E-2C Loads Calibration

In DFRC Flight Loads Lab

History

- NAVAIR needed loads calibration for Advanced Hawkeye program E-2C test aircraft to support flight tests
  - Weight growth over many programs required conformation that old E-2C wing design had sufficient margin for next generation aircraft
- DFRC Flight Loads Laboratory had expertise & availability

Objectives

- Safely and efficiently perform structural load tests on NAVAIR E-2C aircraft to calibrate strain gage instrumentation installed by NAVAIR
- Collect load test data and derive loads equations for use in NAVAIR flight tests
- Assist flight test team with use of loads equations measurements at PAX River

Approach

- Understand NAVAIR requirements
- Concur with appropriate flight load cases
- Design calibration cases and test techniques to provide test data required to assure deriving high quality loads equations
- Design and fabricate multiple test fixtures
- Set up and execute complex load tests
- Derive loads equations using DFRC EQDE program

E2-C Loads Calibration Preliminary Design Review

May 17-18, 2004

NASA Dryden Flight Research Center

Advanced Hawkeye
(AHE)

A123 Loads PDR

17-18 May 2004

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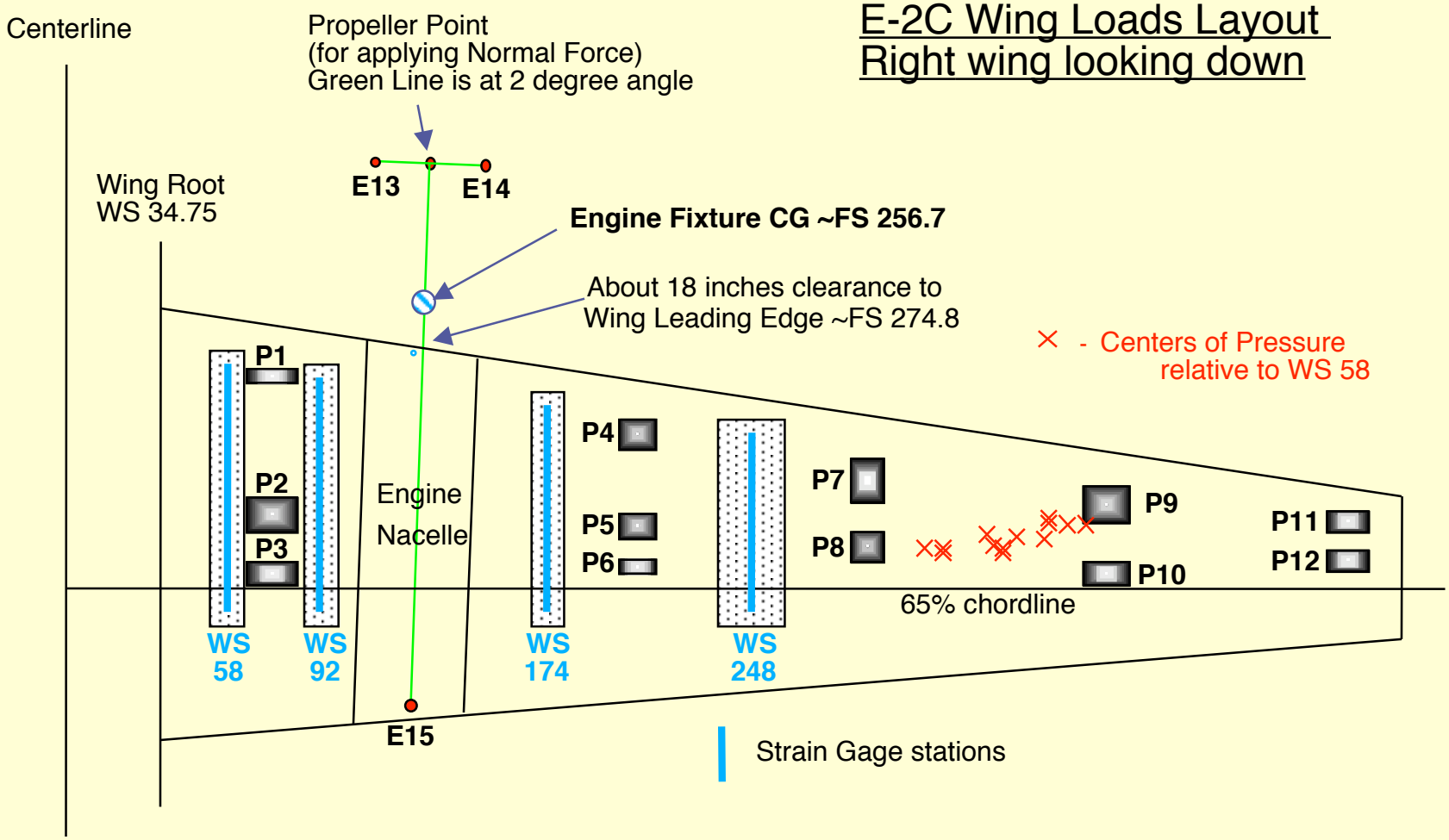
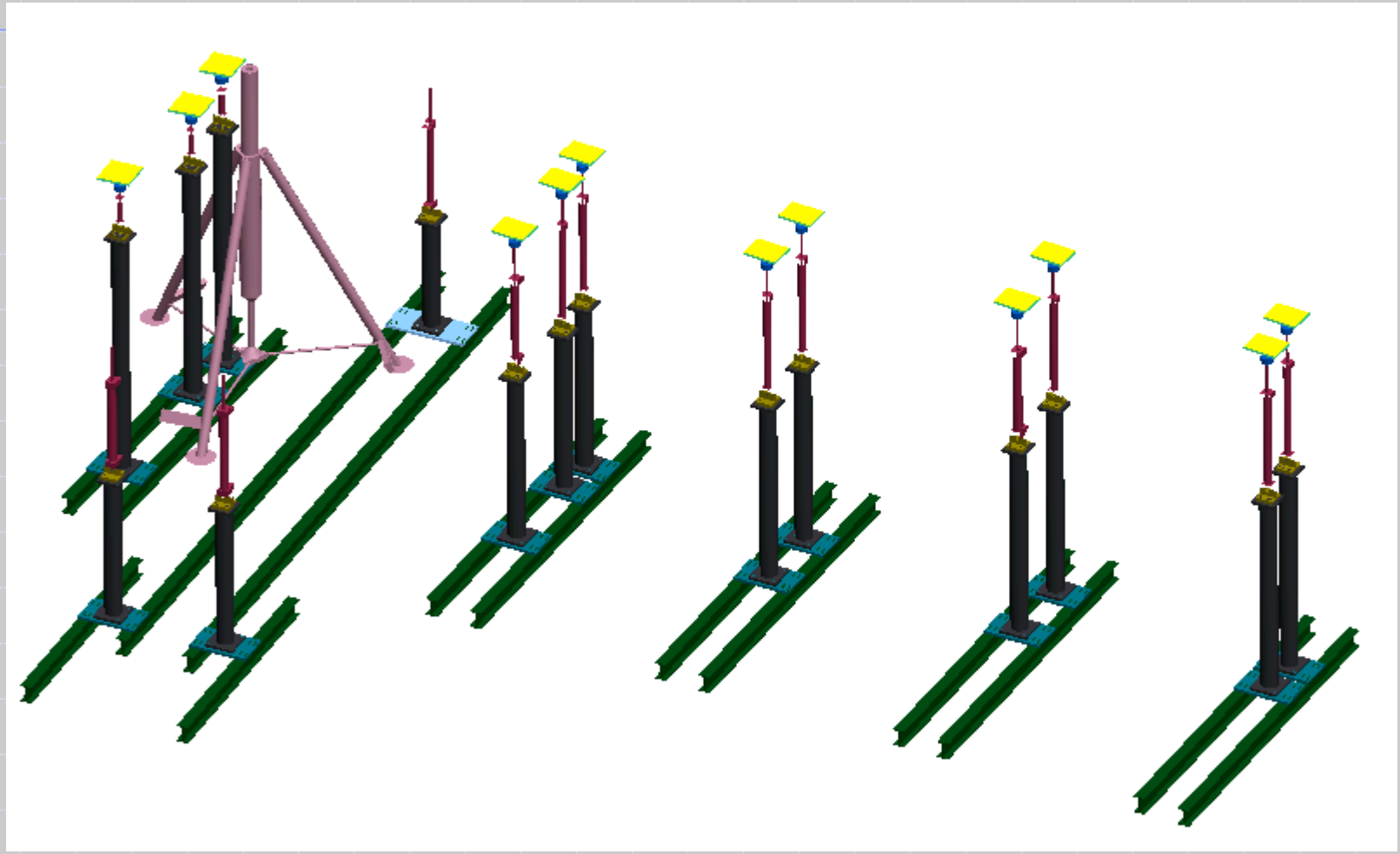
Preparations for the Tests

- Designed load cases to meet multiple requirements:
  - Multiple load distributions, aircraft skin pressure limits, aircraft local structure load limits, test operation safety considerations, multiple strain gage measurement stations
- Designed and fabricated test setup to apply a variety of test loads, and properly handle reaction loads at aircraft interfaces:
  - Wings, tails, engine nacelles, nose landing gear, skid and tail hook interfaces, A/C jack points

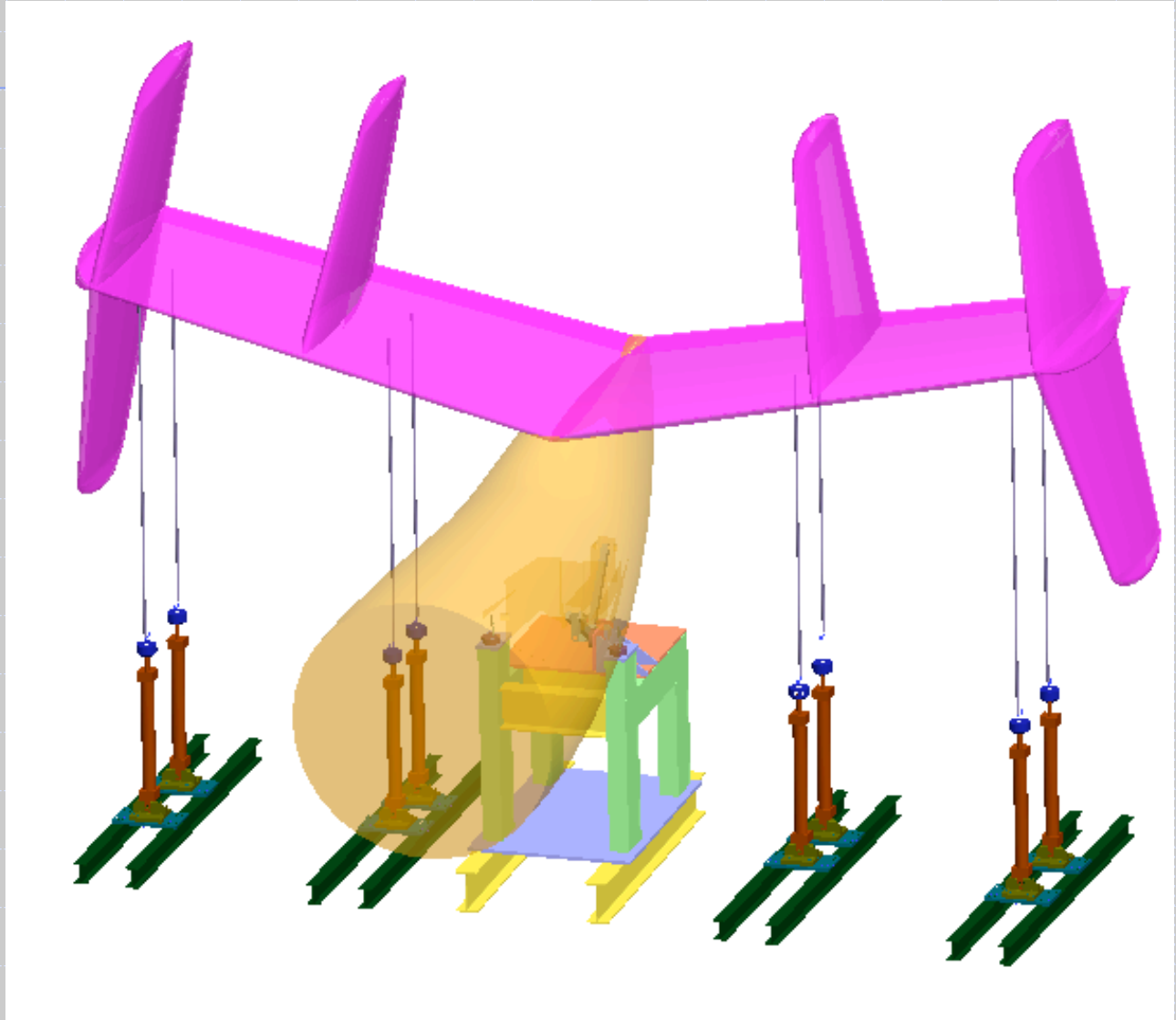
Wing Loading Layout



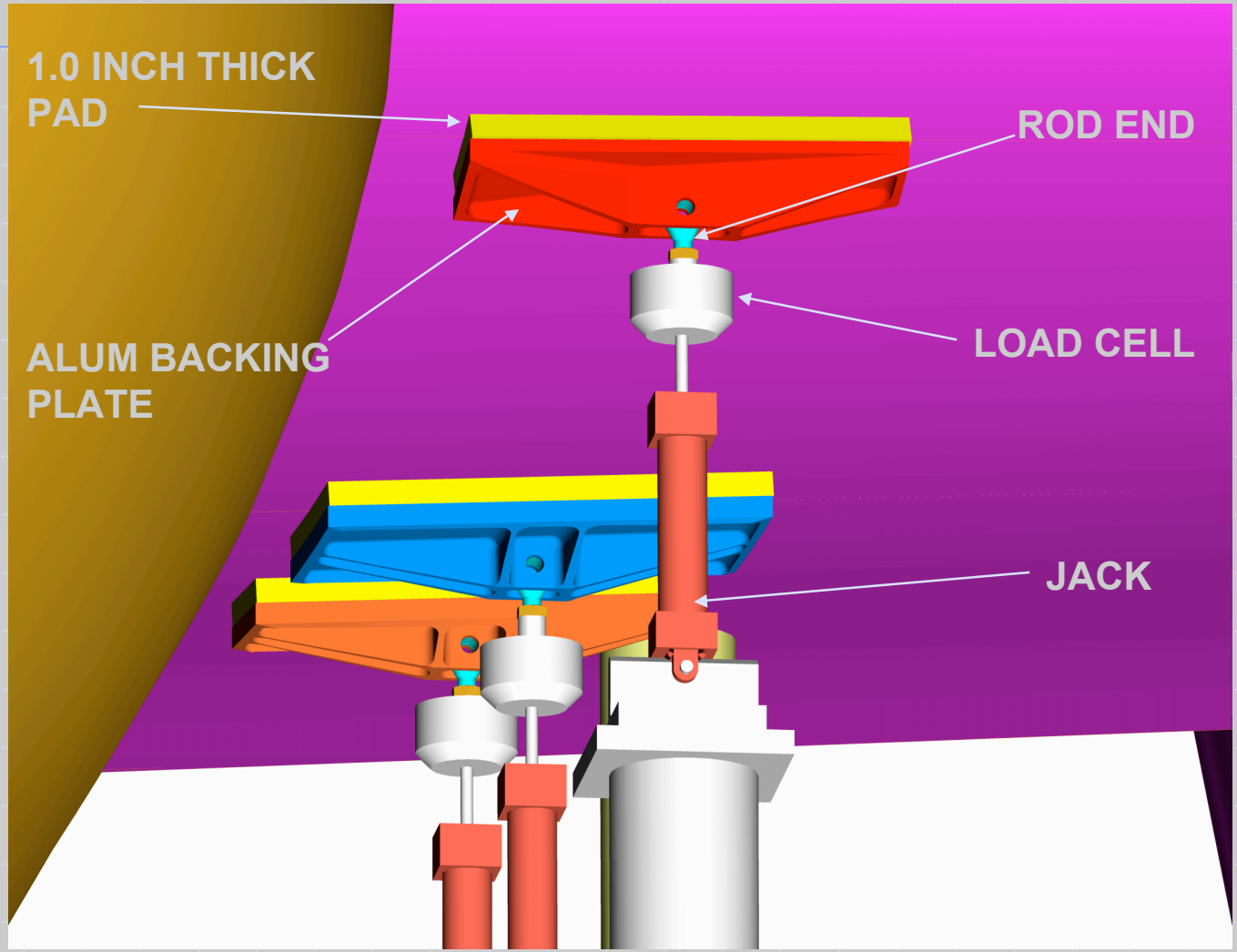
Wing Loading Hardware



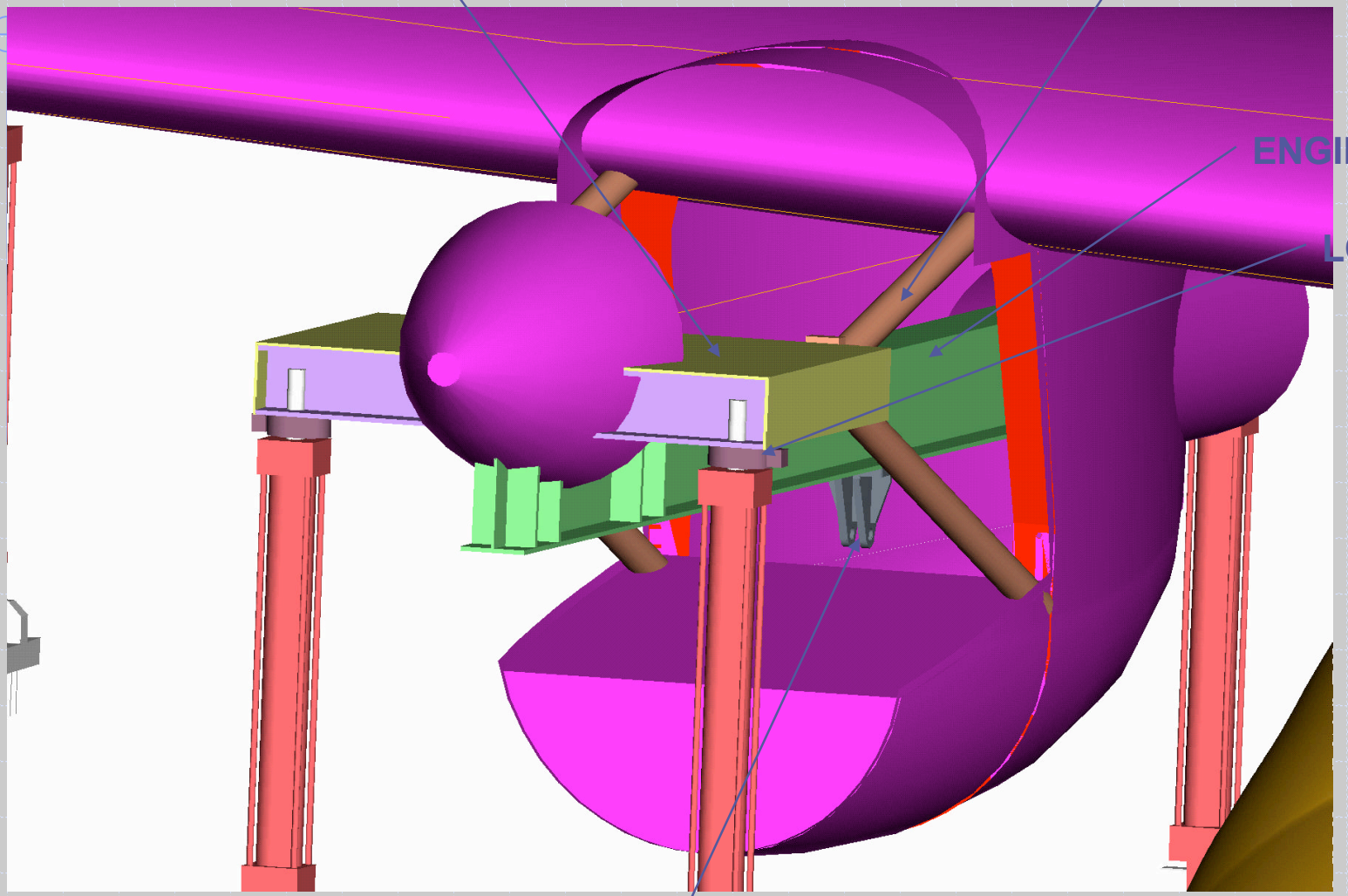
Horizontal Tail Loading System



WING PADS/PLATES



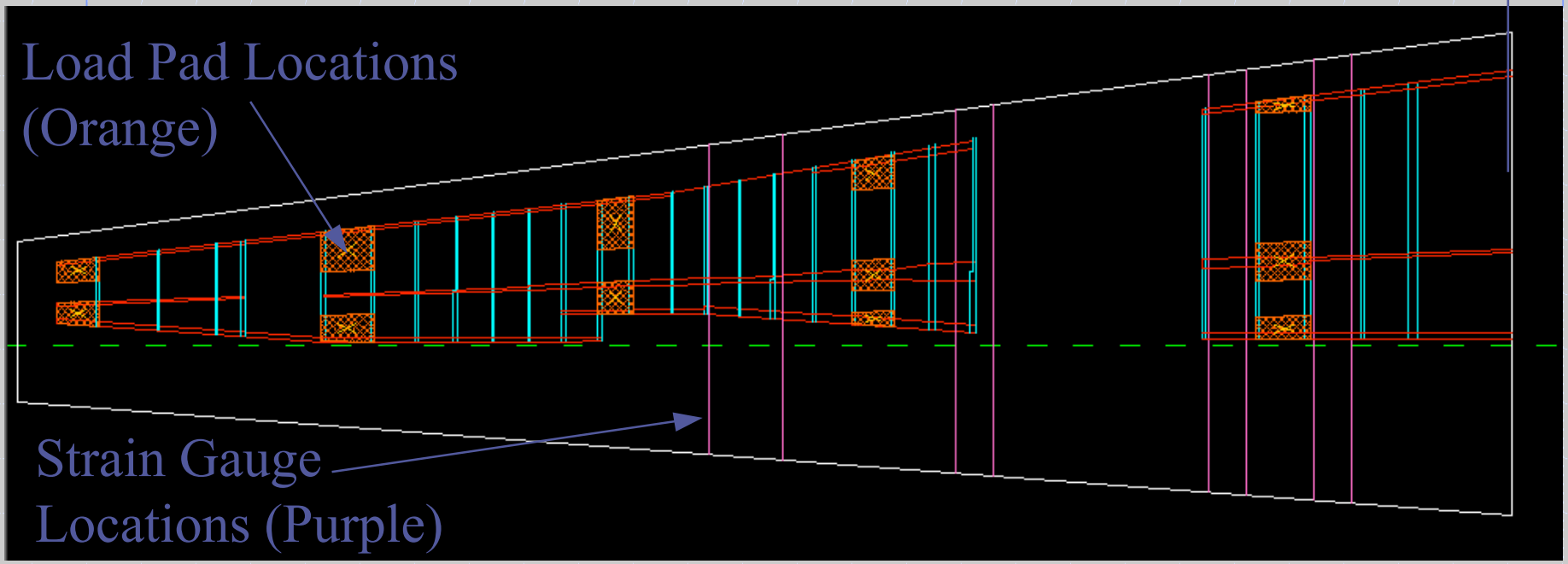
Nacelle Loading Fixture
Isometric View



Load Pad Locations

Forward

- Pad relationships to wing internal structure



View Looking Up

Preparations for the Tests

- Set up and used nearly all 40 load control channels on aging hydraulic control system (recently replaced by modern equipment):
  - Loaded both sides of aircraft simultaneously
  - Provided operational techniques and unique approach/fixtures to protect aircraft from overload in event of any load control system malfunction
  - System provides automatic collection of test data at proper data rates while applying loads as designed by loads engineers (automatic, pre-programmed load application by computer control)

NAVAIR Constraints

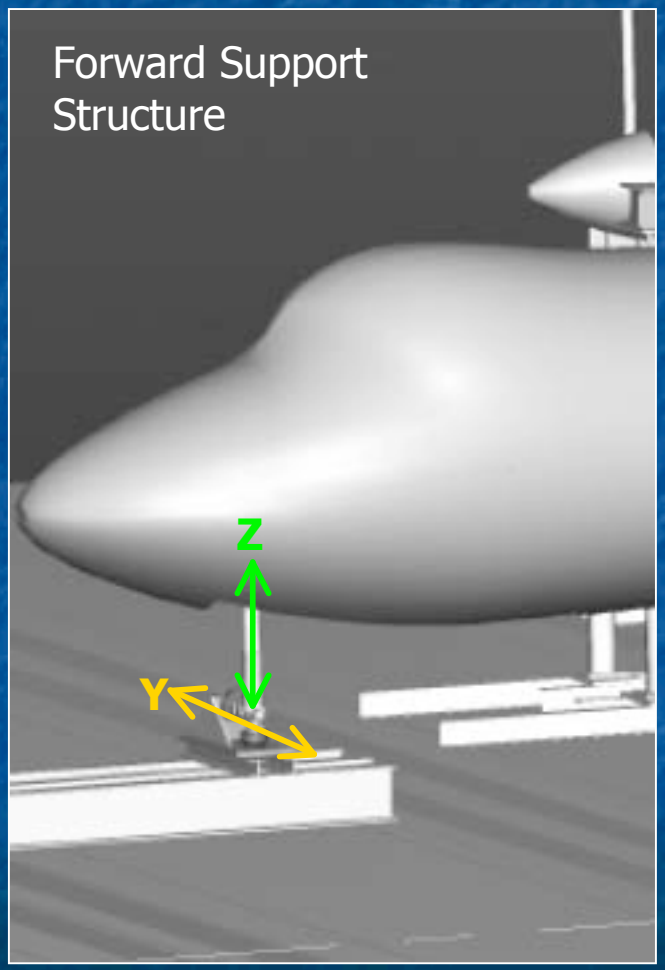
- Loading restricted to 40% of the E-2 Design Limit Loads (DLL) as defined in the AHE Loads Calibration Objectives and Requirements Document, Revision A.
- Surface loading of the wing and horizontal tail to be adequately supported by underlying structural members.
- Surface loading allowable restricted to 20 psi for all surfaces.
- Loading applied at the nacelle interface only for propeller normal force sensitivity study, engine shaft torsion sensitivity study and engine inertia and nacelle loads.

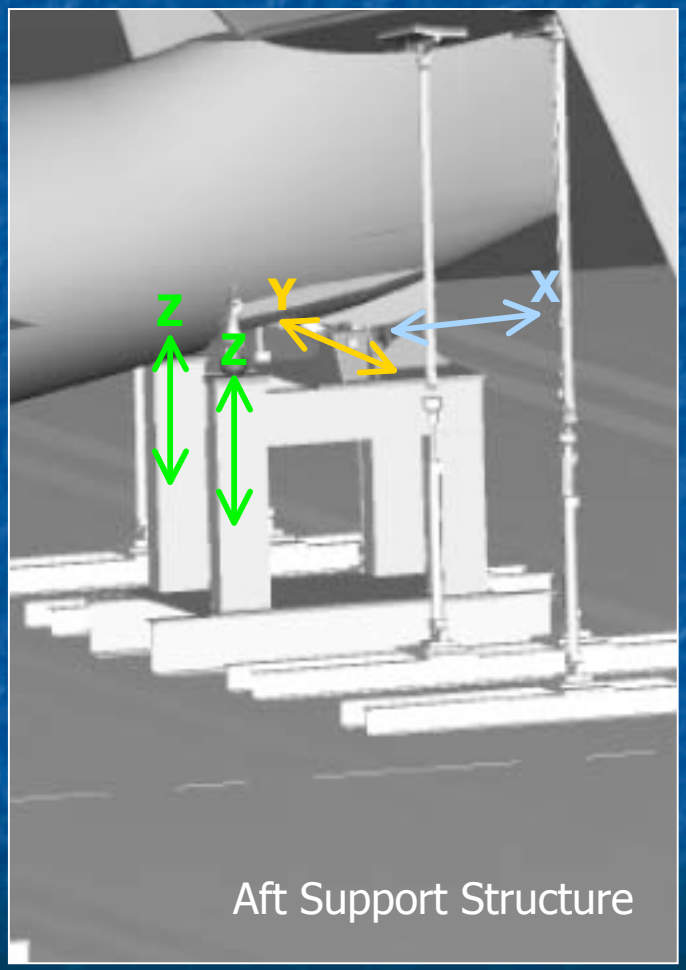
Flight Loads Laboratory Constraints

- Aircraft will be de-fueled and the tanks pencil drained and purged before entering the Loads Lab. Additional purging will take place in the unlikely event it is required.
- Strain gage signals will be made available to the Flight Loads Laboratory data system using a mutually agreed upon wiring harness and connector configuration.
- NAVAIR will provide aircraft support equipment and personnel as agreed to during test preparation, test execution and for aircraft related pre-test and return-to-flight activities

Airframe Support

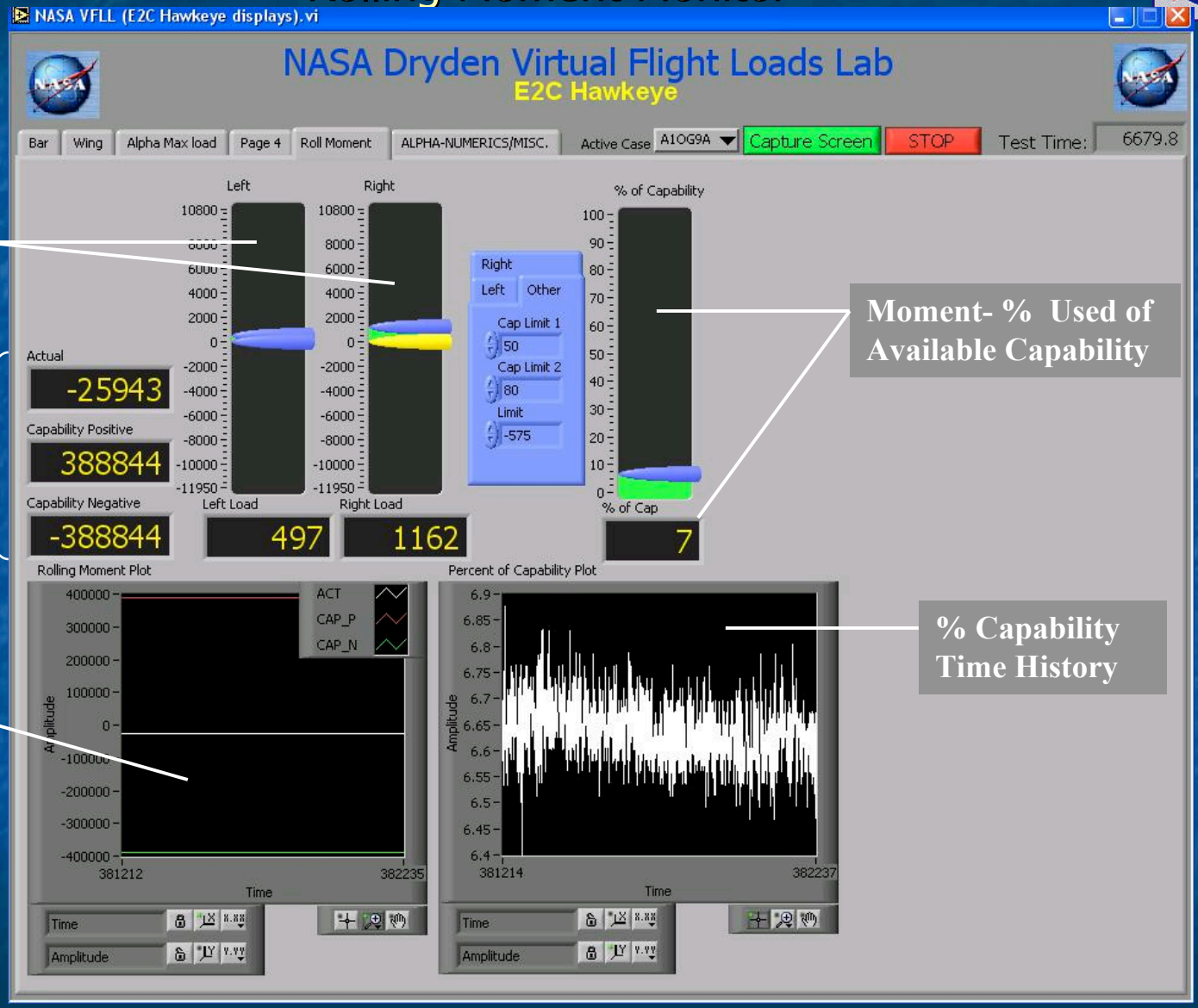
Reaction System is Tied in 6 DOF and Statically Determinate
Load Cells Allow Real-Time Monitoring and Control of All Reactions





Calibration Test Real-Time Displays

Rolling Moment Monitor



Actual Moment Left and Right

Moment- Actual and Available

Actual Moment Time History

Moment- % Used of Available Capability

% Capability Time History

Calibration Test Real-Time Displays -DACS III

- Pairing or grouping can be done on time plots, as on the previous slide, or on bar graphs.

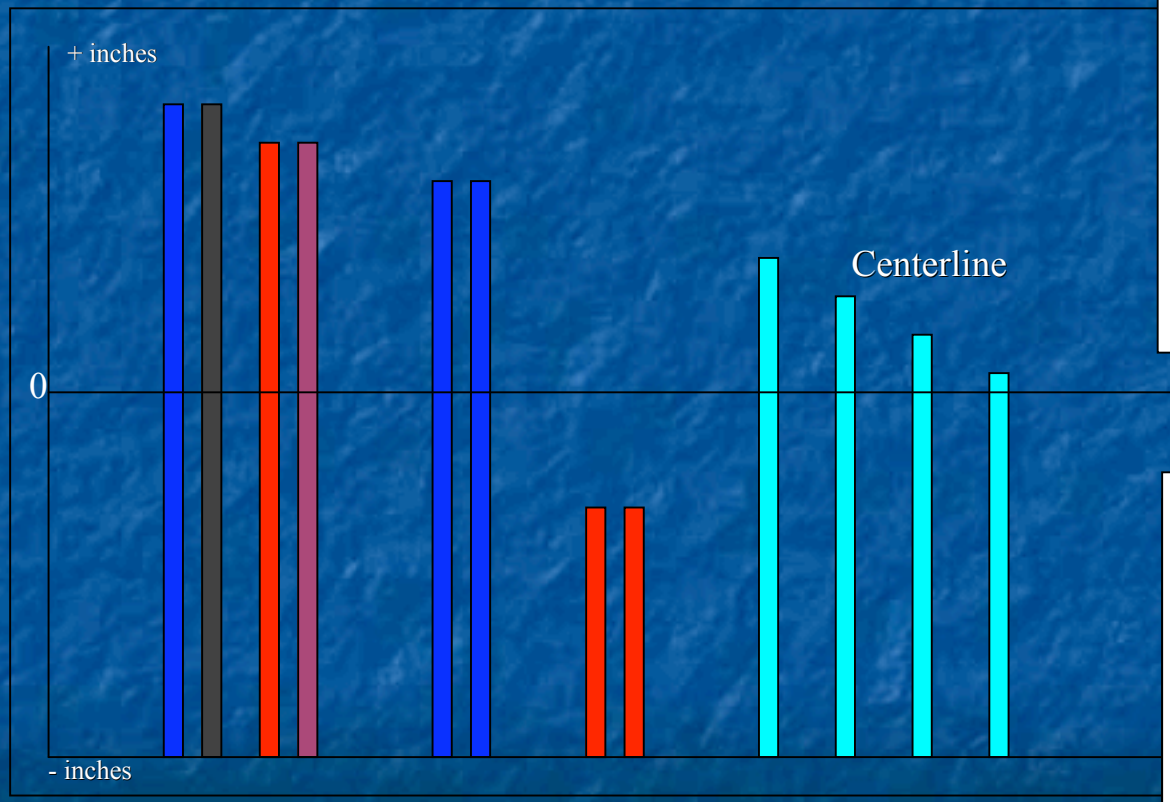


Figure 6 – LHS vs. RHS and Centerline Deflections

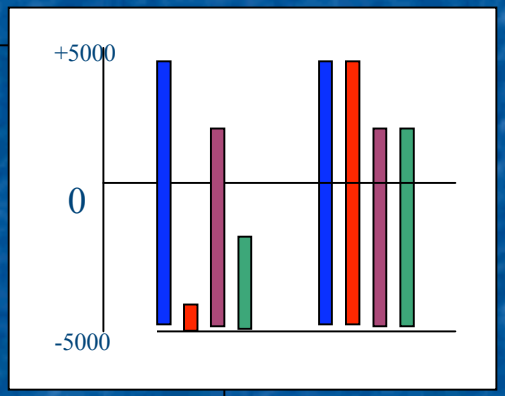


Figure 1 – Load Cell Readout

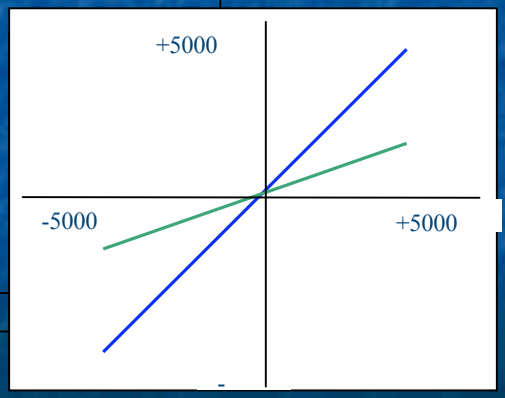
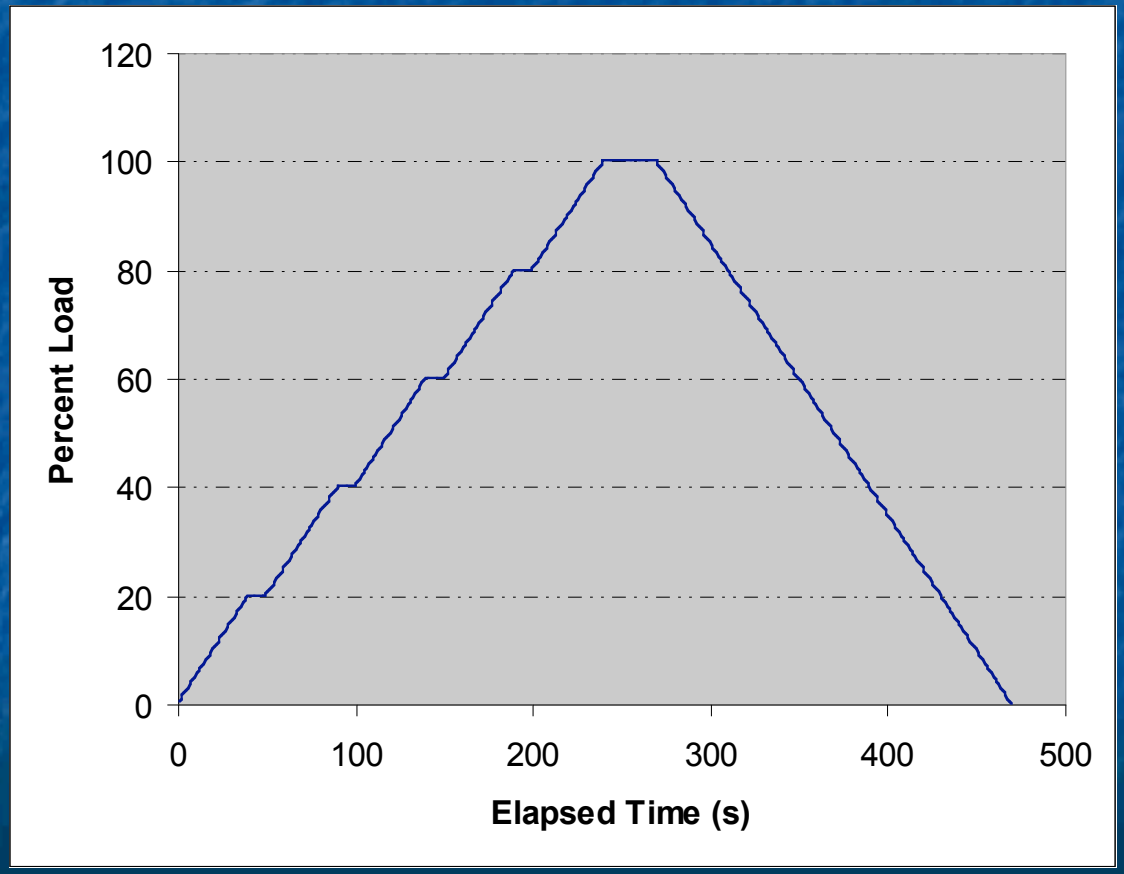


Figure 2 – Load vs. Time Plots

Calibration Test Real-Time Displays -DACS III

- Any parameter or group of parameters, up to 16 per display, can be plotted as a function of time.
  - Example Load Profile – Load vs. Time for a single load cell.



Test Safety and Risk Management

- Test Hardware Analysis and Factors of Safety
- Aircraft and Test Systems Physical Constraints
- Controlled Access to the Test Article, FLL High Bay and Control Room
  - Separate area will be set up for observers.
- Hydraulic System
  - Pressure reduction regulator for each actuator limits maximum load capability
- Load Controller Safeguards
  - Inner error detector provides warning when the difference between commanded load and load cell feedback circuit exceeds a specified value.
  - Outer detector on controller trips hydraulic pump when the difference between commanded load and load cell feedback circuit exceeds a specified limit.
  - Load limits on controller trip the hydraulic pump when exceeded. Limits are set just above maximum load magnitudes

Hazard Summary (cont.)

HAZARD SEVERITY	PROBABILITY				
	A Likely to occur frequently	B Likely to Occur Several Times in Program	C Likely to Occur at Some Time	D Unlikely, but possible	E Extremely Improbable
Category I Catastrophic. Death, life threatening injury, loss of FLL system, loss of test article*					**HR001**
Category II Critical. Lost time injury, substantial damage to FLL systems, substantial damage to test article* or test systems*.					**HR002** **HR003** **HR004** **HR007 test** **HR009**
Category III Marginal. Test system failure, minor damage to test article*, loss of test				**HR005** **HR006** **HR007 non-test**	**HR008**
Category IV Negligible. Safe					

Shading Key:

	Project decision on actions
	Must be presented to TRR as Accepted Risk and approved by RS Branch Chief and Director of Research Engineering
	Normally, corrective action must be taken to reduce probability below "C". This restriction may be waived, under extreme circumstances, by the Dryden Flight Research Center Director.

Test Execution

- All tests were conducted per approved test plan, and detailed test checklists assured a safe and well-organized test operation
- Loads were applied in a build-up fashion, and each load case was applied multiple times for data quality
- Real-time data display allowed immediate assessment of test safety and test data quality
- All pertinent test data was immediately available to test team during the tests, and in archival files immediately following each test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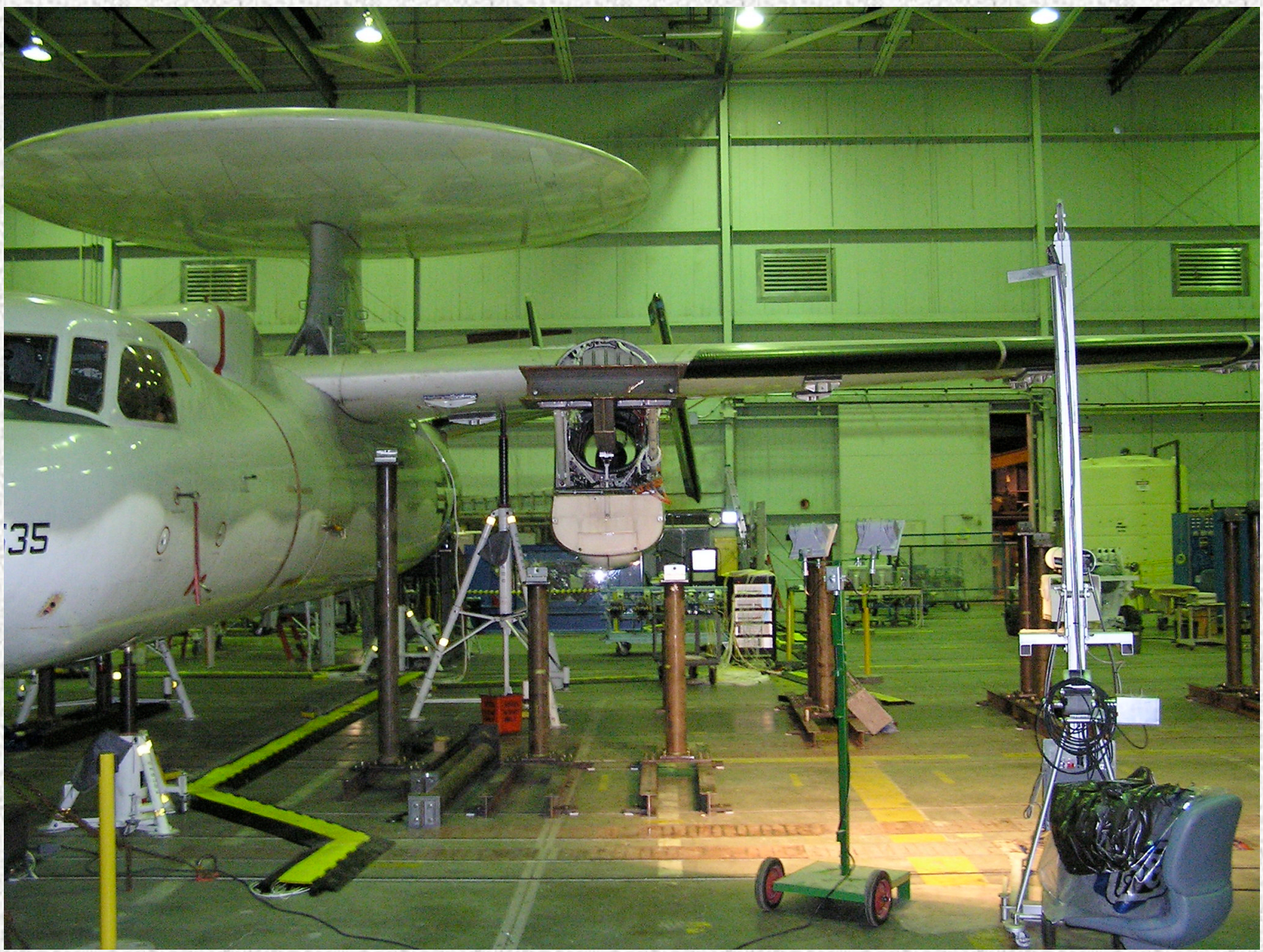
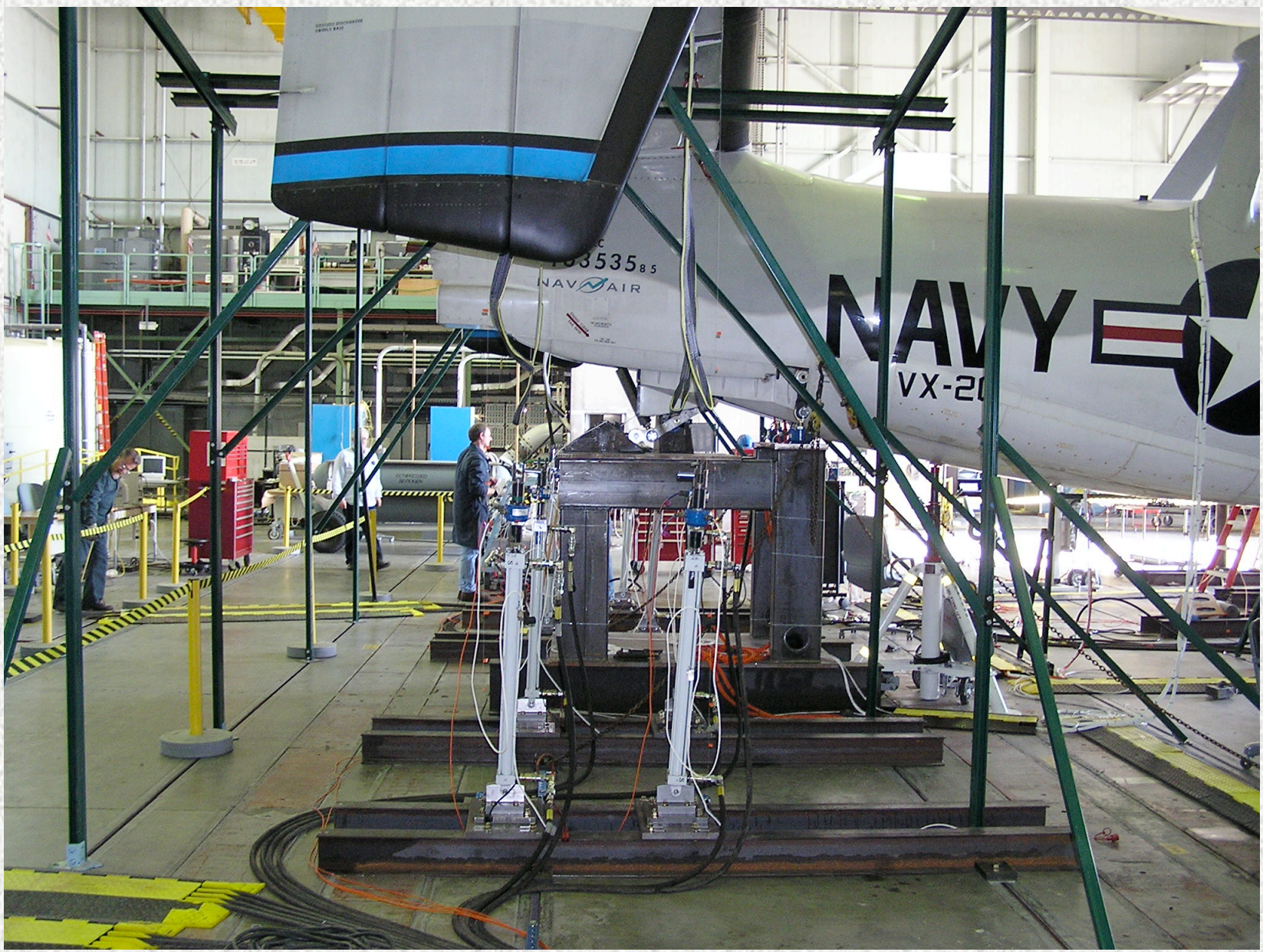
163535 85
NAVAIR
NAVY
VX-20

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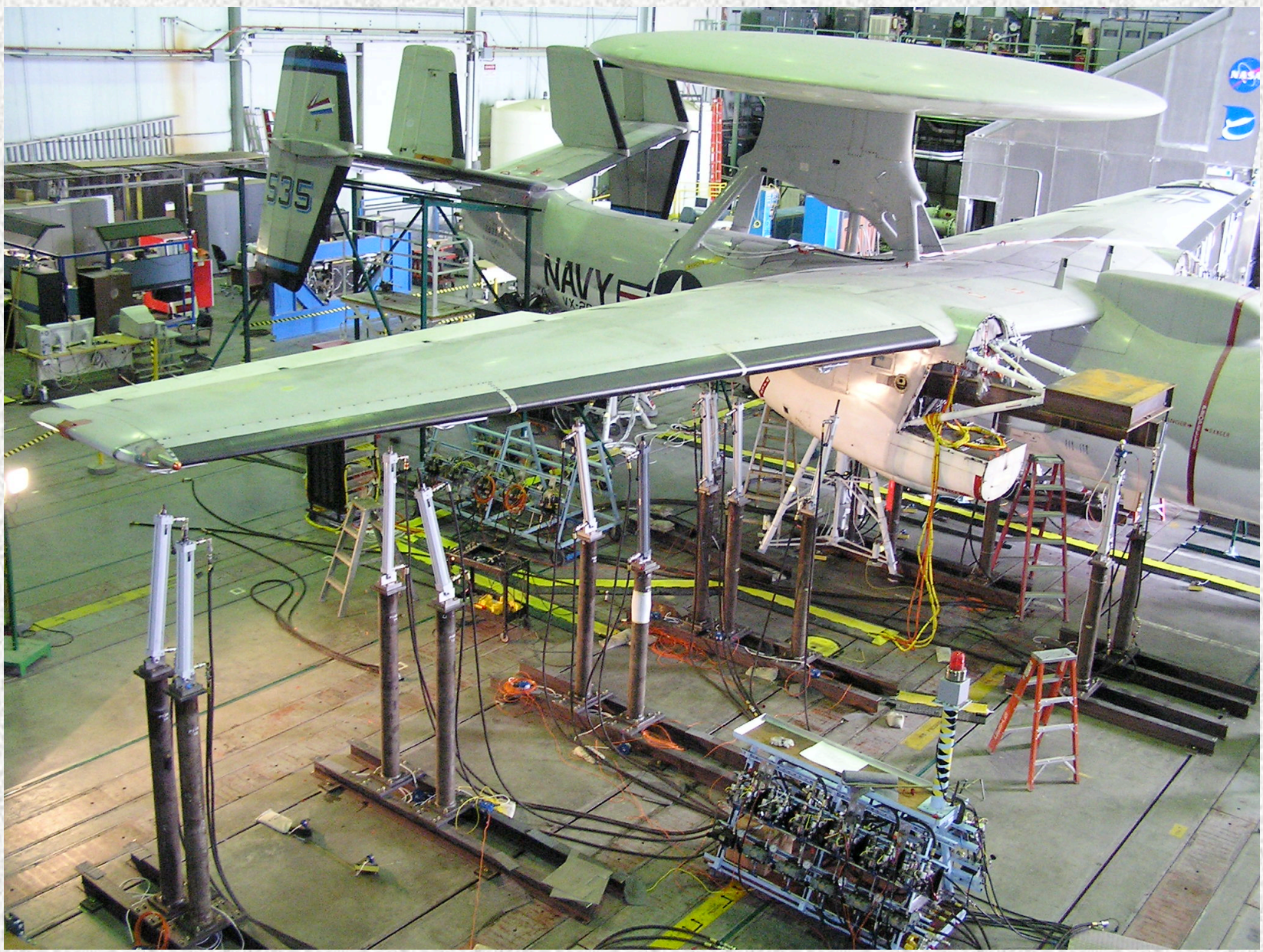
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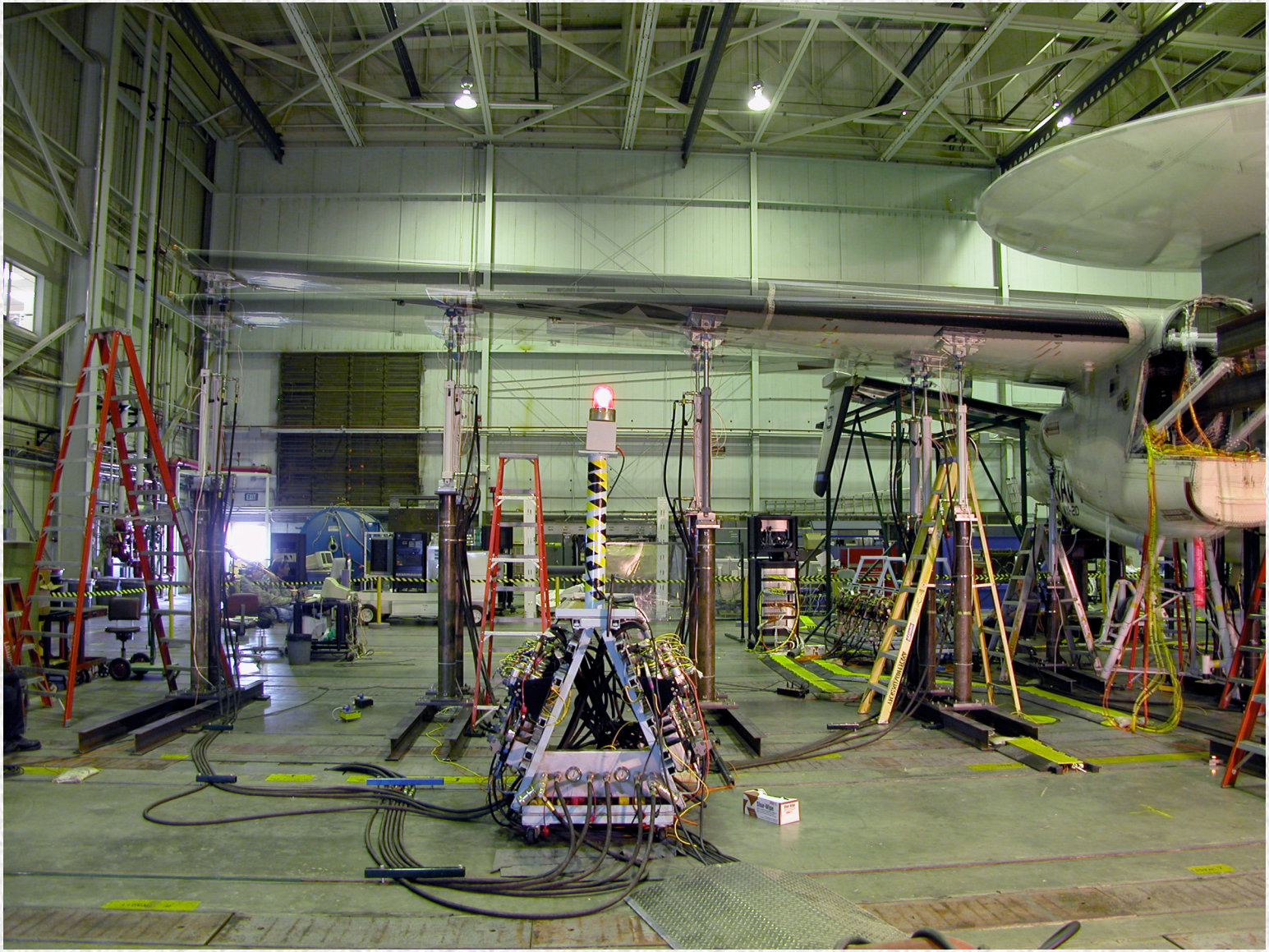

Results

- Excellent quality test data was acquired
- All required loads equations were derived and provided to NAVAIR in a timely fashion to support their flight test schedule
- Overall program was accomplished under original budget and ahead of schedule
  - Ability to work well with NAVAIR to reduce test complexity while improving test quality was key to performing so well

Summary

- DFRC Flight Loads Lab has capability to perform extensive loads test required for aircraft strain gage loads calibrations
- Recent hydraulic control equipment replacement has expanded capability and improved reliability

Future Work

- We welcome opportunities to work with NAVAIR again
- Facility, equipment, and techniques must be exercised on a regular basis to maintain capability to perform these tests and analyses