National Aeronautics and Space Administration

JWST Program Office

Eric P. Smith

Astrophysics Subcommittee
August 12, 2014

Changes Since Last Meeting

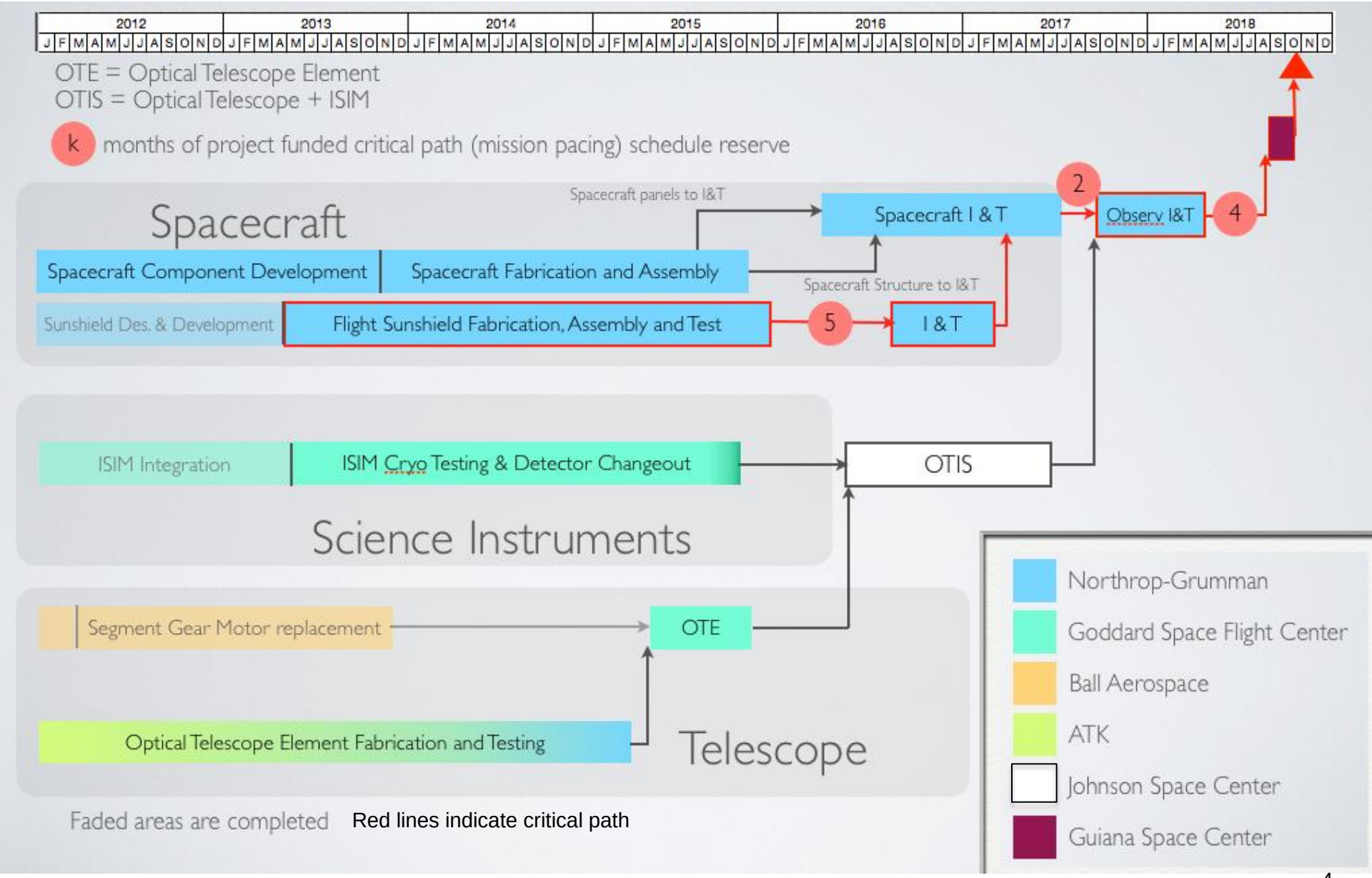
- Working with GAO providing information for their FY14 report, completed ISIM schedule risk analysis (SRA), and OTE SRA.
- ISIM cryo-vacuum test #2 (CV2) underway, proceeding nominally
- NIRSpec new detectors installed into focal plane array, All new FGS detectors selected, focal plane assembly underway. Both sets are on schedule for installation after CV2.
- NIRCam DC-DC converters manufactured and being integrated into new focal plane electronics (FPE) cards, will be inserted into FPE boxes after CV2.
- New microshutter assembly in testing and on schedule for insertion into NIRSpec after CV2
- Spacecraft CDR and System Look-back Review (SLR) completed and successful
- Backplane center section/Backplane Support Fixture finished at NGAS.
- Pathfinder center section delivered to GSFC for engineering mirror installation activities.
- Flight secondary mirror support module delivered, flight secondary mirror support struts completing testing.
- Schedule reserve consumed (~2 months) for Unitized Pallet Structure manufacturing. Initial flight build did not meet strength margins.
- Flight Sunshield Layer 3 complete and in testing, Flight sunshield Layers 4 & 5 manufacturing underway.
- Ground support equipment for 2016 OTIS test being installed on schedule at JSC Chamber A
- Flight MIRI cryocooler cold head assembly (CHA) not used in ISIM CV2 this Summer. Unit that is installed and went through CV #1 test will be used.
- Cryocooler Compressor Assembly schedule performance not improving.

JWST Program Office

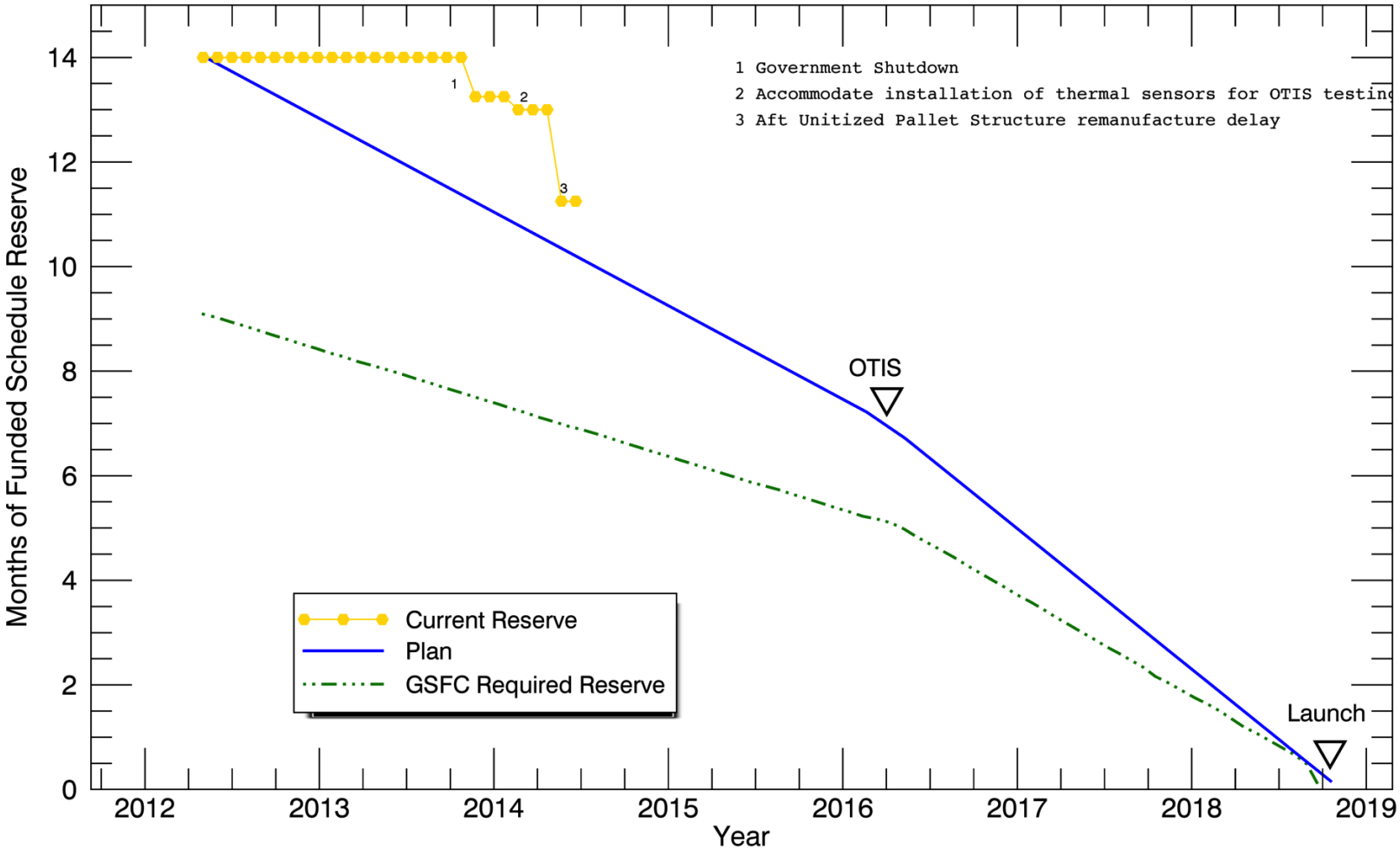
Program Manager Watch List

- **Cost: FY14 reserves are tight, but will have enough for this year. NGAS-observatory is performing well to their cost plan. NGAS-cooler, though, is having significant difficulty staying on its cost plan. FY15 reserves will be tight entering the fiscal year.**
- **Schedule: Critical path funded schedule reserve decreased from 13 to 11.25 months due to UPS manufacturing issue; moisture barrier solution found, working on full manufacturing process and MRR.**
- **Cryocooler: CCA delivery schedule slips, cost growth consuming disproportionate share of Project UFE, jitter disturbance, workmanship and quality**
- **3/4" Non Explosive Actuator**
- **Star Tracker Strut Assembly**
- **20 micro mid-infrared stray light (Level 2 requirement). Good test results from 5-layer membrane deployment might reduce this stray light.**
- **New ITAR regulations (could necessitate rework or new licenses; completed cross-walk of new ITAR threshold criteria against JWST design).**

JWST Simplified Schedule



Project Funded Schedule Reserve



Fiscal Year 2014 HQ Milestones

Month		Milestone	Comment
Oct-13	1	Primary Mirror Backplane Support Structure Cryogenic Testing Readiness Review	Completed 9/10/13
Nov-13	2	Mirror Deployment Electronics Unit Manufacturing Readiness Review	Completed 10/8/13
	3	Jet Propulsion Lab. (JPL) Cryogenic Test Chamber Readiness Review	Completed 12/19/13
	4	Johnson Space Center (JSC) Telescope and ISIM support structure fabrication complete	Completed 11/4/13
Dec-13	5	Spacecraft Critical Design Review Complete	Completed 1/16/2014 [shutdown delay]
	6	MIRI Cryocooler Flight Cold Head Assembly (CHA) delivered to ISIM	Delayed 8/2014 due to harness short and valve issue, non-flight CHA to be used for CV2
	7	JSC Clean Room ready to receive ground support equipment	Completed 12/23/13
	8	Complete ISIM cryogenic-vacuum risk reduction test	Concluded 11/13/2013, but not all tests completed because of shutdown
Jan-14	9	Delivery of last Primary Mirror Segment to GSFC	Completed 12/16/13
	10	Observatory Operations software scripts Build 3 Complete	Completed 1/16/14
	11	New detector focal plane arrays for NIRCam ready for integration into instrument	Completed 11/20/13
Feb-14	12	Secondary Mirror Mount delivery	Completed 2/19/14
	13	MIRI Cryocooler flight electronics delivered to JPL	Delayed to August, resolving parts issues, small cost, but no schedule impact
	14	Final Data Management Subsystem Design Review	Completed 11/22/13
	15	Flight NIRCam and NIRSpec ready for integration into ISIM	2/4/14 (NIRSpec), 3/8/2014 (NIRCam: harness issues and snow delays)
Mar-14	16	Spacecraft Solar Array Manufacturing Readiness Review	Completed 2/21/14
	17	JSC Chamber A Telescope ground support equipment test #1 design review	Completed 2/26/14
Apr-14	18	Telescope actuators electronics drive unit delivery	Completed 4/1/14
	19	Flight MIRI cryocooler assembly delivered to JPL	Delayed to September, VM welding issue
	20	MIRI Cryocooler Flight Refrigerant Line Deployment Assembly delivered to integration and testing	Completed 4/30/14
	21	Sunshield Membrane Cover Assembly Manufacturing Readiness Review	Completed 4/30/14
	22	MIRI cryocooler Test Readiness Review	Delayed to Dec., due to late cryo-cooler assembly
May-14	23	Updated Observatory Commissionning Plan (rev C) delivery	Completed 4/28/14
	24	Start acceptance testing of flight cryocooler assembly and associated electronics	Delayed to Jan, 2015 due to late cryo-cooler assembly
	25	Start cryo-vacuum test with fully integrated ISIM ("CV2")	Completed 5/29/14
Jun-14	26	Flight spare MIRI cryocooler assembly delivered to JPL	Delayed to Dec., VM welding issue
	27	JSC Chamber A bake-out and cryogenic proof testing complete	Proof test complete, bake-out concluding in July, no schedule impact
	28	Hardware ready for MIRI cryo cooler test #3: checkout complete	Delayed to Feb 2015, due to late cryo-cooler assembly delivery to JPL
Jul-14	29	Spacecraft Mid-Course Correction Thruster Final Assembly complete	Delayed to Jan 2015, 3 mo. schedule slack to need date remains
	30	Proprosal Planning Subsystem build 9 complete	Completed 4/30/14
Aug-14	31	Sunshield Mid-boom and Stem assembly Manufacturing Readiness Review	
	32	Spacecraft Flight Software Build 2.2 Test Readiness Review	Delayed to 4/30/15, 5 mo. Schedule slack to need remains
	33	NIRSpec and FGS/NIRISS new Focal Plane Arrays ready for integration	Delayed to 9/2014 [shutdown]
Sep-14	34	JSC cryogenic test telescope and ISIM test ground support equipment integration complete	
	35	Complete cryo-vacuum test of fully integrated ISIM ("CV2")	Delayed to 10/2014 [shutdown]
	36	NIRSpec new microshutters ready for integration	Delayed to 10/2014 [shutdown]

7/3/14

Blue font(underline) denotes milestones accomplished ahead of schedule, orange font denotes milestones accomplished late.

Milestone Performance

- Since the September 2011 replan JWST reports high-level milestones monthly to numerous stakeholders

	Total Milestones	Total Milestones Completed	Number Completed Early	Number Completed Late	Deferred to Next Year
FY2011	21	21	6	3	0
FY2012	37	34	16	2	3
FY2013	41	38	20	5	3
FY2014	36	21	9	13*	6

*Late milestones have been or are forecast to complete within the year. Six shutdown-related delayed milestones included in this tally. Deferred milestones are not included in the number-completed-late tally.

Delayed Items Details

- #3 JPL readiness review for test chamber used in MIRI testing delayed by one month to better spread workforce. Because of delays in other MIRI components readiness review could move by one month with no schedule impact.
- #6 Cold Head Assembly (CHA) delivery delayed after testing before shipment revealed an electrical short. Insulation rubbed off wires during vibration testing. Potting being used around wire harness. Will be delivered for use in JPL end-to-end testing. Existing non-flight CHA will be used for CV2, no schedule impact, cost impact covered with project UFE.
- #13 Unexpected ripple in signal from MIRI electronics for Cryocooler Compressor Assembly (CAA) require study before JPL can accept delivery from NGAS. No schedule impact as CCA electronics are not needed until CCA delivered, cost impact covered with project UFE.
- #15 GSFC closed for snow several days and difficulties associated with installing wire harness on the ISIM caused NIRCam to miss this milestone by a week. There is no impact to the ISIM CV2 schedule because of this.

Delayed Item Details

- #19, #22, #24, #26, #28 All delays in the MIRI CCA arising primarily from difficulty in achieving good weld for verification model. Verification model subsequently has passed its test, but flight units must now be built-up. Schedule impacts to JPL testing being investigated, ultimately needed for integration into spacecraft in 2016.
- #27 Chamber A cryo-proof testing completed on schedule. Some minor contamination clean-up meant a later start to the bake-out which will complete in July rather than June. There is no schedule impact to this shift.
- #29, #32 In both cases work schedules at NGAS adjusted following “replan” contract definitization to match workforce numbers with available budget.

Primary Technical Performance Metrics

Performance / Resource Parameters	Capability / Requirement	Estimate or Predict 6-14	Comments
Sensitivity Parameters			
NIRCam SI Sensitivity @ 2 microns (nJy) Level 1	11.4	10..2	Prediction at EOL from 6-19-13 SI TPM Report
MIRI SI Sensitivity @ 10 microns (nJy)	700	679	Prediction at EOL from 6-19-13 SI TPM Report
Straylight (MJy/ster @ NIR 2 microns)	0.091	0.089	Prediction from 4-7-14 Integrated Modeling Review
Straylight (MJy/ster @ NIR 3 microns)	0.07	0.066	Prediction from 4-7-14 Integrated Modeling Review
Straylight (MJy/ster @ MIR 10 microns)	3.9	1.59	Average of Non-Grey Only Case (12-16-13 AWG) and Worst Case R4 Estimate from TRACEPRO
Straylight (MJy/ster @ MIR 20 microns)	200	386	Average of Non-Grey Only Case (12-16-13 AWG) and Worst Case R4 Estimate From TRACEPRO
OTE Transimission* Ap m^2	22	22.219	2013 03 20 Transmission X Budget - RevE.xlsx predictions at 2 microns min margin wavelength
Image Quality Parameters			
Strehl (NIR 2 microns)	0.80	0.836	Strehl at λ = 2.0 µm From SLR
Strehl (MIR 5.6 microns)	0.80	0.936	Strehl at λ = 5.6 µm from SLR
NIRCam ChannelWavefront Error (nm)	150	125	Rev W (v2.1 (2) WFE Budget
NIRSpec Channel Wavefont Error (nm)	238	218	Rev W (v2.1 (2) WFE Budget
NIRISS Channel Wavefront Error (nm)	180	135	Rev W (v2.1 (2) WFE Budget
MIRI Channel Wavefront Error (nm)	421	224	Rev W (v2.1 (2) WFE Budget
EE Stability at 2 microns Over 24 hours	2.30%	0.81%	From SLR
EE Stability at 2 microns Over 14 days	3.00%	1.95%	From SLR
Image Motion rms for 15 sec Slidinging Window for NIRCam (mas)	6.6	5.3	From SLR
Operations Parameters			
Observing Efficiency	70%	77.0%	From "Observation Efficiency Allocations Report JWST-RPT-004166, Revision F"
Slew Time for 90 Degree Slew with 5 RWAs (min)	60.0	57.3	Prediction as cited in Pointing Budget D36177 RevH Para 5.1
Momentum Accumulation LV1 (Nms/d)	22	18.10	Updated on 8-1-2013 (13-JWST-207D) from Torque Tables for SC Bus IM Cycle (Nom+rss)*MUF
Momentum Accumulation LV4 (Nms/d)	23	18.50	Updated on 8-1-2013 (13-JWST-207D) from Torque Tables for SC Bus IM Cycle (Nom+rss)*MUF
Thermal Parameters			
Cryo Parastic Margin (NIRCam)	60%	69.1%	Predicts with Liens and Accepted Opportunities per 2014.04.07_Obs_v5.3h2_0R_P5P_v61.xlsx
Cryo ParasiticMargin (NIRSpec FPA)	60%	65.3%	Predicts with Liens and Accepted Opportunities per 2014.04.07_Obs_v5.3h2_0R_P5P_v61.xlsx
Cryo Parasitic Margin (FGS/NIRISS)	60%	58.9%	Predicts with Liens and Accepted Opportunities per 2014.04.07_Obs_v5.3h2_0R_P5P_v61.xlsx
ISIM Cavtity Temperature (K)	41K (TBR)	43.2	Area Average with Liens and Accepted Opportunities per 2014.04.07_Obs_v5.3h2_0R_P5P_v61.xlsx
Cryo-Cooler Line Load Margin (Pinch Point / Steady State)	83%	64%/69%	Cryo-Cooler Predicts from K. Banks and S. Thomson Feb 2014
Cryo-Cooler OM Load Margin (Pinch Point / Steady State)	83%	157%/69%	Cryo-Cooler Predicts from K. Banks and S. Thomson Feb 2014
Data and Link Parameters			
S-Band Uplink Margin (dB)	3.00	5.80	Adverse Margin From 2013.11.01 S-Band Link (SC CDR) .pdf (SC Omni at 2000 bps)
S-Band Downlink Margin (dB)	3.00	3.90	Adverse Margin From 2013.11.01 S-Band Link (SC CDR) .pdf (Both Omni's at L2 at 200 bps)
Ka-Band Downlink Margin (dB)	3.00	4.44	Adverse Margin From 2013.10.31 Ka-band Link (SC CDR).pdf (28 Mbps)
Observatory Resources			
Observatory Wet Mass (kg)	6620	6055	Estimate with Pendings From 6-12-14 Mass Report
Observatory CG Offset (mm)	Area in DCI	20.6	CG uncertainty ellipse to 5 mm margin Ariane Static Unbalance Domain with Pendings (6-12-14)
Observatory Power Load (W)	1808	1510	Estimate + Pendings, 6-12-14 Power Report vs SA at 6 years
Observatory Power Generation (W)		2055	Power Generation at 6 Years, 6-12-14 Power Report
I&T Parameters			
JSC Timeline (Days)	120	88	Partners Workshop Presentation 2-11

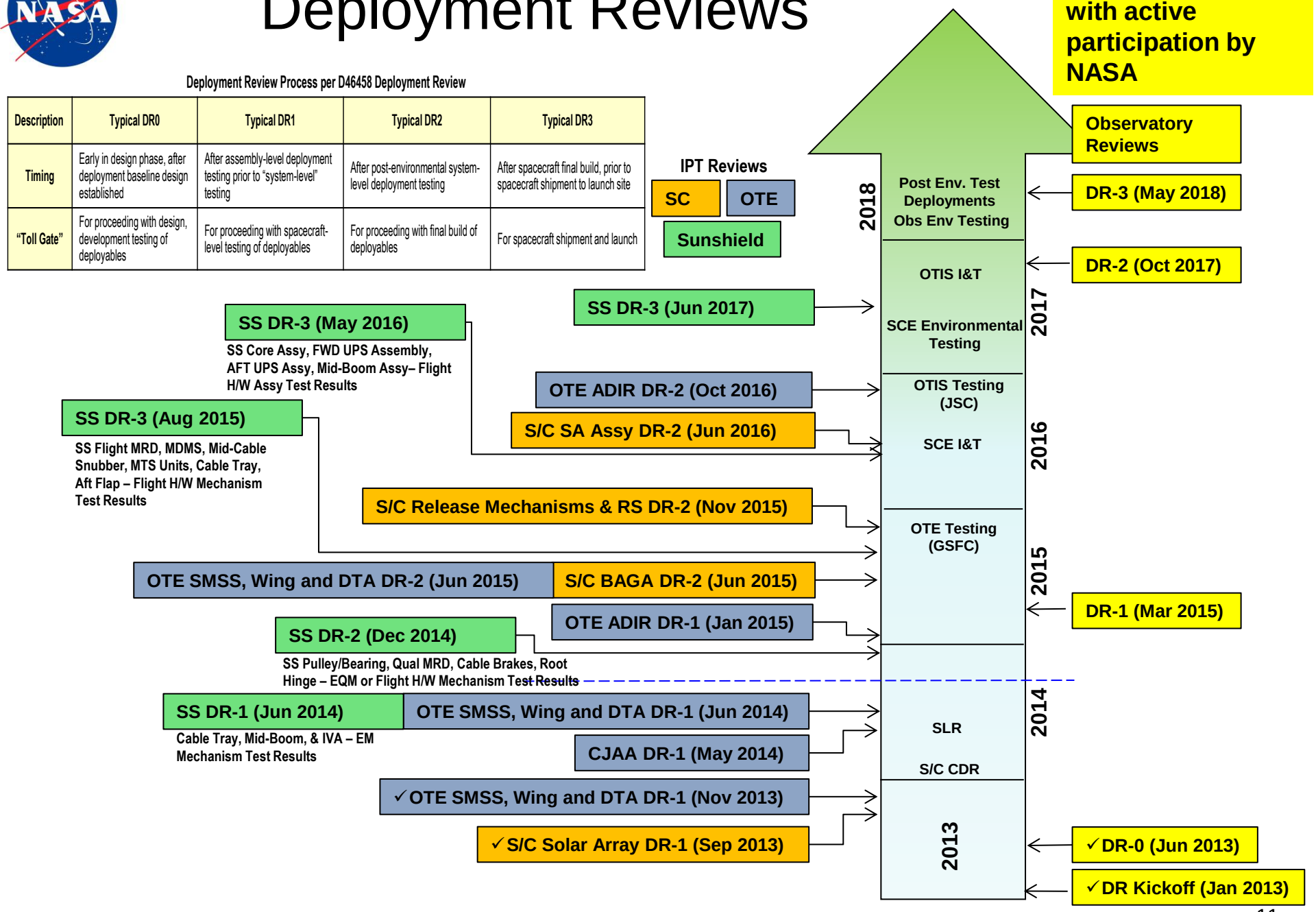
2-3 micron micro stray light is in spec, but small margin, maintained yellow for caution. 20 micro stray light is red, but not Level 1; modelling continues, likely Level 2 requirements change. Recent 5-template test results on edge alignment might reduce layer 5 temperature.

Deployment Reviews

NGAS process, with active participation by NASA

Deployment Review Process per D46458 Deployment Review

Description	Typical DR0	Typical DR1	Typical DR2	Typical DR3
Timing	Early in design phase, after deployment baseline design established	After assembly-level deployment testing prior to "system-level" testing	After post-environmental system-level deployment testing	After spacecraft final build, prior to spacecraft shipment to launch site
"Toll Gate"	For proceeding with design, development testing of deployables	For proceeding with spacecraft-level testing of deployables	For proceeding with final build of deployables	For spacecraft shipment and launch



Observatory Deployment Design

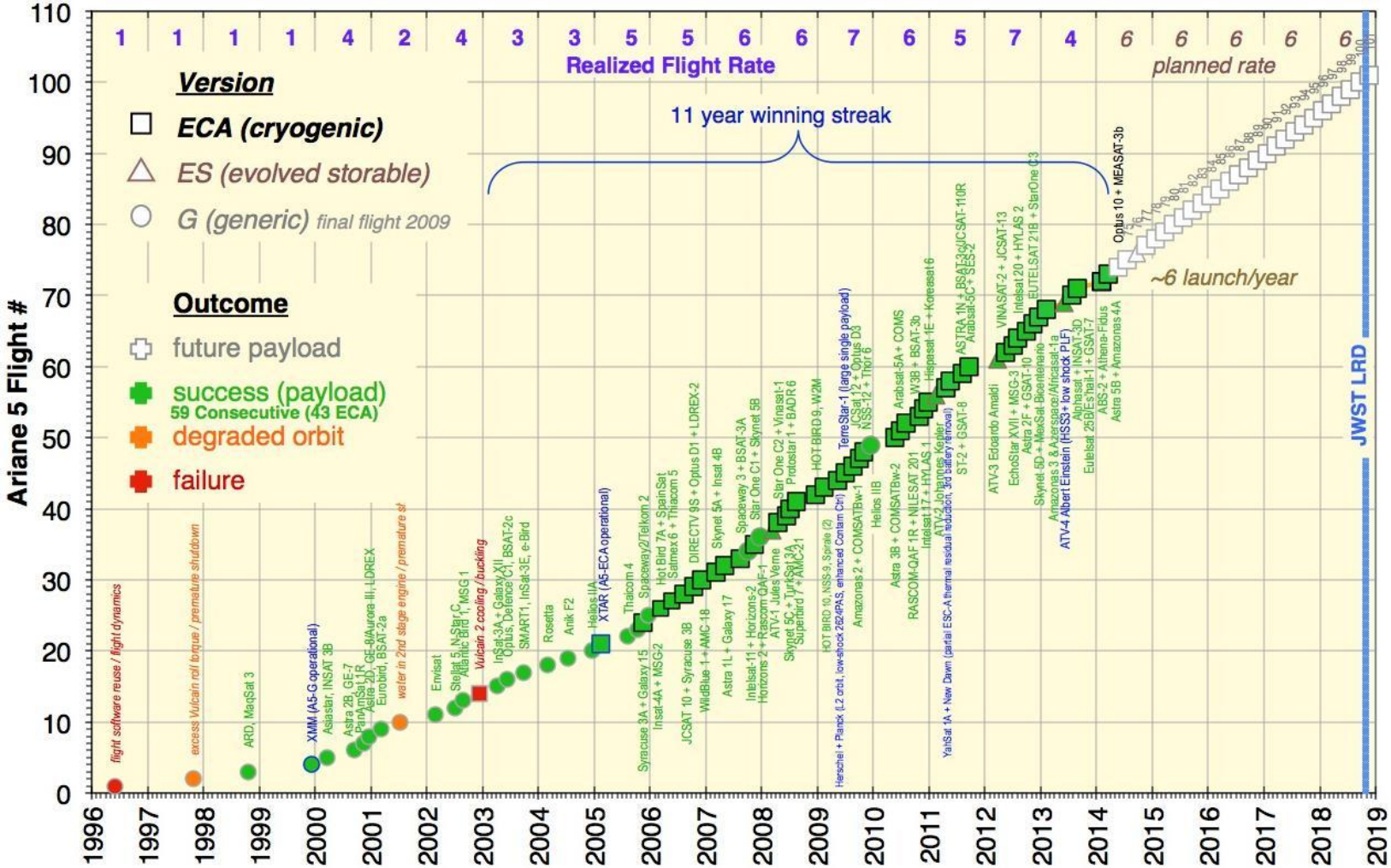
	LV	Spacecraft							Sunshield										OTE								
	Launch Vehicle	Solar Array	STA (Upper/Lower LL & Radiator)	Gimbaled Antenna Assy	Cryocooler Support	DRSA -- Vertical	Bus-to-OTE	Bus-to-IEC	Pre-UPS Deploy Release of MRDs	Fwd & Aft UPS	Mid-Spreader Bars to OTE	Membrane Covers	Mid-Boom Assembly	DRSA -- Horizontal	Core Covers	Rim	Cable Brakes	Trim Flap	ADIR	DTA/Harness Tray	+V3 LRM/IEC	SMSS	Bat Wings	Bib	Frill Flap	PMBA Wings	CJAA
Function																											
Release	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√				√	√
Deploy		√		√		√				√		√	√	√	√	√			√	√		√	√	√	√	√	
# of NEAs	--	4	3	1	3	4	4	2	23	4	2	86	6	4	4	7	4	1	4	1	1	3	--	--	--	8	1
Total # of NEAs		21							141										17								1
Mechanism Type	S	S	R	M	R	S	R	R	R	M	R	S	M	M	S	S	R	S	S	M	R	M	PD	PD	PD	M	R
Release Controller (Ord)	LV	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	TAU	N/A	N/A	N/A	TAU	TAU
Motor Controller				DEU									DEU	DEU						ADU		DEU				DEU	
Telemetry																											
IRU	S	S								S			S	S				S	S	S		S				S	
Microswitch	I	I	I	I	I	I				C					C	C		I	C								★
Resolver				P					P	P			P	P						P		P				P	
Motor Torque									S	S	I		S	S			I										
Reed Switches												C															
Bus Current		S																									
Temp Sensors		S				S								S							S		S	S	S		
Stray Light																							S	S			
Strain Guage																				C							
Flexure (1st Motion)							I	I												S							
Breakwire	C																										

M = Motor
R = Release Only
S = Spring
PD = Passive Deployment
I = Initiation C = Completi
P= Position S = Secondary Telemetry Indicator
★ Deviation ADR-D081

Ariane V Launch History

- Next launch on A5–ECA:
  - Optus 10 & MEASAT-3b (5/14 launch postponed): added SC verifications

JWST uses the ECA variant (square symbols).

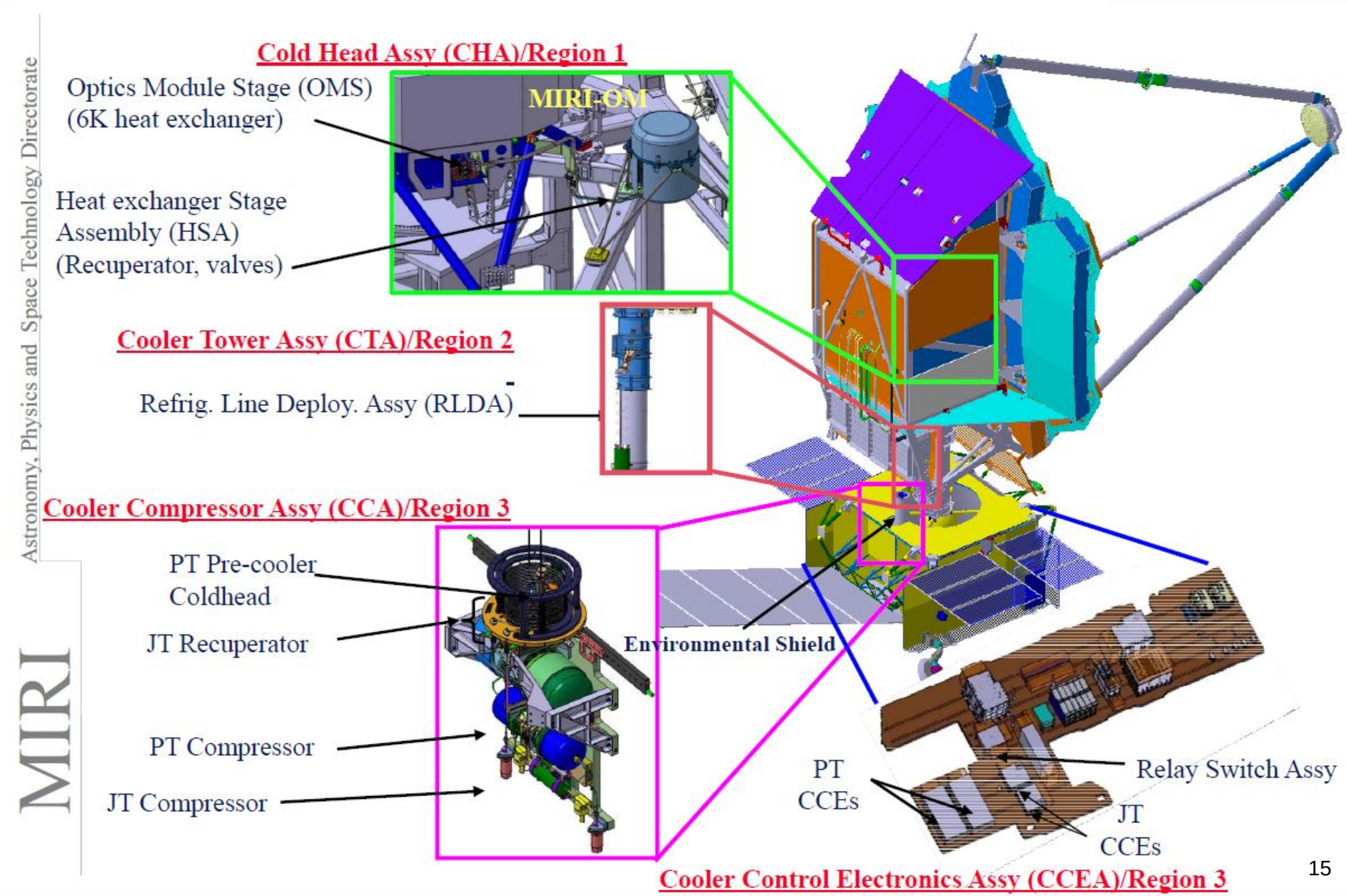


Current Technical Issues

Cryocooler

Spacecraft Subsystems

Cryocooler Hardware on JWST

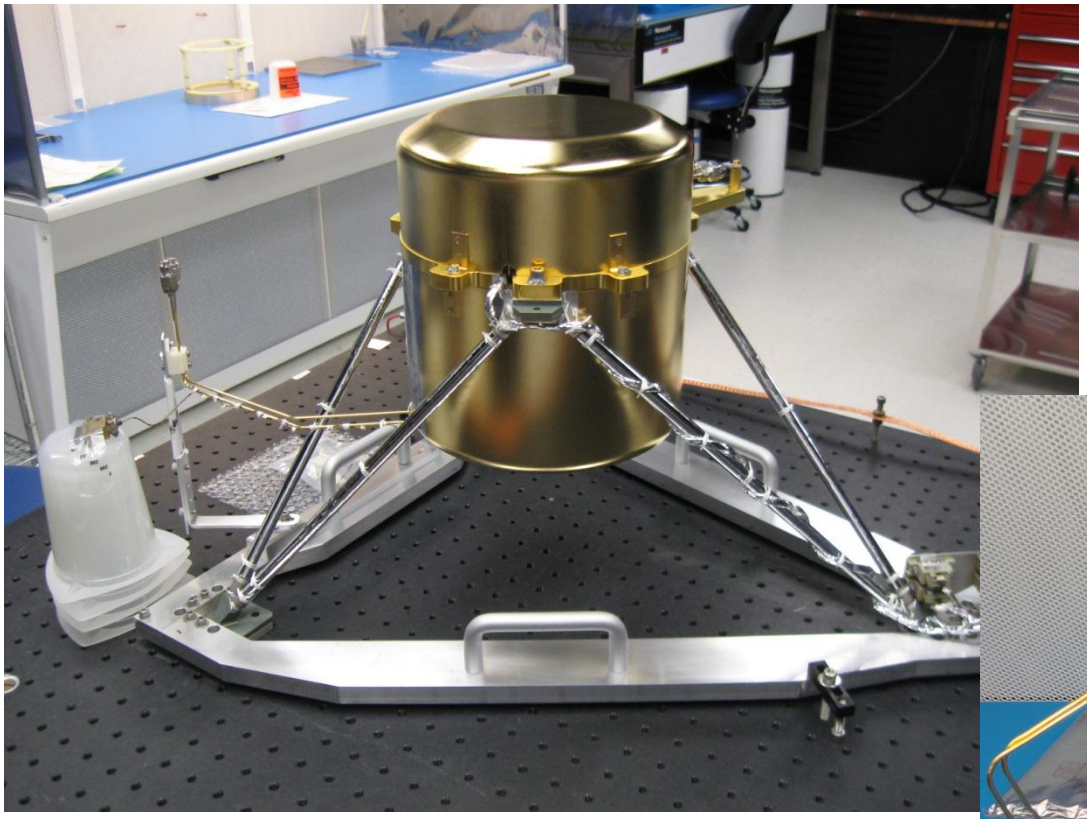


Cryocooler Summary

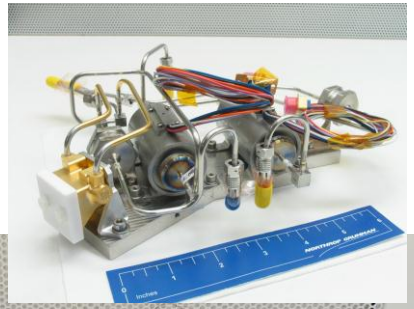
- Cryocooler design risk is essentially retired
  - Verification Model (prototype stage 2/3 precooler) works and slightly exceeds derived heat lift requirements, flight Cryocooler Compressor Assembly (CCA) in manufacture
  - Flight electronics work, albeit with minor issues that are being addressed prior to acceptance testing
  - Cryo-Valves understood and issue resolved, HSA harness fixes implemented, flight unit for ISIM (Flight Model 2: FM2) and spare unit for CCA+CCE acceptance testing (FM1) are finishing-up
- Many more manufacturing issues at vendor than anyone anticipated, or should be expected. Serious drain on funding reserves and a serious threat to Spacecraft I&T schedule
  - Remediation in-process

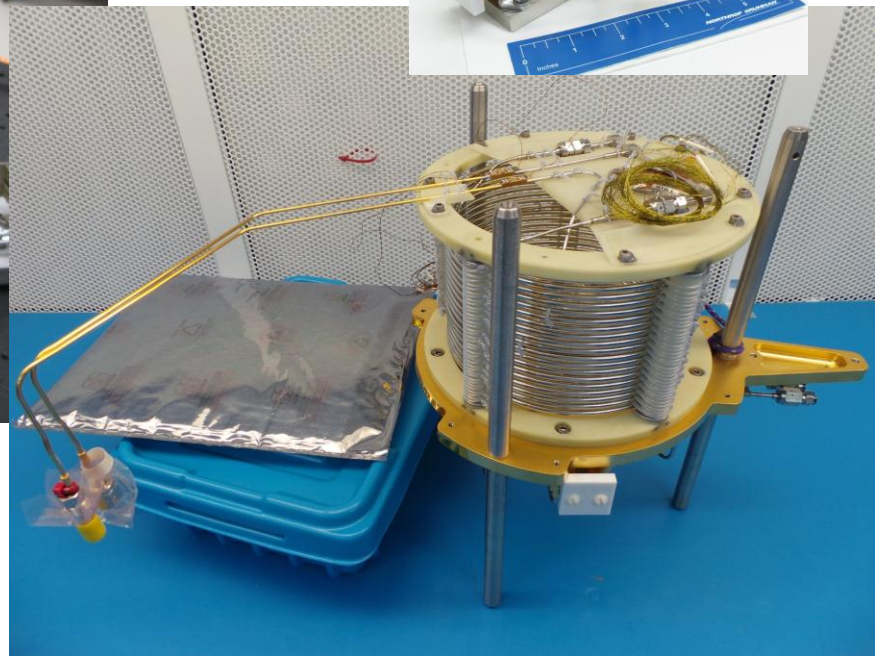
Cold Head Assembly

FM1 HSA (to JPL for testing w/ CCA+CCEA)

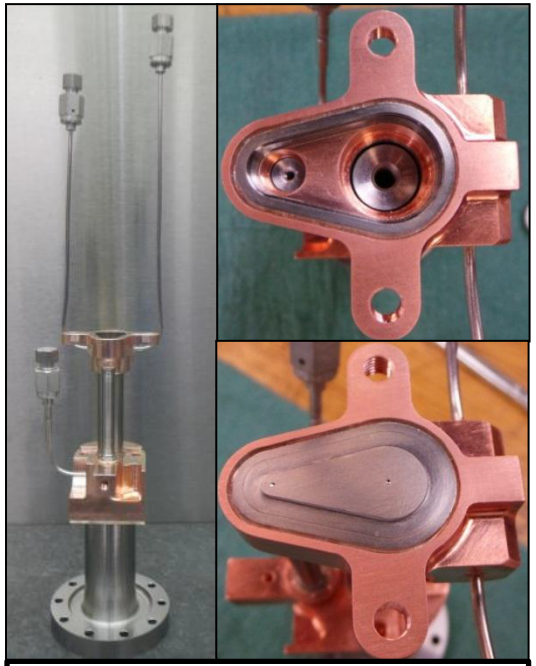


FM2 HSA (to ISIM for CV3 and flight)

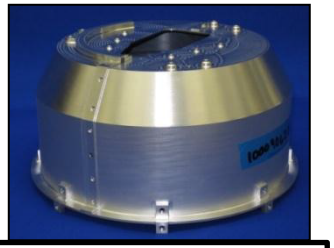




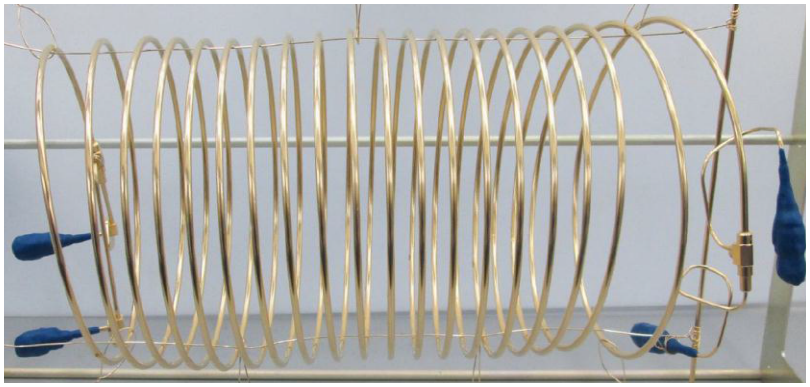
Cryocooler Compressor Assembly



Flight 2nd/3rd Stage Coldhead 460046-31

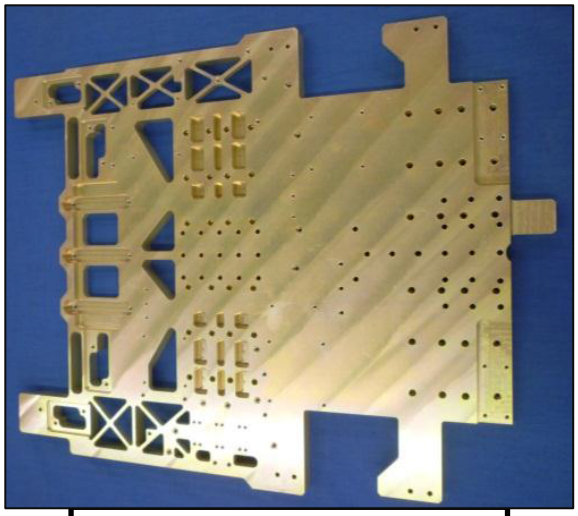


460155-1/-2 Split Bucket

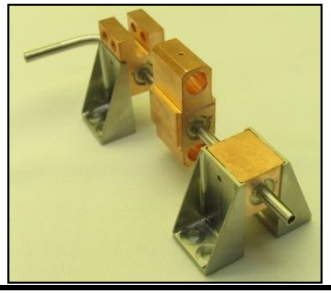


Gold Plated CCA Recuperator460073-21

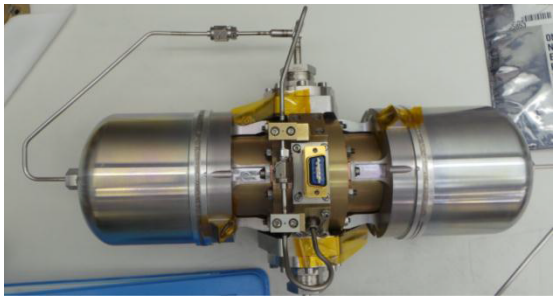
Both PT Compressor's 460026-11-2000



460023 Thermal Interface Plate



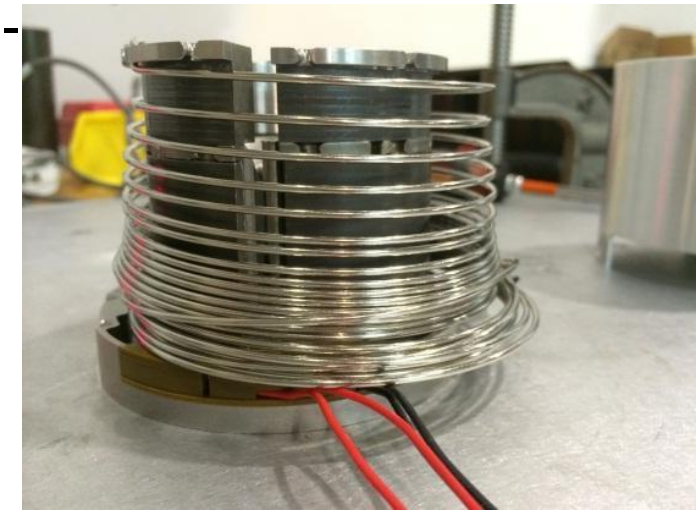
460072-1-EM_BRAZE_QUAL, MFS



JT Compressor 460129-1

3/4 inch NEA Separation Shock Exceedence

- ¾” NEA output shock exceeded requirement
  - Device successfully separates and allows deployment
  - Output shock increase created by premature wire breakage during spool separation
  - Device was redesigned to decrease wire stress and has been successfully tested
  - Will modify one-piece spool design and processing to reduce workmanship stresses and pay special attention to workmanship during spool build-



Post Firing Restraint Wire with new Winding Process

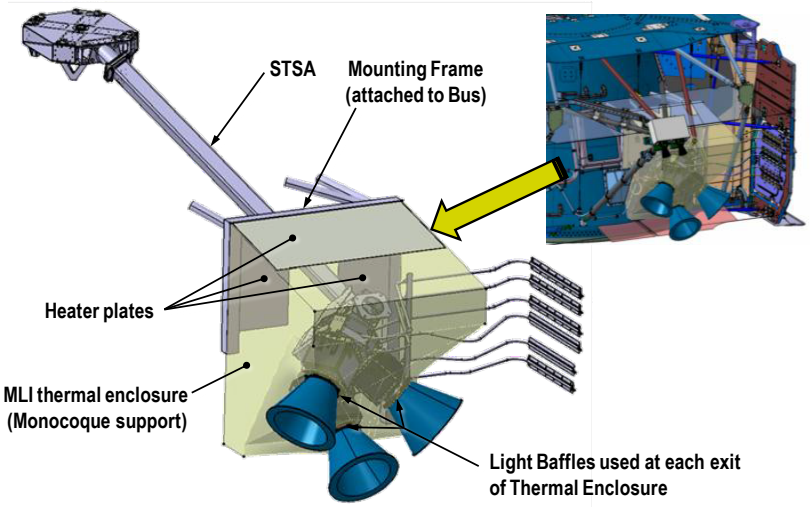
Star Tracker

- ISSUE: GSFC deemed the Star Tracker CDR not successful. There was insufficient objective evidence presented to assure that:
  The mount would meet its fundamental stability and alignment requirements (thermal drifts).
  The test methods were accurate enough to screen composite billets to meet these requirements.
  Additionally there was no evidence presented that indicated a thermal cocoon could be eliminated from the design.

- PROGRESS: System level margins are positive, and it appears there is enough margin to handle anticipated threats at the STSA level.

  - Star Tracker Support Assembly (STSA) will complete delta CDR 8/5-6/2014. MRRs in mid-August
  - Star Tracker Support Enclosure CDR scheduled for 8/22/2014, judged to be low risk by system engineering

Cocoon Concept



Sunshield Unitized Pallet Structure (UPS)

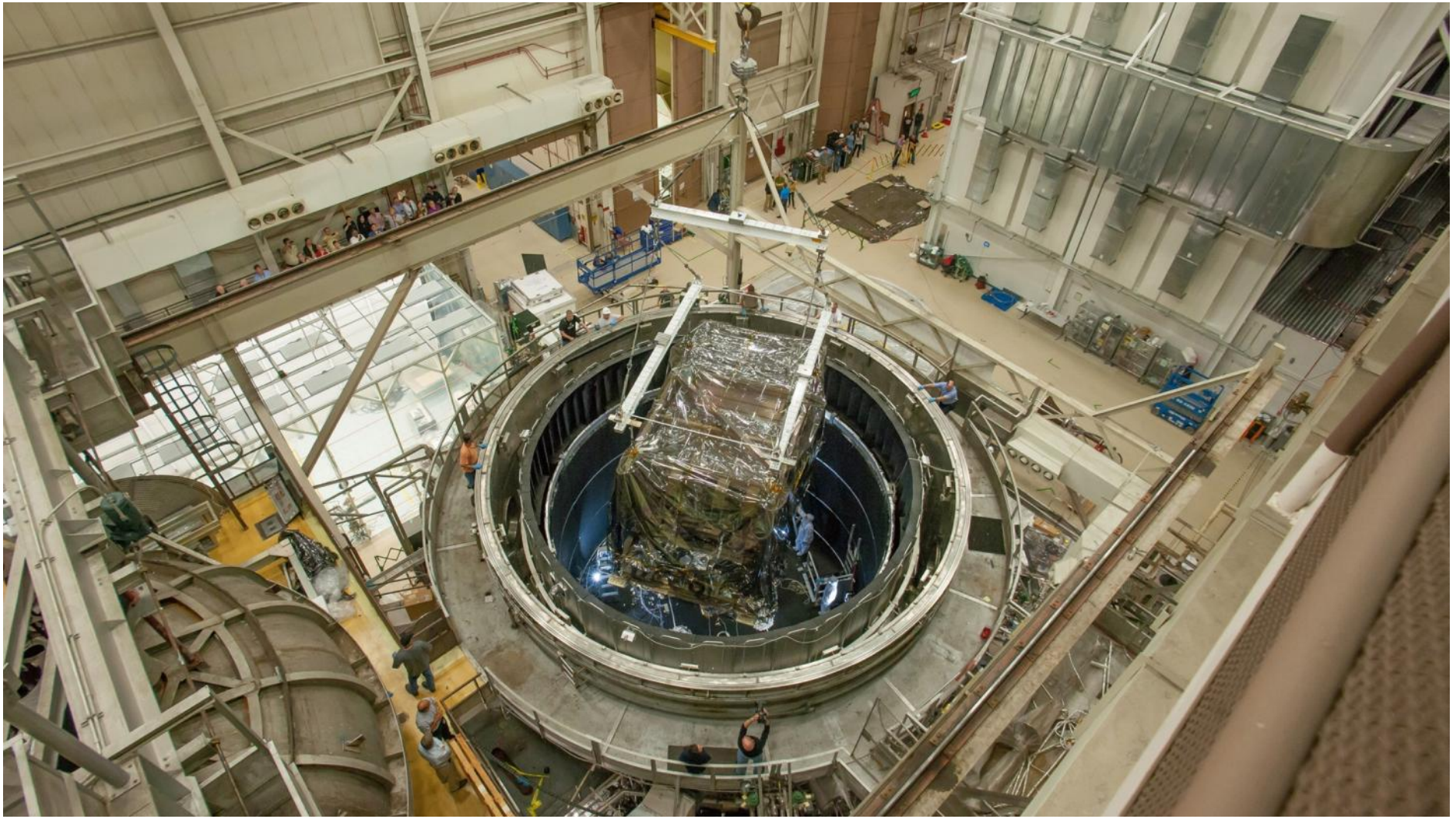
- Strength margins of UPS coupons did not meet requirements
- Root cause determined (moisture penetration into composite structure)
- New manufacturing process developed to address moisture issue
- MRR for new build scheduled for August 8
- Non-flight unit will be used to test subsequent manufacturing and assembly steps (e.g., bonding to structural beams)

UPS

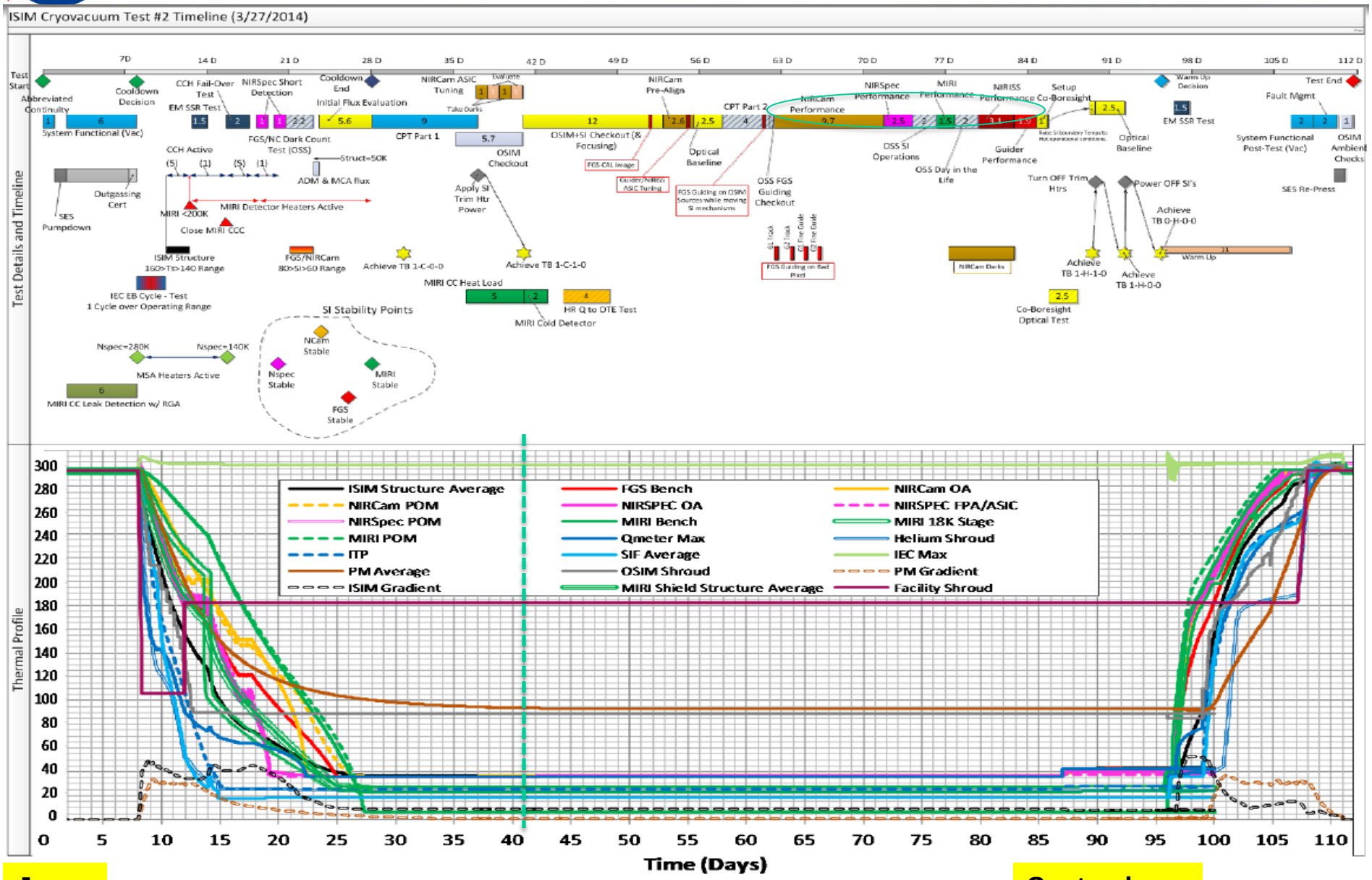
UPS structural beam ready for bonding

RECENT HARDWARE PROGRESS

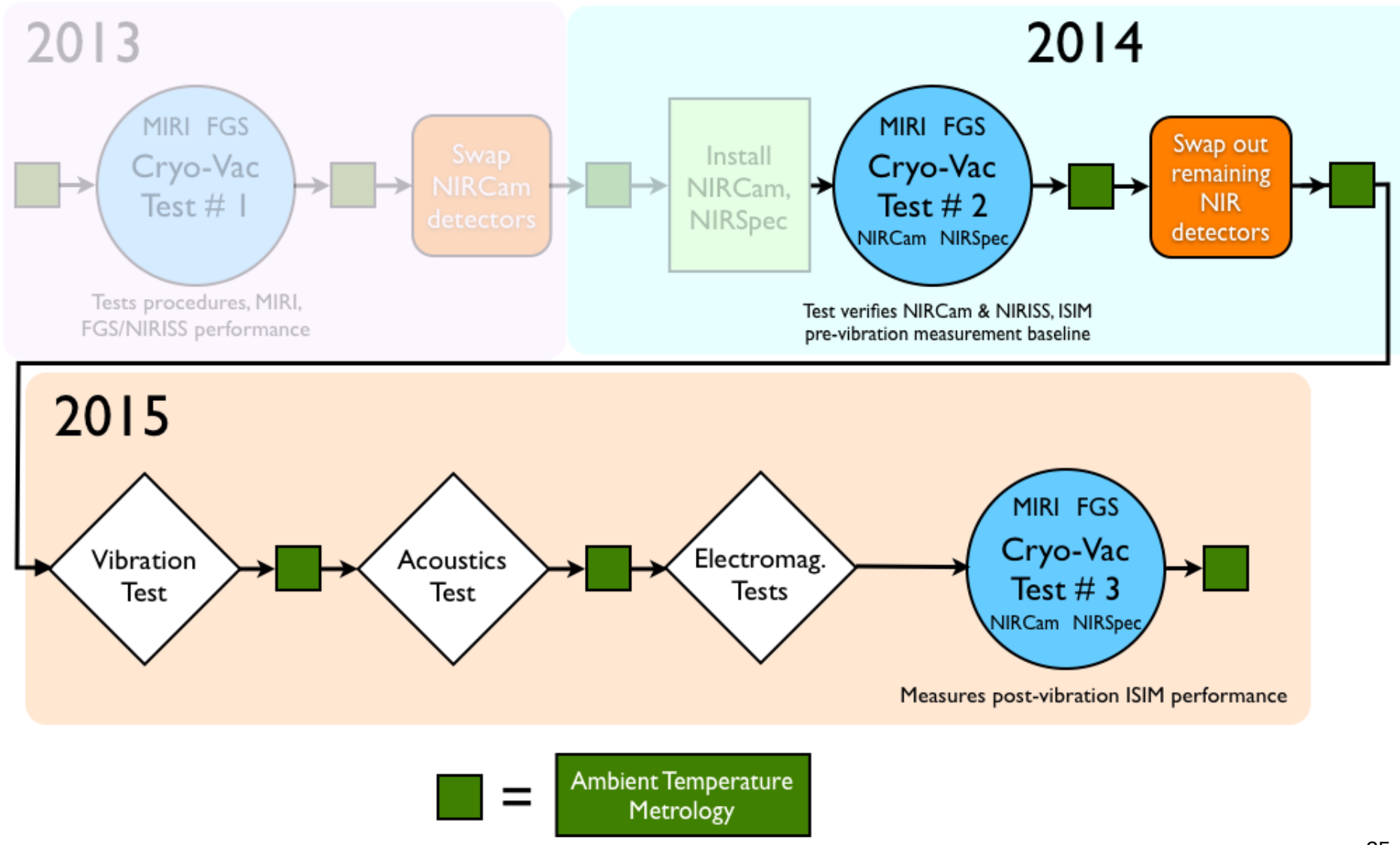
ISIM Heading into the SES Chamber



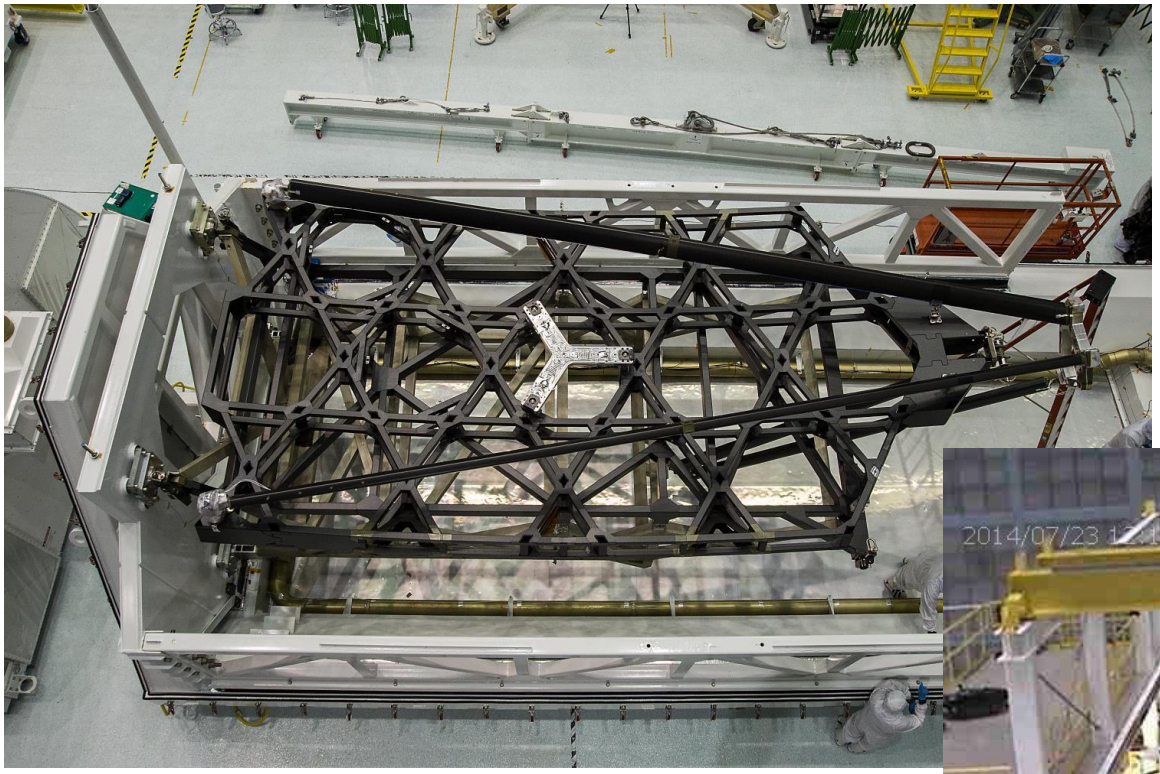
Timeline – CV2



ISIM Integration and Test Flow



Pathfinder (Center Section + SMSS)
NASA GSFC July 18, 2014

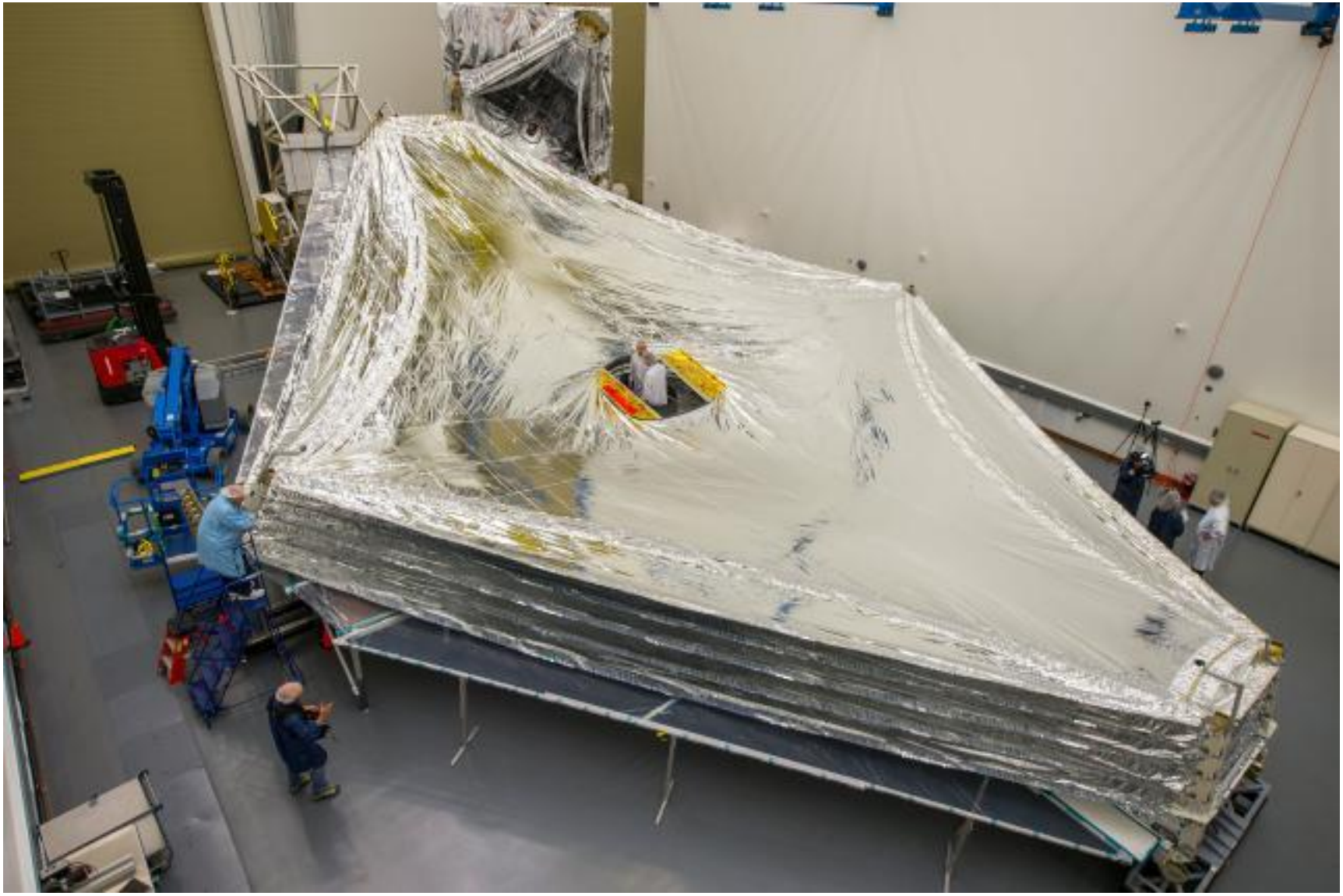


Credit: NASA/C Gunn

Flight Primary Mirror Backplane Support Structure

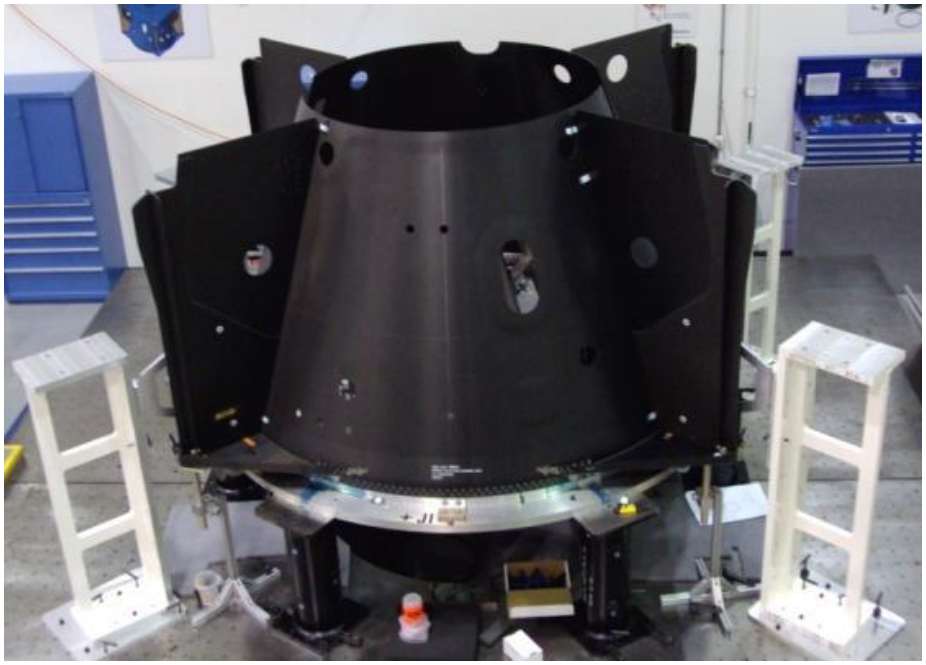
Flight Backplane Suspended from Strong Back in Load Test Fixture at NGAS
(Center Section and Backplane Support Fixture)

Engineering Sunshield Deployment Test

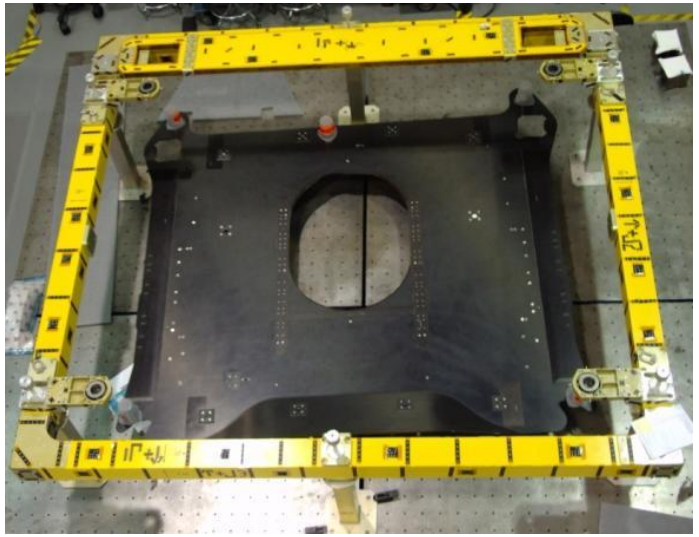


Spacecraft Bus Status

- Spacecraft bus structure coming together (Spacecraft element is ~68% complete) but running over in cost. Overruns have all been accommodated within available project UFE.
- Issues related to manufacturing of composite structures have affected cost and schedule performance.



Cone, spacecraft bottom panel and shear panels

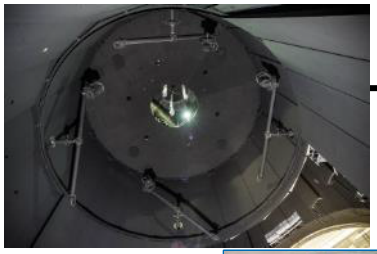


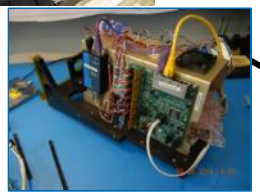
Spacecraft Bus Top panel

OTIS Ground Support Equipment Status

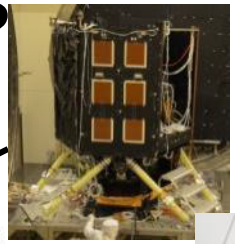
Chamber Isolator Units
Dynamically isolates OTIS Optical Test – Integration of 6 units complete

Cryo Position Metrology (CPM)
Photogrammetry System
Integration Complete





ADM - new Leica delivered and under test



Center of Curvature Optical Assembly (COCOA)
- Multiwavelength interferometer (MWIF), null, calibration equipment, coarse/fine PM phasing tools, Displacement Measuring Interferometer – Moved to JSC

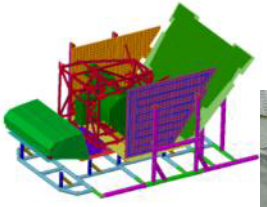
USF Structural Frame – supports Metrology
In bakeout

3 Auto collimating Flat Mirrors (ACFs)
1.5 M Plano for Pass and Half Testing
ACF 1 complete, ACF 4 through second ion cycle, ACF 5 starting Cryo test.

AOS Source Plate
Sources for Pass and Half Test
72 optical fiber support cont.

Space Vehicle Thermal Simulator (SVTS) and Sunshield Simulator
Passed design review and started Procurements and fab subcontratcs

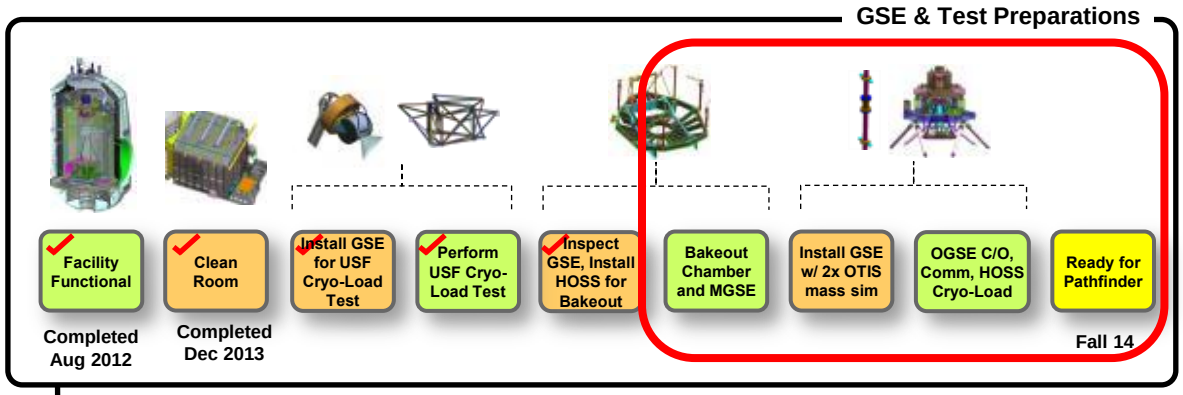
HOSS – OTIS support structure
Installed in chamber for bakeout



Deep Space Edge Radiation Sink (DSERS)
Frame installed in chamber for bakeout

Mag Damper Cryo Test Article
Delivered

OTIS Process Flow

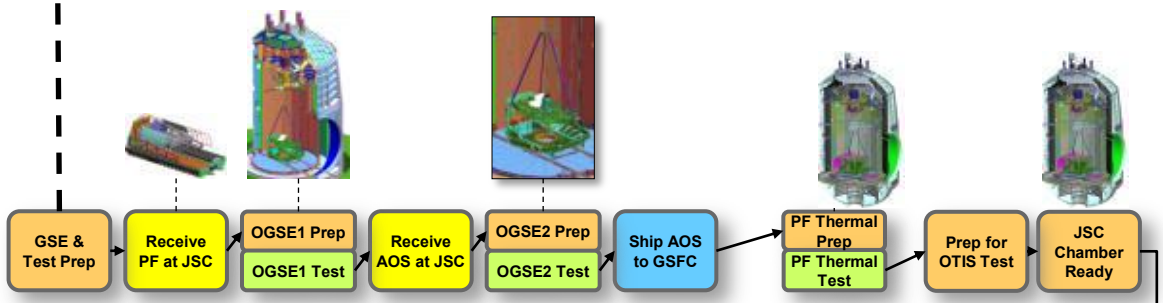


Acronyms

AOS	Aft-Optics Subsystem
GSE	Ground Support Equipment
MGSE	Mechanical Ground Support Equipment
NGAS	Northrop Grumman Aerospace Systems
OGSE	Optical Ground Support Equipment
PF	Pathfinder

Legend

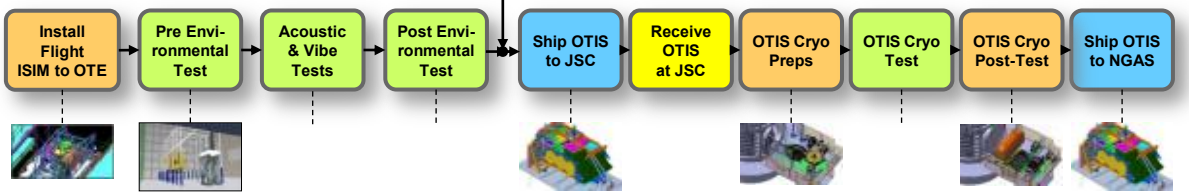
Prep & Transport | Functional / Test | Assembly / Integration | Delivery



Risk Reduction Activities

Fall 14 ——— Fall 17

Flight OTIS I&T



Yearly Themes

- ✓ 2013: Instrument Integration: The Science instruments will be finished and begin their testing as an integrated science payload
- ✓ **2014: Manufacturing the Spacecraft: Construction will commence on the spacecraft that will carry the science instruments and the telescope**
- ✓ 2015: Assembling the Mirror: The mirror segments, secondary mirror and aft optics will all be assembled into the telescope
- ✓ 2016: Observatory Assembly: The three main components of the observatory will be completed (instruments, telescope, spacecraft)
- ✓ 2017: Observatory Testing: The three main components of the observatory will be tested and readied for assembly (instruments, telescope, spacecraft) into a single unit
- ✓ 2018: Kourou Countdown: All parts of the observatory will be brought together, tested and readied for launch in Kourou, French Guiana

Summary

Challenges arising in critical manufacturing and I&T phases.

- UFE tight in FY15, (but good performance with similar entry percentages for FY14 show it can be managed)
- MIRI Cryocooler Compressor Assembly cost and schedule performance still subpar
- ISIM team in their most challenging portion of the program.

JWST team continues to execute to the Launch Readiness Date commitments within budget.