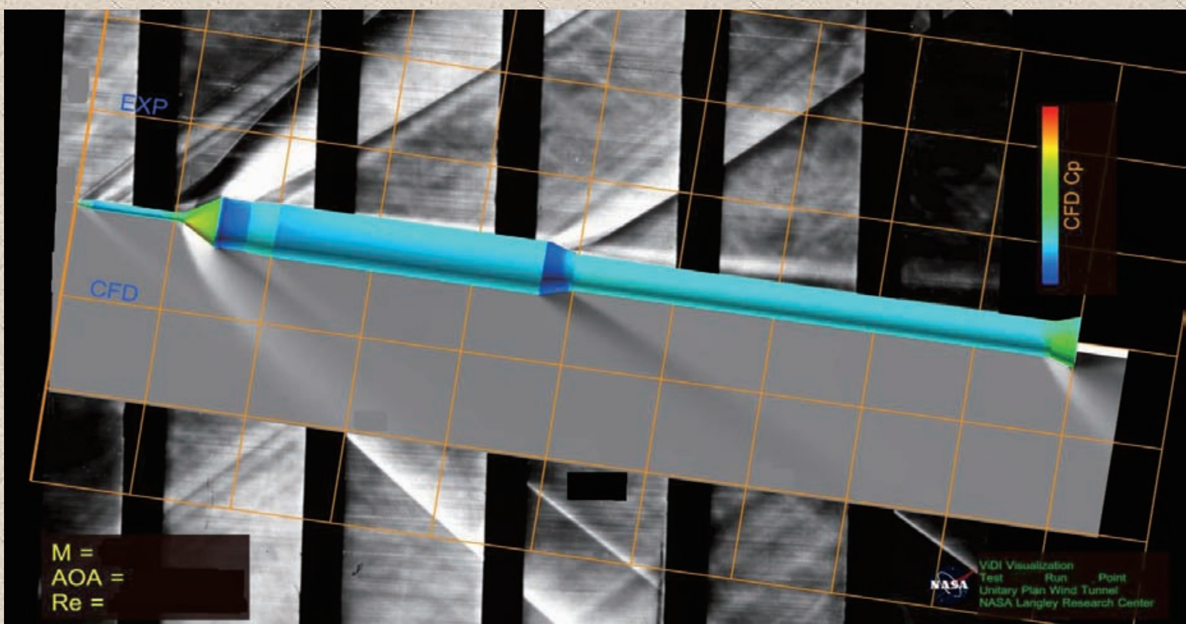
Schlieren Comparisons



The schlieren image is mapped into the virtual environment along with the CFD prediction of flowfield density. The CFD derived Cp distribution is mapped to the surface of the booster rocket.

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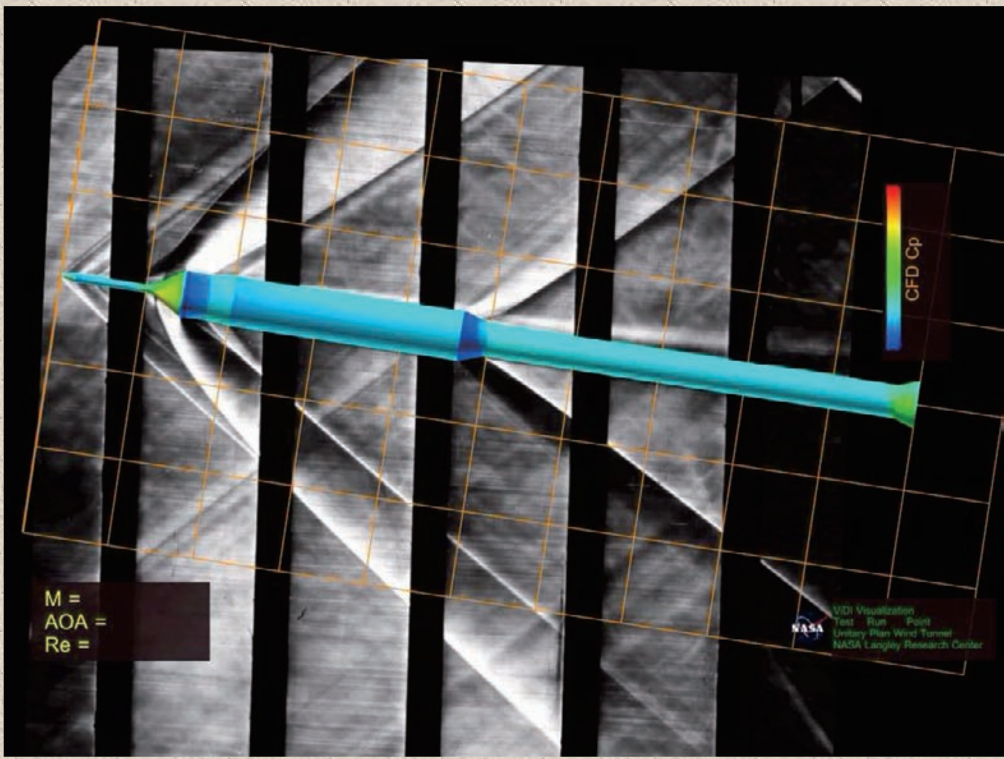
Schlieren Comparisons



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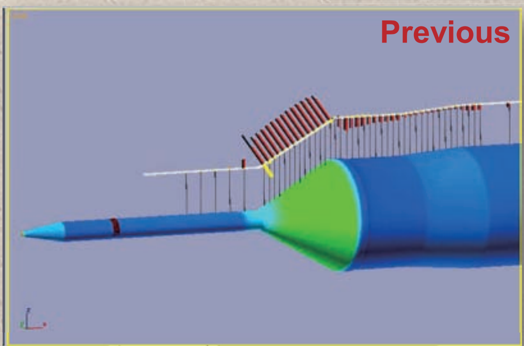
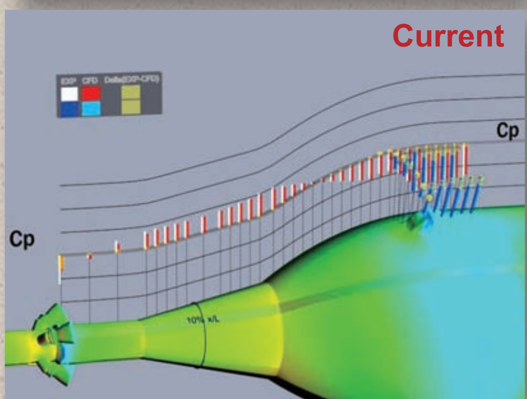
Introduction





- This work expands upon ViDI capabilities that were first employed in support of the NASA Ares I Crew Launch Vehicle (CLV) in the NASA Langley Research Center (LaRC) Unitary Plan Wind Tunnel (UPWT)
- The purpose of the (Boeing) test was to generate an aerodynamic database for validation of CFD
- ViDI was implemented to provide post-test comparisons of experimental and computational pressure measurements

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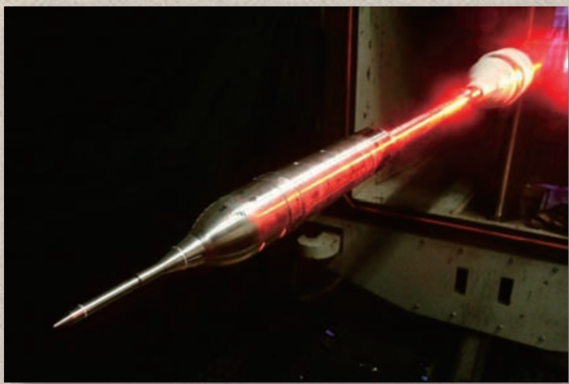
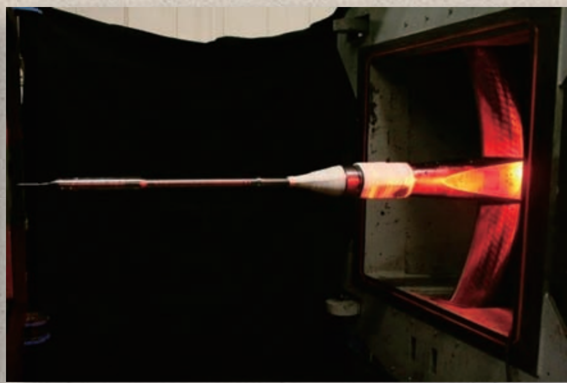
Experiment

- The pressure test was conducted at Boeing's Polysonic Wind Tunnel (PWST)
- The model was put through pitch and roll sweeps
- Two model configurations were tested
  - "Clean" configuration, only axisymmetric protuberances
  - "Dirty" configuration, full protuberances
  - 199 taps, 115 along top centerline, remaining taps located around the protuberances





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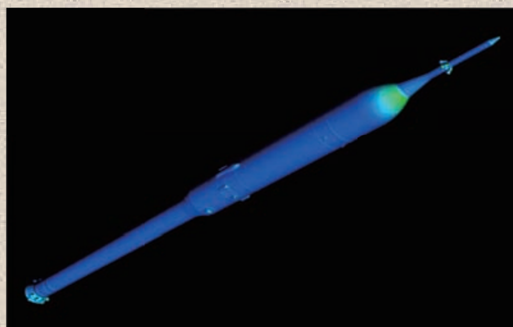
Computational Data

- CFD solutions created using the NASA developed USM3D were provided for select Mach numbers and angle conditions
- CFD Format #1 - 3-D meshes with surface C_p in Tecplot 360™ 2008 format
- CFD Format #2 - text files that contained the C_p data at every discrete tap location for each CFD solution
- Both formats of the CFD solution were used for comparison against the experimental values to create a complete visualization



Tecplot 360 conversion:
CFD mesh files were translated into Autodesk 3ds max® 2008 using MaxScript code
A 3-D surface mesh was formed by creating triangular faces from 3 vertices
A 256 color palette was applied to the entire mesh based on the C_p value of each face

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Experimental Data

Before the test

- Received a Microsoft® Office Excel spreadsheet of expected variables from the test facility's Data Acquisition System (DAS) before test

During the test

- After a day of testing, a spreadsheet with all the run data collected by the DAS was uploaded to a secure NASA server
- Data were exchanged over the server and saved to disk locally at LaRC
- Having this channel to transfer files back and forth on was crucial to providing visualization support and interactive feedback

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Data Visualization

- Test was supported remotely from LaRC in Hampton, VA
- All components of the visualization were agreed upon by the researcher before the test began at PWST
- MaxScript code was written to read in DAS files
- ViDI software designed to be semi-autonomous

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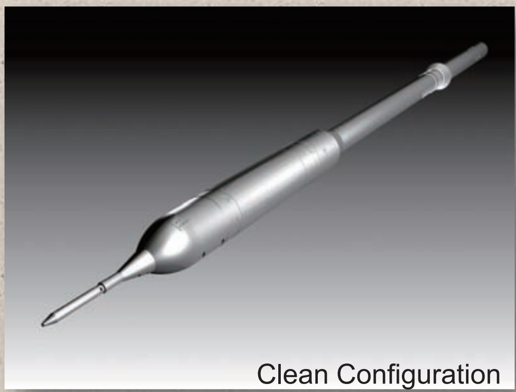
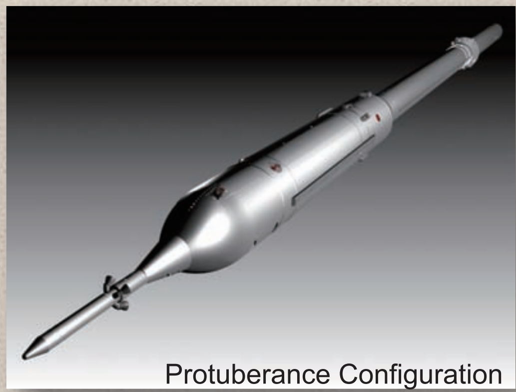
Importing the Model

- Computer Aided Design (CAD) files were received from the model designer in Initial Graphics Exchange Specification (IGES) format
- Translated into the virtual environment using Okino Computer Graphics Inc. Nugraph Rendering System
- IGES files → 3ds max meshes


Clean Configuration


Protuberance Configuration

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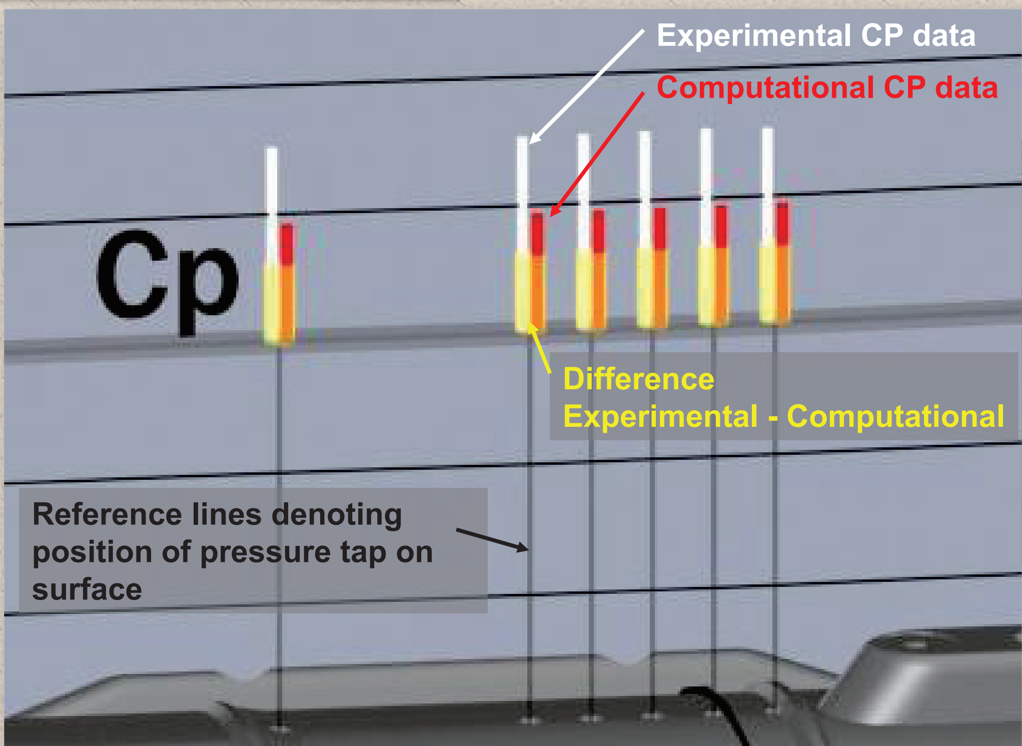
Adding Pressure Bars



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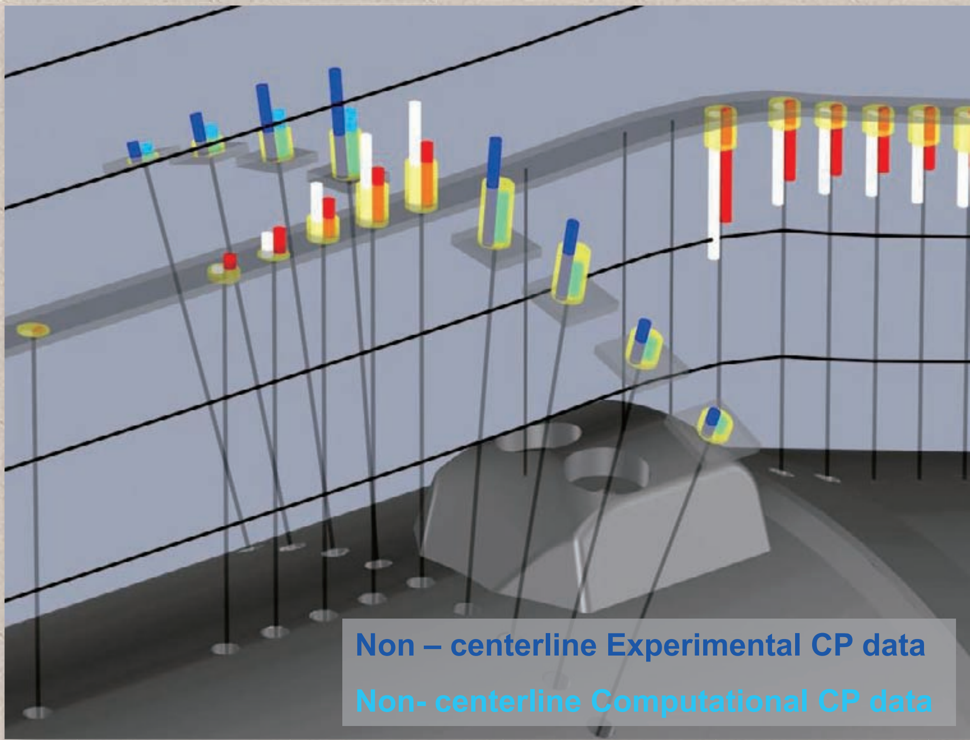
Adding Pressure Bars – Cont.



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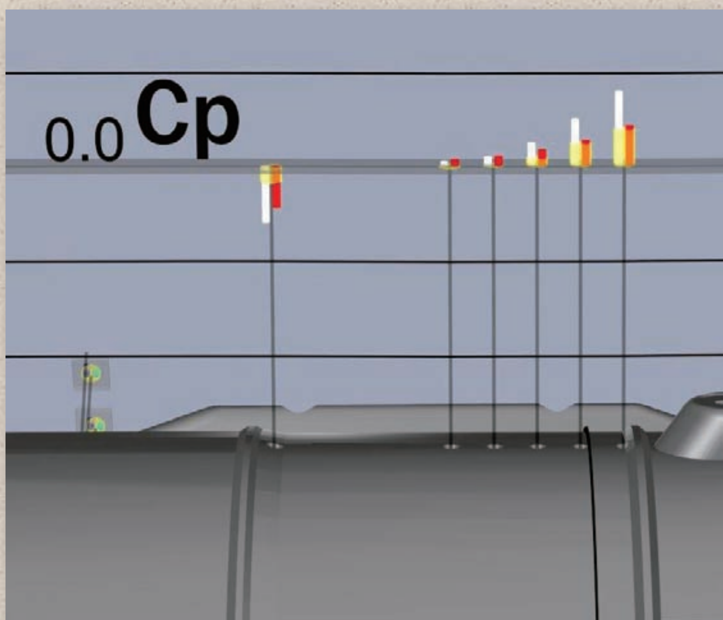
Axis System

- Built-in a C_p axis system for all of the pressure bars
- Pressure bars raised to a C_p=0 reference, allowed negative C_p values
- Pressure bars on centerline were translated vertically from the model surface
- On centerline, minor axes were drawn at equal increments above and below the C_p zero line



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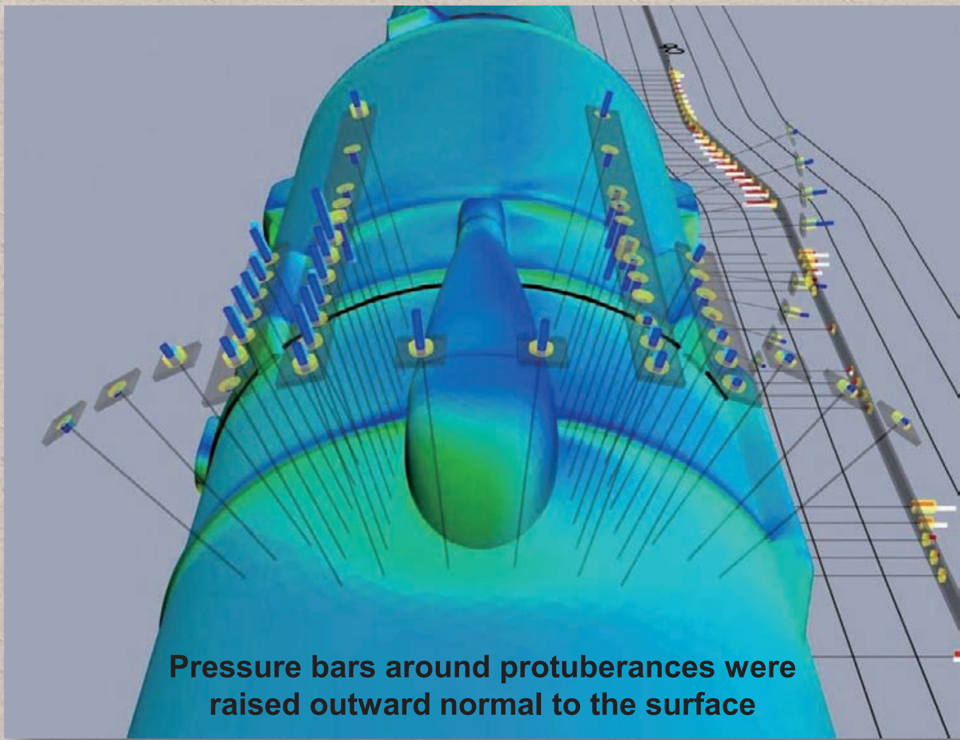
Axis System



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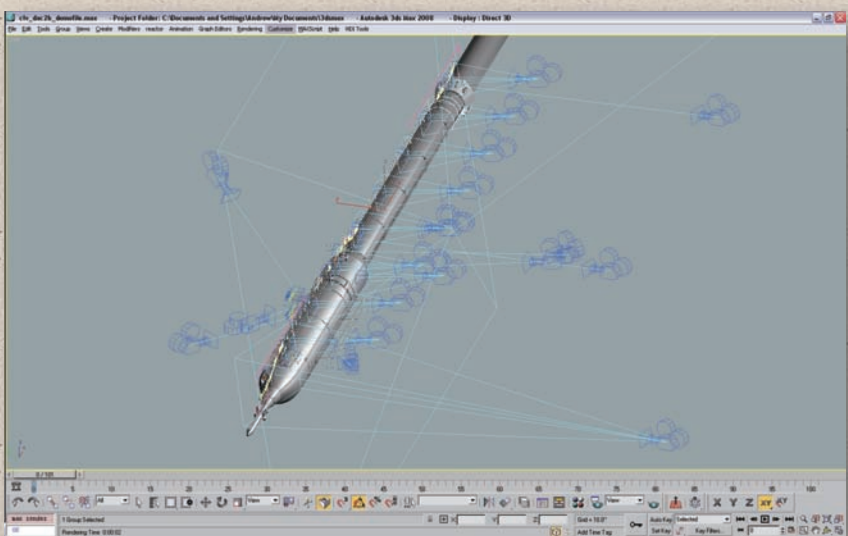
Adding Cameras

- Created 20 cameras in the virtual environment
- Views of all protuberances
- Nose to aft skirt coverage of centerline taps



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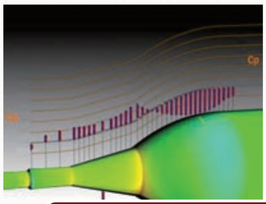
Remote Adjustments

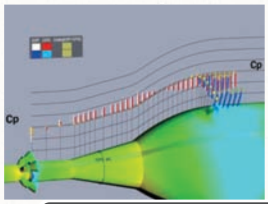
Able to make changes to the visualization as the test was being conducted



Original Setup

Researcher Requests

- Adjust camera placement
- Change Colors
- Increased lighting
- More transparency



Final

Changes made to maximize the amount of information learned from the graphics

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Post-Test Visualizations

MaxScript code autonomously processed all visualizations using DAS files

- Adjusted the magnitude of the pressure bars
- Displayed the proper CFD mesh
- Generated output data files
- Processed over 200 runs
- Rendered over 15,000 images

Excel Macro autonomously packaged visualizations

- Imported renderings
- Created 2-D line plots
- Imported text file

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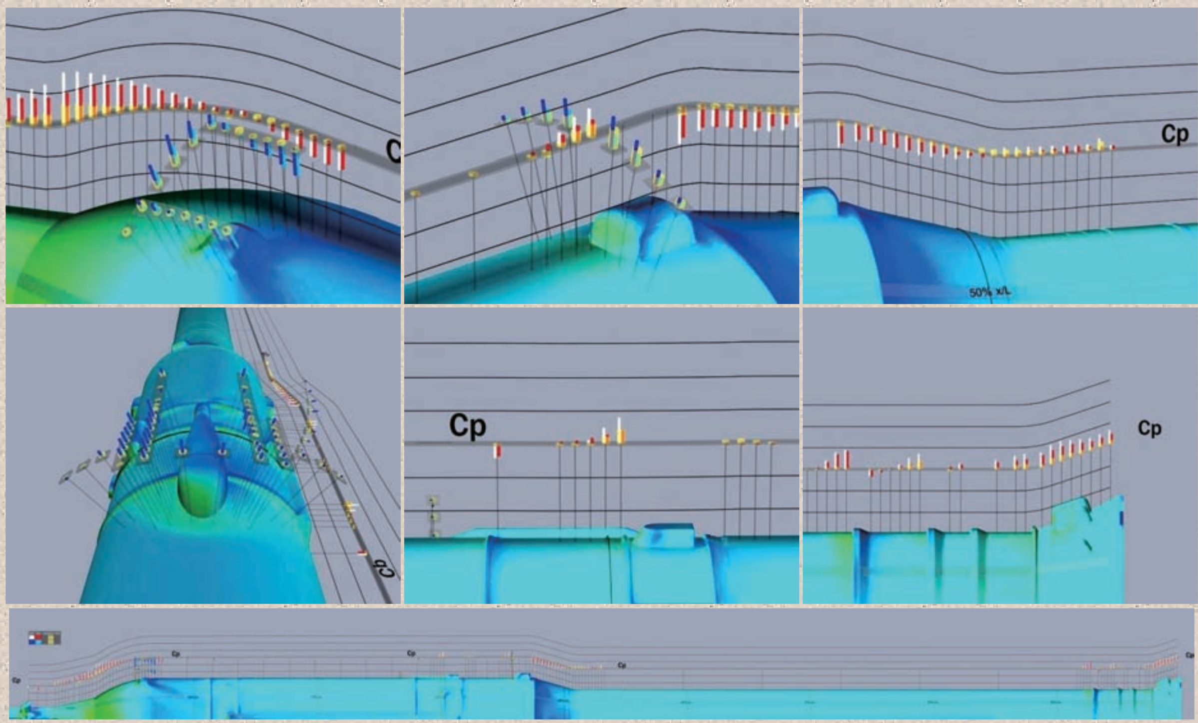
Rendered Views



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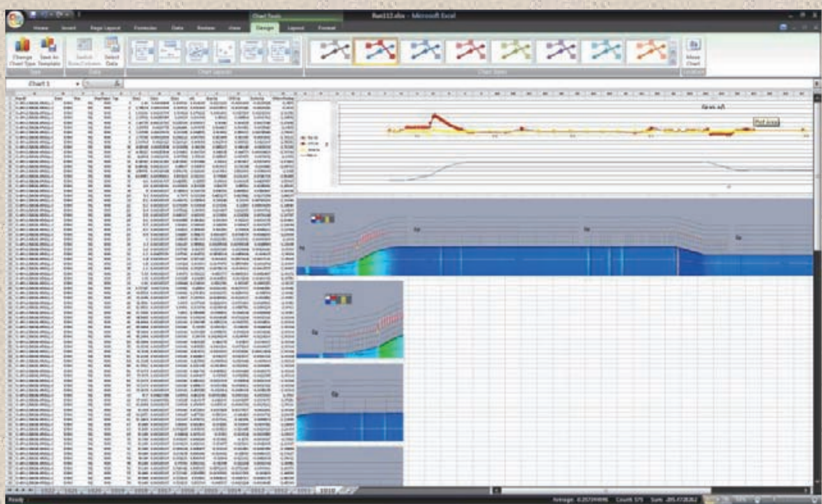
Excel Macro

- Microsoft Excel workbooks
- Multi-platform
- Efficient method to organize and view various data types
- Each run point had its own worksheet
- Each run number was saved to its own workbook
- In addition to all raw data files



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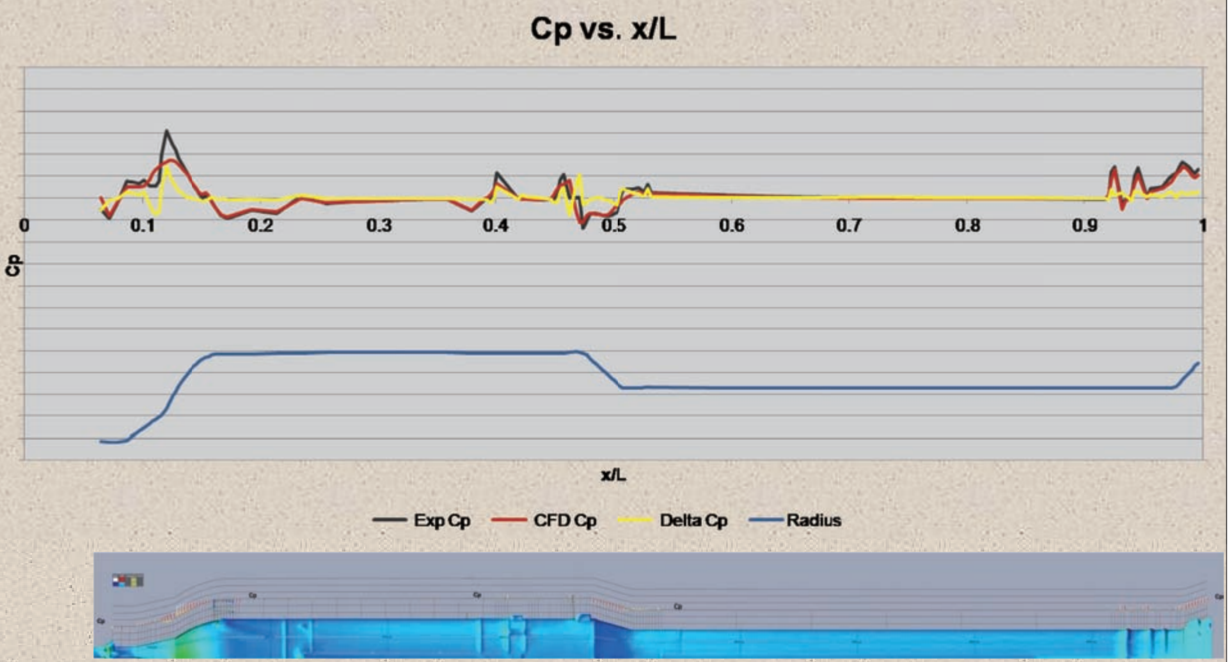
Data Plots



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Data Analysis

CFD Validation

- Rapid assessment
- Reveals any discrepancies with the wind tunnel surface measurements
- Visualize and quantify differences between two sources of data

Complete representation of results

- Ability to intuitively comprehend large amounts of data in context
- Easily switch between global and local views
- Straightforward and descriptive

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Future Plans

- Multiplatform, stand-alone visualization applications that are user-interactive and can be executed without any third party software
- Software and hardware designed to view real-time visualizations in 3D
- These software improvements are planned to be available in the near term to support further testing for the full scope of NASA's aeronautics and exploration programs.

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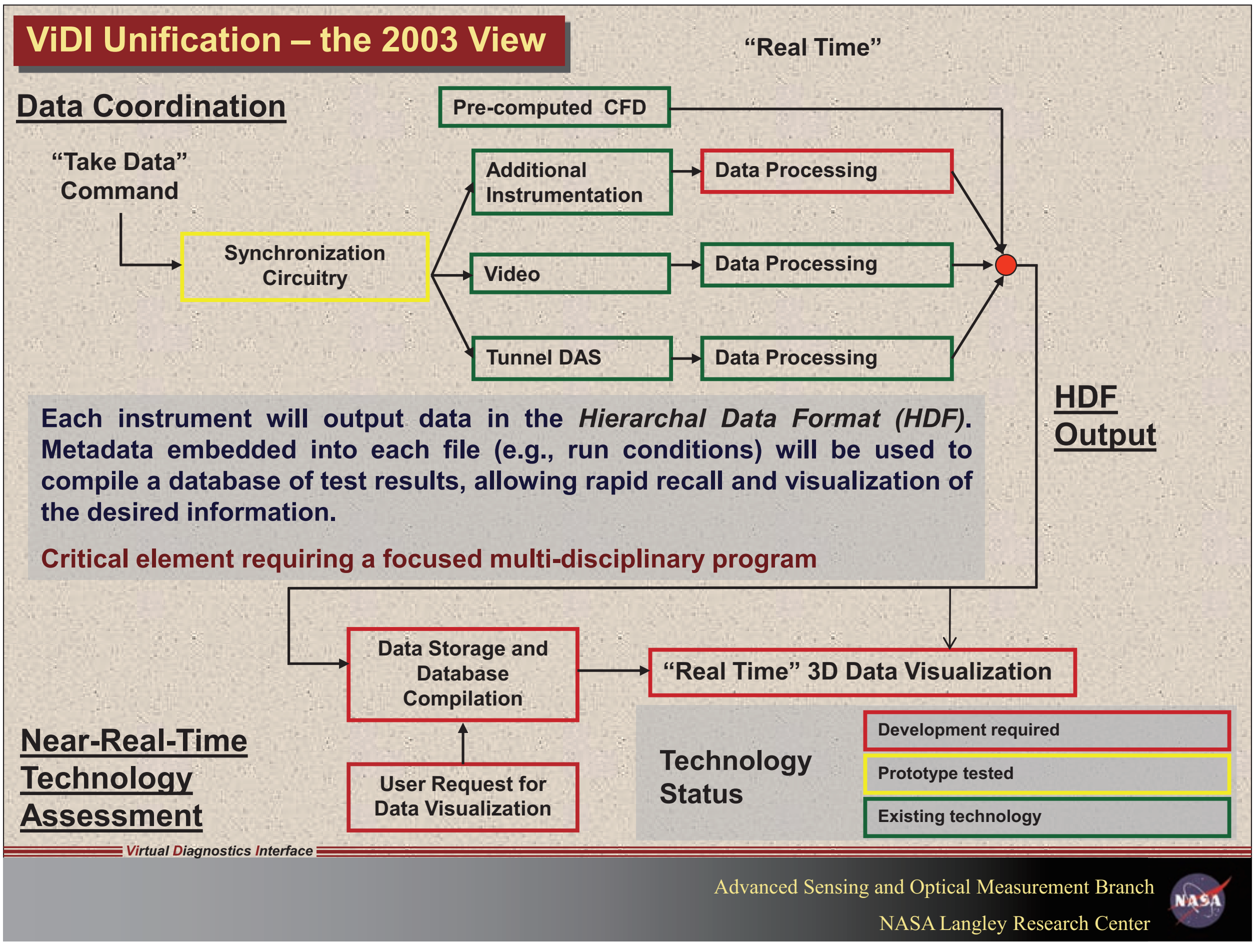

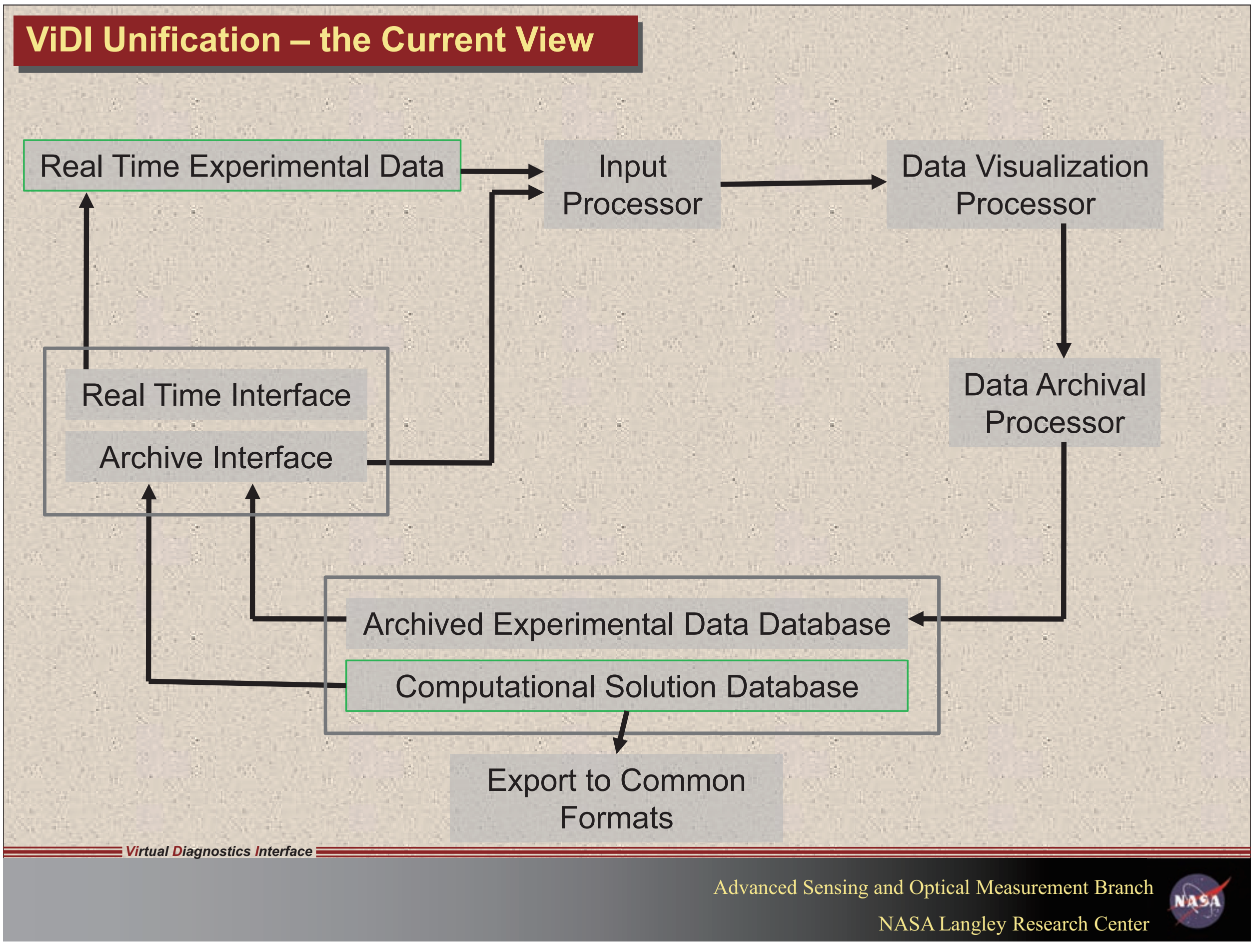

Summary

- Applications of ViDI
- Early data visualization – different forms of experimental data displayed together
- Development of real-time data visualization
- Expansion of real time data visualization to include computational data
- Post – test experimental and computational data visualization work
- Future Directions

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