Segment 3 Platform Upgrade

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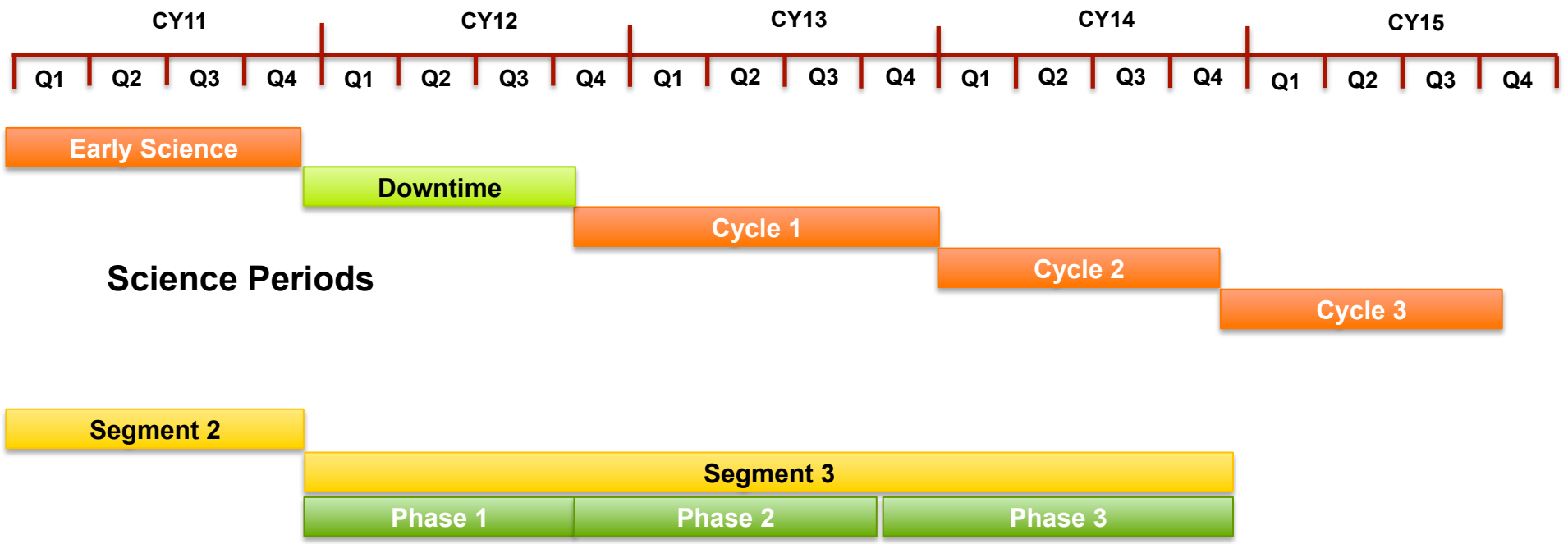
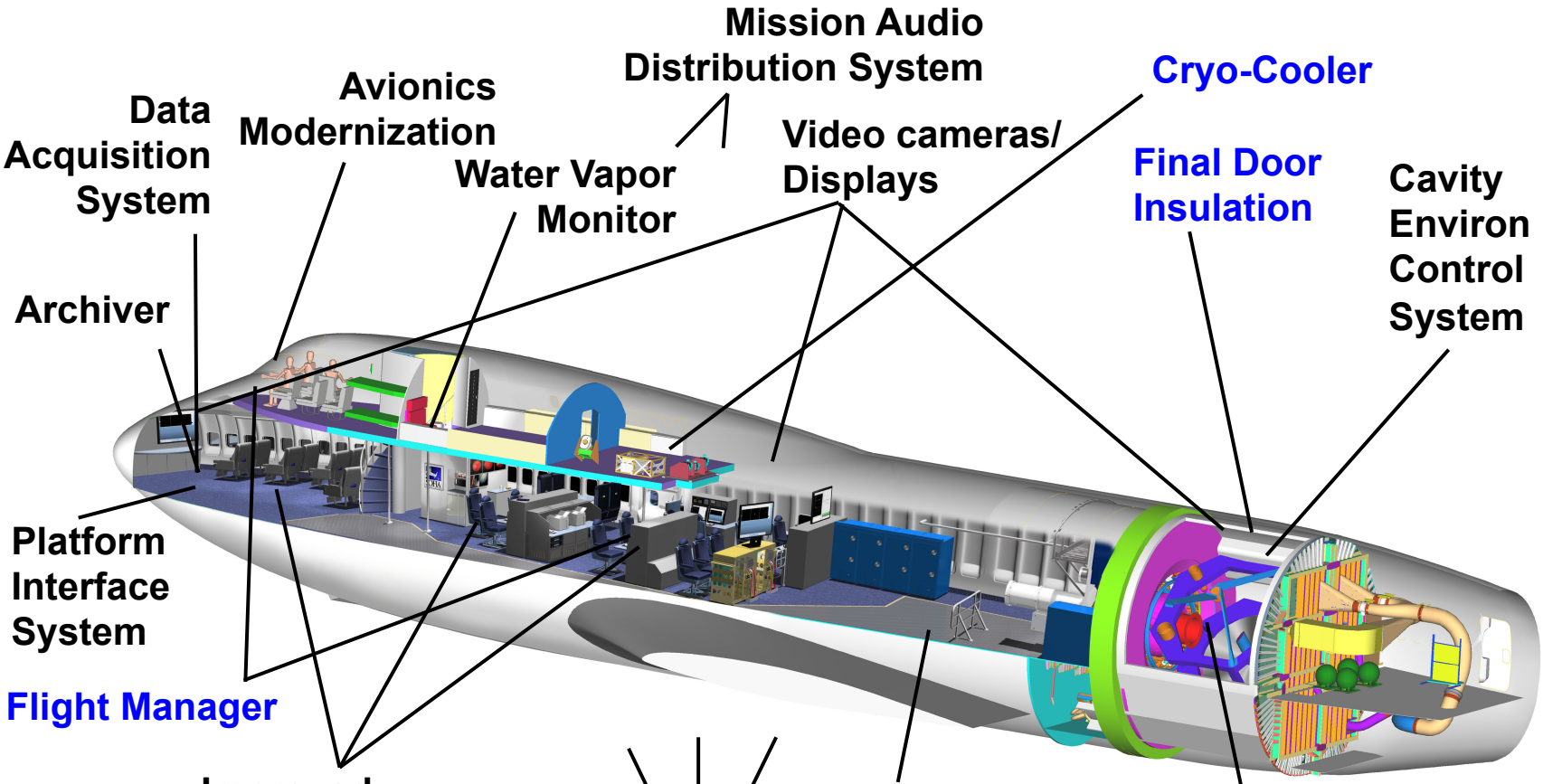
Science vs Development Periods

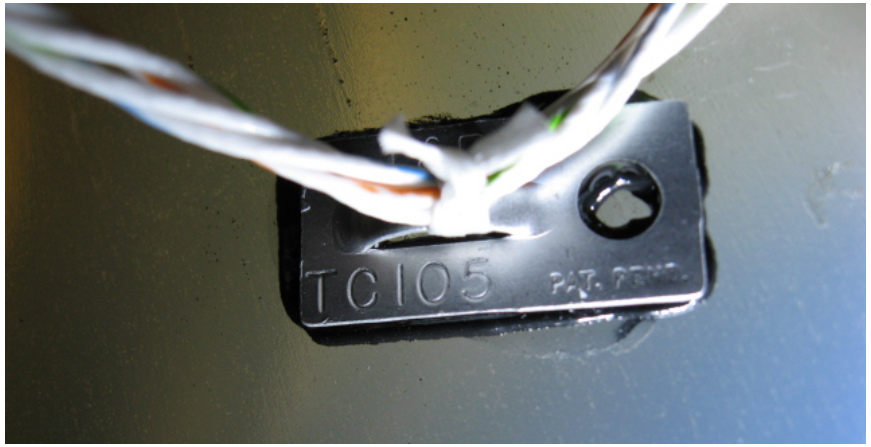


Segment 3 Overview



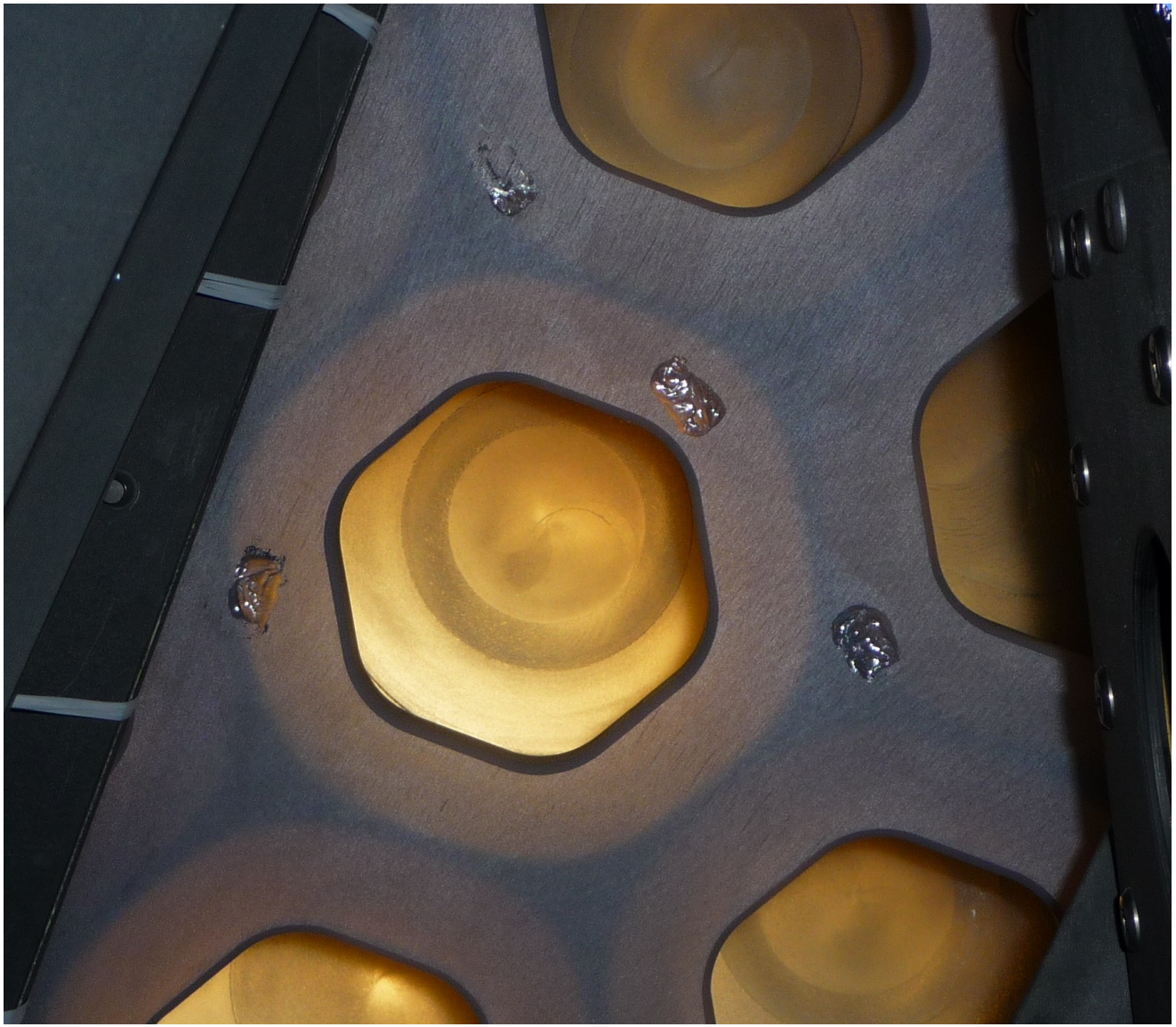
Mirror repair history and status

- August 2011-it was discovered that some small aluminum tabs that had been bonded on the back side of the mirror were flaking off, taking some of the substrate glass with them.
- Glass experts did an independent assessment of the state of the primary mirror and the aluminum tabs.
- 2 sites were determined to be dangerous and were repaired.
- Lab testing was conducted to prototype and test a tab removal process. All tabs were subsequently removed
- After an extensive review of procedures and the hazards associated with them, all remaining tabs were removed and all sites repaired and smoothed.
- 2 cracks which were in the mirror from the original machining of the mirror blank to remove weight were also repaired.
- The manufacturer (Schott) then inspected the mirror and concurred that there were no remaining issues. Mirror is in the best condition it has been since it was manufactured.



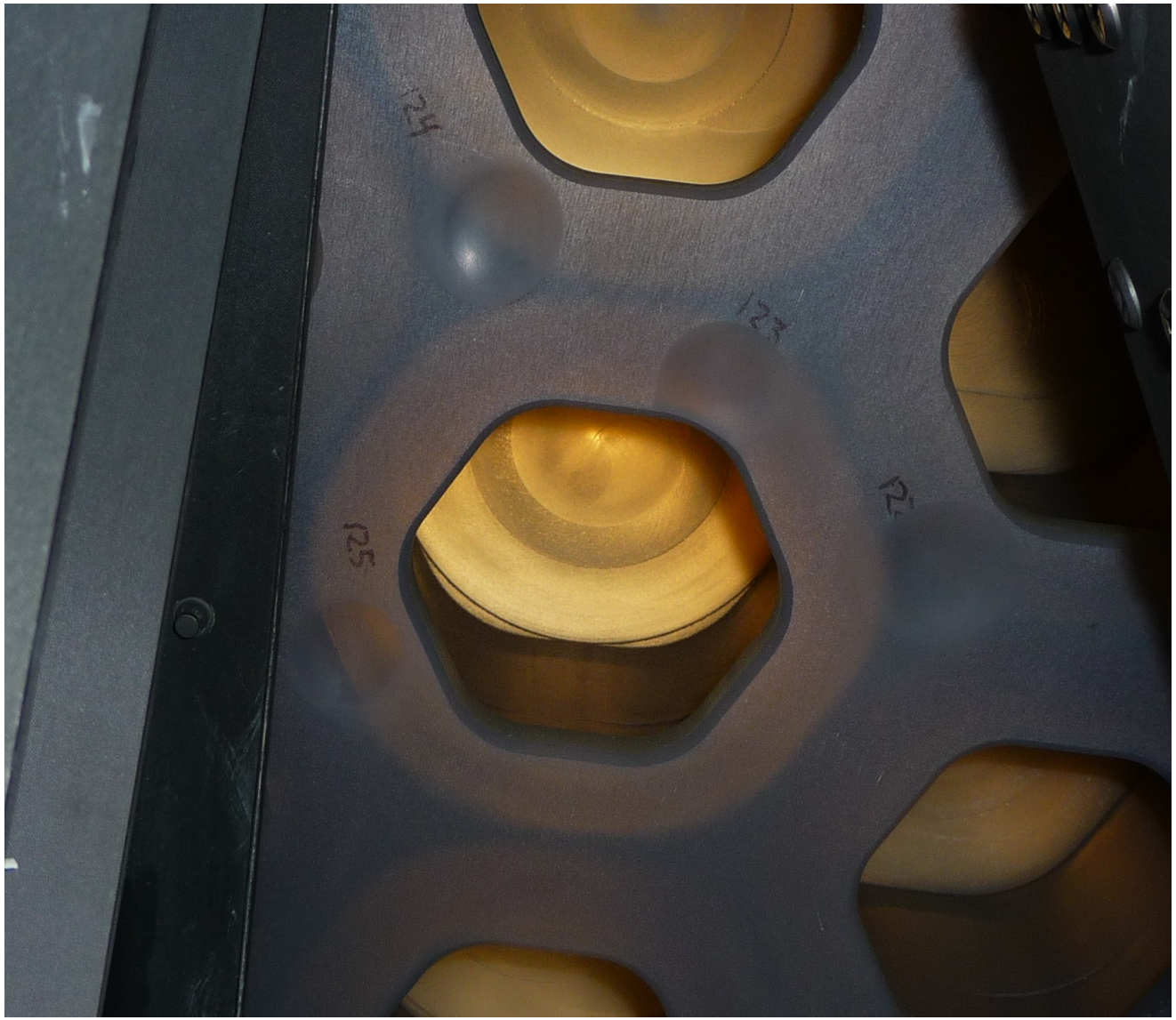
Mirror Repair

Example - Before repair



Mirror Repair

Same sites - After repair

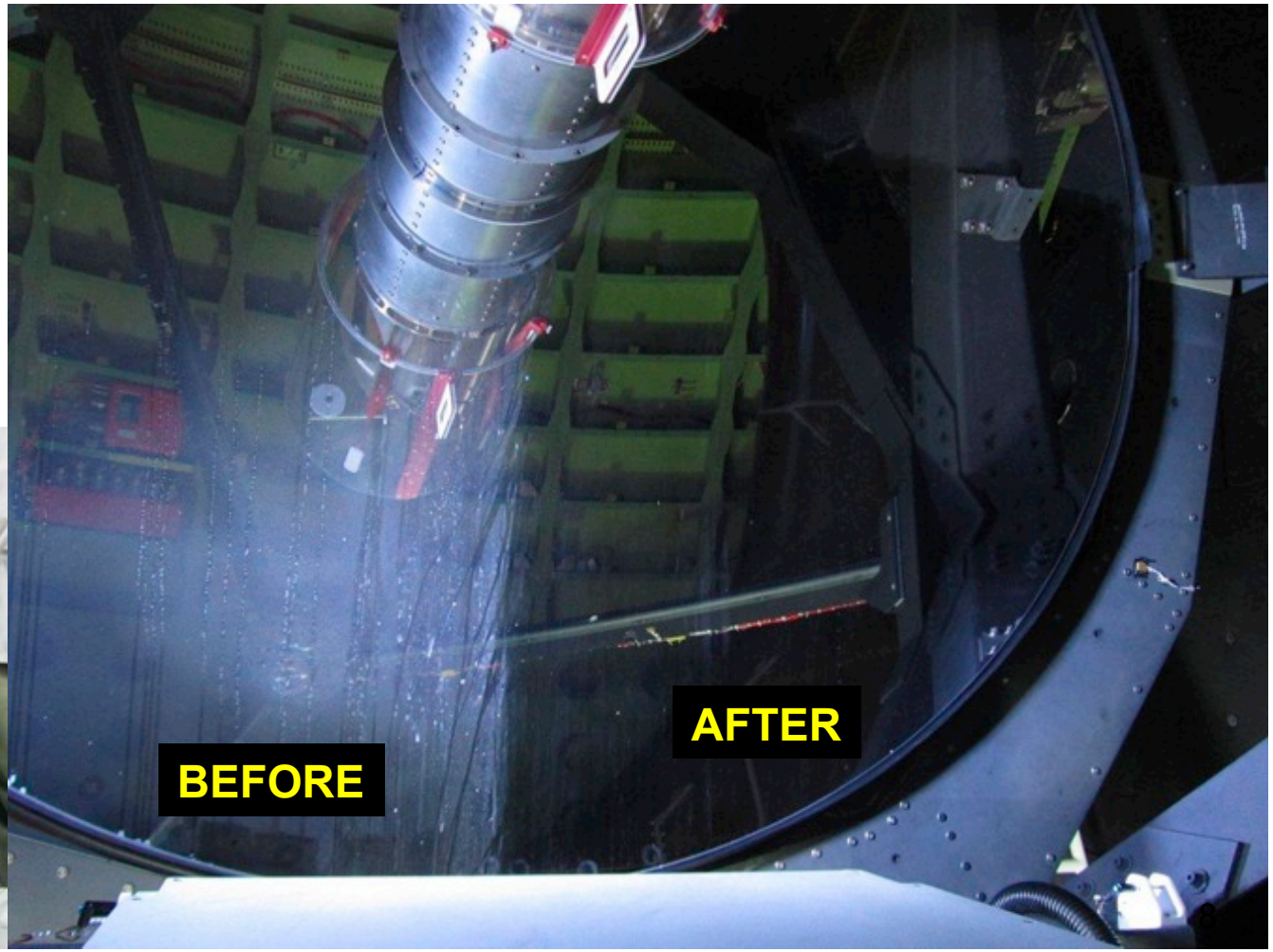


Telescope Improvements

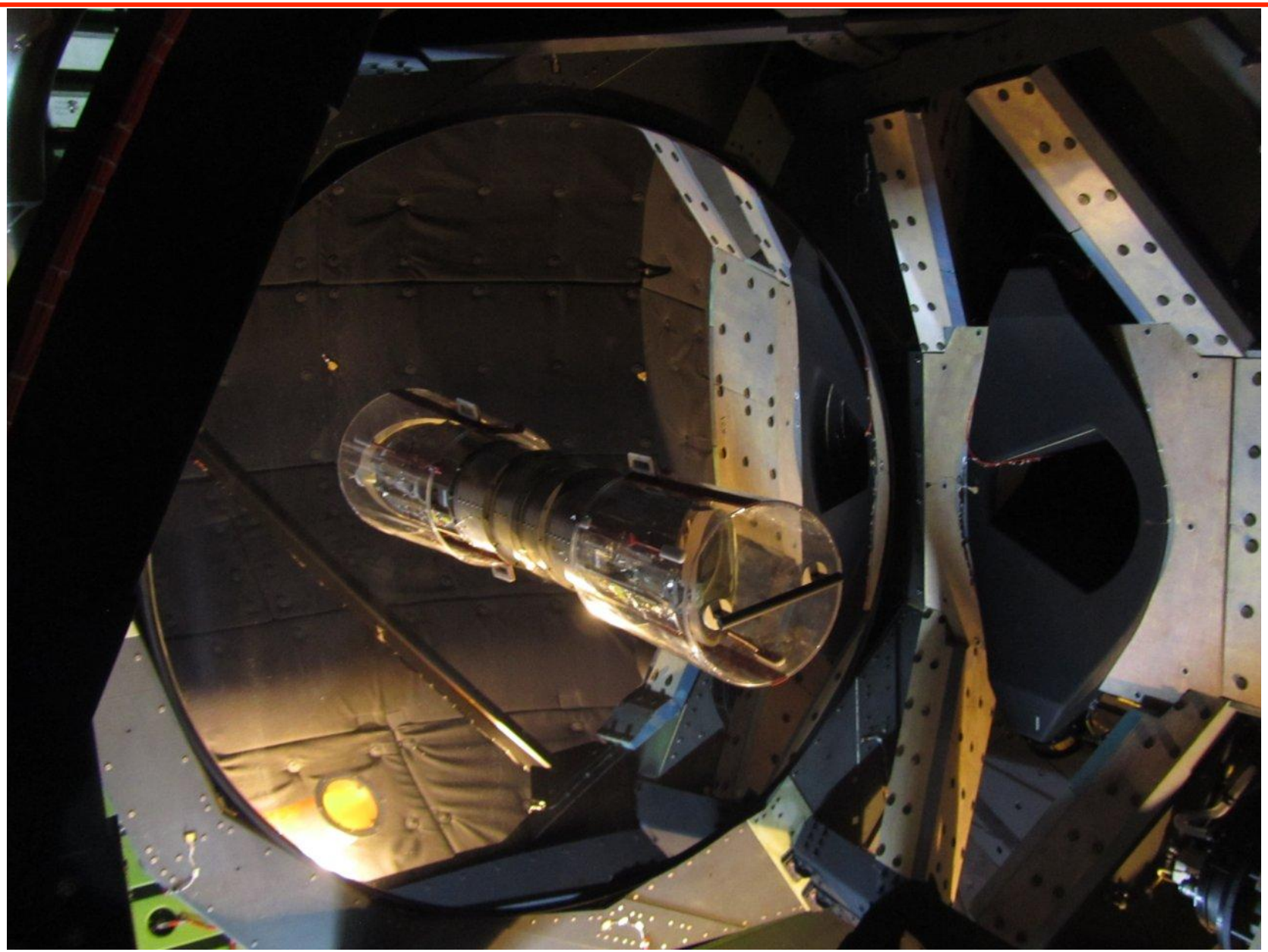
- Dozens of changes made to the Telescope Assembly software to correct errors, improve efficiency, improve monitoring/warnings, and increase capability
- New/improved Telescope Capabilities include:
  - Secondary Mirror Control Unit (SMCU) software:
    - SMCU software has improved and has now reached a high level of stability
    - Command execution is very efficient; rate-dependent delays are gone
  - Tracker Changes:
    - Tracker is now aware of the Secondary Mirror position
    - Significantly improved tracking (~1” during ground test)
    - IRF Offset-Tracking:
      - Works very well (can fix pointing errors up to 2 arcminutes)
  - Telescope alignment improved through new software and processes
  - Flexible Body Compensation algorithms improved to better align cameras and SI
  - Absolute Pointing improvement (~1” during ground test)

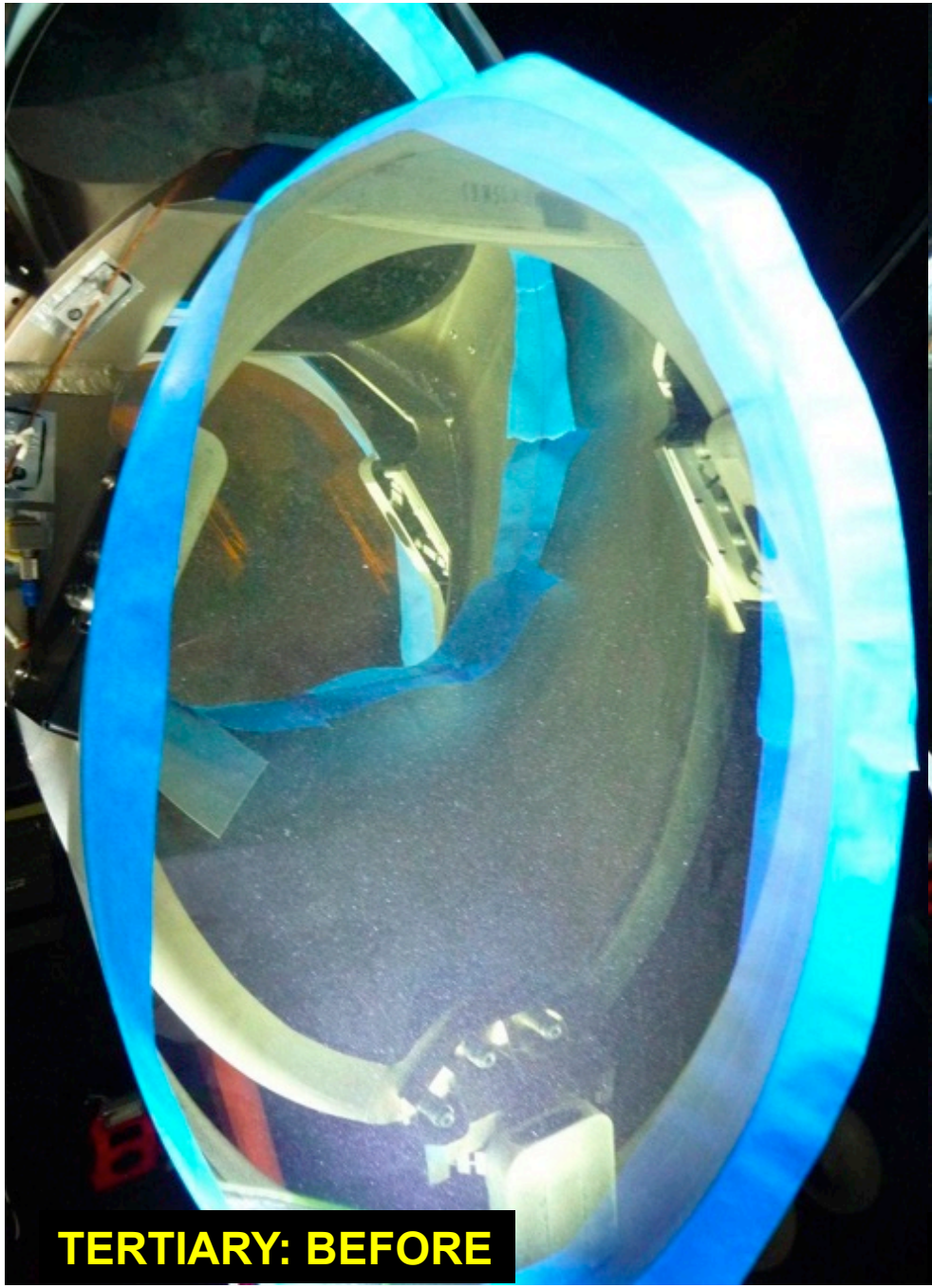
PMA Wash

- First Mirror wash completed in August.



Mirror Wash Complete




TERTIARY: BEFORE


TERTIARY: AFTER

Cockpit Modernization

- SOFIA Cockpit/Avionics modernization has several benefits:
  - Allows World-wide operations in current and future airspace systems
  - Automates navigation functions and enhances in-flight mission re-planning reducing crew workload/size (navigator)
  - Increased situational awareness/safety
  - Equipment reliability and supportability
- Modern glass cockpit (maintainable, reliable, capable)
- Modern weather radar and satellite information
- Modern flight management system
- Traffic and Ground Collision Avoidance systems
- Improved radios and long range communications

Cockpit Modernization

Platform Interface System

Heart of the Mission Command and Control System (MCCS)

- Data processing and control hub for the entire observatory
- Collects, processes, and distributes data from various elements of the observatory
- Receives, validates, and interprets commands
- Routes the interpreted commands to the appropriate observatory system (including the telescope system)

Segment 3 hardware improvements

- Additional processor cards & S/W architecture changes to reduce system workload and interface with new seg 3 systems (phase 1)
- Increased processor capacity for future expansion (phase 2)

Platform Interface System Software

Segment 3 improvements

- Static memory allocation for the majority of the architecture
- Better processor resource management
- Improved exception handling
- Telescope modes
  - Matched Chop Nod with Dither
  - Perpendicular Chop/Nod with Dither
  - Chop with large not to sky with Dither
  - Dither
  - Dither while Nodding
  - Nod along slit with Chop and Dither
  - Tweaking in Science Instr Ref Frame
  - Position switch (ta.pos.goto on/off)
  - Line of Sight rotation
  - Matched Chop Nod
  - Perpendicular Chop/Nod
  - Chop with large Nod to sky
  - Beam switch
  - Chop along slit
  - Chop along slit with Nod
  - Nod along slit
  - Nod off slit
  - Nod along slit with Chop
  - Tweaking in Earth Ref Frame
  - Scanning with Position switch
  - Scanning while Chopping
  - New Scanning capabilities (phase 2)
  - Auto-focus (phase 2)
  - Better health and status (phase 2)

Workstations

Command and control stations used by all mission crew to control and monitor the observatory and mission execution

Segment 3 improvements

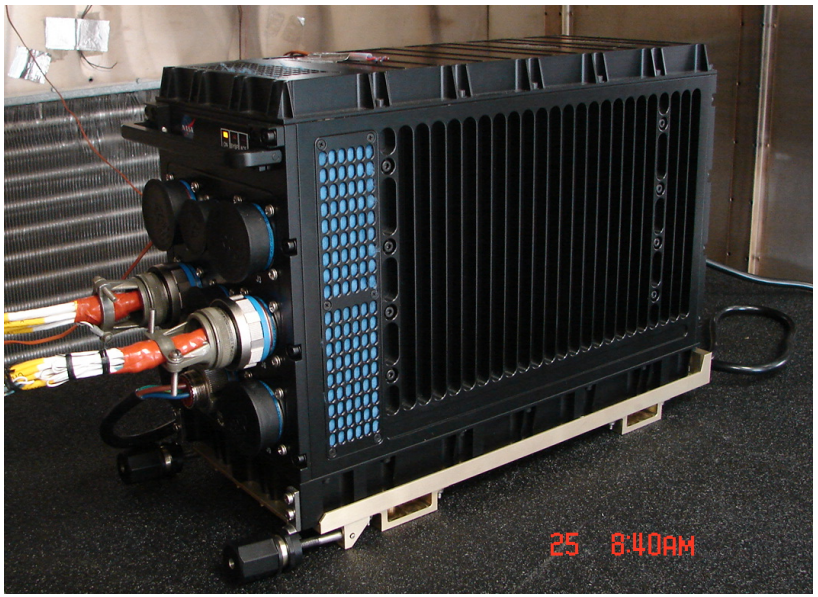
- Higher reliability & better performance (phase 1)
- Two Additional systems added for new Education console (phase 1)
- Quad displays for Telescope Operator (phase 1)
- Extensive updates of the display software to enable new capabilities and increase the capability and efficiency of observing operations (phase 1)

Data Acquisition System

System gathers data from various sources, timestamps it, formats it, archives it, and forwards much of the data to the PIS so it becomes available as housekeeping data

New capability for Segment 3

- Aircraft instrumentation (engine data, cavity environment, cabin environment, mirror temps, etc) (phase 1)
- Aircraft avionics (INS, GPS, airdata, aircraft data) (phase 1)
- Vacuum pump HK data (phase 2)
- Cryo Cooler HK data (phase 3)



DAS Instrumentation Measurements

Avionics

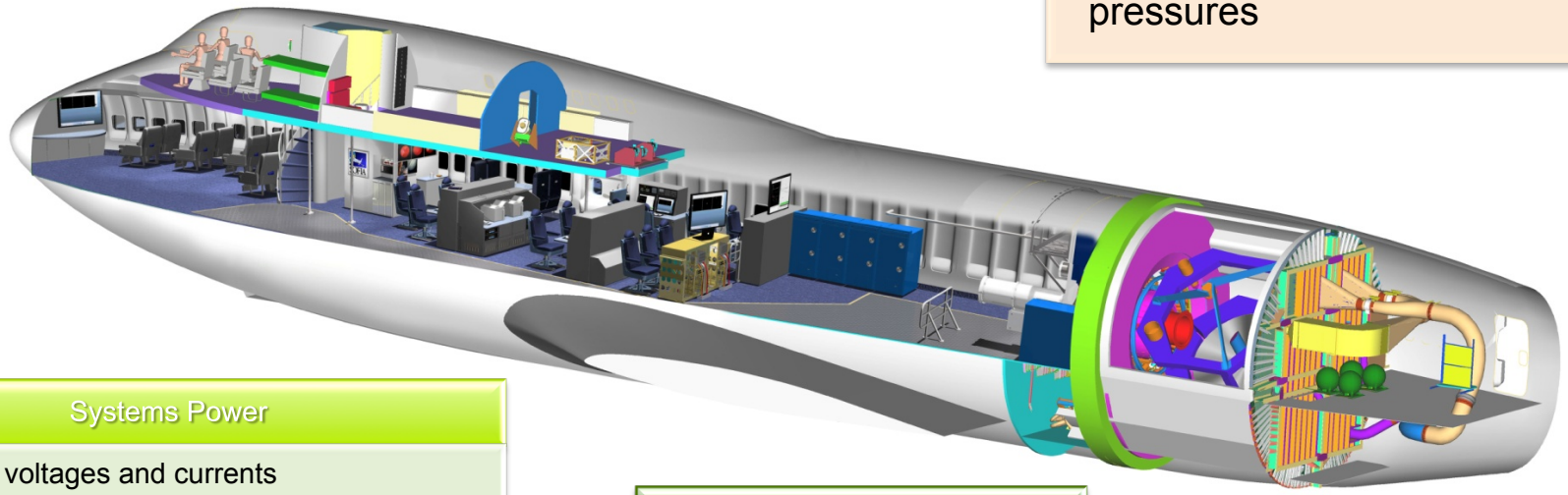
- Position, Velocities, Accelerations
- Attitudes & Rates
- Pressure Altitude, OAT, Airspeeds, Mach
- Wind info
- Waypoint info
- Fuel Quantities, Weight, & Thrust

Cabin Environment

- Cabin temperatures, humidity, altitude
- FWD rack 5 temperatures

Cavity Environment

- Cavity dew point, humidity, temperatures, pressures
- Cavity door seal pressure
- Cavity door & VIS air bottle pressures



Systems Power

- UPS RMS voltages and currents
- UPS discretes
- Frequency Converters RMS voltages & currents
- 3-Phase AC Power Buses RMS voltages and currents
- DC Power Buses voltages & currents

Telescope

- Nasmyth temperature & humidity
- SI mounting flange vibration
- SI Patch Panel Analogs
- Mirror temperatures
- Spider temperatures
- WFI & FFI Temperatures
- SMA tip/tilt

Vacuum Pump

- Flow Rates
- Pressures

Archiver

New capability for Segment 3 (phase 1)

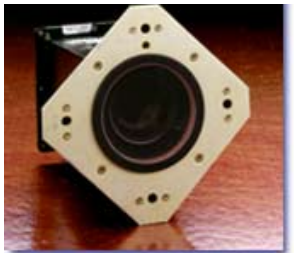
- Records data from most onboard systems
  - Science instrument data
  - All housekeeping data
  - Video and imager data from video system
  - Water Vapor Monitor engineering data
  - Aircraft instrumentation data (power, structural, etc)
  - Aircraft state data
- Redundant recording for reliability
- Allows access to recorded data in flight
- Removable disk packs provide for quick data transfer
- Storage for up to 3 flights while on deployment (>9 TB initially)
- Expandable to larger memory as program requirements change

Digital Video Distribution System

Collects, encodes, manages, routes, displays, and records observatorv video signals and Telescope Assembly images.

Segment 3 improvements

- Increased TA image rate capability (phase 1)
- Video encoders at all primary workstations (phase 1)
- Record and make video sources available as network streamed video and for projection on large displays. (phase 1 & 2)
- Video cameras covering EPO and Mission areas, TA and Aft cavities (phase 2)
- Large Displays in cabin (phase 2)
  - 42" above TO console and forward EPO area
  - 52" port/starboard side walls in mission area and side wall near EPO console



Mission Audio Distribution System

Provides a communication system so the observatory operators, crew, and guests can maintain clear communications and situational awareness during observatory missions.

Segment 3 improvements

- Additional systems for Education stations (phase 1)
- Audio recorded to Archiver (phase 1)
- Audible Alarms and Alerts (phase 2)
- Wireless Headsets (phase 2)

NTP Time Sever

Provides GPS-based high accuracy time to all networked systems

Segment 3 improvements

- Segment 3 system adds in-flight reset capability (phase 1)
- Greater reliability (phase 1)

Network

Provides gigabit data communication between the observatory elements. Two separate networks currently exist on the aircraft.

Segment 3 improvements

- Network connections for all new systems (phase 1)
- Additional "Guest" network being added for Education/ Public Outreach (phase 2)

Power Distribution System

System allocates approximately half the aircraft power to the observatory systems

Segment 3 updates

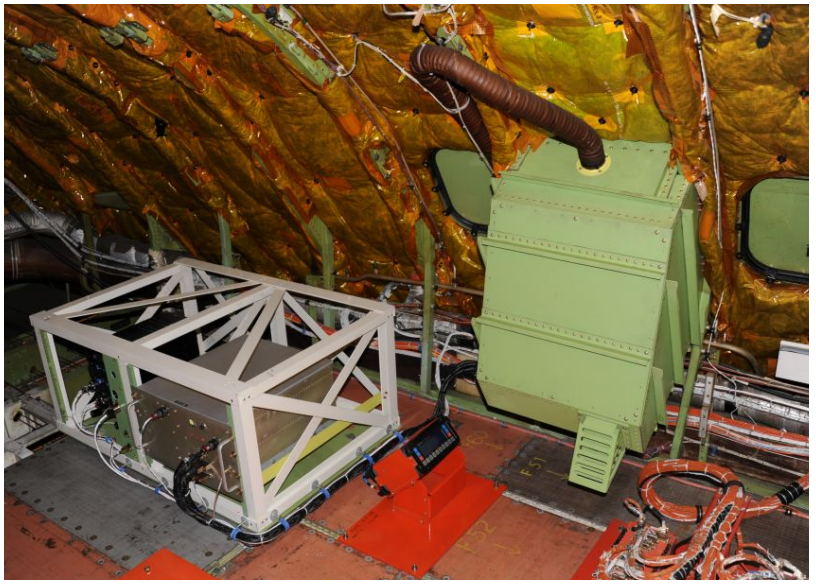
- Additional Battery Back-up for protecting critical systems including the SI (phase 1)
- Increase power allocation to Science Instrument from 5kVA to 6.5 kVA and add 20 kVA for next generation Cryo-coolers (phase 1)
- Higher efficiency and reliability power converters (phase 1)
- Power distribution to new and future systems (phase 1)
- Science Instrument on separate bus (phase 1)
  - Supports possible 24/7 power to SI in the future

Water Vapor Monitor

Existing system measures the integrated water vapor along the telescope line-of-sight and directly to the zenith.

Segment 3 improvements (phase 1)

- Will be connected to MCCS network so:
  - It can report the measured water vapor overburden to the SI teams as part of the observatory housekeeping data
  - Receive critical data (such as aircraft roll angle, outside air temperature and pressure) Can be commanded from MCCS by the Mission Director
  - With connectivity to the rest of the MCCS it becomes largely autonomous and does not require a WVM operator to fly.
- WVM will be more accurately calibrated over the upcoming flights
- WVM data can be used for post-flight correction of SI data

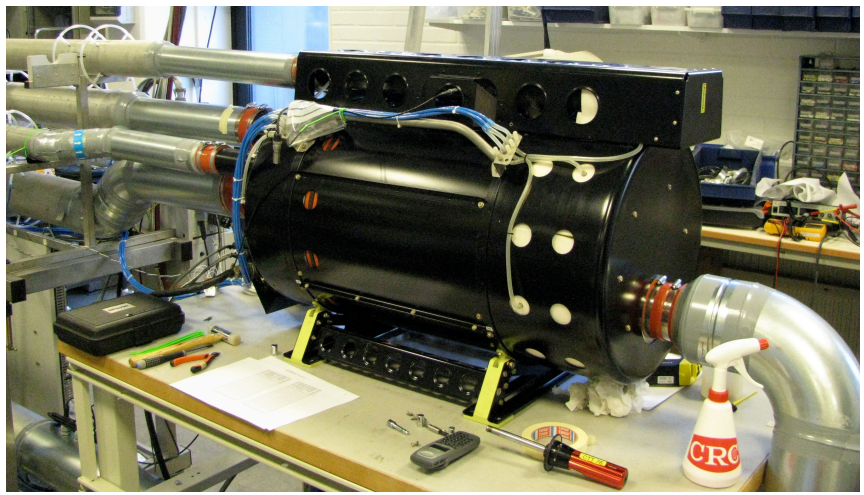


Cavity Environmental Control System

Generates positive pressure in cavity during descent and while on the ground with warm/dry air to eliminate moisture/ice when door is closed and sealed

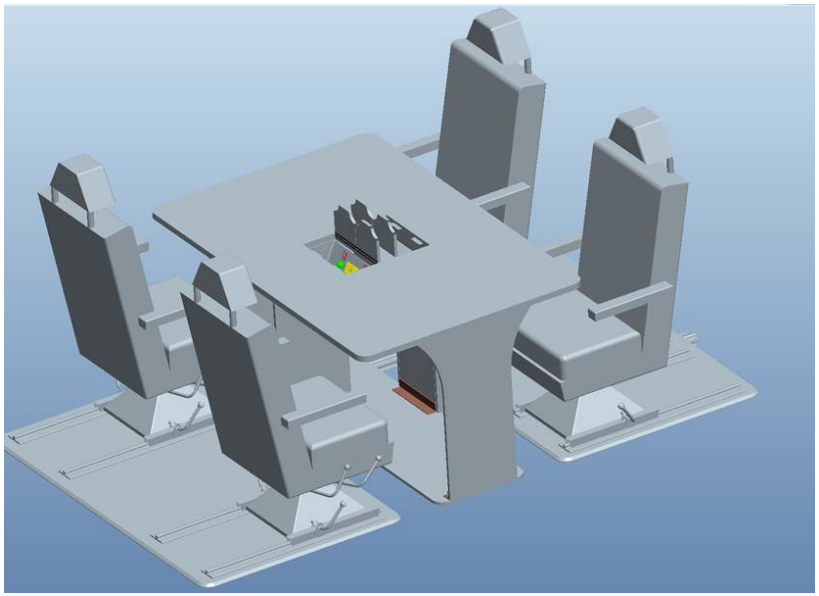
Segment 3 improvements

- Major overhaul & upgrade to the desiccant dryer to significantly improve performance and eliminate faults (phase 1)
- Bringing on-line new systems to warm cavity faster (phase 1)
- Cavity Pre-cooling system that uses liquid nitrogen to chill the telescope to -40 deg C prior to takeoff (phase 2)
  - Allows longer quality science time (0.5+ hrs increase)
- Higher reliability controller (phase 2)



LOPA (Interior Changes)

- New Education Console with 2 workstations (phase 1)
- Protection for SI patch panel cables (phase 1)
- Additional/larger conference table (early phase 2)
  - With MADS and Network connections
- Expansion of current conference table (phase 2)
- Better/adjustable lighting (phase 2)
- Mission crew storage (phase 2)
- Improved ergonomics at the center SI seat (phase 2)
- Galley (phase 2) ?



Phase 2 & 3 upgrades

Upcoming Improvements

- Vacuum Pump (Phase 2)
  - For evacuation cryogenic plenum
  - First use expected to be FIFI instrument in 2014

- Flight Manager (phase 2)
  1. Heading Turner that uses existing aircraft autopilot to fly curved trajectories that allow astronomical targets to remain centered on the telescope line of sight.
  2. Flight Planner system that allows development, modification, and monitoring of mission plans and transfer to the pilot for execution.

- Airborne Network (phase 3)
  - Funding in FY14
  - Expect to use commercial airborne internet as being developed for airline use.

- Cryo-Coolers (likely phase 3)

- Blower (proposed)
  - May be needed for short wavelength instruments