Project Management Challenge 2010
Ares I-X Roll Control System Development

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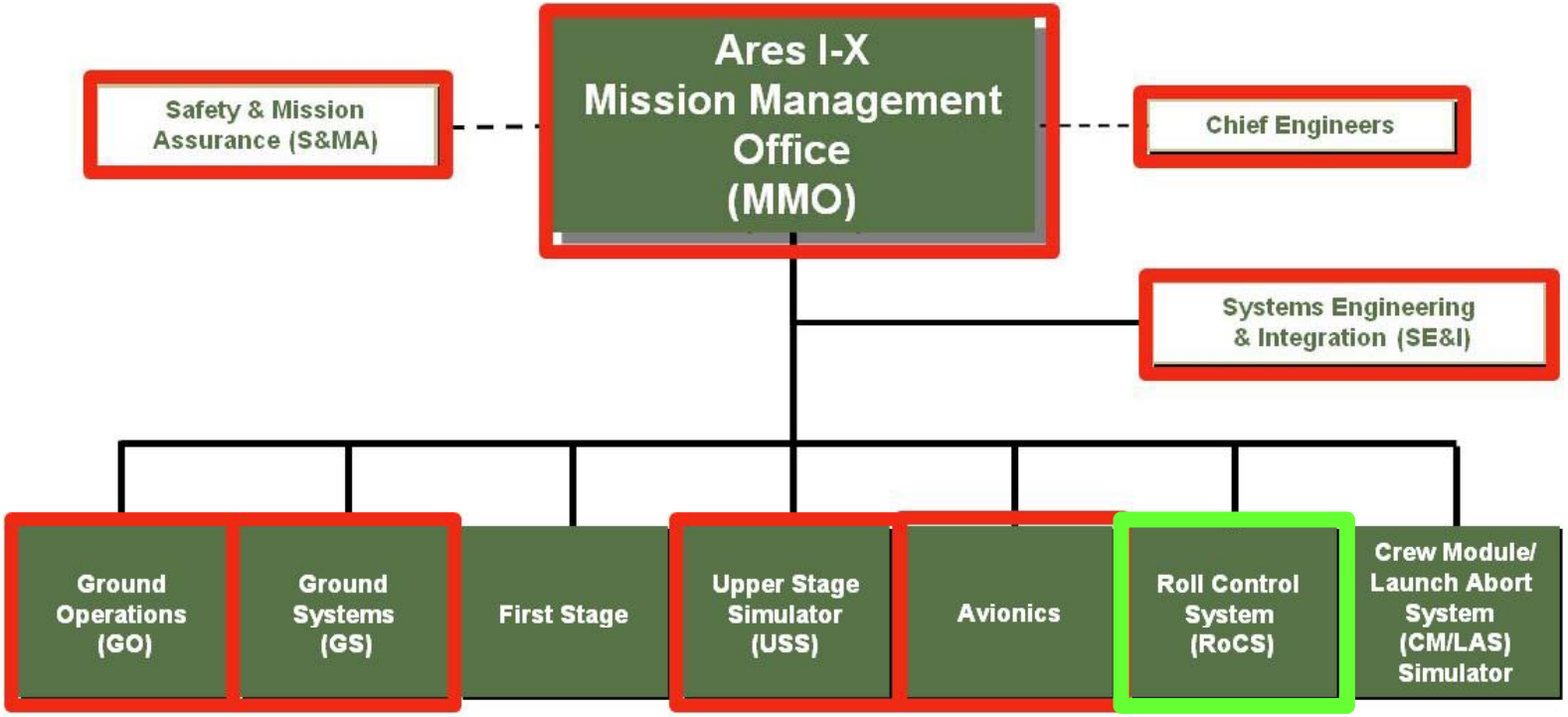
Ares I-X Roll Control System Project Management Model

- **The Ares I-X Roll Control System (RoCS) represents a successful project management model of a rapid-development, functionally complex, flight hardware system. The Integrated Product Team (IPT) model was executed at the RoCS level concurrent with the other Ares I-X IPTs to support the successful Ares I-X launch on October 28, 2009.**



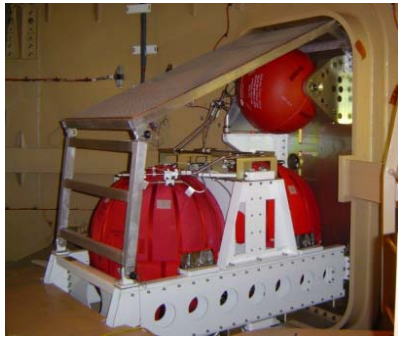
Integrated Product Teams (IPTs)

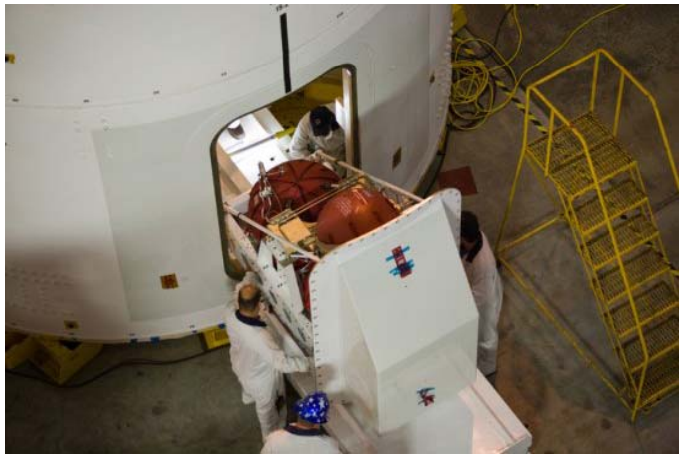
Ares I-X Roll Control System Overview

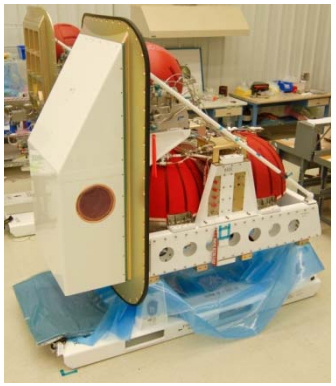
- **Description**
  - Roll Control System provides rotational azimuth control for:
    - mitigation against adverse vehicle roll torques (self- and aero-induced).
    - antenna and simulated crew launch positioning.

- **Salient Features**
  - The Roll Control System is an integral, modular, bi-propellant propulsion system installed in the Ares I-X Upper Stage Simulator Interstage.

  - RoCS utilized off-the-shelf and Government-furnished components that have been harvested from USAF Peacekeeper Stage IV, then re-integrated into a system.







The Challenge

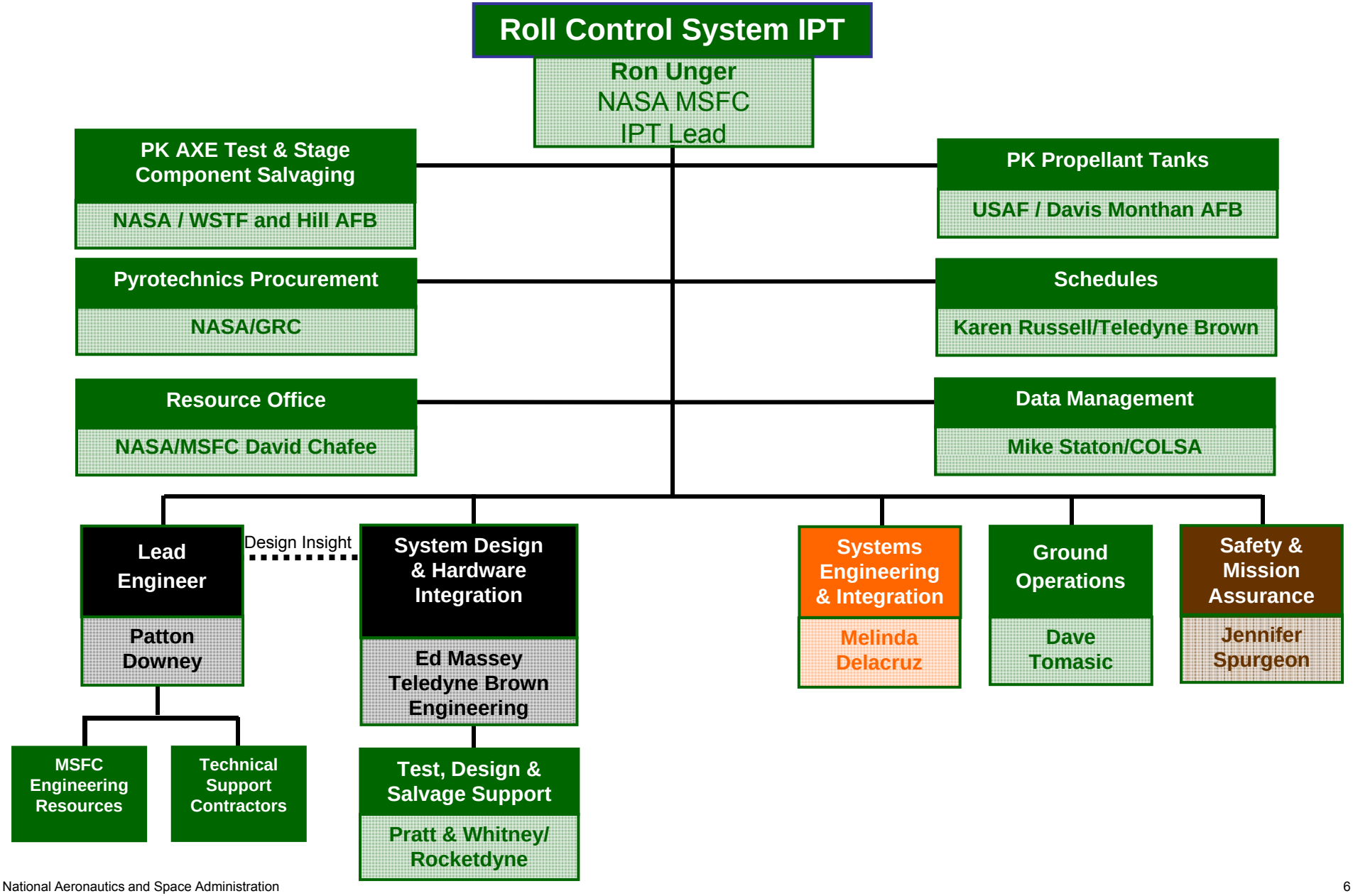
- **Deliver the requisite Roll Control System to Ares I-X:**
  - on time … support April 15, 2009 (original) launch date
  - within budget … $24.7M budget guideline
  - and of high quality.

- **How we did:**
  - RoCS modules delivered to KSC on February 5, 2009, were fully integrated into Upper Stage by April 26, 2009 (well off the integration critical path).
  - Current cost – over guideline by 3%, attributable to launch date changes requiring standing team.
  - Flight hardware accepted by Ares I-X May 27, 2009. All waivers and verifications closed by July 14, 2009. Noticeably low number of KSC problem reports were generated for a first article prototype system.

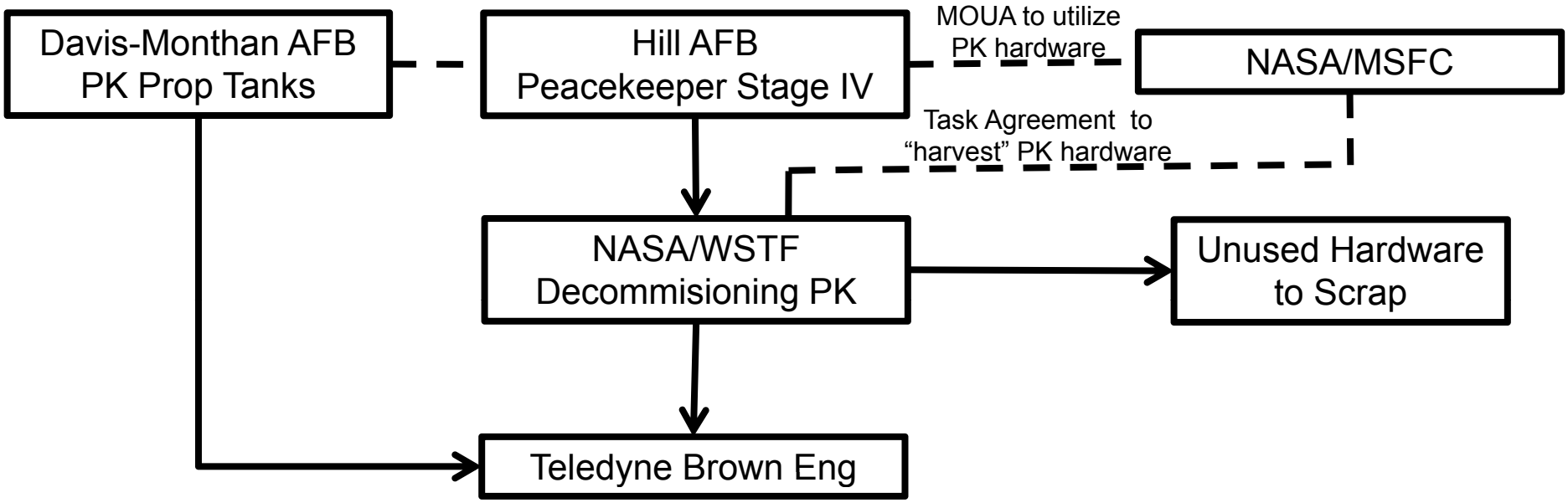
Major Keys to Success

Description	Stakeholder Value
Establish small, “badgeless,” accountable team between contractor and NASA, while maintaining compliance with governance model/Independent Technical Authorities.	Efficient decision-making.
Development of early Memorandum of Understanding and Agreement with USAF and Task Agreement with White Sands Test Facility.	Clear lines of responsibilities.
Designing for robustness, anticipating upward movement of loads levels.	Structural problems averted over a series of changing loads.
Early identification and development of waivers.	Waiver acceptance justification built into test and analysis plans.
Front end load the schedule with design and testing activities, waiver submittal, and verification closures.	Avoid bow wave of activities and related resources availability issues.
Co-location of MSFC Engineering Lead System Engineer to Teledyne Brown facility.	Rapid issue definition and resolution planning.
Maintain cognizance of the end game.	Primary and urgent issues resolved first. Secondary issues pushed down to lower levels.

Ares I-X Roll Control System Organization

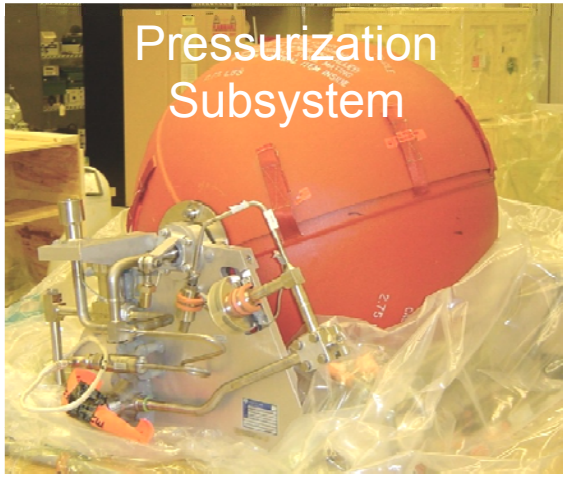


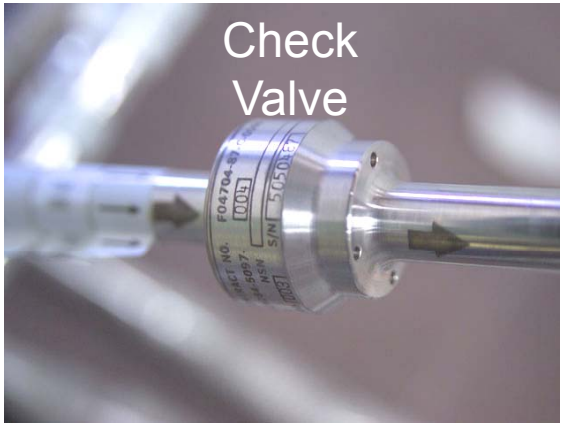
Peacekeeper Hardware Acquisition



- **Each RoCS Module utilized from PK:**
  - Two Propellant Tanks
  - Pressurization Subsystem
  - Two PK Axial Engines
  - Two Propellant Filters
  - Four Pressurant Check Valves
  - Pyrovalve Ordnance
- **The RoCS Team ended up with enough hardware for:**
  - Three Flight Modules
  - Ground Test Cold Flow Module
  - Hot-Fire Engine Tests
  - Dynamic Tests
  - Plus Odds and Ends Spares
  - > $10M Cost Avoidance

Peacekeeper Hardware Acquisition





Design for Robustness and Growth

Robustness

- Implementation of two independent RoCS modules provided system redundancy. Ares I-X could complete its mission with reduced roll control capability using one module.
- In-line mounting configuration minimized opening in Interstage sidewall and provided rugged platform to support components in the axial direction.
- Single regulator with high quality performance selected as most reliable option.
- Multiple temperature sensors provided back-up for Launch Commit Criteria in case of sensor failures.
- Positive monitoring of Helium tank pressure switch sensor provided immediate indication of system leak well before launch.
- Redundant pyrotechnic trains provided system reliability for initiation. Pyrotechnic activation of modules shown to be simple and reliable.
- Offline fueling of modules reduced impacts to vehicle integration schedule.
- Spare RoCS module available as line replaceable unit in case of module failure during integration flow.

Design for Robustness and Growth

- **Growth**
  - Separate pressurant and propellant systems provided approximately double the required resources for accomplishing mission profile.
  - Peacekeeper engines provided capability for growth in thrust requirements.
  - Module structure was intentionally over-designed to address changing loads.

Early Identification of Waivers

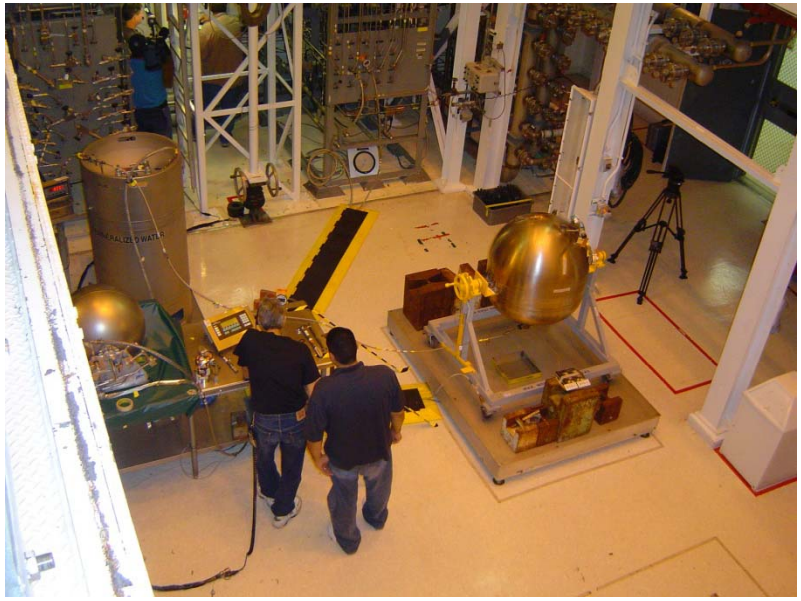
- **Coming out of RoCS Critical Design Review (CDR), six waiver situations were identified for Peacekeeper hardware, either against NASA standards or Ares I-X requirements.**
  - No Vibro-Acoustics Acceptance Testing Planned for Flight Components or Assemblies
  - Pressure Testing Levels on the Propellant Filter Assemblies
  - Heritage Pyro Component Quantities not Available to Meet Lot Acceptance Requirements
  - No Vibro-Acoustics Qualification Testing Planned for Propellant Tanks
  - No Vibro-Acoustics Qualification Testing Planned for Pyro Valves and Ordnance
  - Pressure Testing Levels on the Engine Bi-Prop Valve

- **Drafting of waivers, including Engineering rationale for acceptance and the residual risks, began in July 2008.**
  - First three were approved at Ares I-X Control Board September 2008.
  - Second three came later in verification process as loads matured and test results became available.

- **<u>Early identification and draft development allowed RoCS to start "talking up" the waivers within the Ares I-X community, so that when final product was presented, everyone was on board.</u>**

Front-End Loaded Schedule

- **Dry run procedures with real hardware or physical facsimiles to work hardware form, fit, function, and procedural bugs out early, well in advance of handling the flight hardware.**



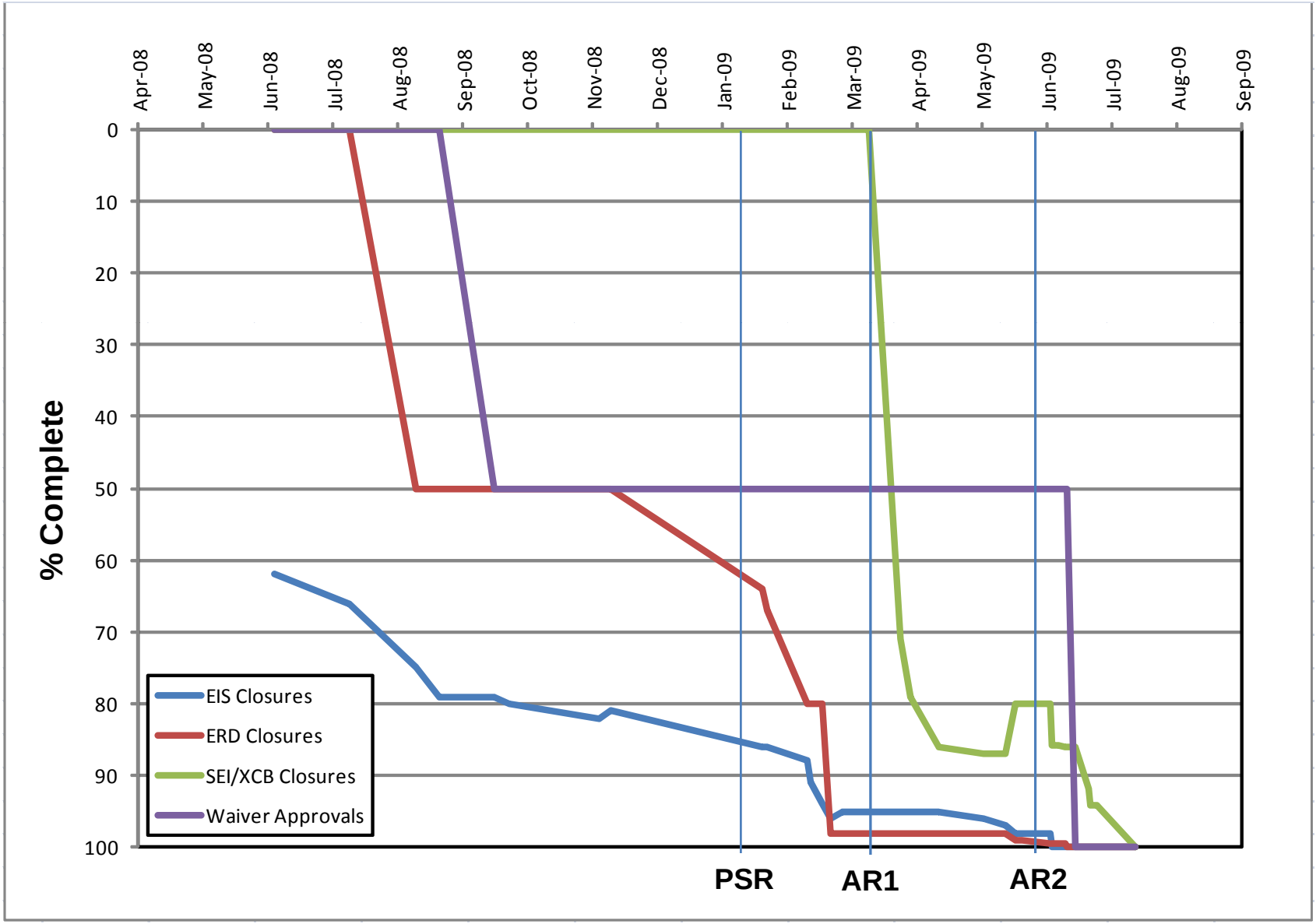
Pressurant and propellant tank filling (with helium and water, respectively) at KSC's Hypergolic Maintenance Facility

Module installation and translation exercise using installation tables, Interstage lip mock-up, and RoCS mass simulator, with KSC personnel

Front-End Loaded Schedule

- **Work parallel paths, as budget allows, to maintain fall-back options.**
- **Use past precedents from prior contracts as models for documentation – modification of an existing document rather than generating a new template and/or authoring from scratch.**
  - As such, Teledyne was able to have many of the motherhood documents (Safety Plan, Quality Plan, Configuration Management Plan, etc., put behind us before new technical requirements even showed up.)
- **Engineering Development Unit (one of four units built and intended for eventual cold flow testing) validated hardware process development and assembly fit checks before committing to final fabrication and assembly of flight units (two, plus one flight spare).**

Front-End Loaded Schedule

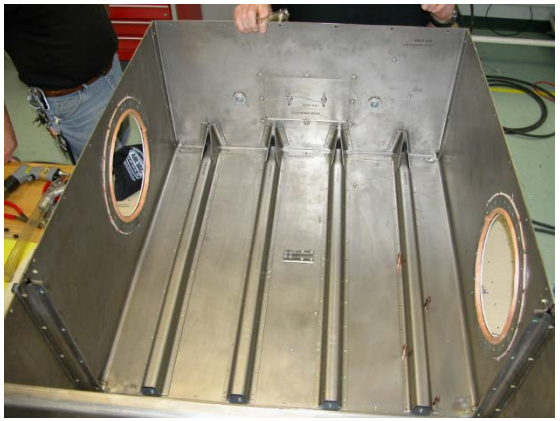


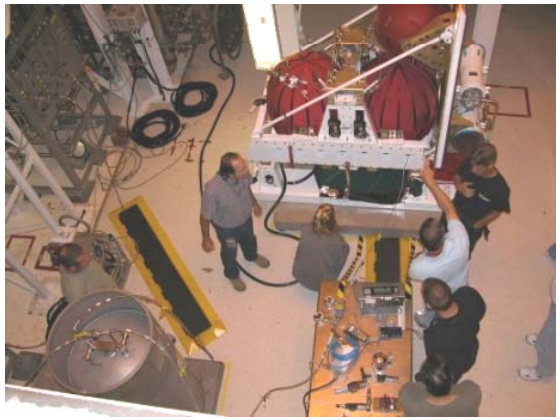
Co-location of MSFC Lead System Engineer to Teledyne Brown Facility

- Greatly facilitated communications between NASA and the Contractor Team.
- Immediate customer interface for the resolution of issues found during the design, fabrication, assembly, and test flow.
- Provided on-site support for interfacing with other IPTs for resolution of interface issues.
- Provided direct customer interface to report status and progress.
- Provided immediate direction to keep project on schedule.
- Provided for expedited verification closure processing.

Maintain Cognizance of the End Game

- This flight was designated as an unmanned, test flight. A mindset shift from Shuttle was in order.
- The original plan to deliver the modules before the end of 2008 would have supported the original April 15, 2009 launch date, and was holding through the fall of 2008.
- Delivery of fairing aero buffet loads and changing vibro-acoustic environments in December 2008 delayed completion of component testing.
- Teledyne-provided field modifications to fairings were implemented at KSC in parallel with off-line propellant/pressurant loading of the modules, minimizing impacts to integration schedule.

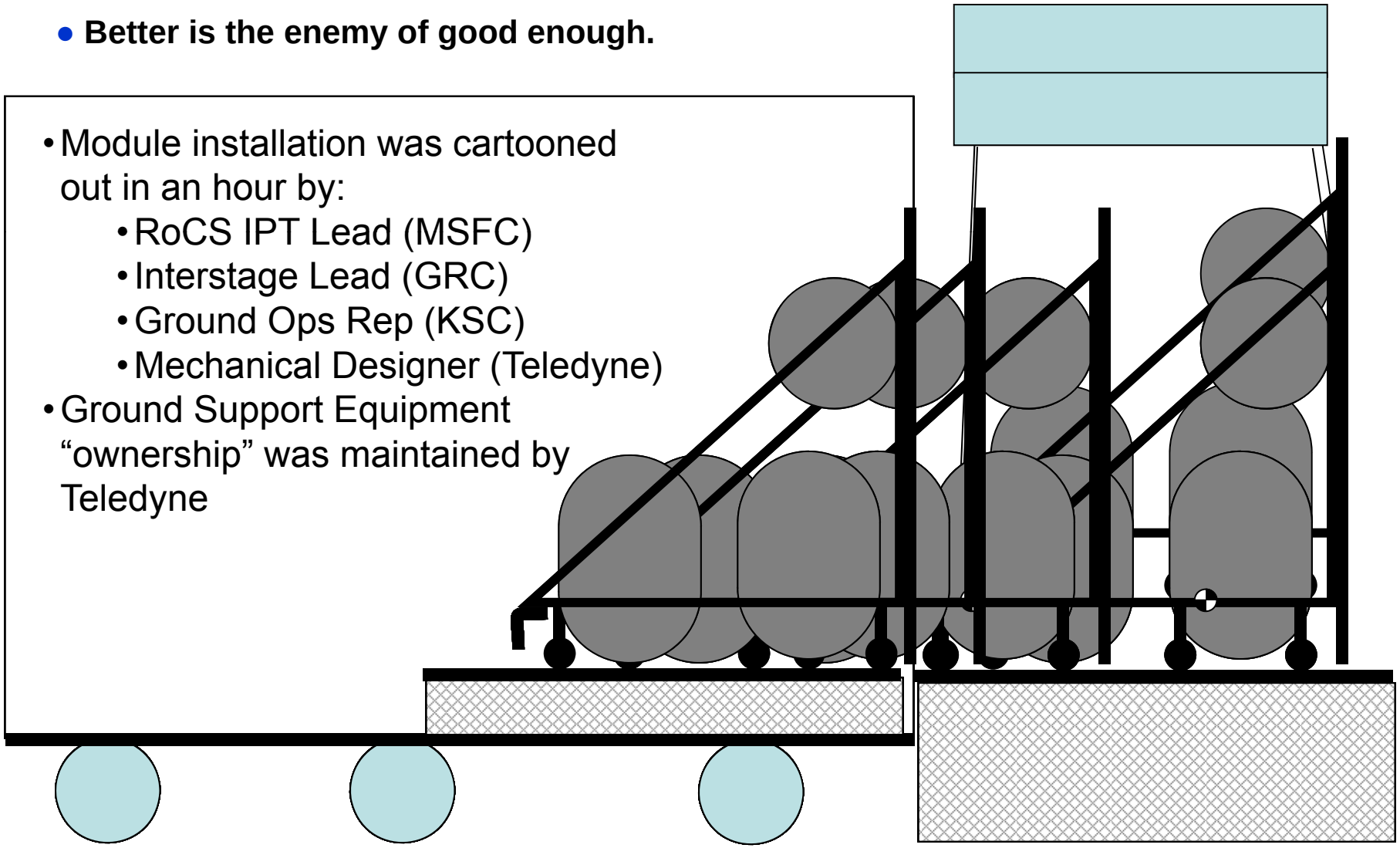




Maintain Cognizance of End Game

- **Work "good enough" options, no need to work optimization for a single test flight**
  - **Better is the enemy of good enough.**

- Module installation was cartooned out in an hour by:
  - RoCS IPT Lead (MSFC)
  - Interstage Lead (GRC)
  - Ground Ops Rep (KSC)
  - Mechanical Designer (Teledyne)
- Ground Support Equipment "ownership" was maintained by Teledyne

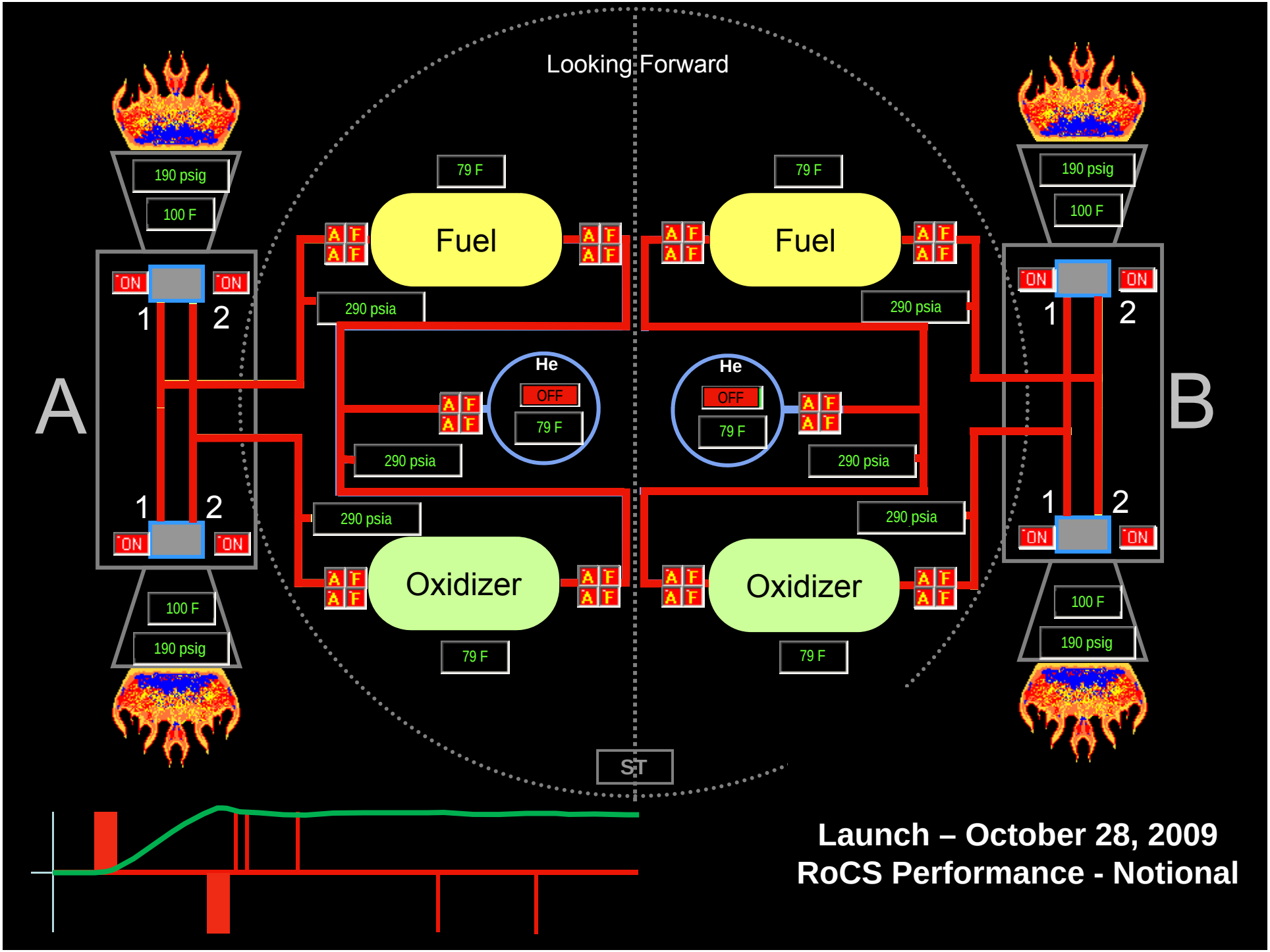


The End Result

Final RoCS Module Shipment
February 5, 2009

Final Integration into Interstage
April 26, 2009

Final Acceptance Review
May 27, 2009



Launch – October 28, 2009
RoCS Performance - Notional

Summary

- **Establish roles and responsibilities**
  - Maintain independence of government Technical Authorities (S&MA and Engineering) per NASA governance model
- **Keep team small and focused**
  - A small team of cross-trained individuals with the necessary core competencies can make decisions quickly and execute plans efficiently
- **Use proven Systems Engineering processes**
- **Start early, keep the End Game in mind**
- **Design conservatively, wherever possible**
- **Develop**
  - Multiple open communications channels while respecting protocol
  - Ownership
  - Trust
  - Friendship

Question and Answer Session