T-97 Large Motor Test Facility

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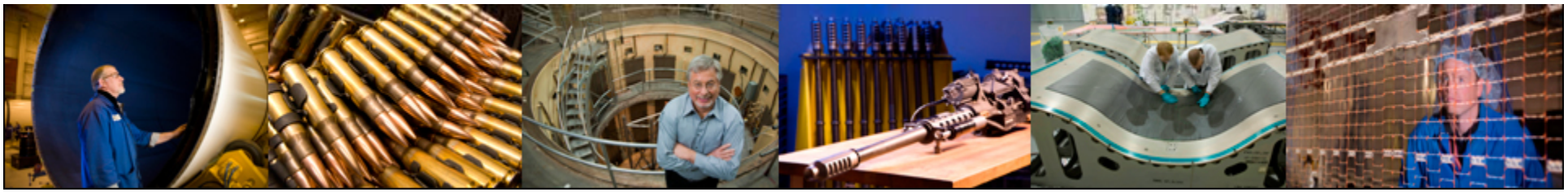


T-97 Large Motor Test Facility

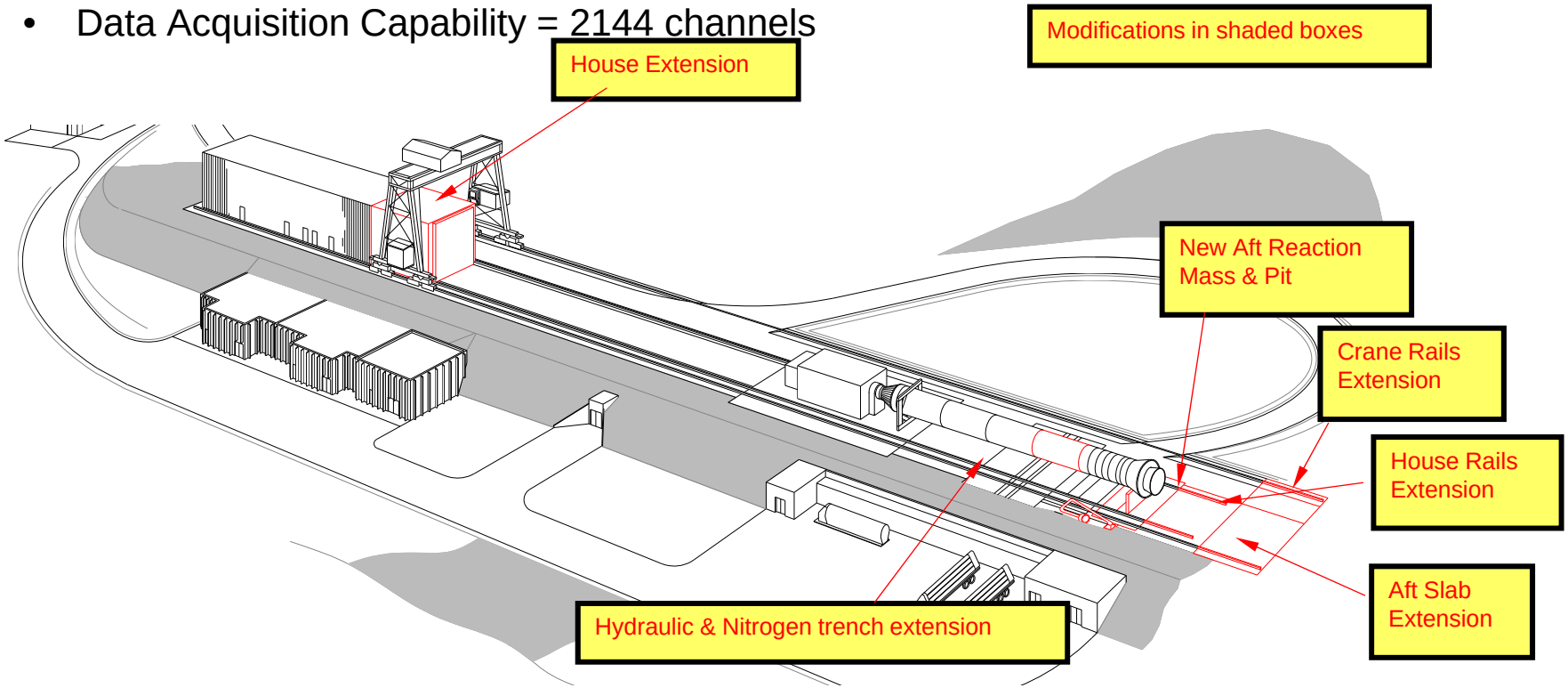
T-97 is one of two ATK facilities capable of testing large full-scale motors

- T-97 can handle next generation Space Launch System Heavy Lift Vehicle 5 segment solid rocket motors
- Facility completed in October of 1987, Modified in 2002 to be capable of testing 4 or 5 segment motor configurations, Refurbished for DM-1 completed in 2009 primarily test stand and systems upgrades

T-97 Large Motor Test Facility

T-97 Test Bay Facts

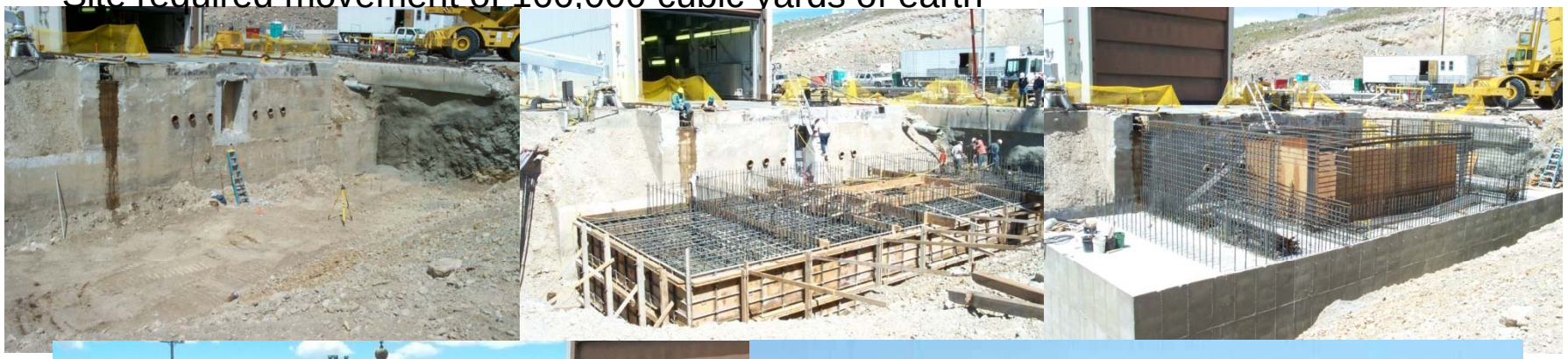
- 8,000 cu. yds. Concrete
- 2 aft pits for Aft Test Stand
- 700 tons of Steel
- 3300 tons of asphalt, 200 ton gantry crane,
- Fwd Reaction Mass = 40’ L x 20’ W x 16’ H
- Capable of 4.3 million pounds of thrust
- Data Acquisition Capability = 2144 channels



T-97 Large Motor Test Facility Modification

2002 Facility Modification

- 2,500 cubic yards of concrete
- 308 tons of reinforcing steel
- 230 tons of steel plates and rails
- Site required movement of 166,000 cubic yards of earth



T-97 Large Motor Test Facility

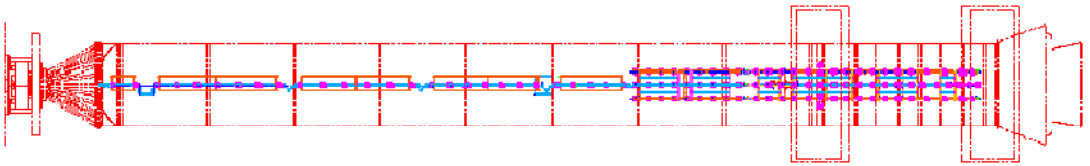
Mobile Conditioning Building

- Dimensions 205 ft long by 32 ft wide by 30 ft high
- Thermal Simulation 20°F to 110°F
- 10-ton bridge crane

T-97 Large Motor Test Facility

Water Deluge System

- Activated at T+105 seconds
- 115 spray nozzles
- 2,300 gal/min
- The majority of the residual hot sludge is concentrated in the Aft 1/3 of the motor



T-97 Large Motor Test Facility

CO2 Quench System

- Activated at T+120 seconds
- Remotely controlled, 31 tons of CO2 plumbed both forward and aft
- Tank is emptied to 50% of capacity within 216 seconds
- Tank is emptied to 5% of capacity over 600 seconds for nozzle, 429 seconds for chamber

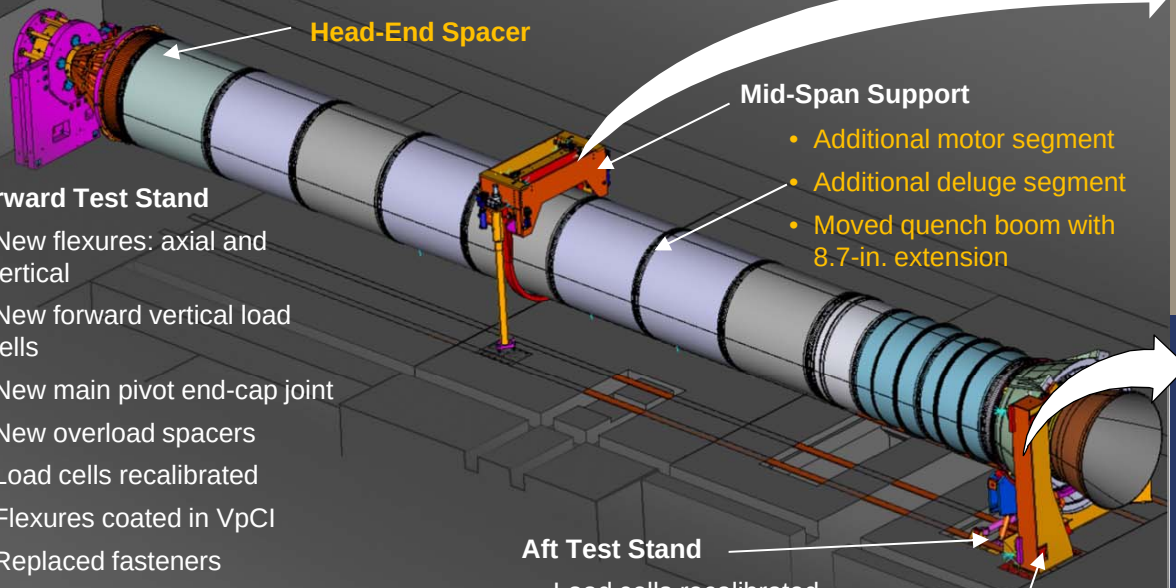
T-97 Large Motor Test Facility

Test Stand

- Designed to a thrust load of 4.3 million pounds
- Comprised of multiple load trains carrying Axial, Lateral and Vertical Motor and gravity
- Flexures are an integral part of the RSRM test stands
  - Used in Load Trains
    - Minimizes load cell bending
    - Minimizes interaction
  - Accommodate the motor bending
- Test stand is calibrated to 100% operation load prior to each static test firing

T-97 Overview of Changes

T-97 construction was completed on October 17, 1987. It was designed to test large rocket motors with thrusts up to 4-million pounds. The construction of the complex was a major undertaking. T-97 is one of the most modern large rocket motor test facilities in the world. In order to test the heavier and longer motors
(5 segments vs. 4 segments), T-97 was modified adding a second aft pit and reaction mass. This modification raised the bar, and makes T-97 the largest and most advanced solid rocket motor test facility in the world.



Off-Motor Changes

- New fire control system
- New test stand calibration controller
- New data recording systems

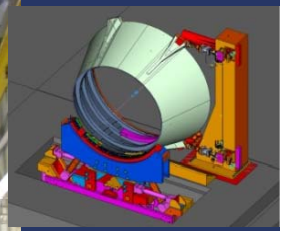
- Capable of supporting 400 kip of motor weight
- Limits motor sag
- Flexurized system mitigates thrust interactions
- Supports motor for approximately 80 sec

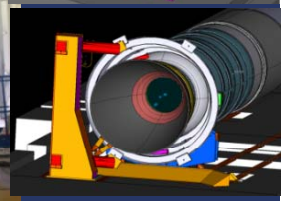
Mid-Span Weight Test

Kevlar Sling

Mid-Span Assembly

Skirt Side Load Fixture





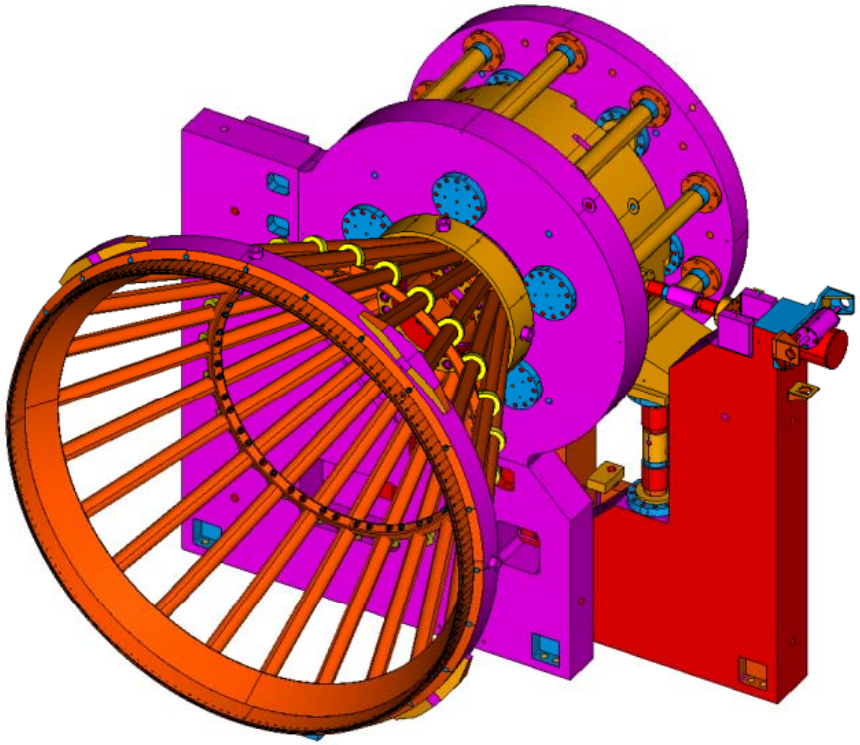
Side Load Fixture Assembly

T-97 Test Stand Upgrades

Forward Test Stand

Component Function

- Supports the RSRMV forward end
- Measures the majority of the axial thrust (3.6 Mlbs)
- Measures forward lateral (side), vertical (weight) force
- The forward test stand also includes an axial and side force in-line calibrator



T-97 Test Stand Upgrades

Forward Test Stand Changes

Description:

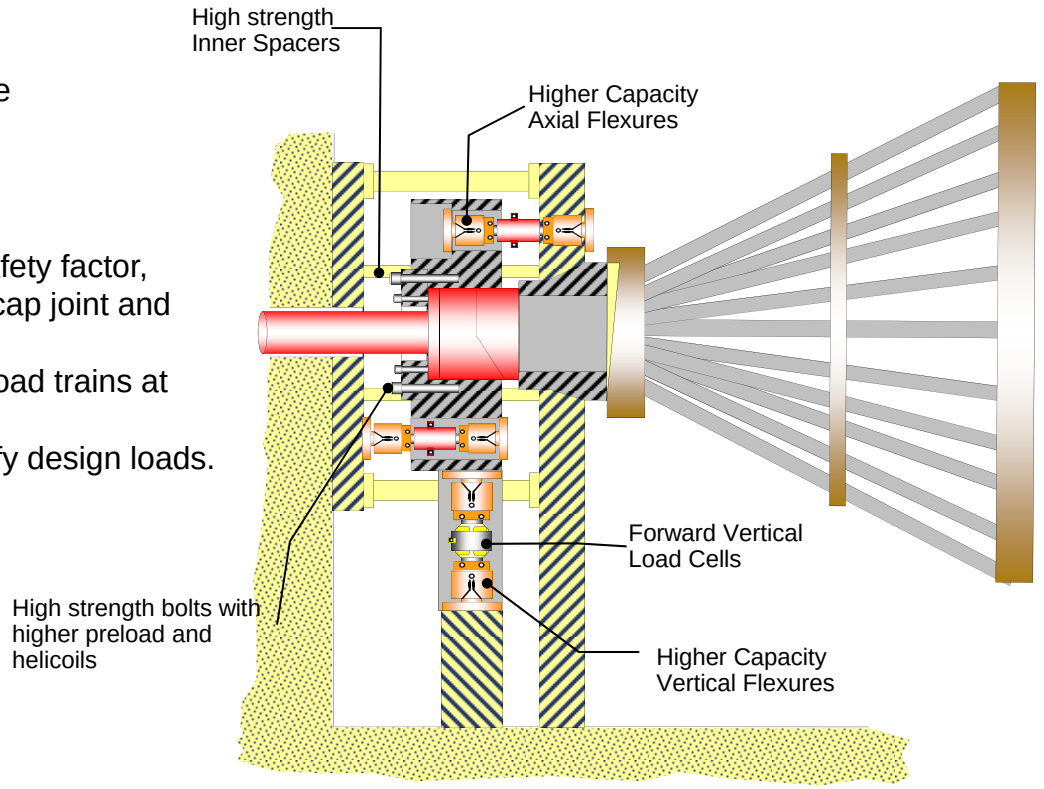
- Extend the depth of the bolt holes and install helicoils to increase the thread engagement in the Fwd end cap joint in the keystone block. Replace socket head cap screws with Inconel bolts.
- Replace axial and vertical flexures with increased capacity flexures (axial 347K to 451K, vertical 359K to 395K).
- Replace vertical instrumented struts that will mate to the new forward vertical flexures.
- Replace mild steel inner overload spacers with identical geometry higher strength steel (4340) spacers.

Reason

Changes are required to increase the safety factor of the test stand for proposed ARES loads.

Justification/Verification:

- Forward test stand components meet the required safety factor, except for the AHOPS waiver for the main pivot end cap joint and forward collar.
- The new flexures meet the AHOPS safety factor for load trains at 4.33 Mlbs thrust
- One of each flexure style was tested to failure to verify design loads.



T-97 Test Stand Upgrades

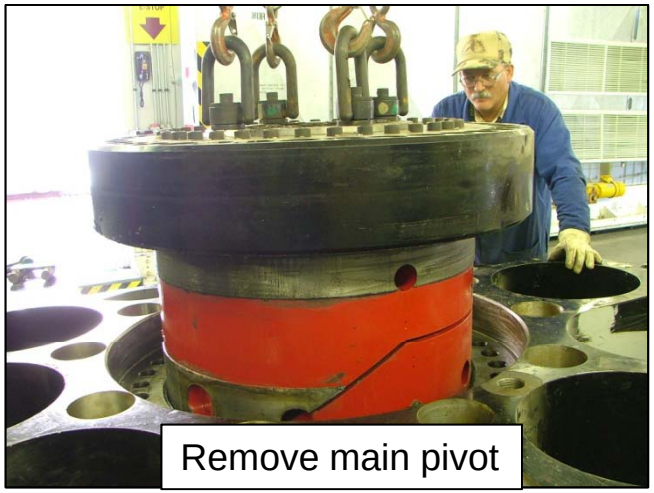
Forward Test Stand Disassembly

Remove axial calibrator rod

Remove overload spacers

Remove load trains

Remove keystone



Remove main pivot

Forward test stand disassembled

T-97 Test Stand Upgrades

Load Train Refurbishment

Recalibrate load cells

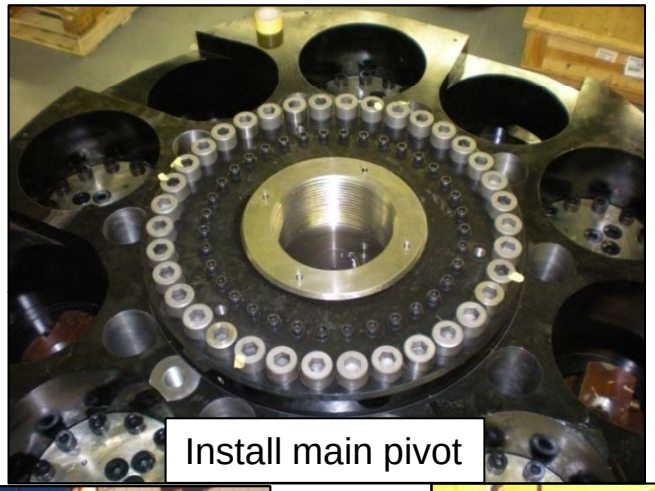
MSFC Gilmore Calibrator
500 kip Dead Weight

Purchase new flexure

Refurbish load trains/VpCI coat

T-97 Test Stand Upgrades

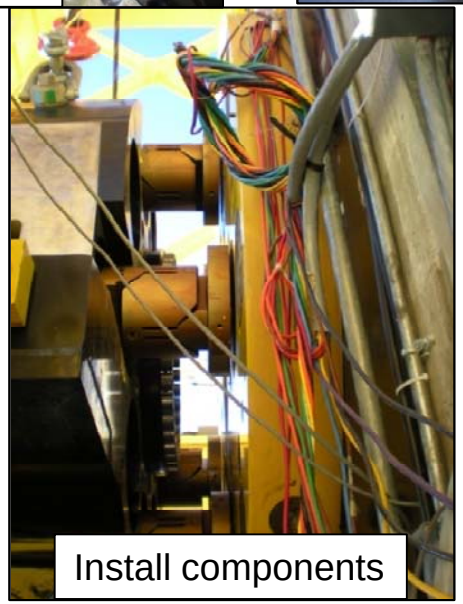
Forward Test Stand Assembly



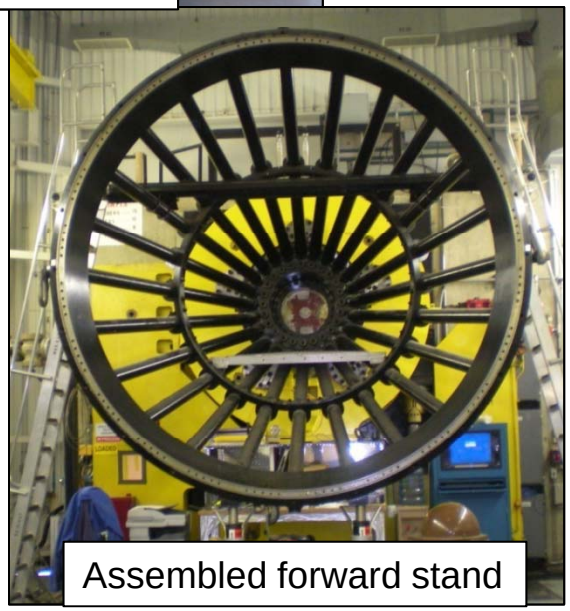
Install main pivot

Install load trains

Install keystone



Install components



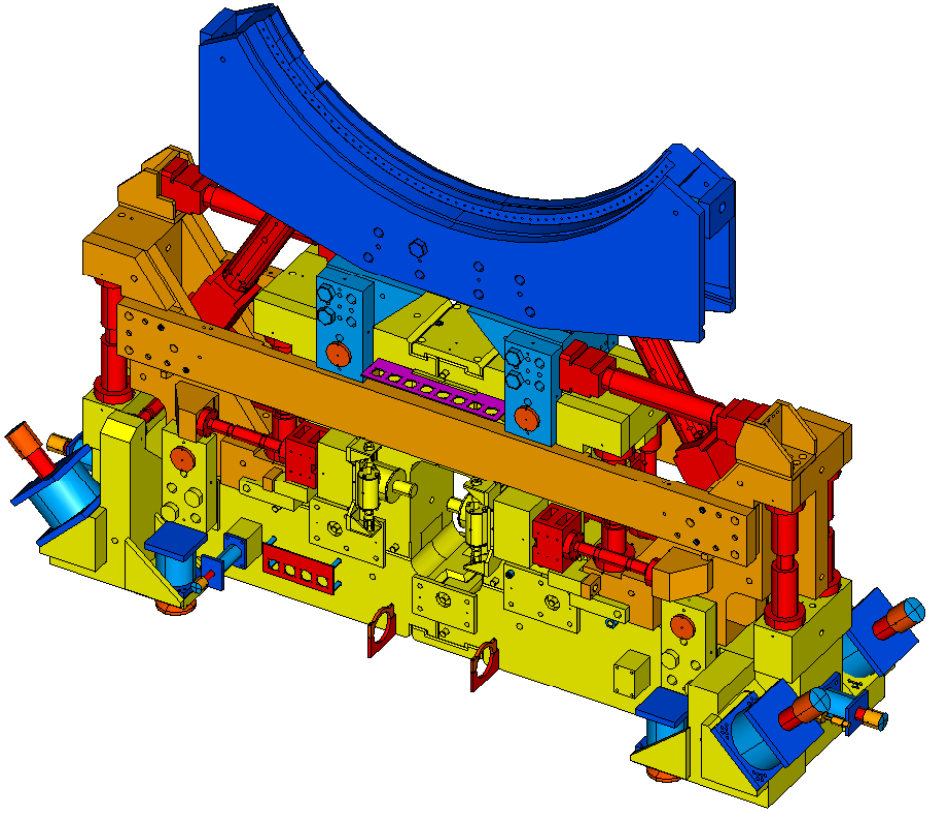
Assembled forward stand

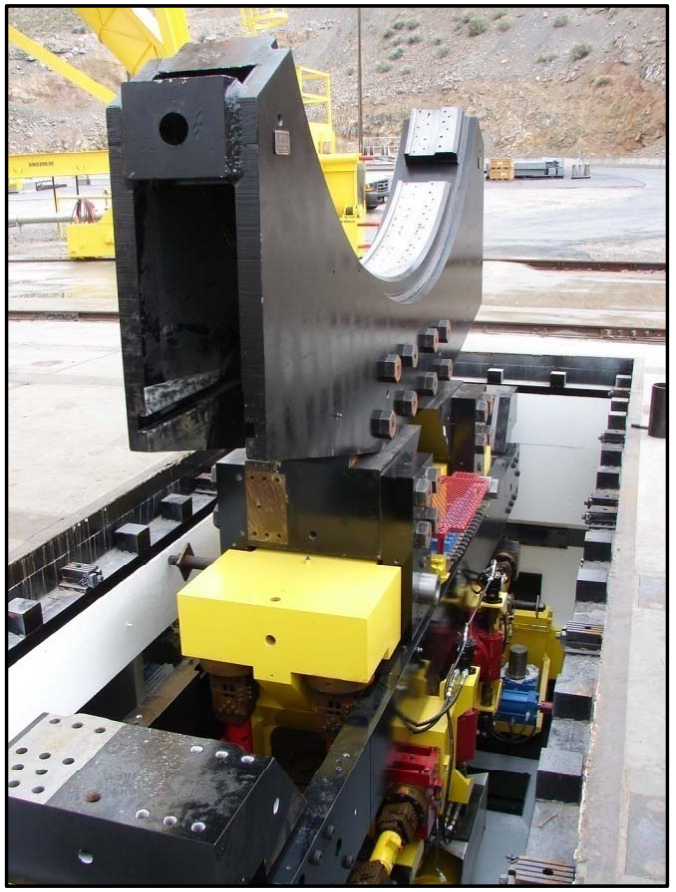
T-97 Test Stand Upgrades

Aft Test Stand

Component Function

- Supports the RSRMV aft end
- Measures the majority of the lateral (side) force
- Measures axial thrust, roll and partial vertical (weight) force



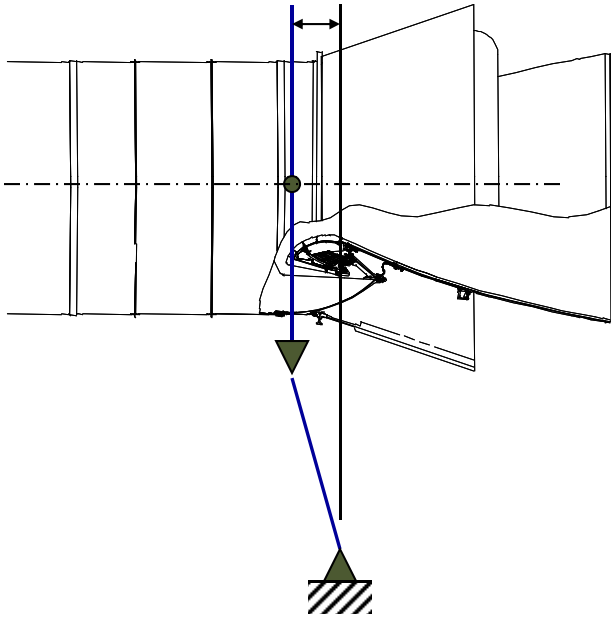


T-97 Test Stand Upgrades

Aft Test Stand

Aft Test Stand Diagonal Strut Positions

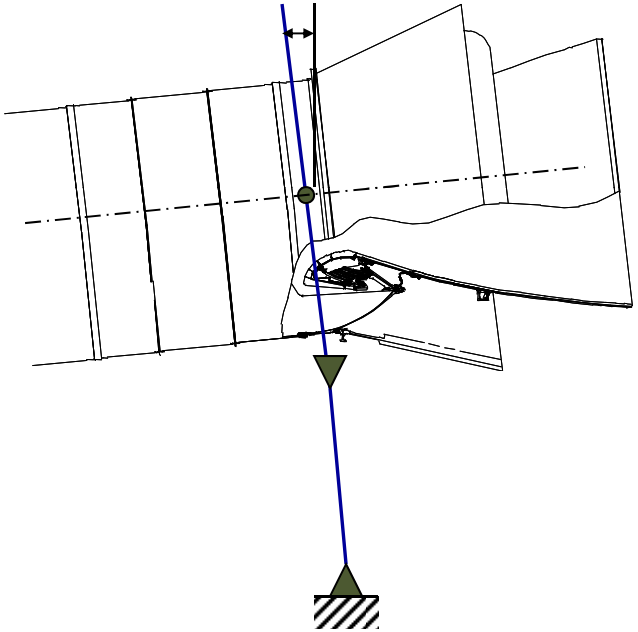
Offset



Rest with chocks

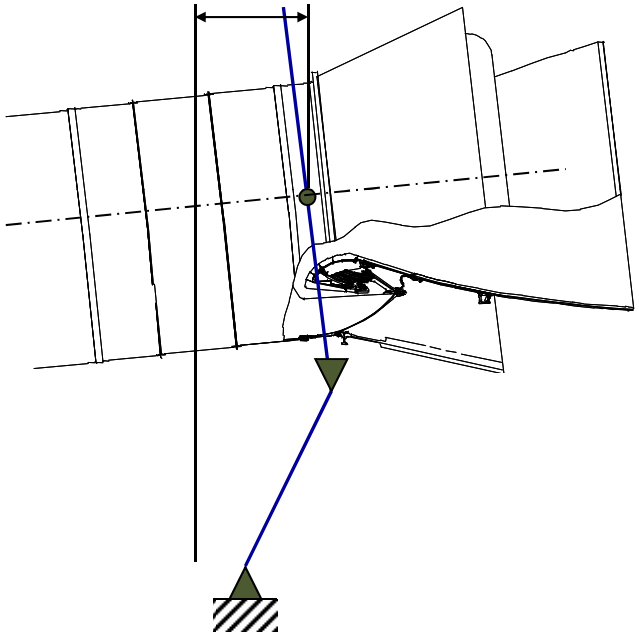
(+ve angle)

Rotation



Pre-fire chocks removed

Growth



Ignition

(-ve angle)

T-97 Test Stand Upgrades

Aft Test Stand

Description:

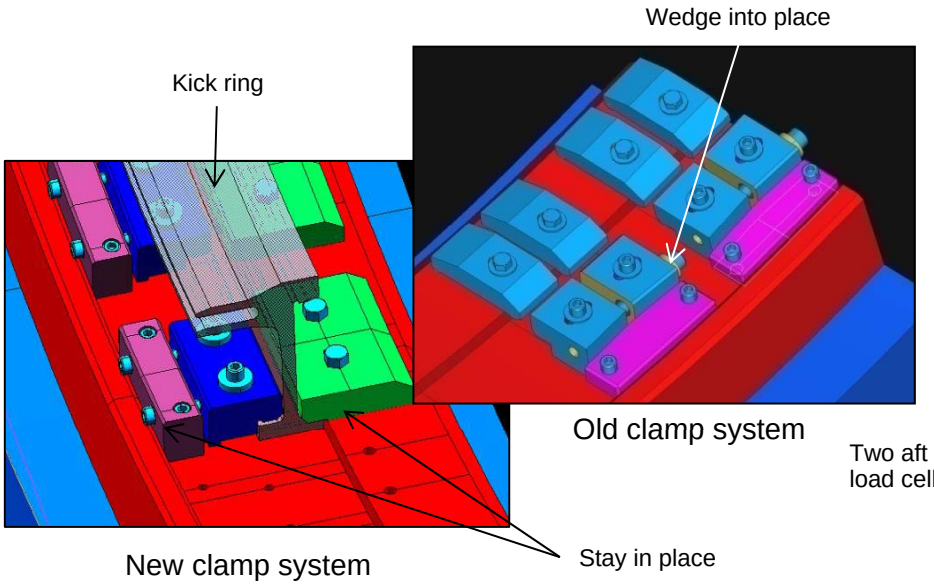
- Replace mild steel overload plates with identical geometry higher strength steel (4340) plates.
- Install 2 aft vertical load cells.
- Modify aft saddle clamping system.

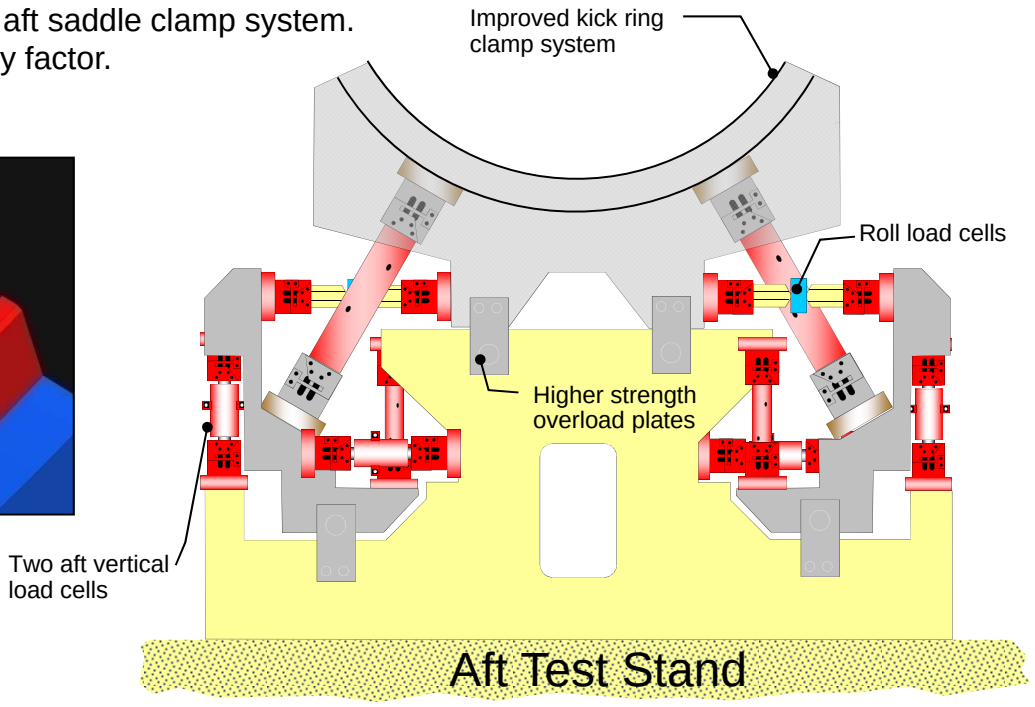
Reason

Changes are needed to increase the safety factor of the aft test stand with increased Ares loads. The current aft saddle clamping configuration is very difficult to install/remove.

Justification/Verification:

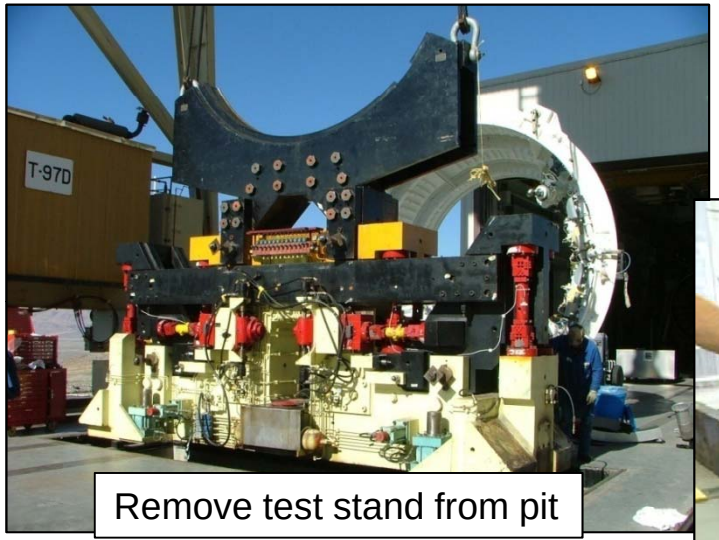
- Aft test stand components meet required safety factor.
- The new aft saddle clamp system is similar to the T-24 aft saddle clamp system.
- The new aft saddle clamp system meets required safety factor.





T-97 Test Stand Upgrades

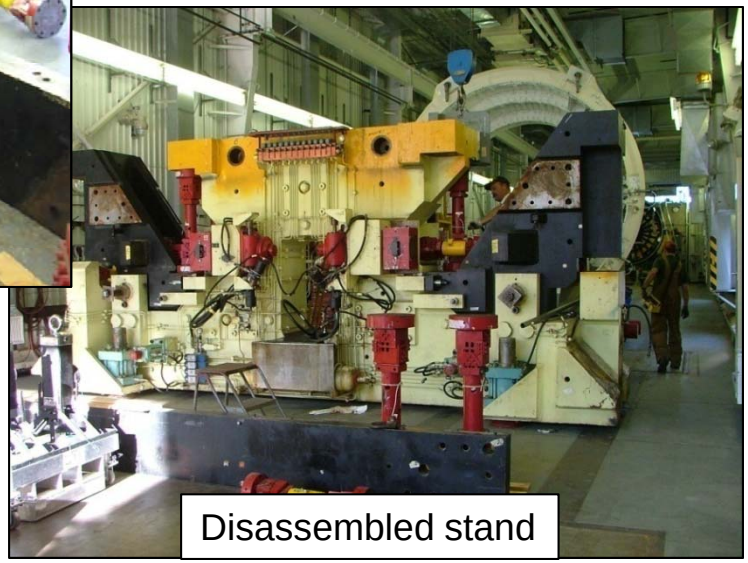
Aft Test Stand Disassembly



Remove test stand from pit

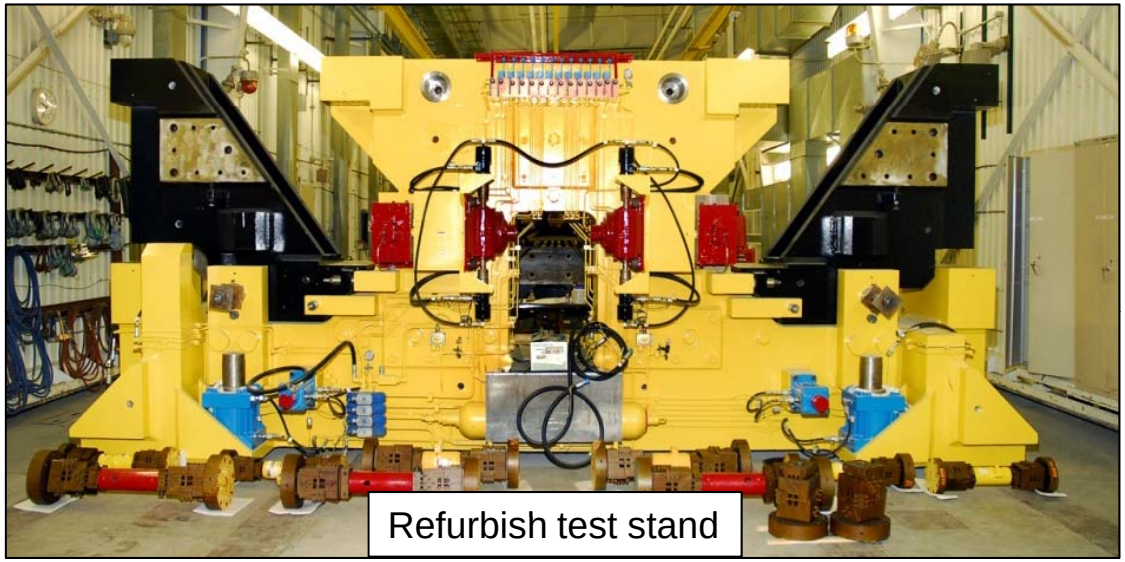

Remove load trains


Remove components


Disassembled stand

T-97 Test Stand Upgrades

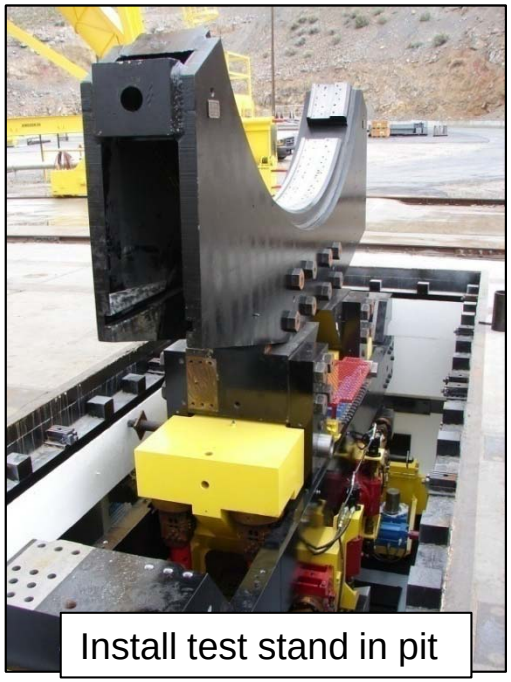
Aft Test Stand Reassembly


Refurbish test stand


Refurbish/recalibrate load trains


New overload plates


New saddle clamps

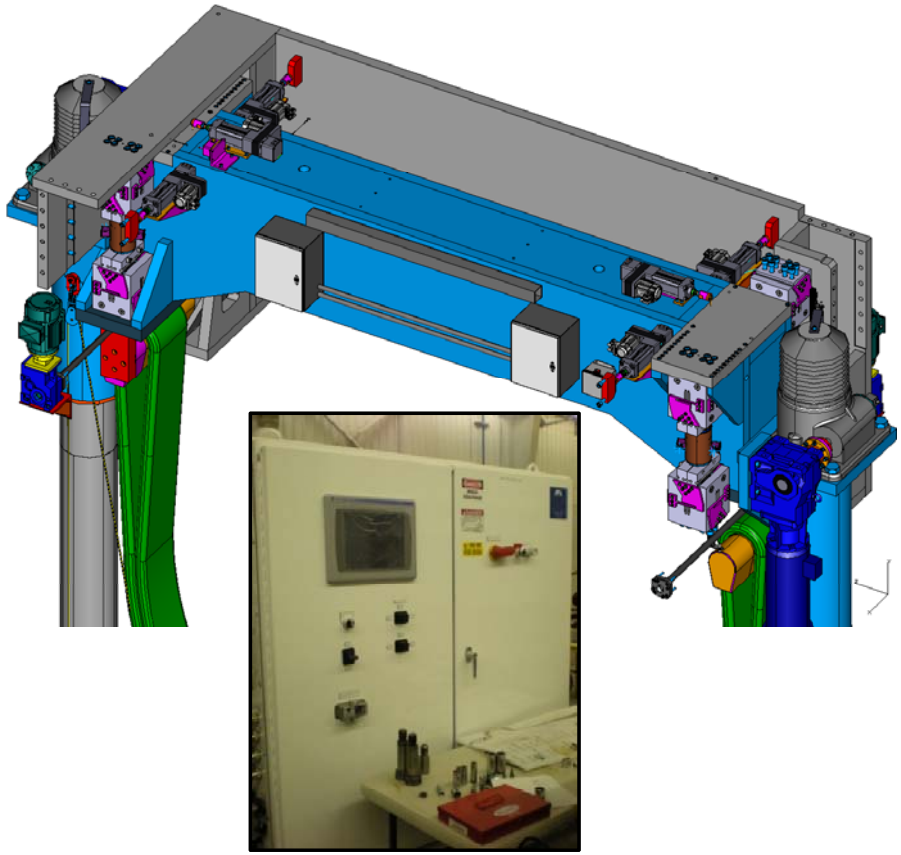

Install test stand in pit

T-97 Test Stand Upgrades

Mid-Span Support

Component Function

- Support the RSRMV mid-section and reduce motor sag using a flexurized system and a Kevlar belt.



T-97 Test Stand Upgrades

Mid-Span Support

Description:

- Add Mid-Span support to the RSRMV test arrangement
- Install the Mid-Span support prior to removing chocks on five segment motor builds.
- During chock lowering, limit pretest motor weight supported by mid-span.

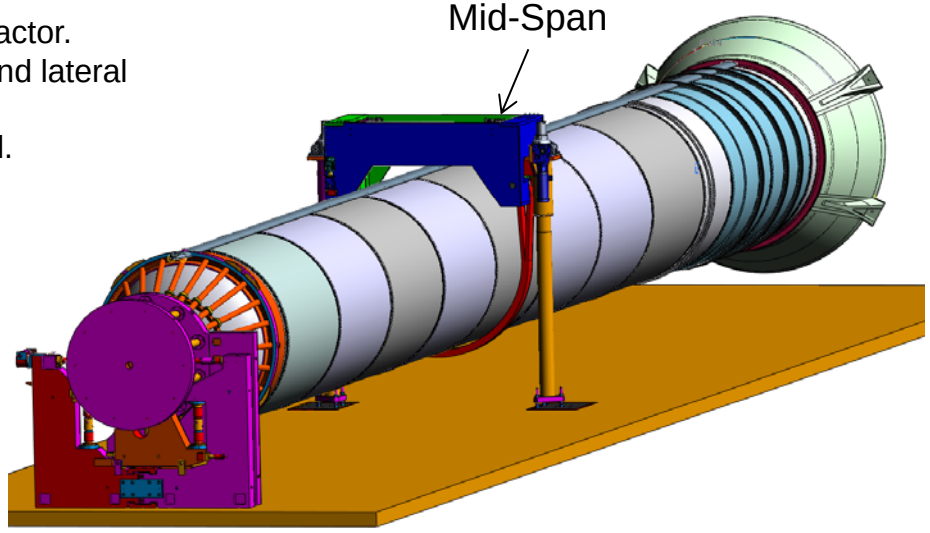
Reason

The sag in a five segment motor overstresses the center cases, the Mid-Span support is needed to prevent case damage in the static test configuration.

Justification/Verification:

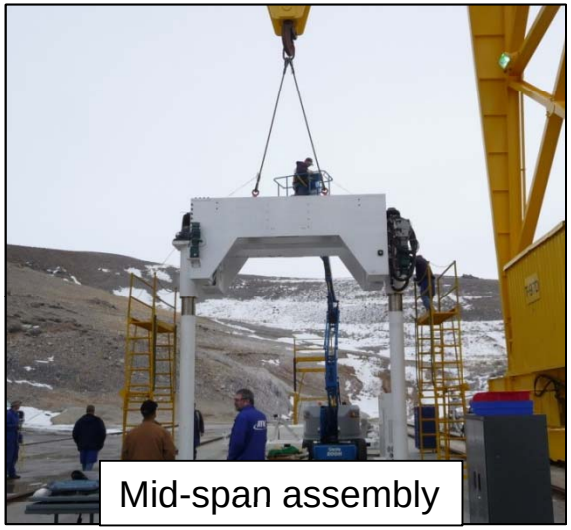
- The case hardware has been analyzed and the stresses caused by the Mid-Span belt are acceptable.
- The Mid-Span support components meet required safety factor.
- The Mid-Span support is designed to have minimal axial and lateral measurement interaction.
- Weight test of mid-span support complete 1.25x rated load.
- Functional tests of Mid-Span is complete.
- Risk assessment complete
- Hazard analysis complete on Mid-span.
- HRT/HET complete

Mid-Span



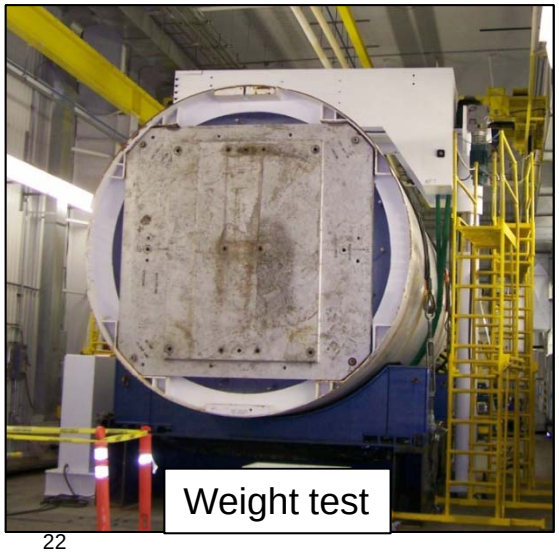
T-97 Test Stand Upgrades

Mid-Span Support Assembly


Mid-span assembly


Mid-span support


Kevlar belt

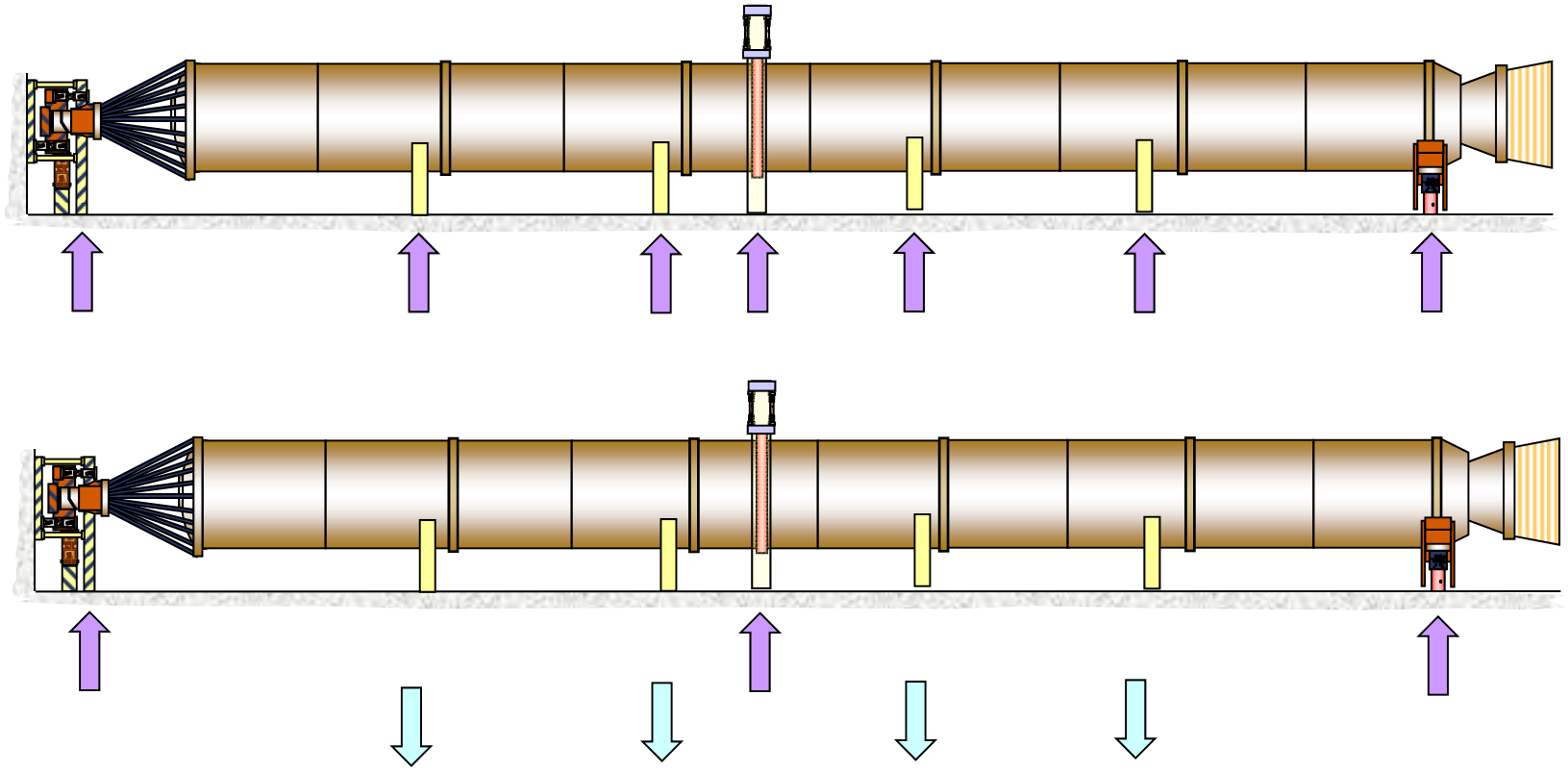

Weight test


Load trains

T-97 Test Stand Upgrades

Mid-Span Support

- The Mid-span support will be installed prior to motor support removal.
- The motor supports will be removed simultaneously per standard practice, motor will lower into Mid-span.
- Motor weight at Mid-Span support will be monitored to verify weight distribution

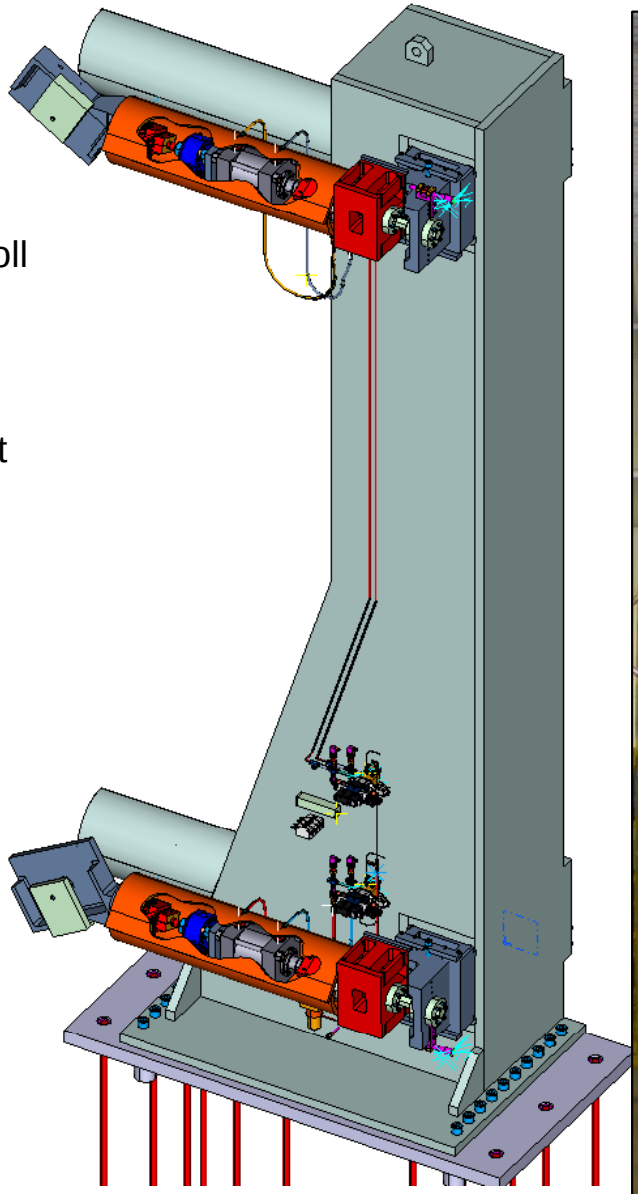


T-97 Test Stand Upgrades

Aft Skirt Side Calibration Fixture

Component Function

- Provides an in-line lateral (side) and roll calibration load to the RSRMV aft end
- Provides better fidelity for test stand calibration
- Aids in determining thrust vector offset
- Used during the pre-test and post-test design of experiments (DOE).



T-97 Test Stand Upgrades

Aft Skirt Side Calibration Fixture

Change Description

- Incorporate Skirt side load calibration fixture to the RSRMV static test configuration.
- Apply side force on the aft skirt hold down post holes.
- Apply roll torque on the aft skirt.

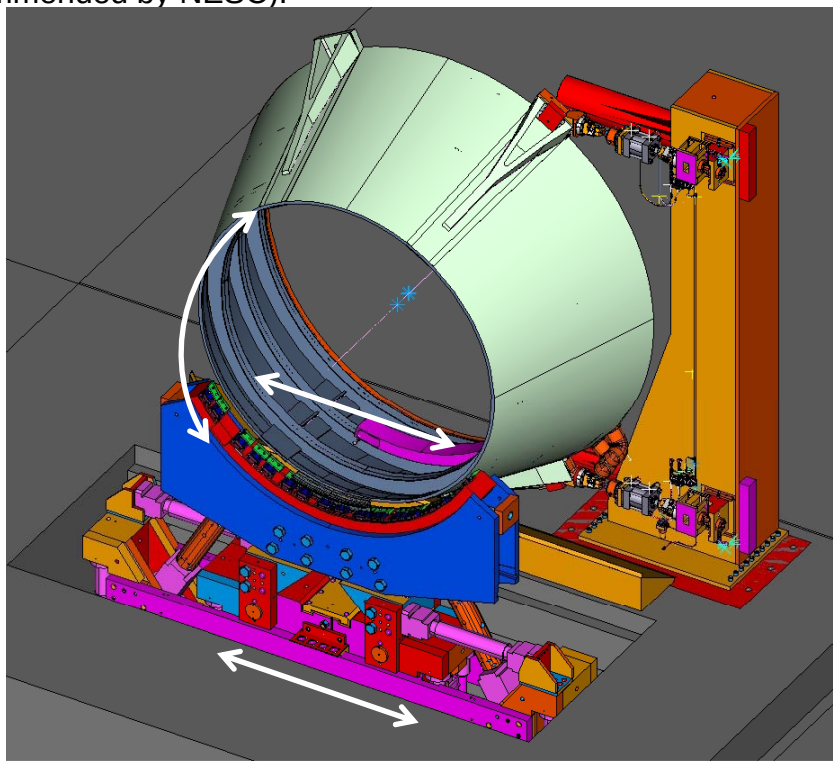
(Note: side load fixture is active during test stand calibration and is decoupled during static tests)

Reason for Change:

An in-line side calibration system is needed to verify the CEI requirements for RSRMV thrust vector offset, and to increase the fidelity of the T-97 calibration system for roll torque estimation (recommended by NESC).

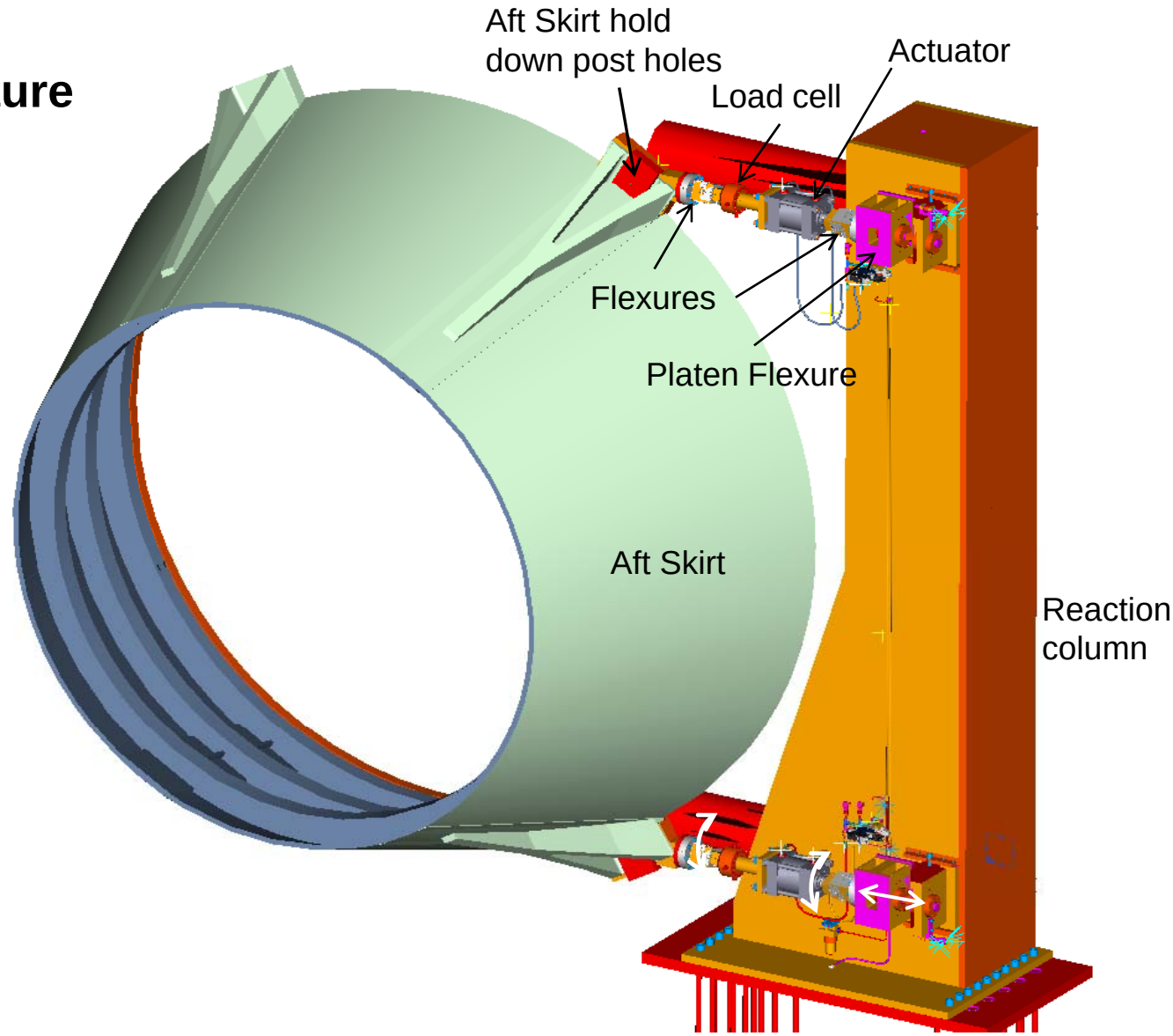
Justification/Verification:

- The standard aft test stand calibration of the side/lateral force.
- The same roll torque application loads were used on FSM-13.
- Structural analysis of the motor shows that motor deflection, case cylinder stress and pin loads are not appreciably changed by the addition loads applied to the aft skirt.
- USA analysis shows that the proposed loading on the aft skirt and kick ring are acceptable.
- The skirt side load fixture load trains will be checked out on a reaction fixture prior to being installed on the aft skirt.
- The side load fixture meets required safety factor, except for the rock bolts which have an AHOPS waiver.
- Hazard analysis complete on rock bolt departure.
- Risk assessment complete.
- HRT/HET complete.



T-97 Test Stand Upgrades

Aft Skirt Side Calibration Fixture



T-97 Test Stand Upgrades

New Test Stand Controller

Component Function

- Provides controls and feedback for 4 calibration systems: forward axial, forward side, aft side, new aft skirt side.
- Replaces the old Ormond controller.

LabView Operator Screens

T-97 Test Stand Upgrades

New Test Stand Controller

Change Description:

Update the controller for the T-97 test stand calibration system by replacing the Ormond controller with a computer based controller.

Reason

The T-97 test stand calibration controller has components that are beginning to fail and replacement parts are obsolete.

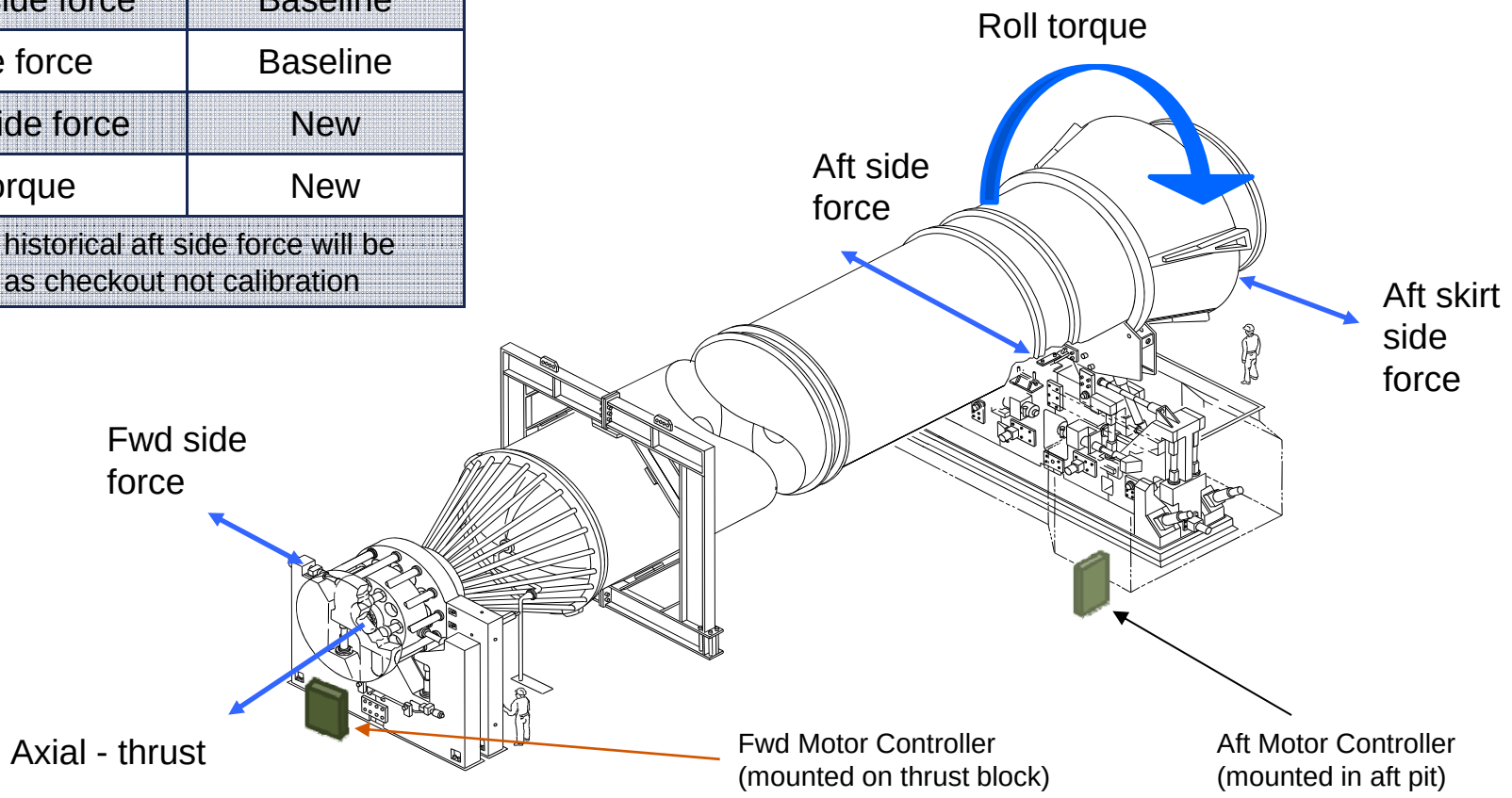
Justification/Verification:

- The modification uses the same method to run the calibration system.
- Load cell bridge A - is recorded and compared to static test load cells.
- Load cell bridge B - used as response to the control system.
- The controller is similar to the new T-24 support system controller.
- Controller includes a new e-stop feature.
- The software will be controlled by the Software Control Board.
- An Operational Readiness Inspection (ORI) of the new controller will be completed.
- Case study completed on the T-97 test stand calibration system.

T-97 Test Stand Upgrades

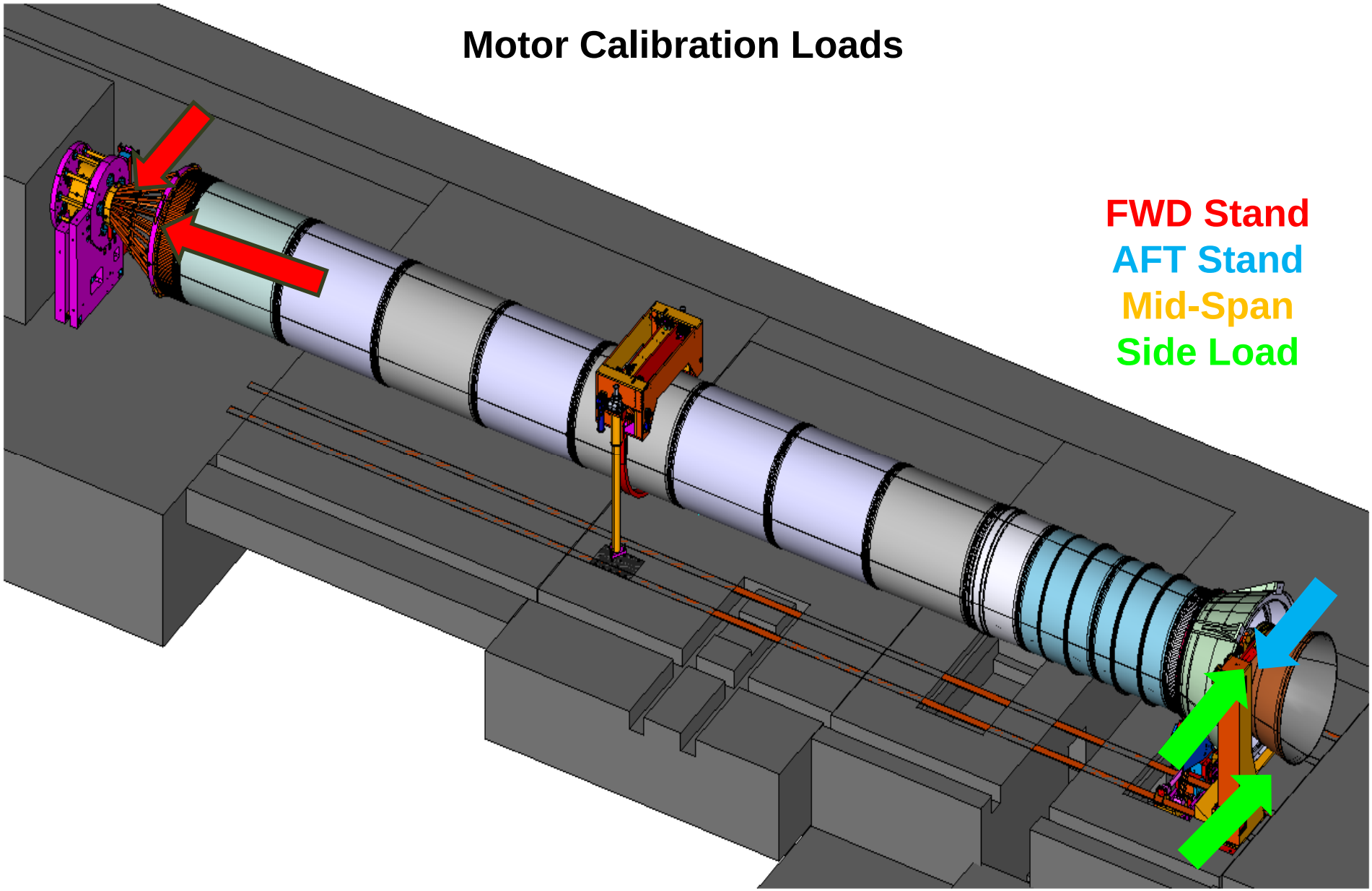
New Test Stand Controller

Checkout System Levels	
System	
Axial thrust	Baseline
Forward side force	Baseline
Aft side force	Baseline
Aft skirt side force	New
Roll torque	New
Note: The historical aft side force will be applied as checkout not calibration	



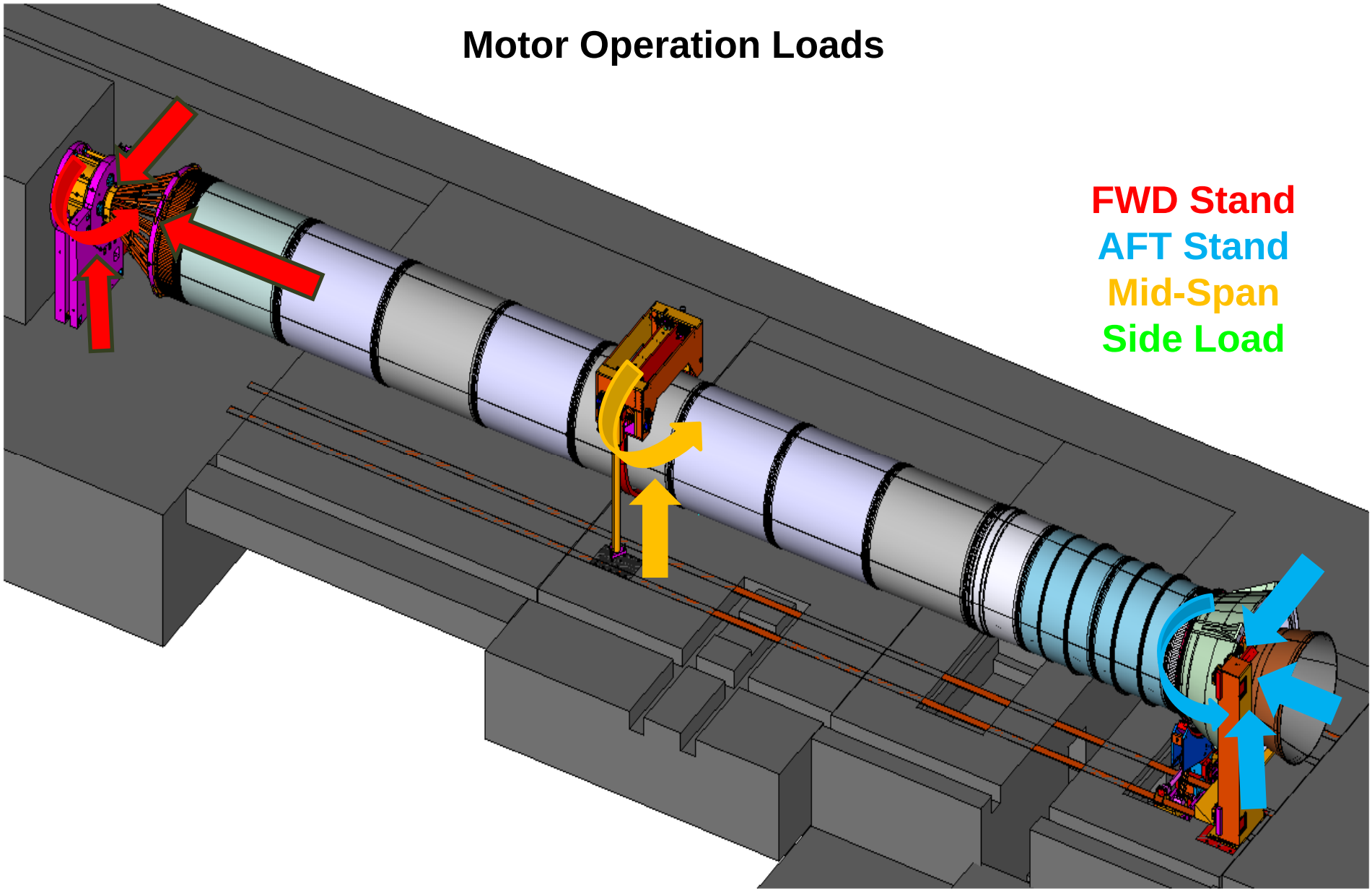
T-97 Test Stands Review

Motor Calibration Loads



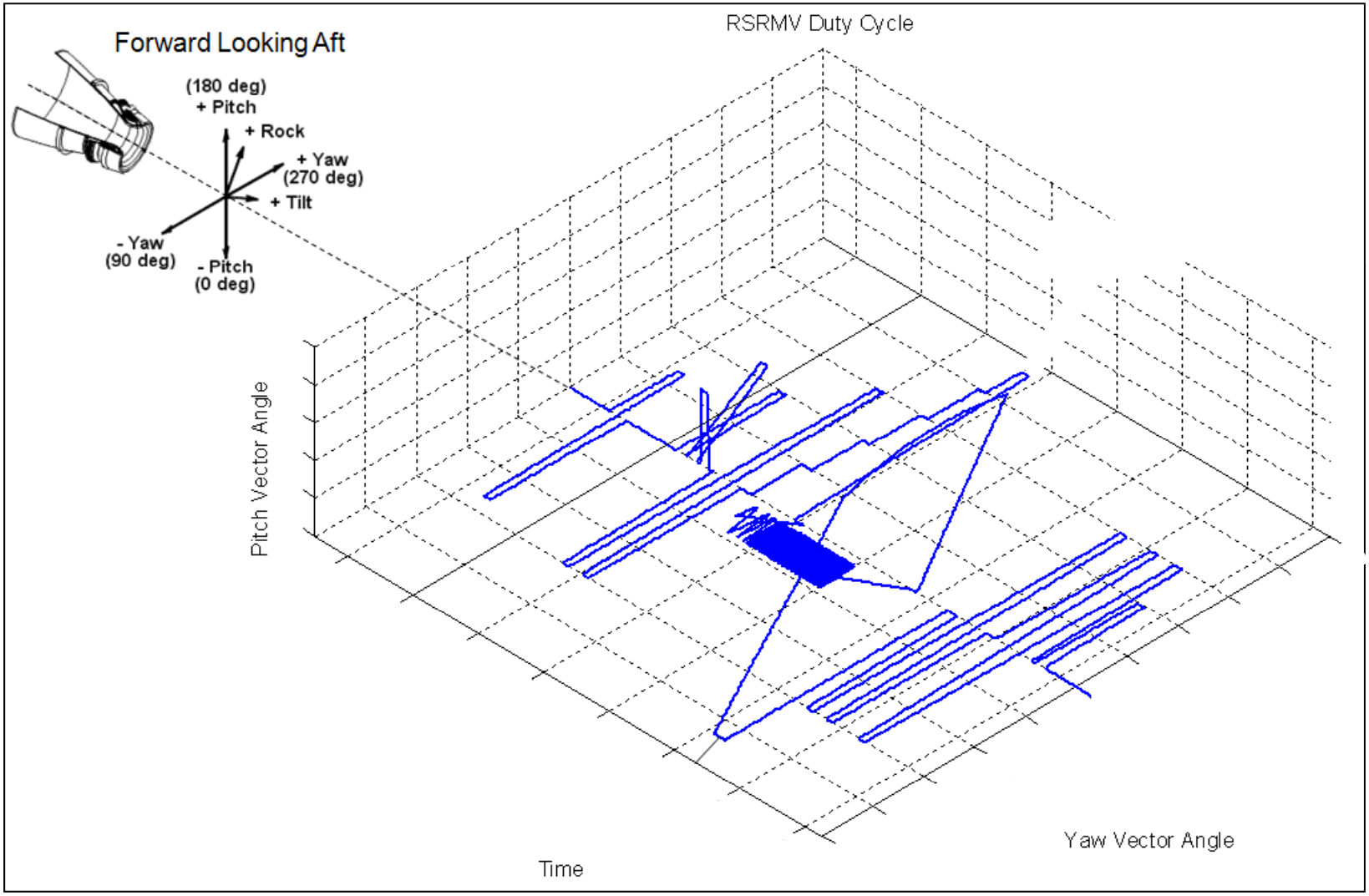
T-97 Test Stands Review

Motor Operation Loads



T-97 Large Motor Test Facility

Current Static Test Nozzle Duty Cycle

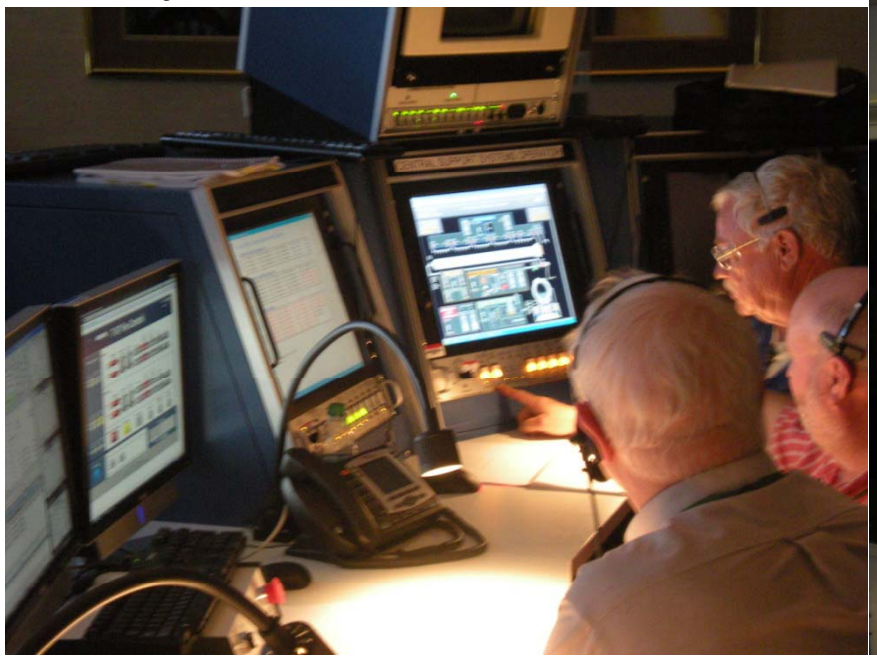


T-97 Large Motor Test Facility

Electrical Systems

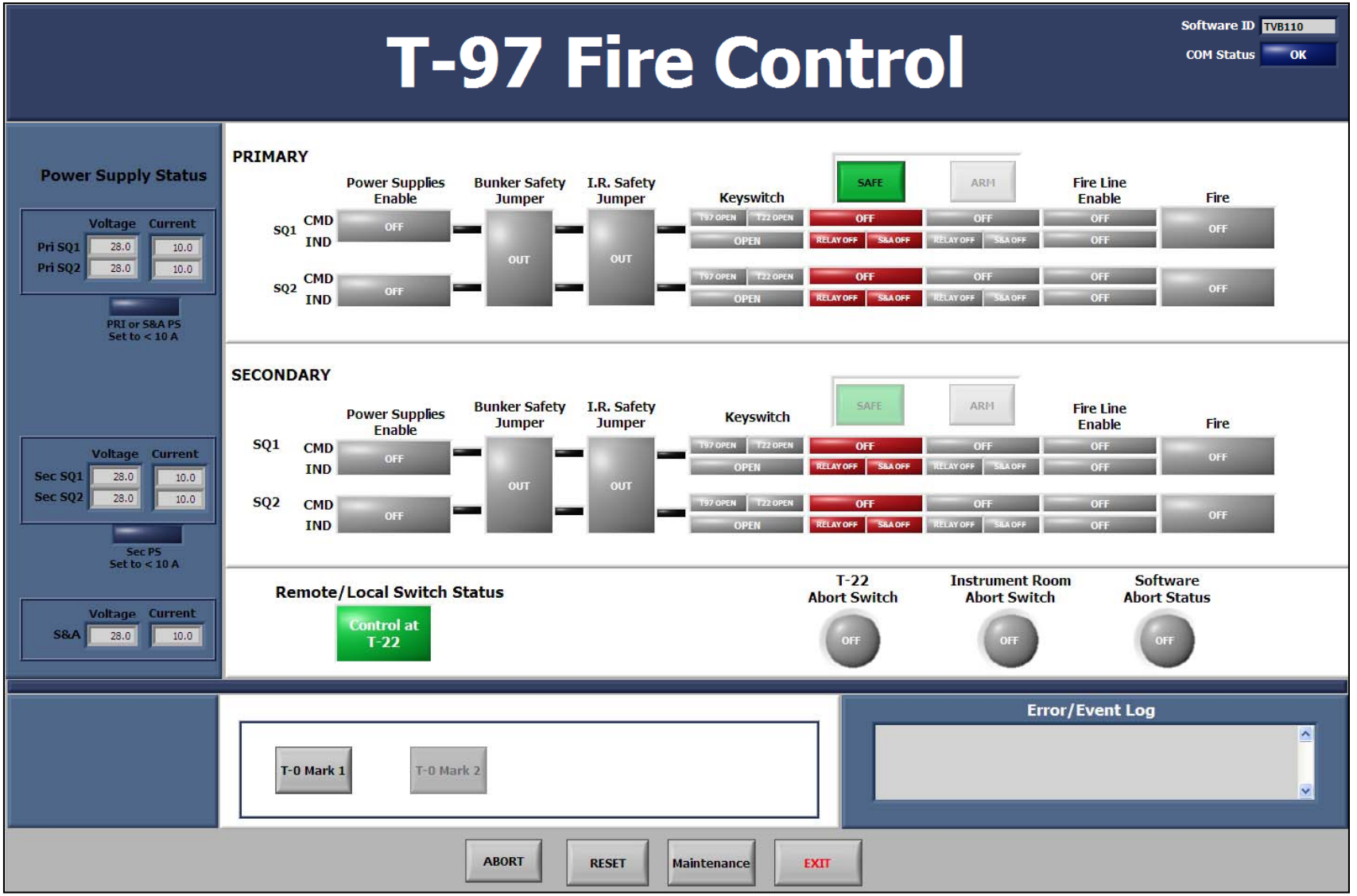
Test Bay T-97 has been upgraded with the following:

- Fire Control System (National Instruments Components)
- Test Bay Support System (National Instruments Components)
- Software Upgrade for Low Speed Data System (In-house Design)
- Move more data channels from legacy Tustin / WIN 600 to VXI and Genesis data systems.



T-97 Large Motor Test Facility

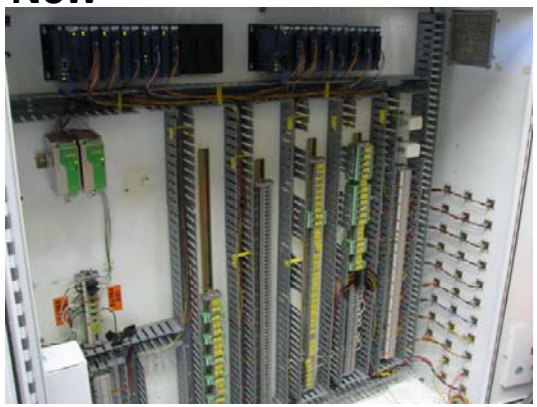
Fire Control System Upgrade screen



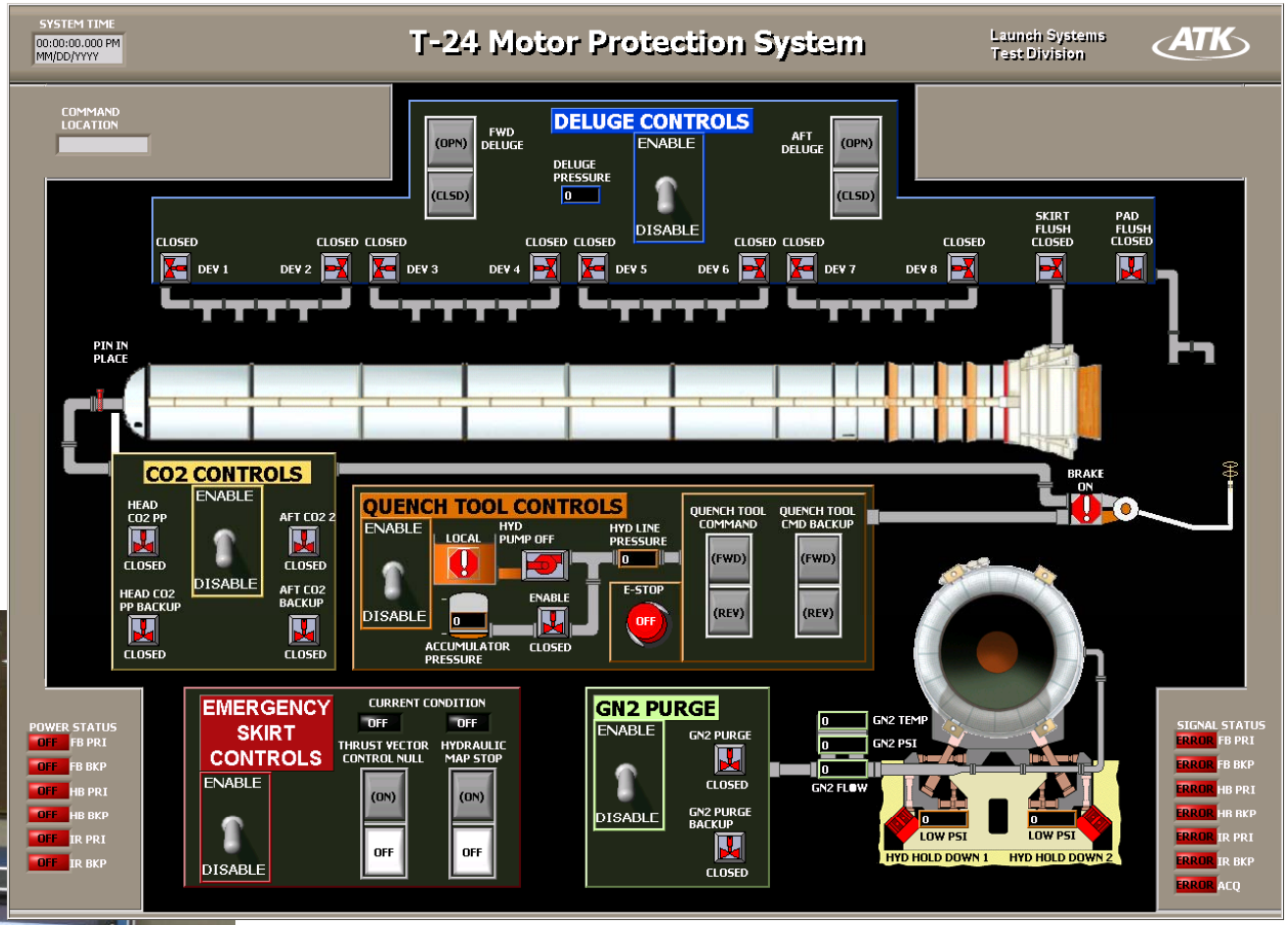
T-97 Large Motor Test Facility

Support System Upgrade

New



Old

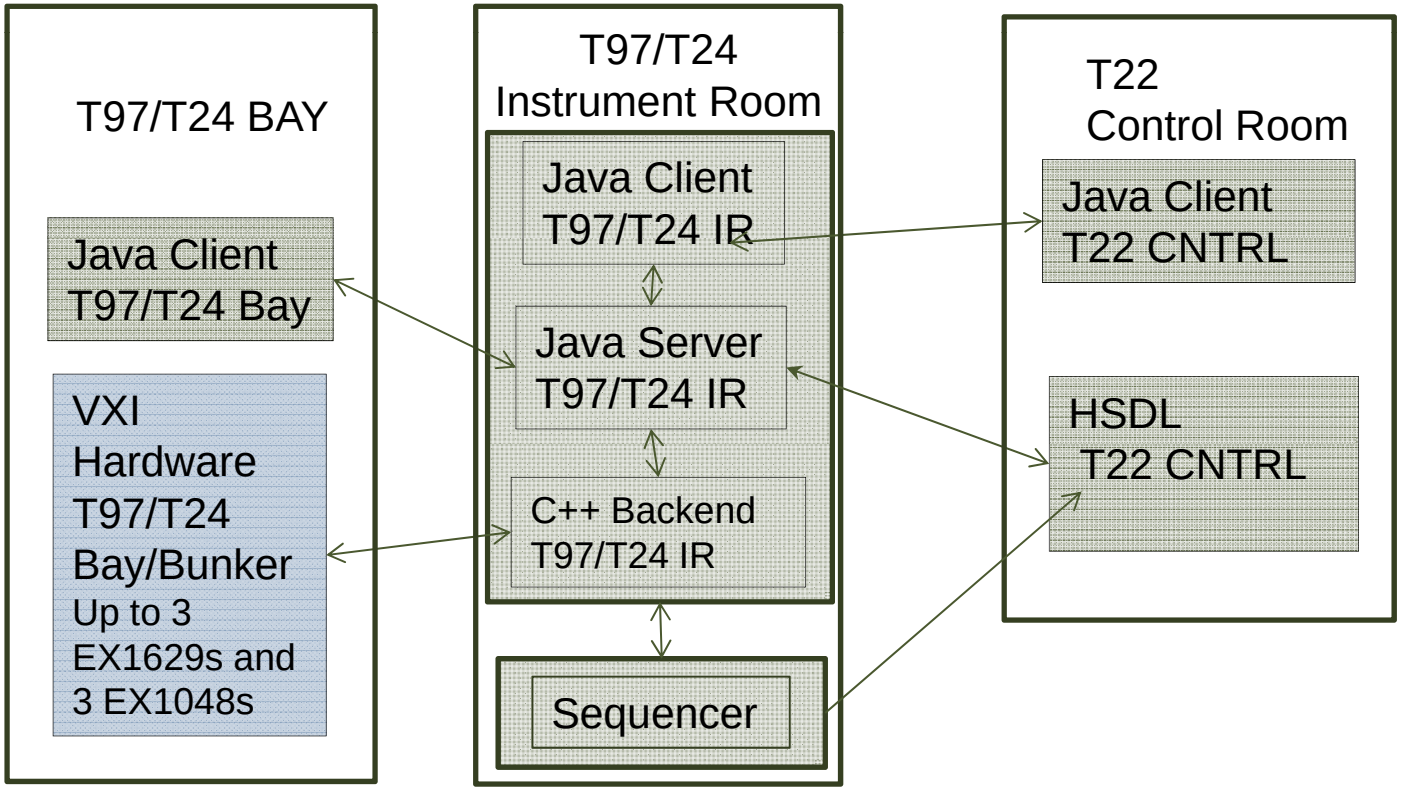


T-97 Large Motor Test Facility

Software Upgrade

Objective – Develop software that operates the VXI data system giving more tools to setup / checkout instrumentation and support static test.

- Vendor's software "DAC Express" has marginal checkout and test capabilities – no transducer load current report, no remote start / stop, no excitation report, no shunt cal verification report, no setup file error proofing, etc.



T-97 Large Motor Test Facility

Move more data channels from legacy Tustin / WIN 600 to VXI and Genesis data systems

Low speed Tustin systems are replaced with VXI

Old System

Tustin and
B&F System

New System

VXI 1048
TC Unit

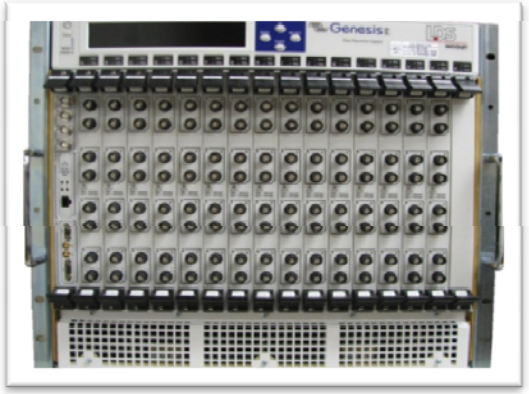
VXI 1629
Strain / Volt
Unit

High speed Win 600e units are replaced with Genesis

Old System

Win 600e

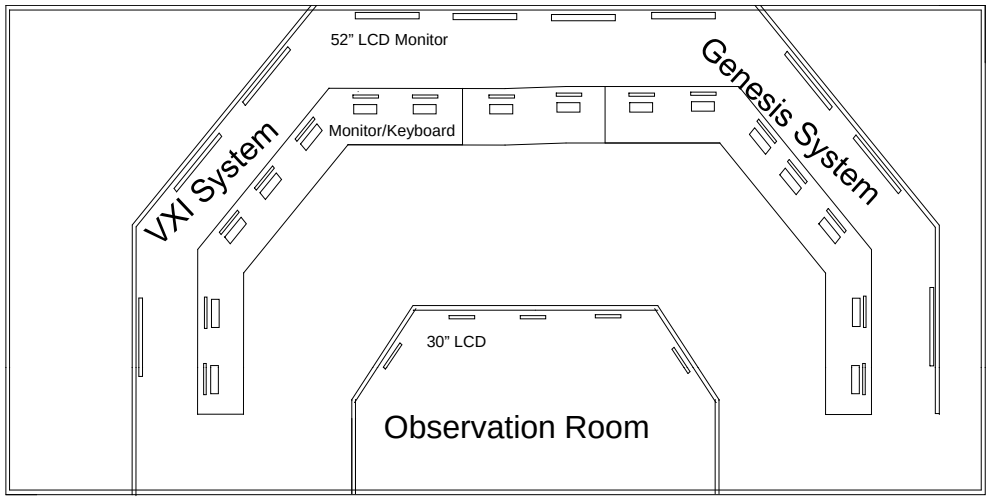
New System



LDS-Genesis

T-97 Large Motor Test Facility

Move more data channels from legacy Tustin / WIN 600 to VXI and Genesis data systems



Transitional Channel Capability

IR # 1

512 chs.	Tustin / B&F
96 chs.	Win 600e

IR #2

384 chs.	VXI EX1048 TC Unit
768 chs.	VXI EX1629 Strain/Volt Unit
288 chs.	Genesis Unit High Speed

T-97 Large Motor Test Facility

Electrical systems

Measurement Capabilities

- Bridge/Voltage Measurements (strain, pressure, load, LVDT, extensometer, OPT, girth, event, etc.)

  4208 Channels

- Accelerometer/Voltage Measurements

  848 Channels

- Thermocouple Measurements

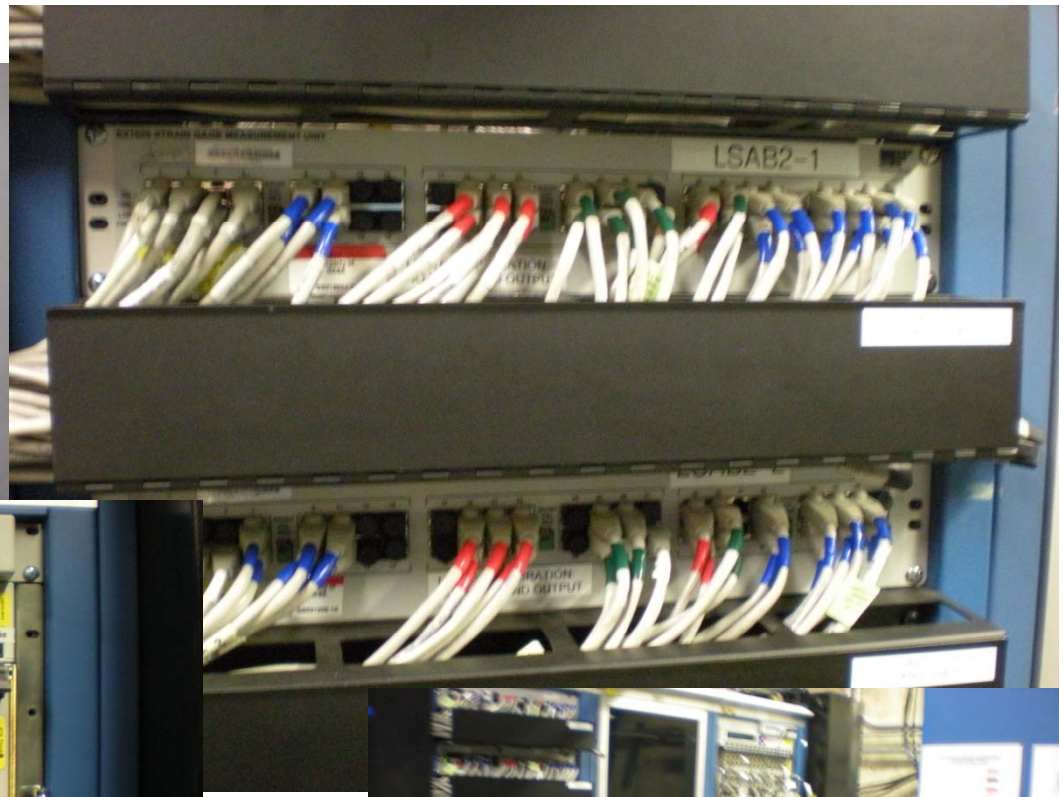
  1072 Channels

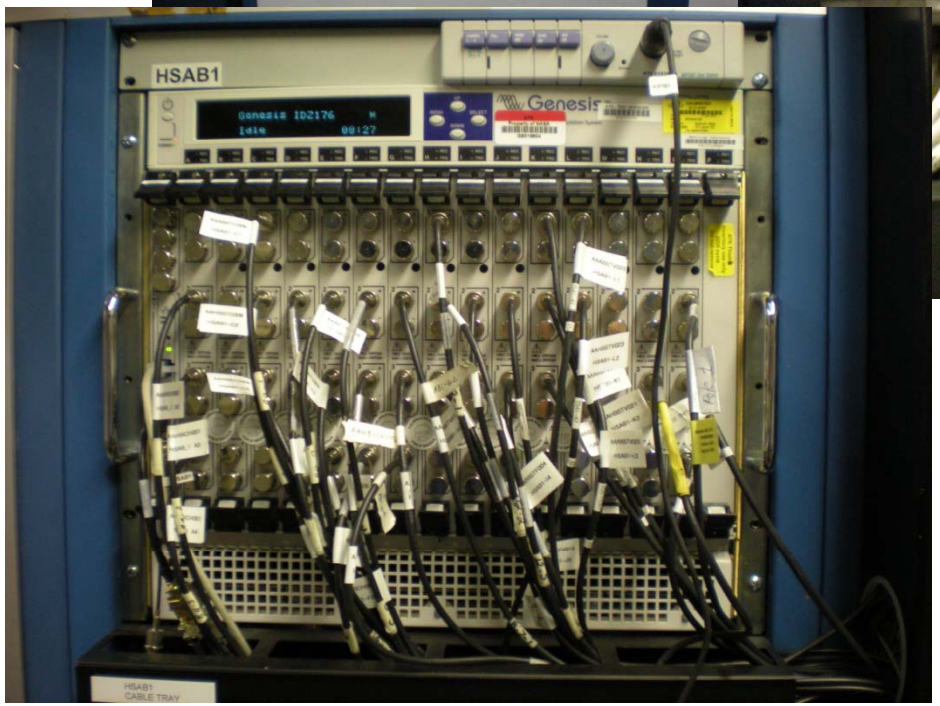
- Acoustic Measurements

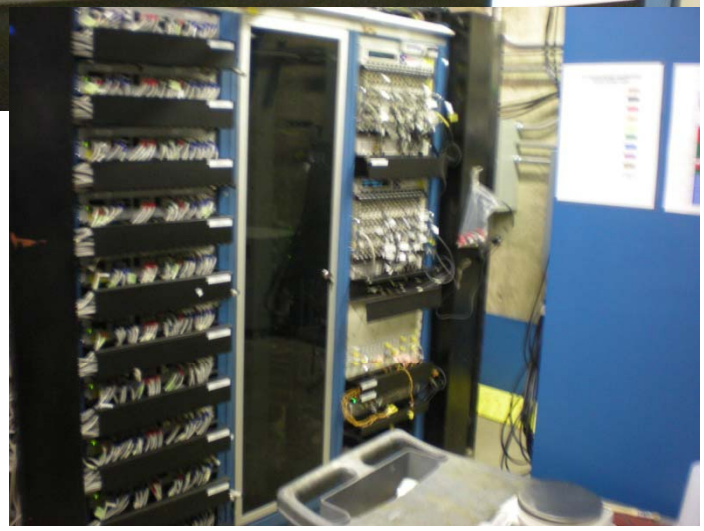
  32 Channels

T-97 Large Motor Test Facility

Electrical systems







T-97 Large Motor Test Facility

Continuing effort for increased capability for larger motors