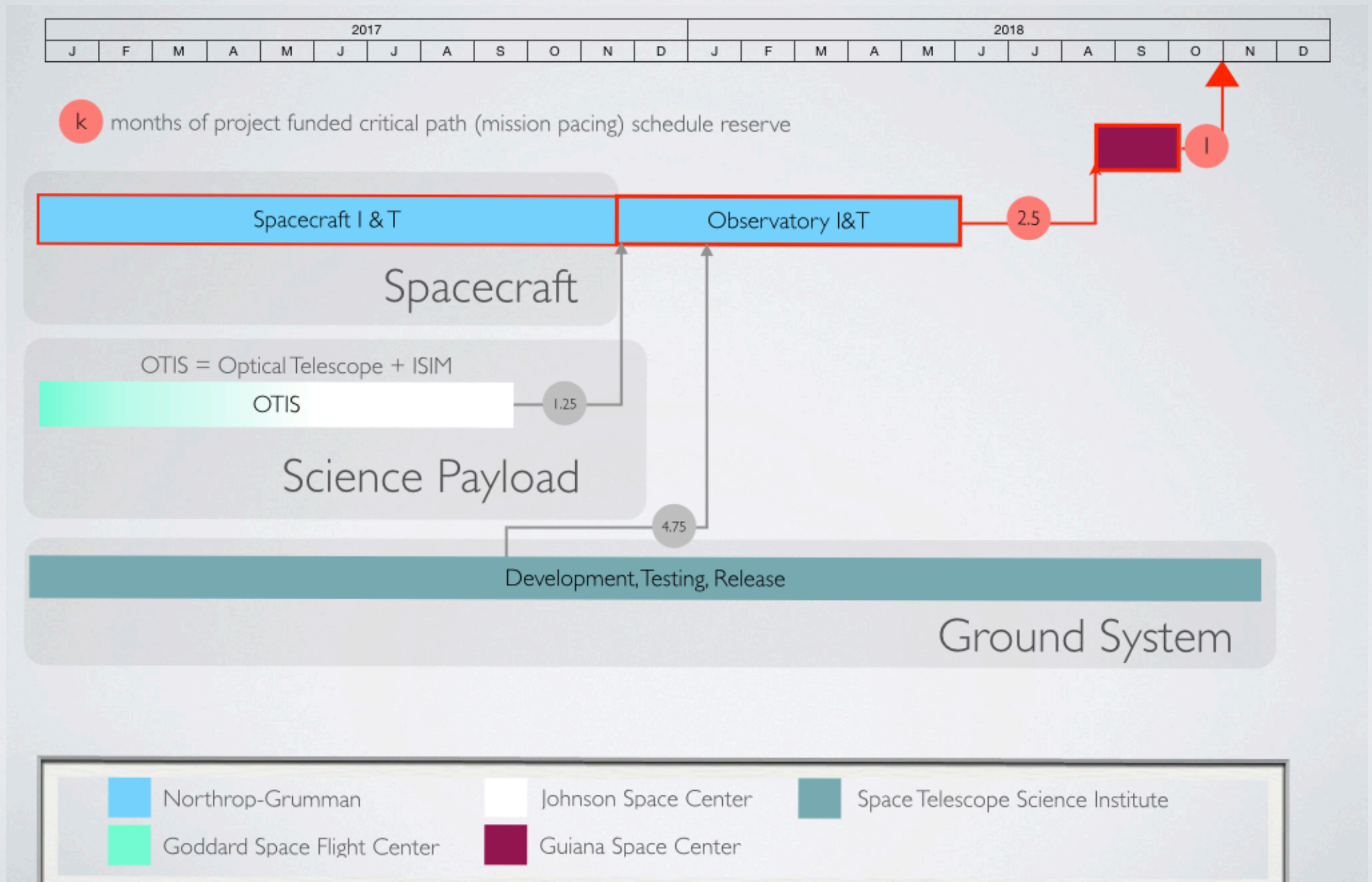


July 19, 2017

Eric P. Smith

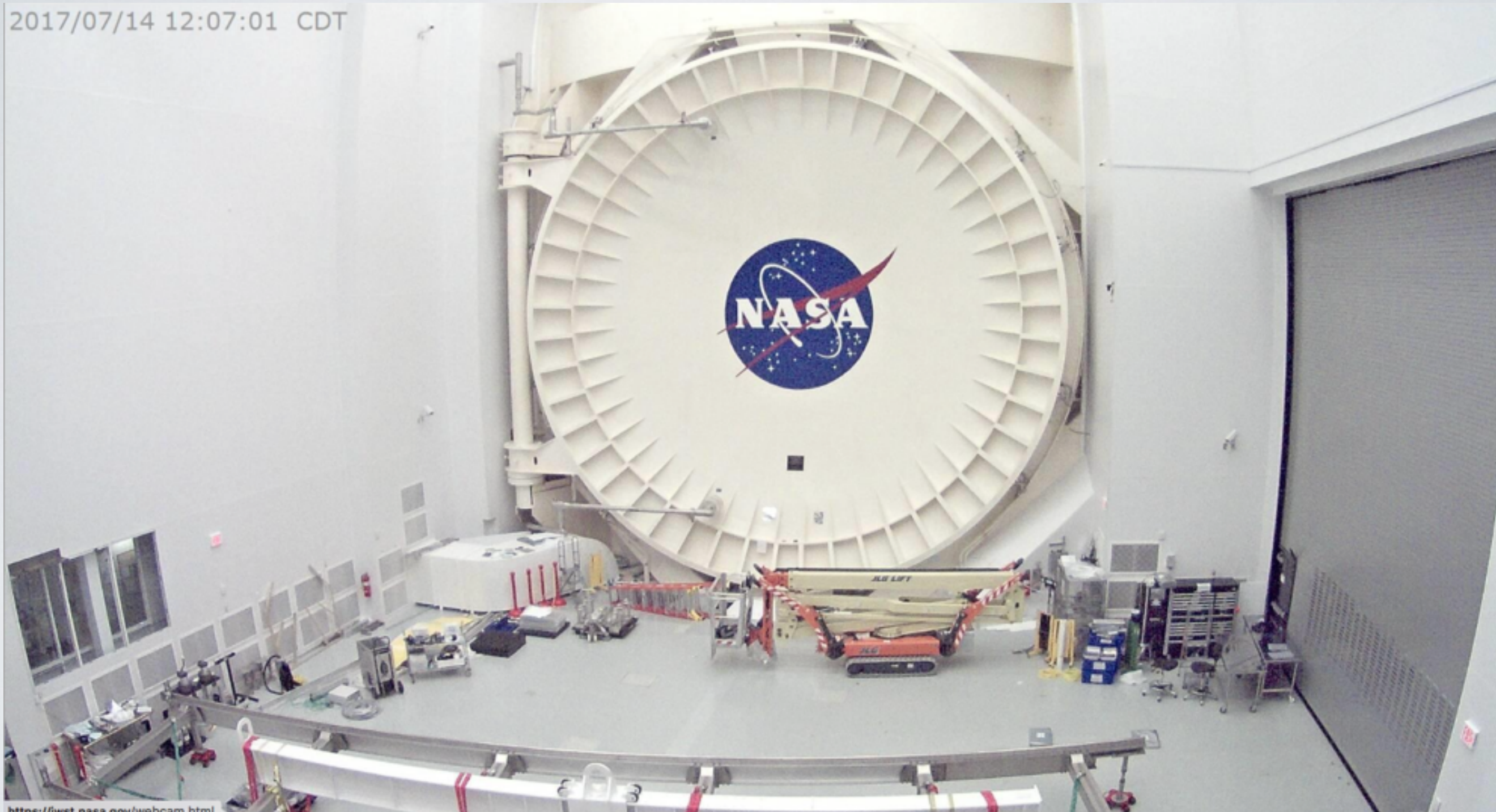
JWST Program Director/Program Scientist

SIMPLIFIED SCHEDULE



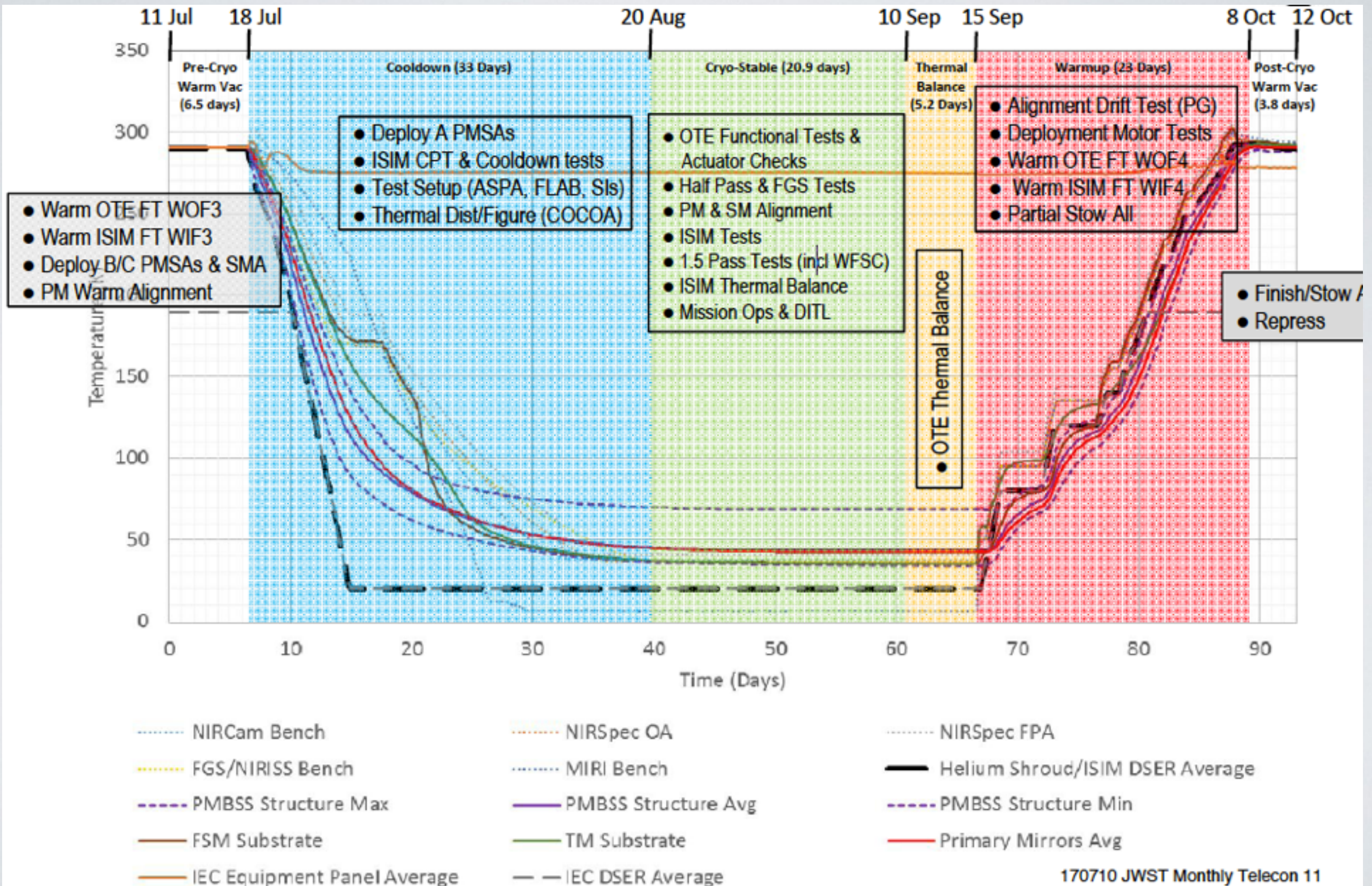
OTIS

2017/07/14 12:07:01 CDT

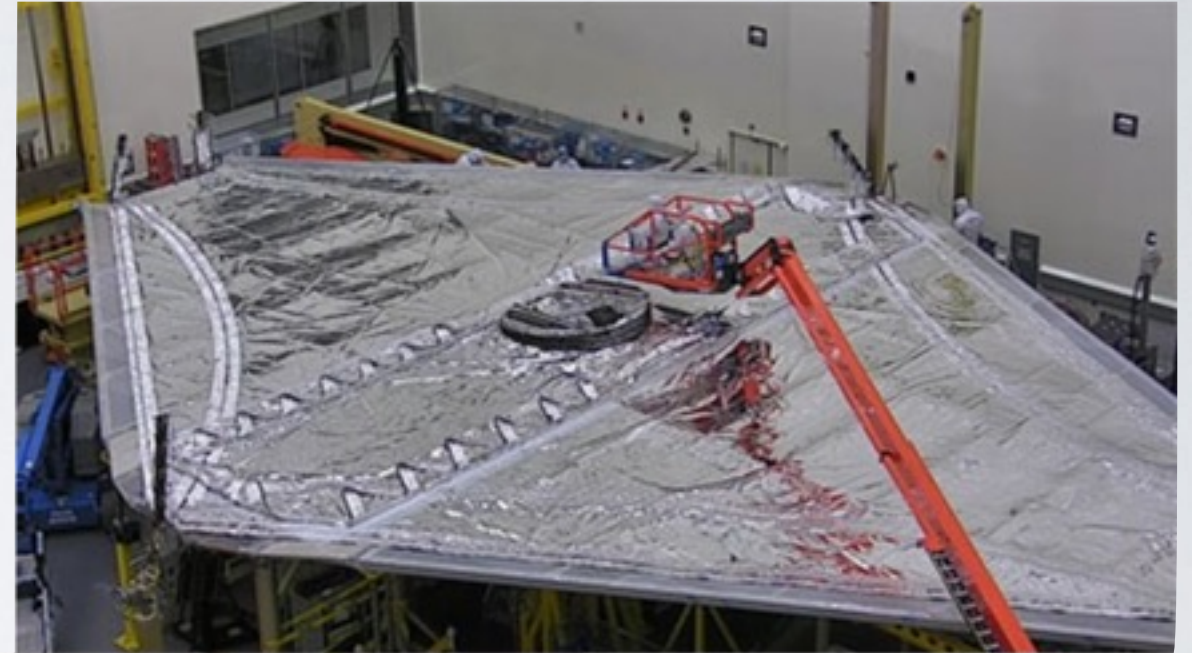
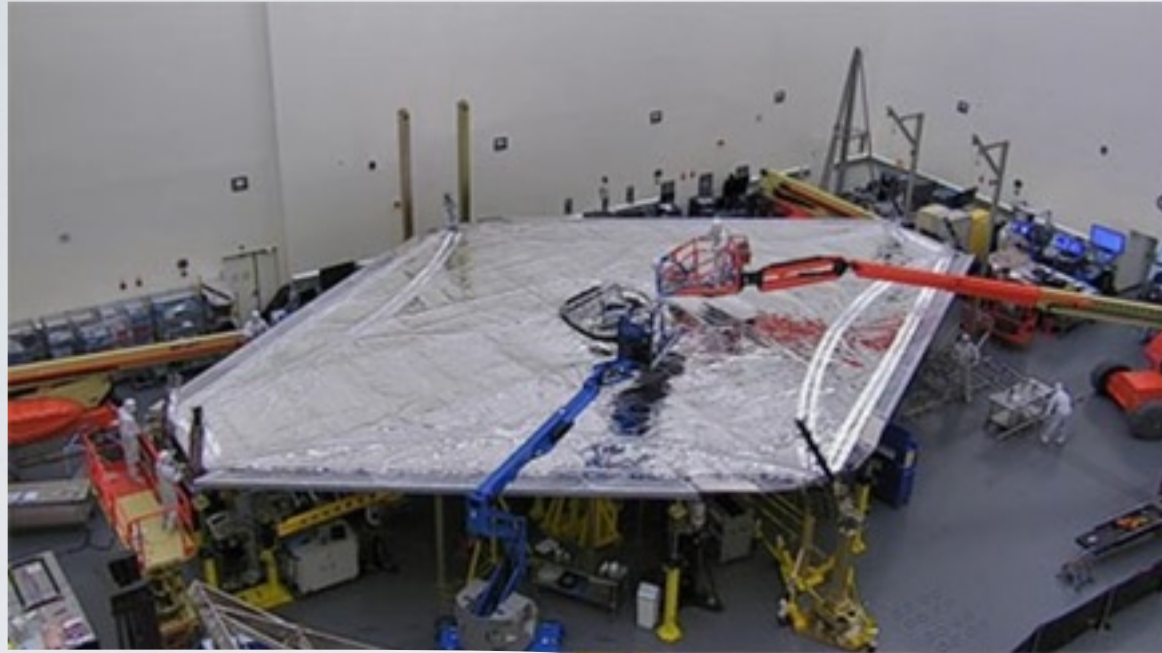


<https://www.nasa.gov/wahnam.html>

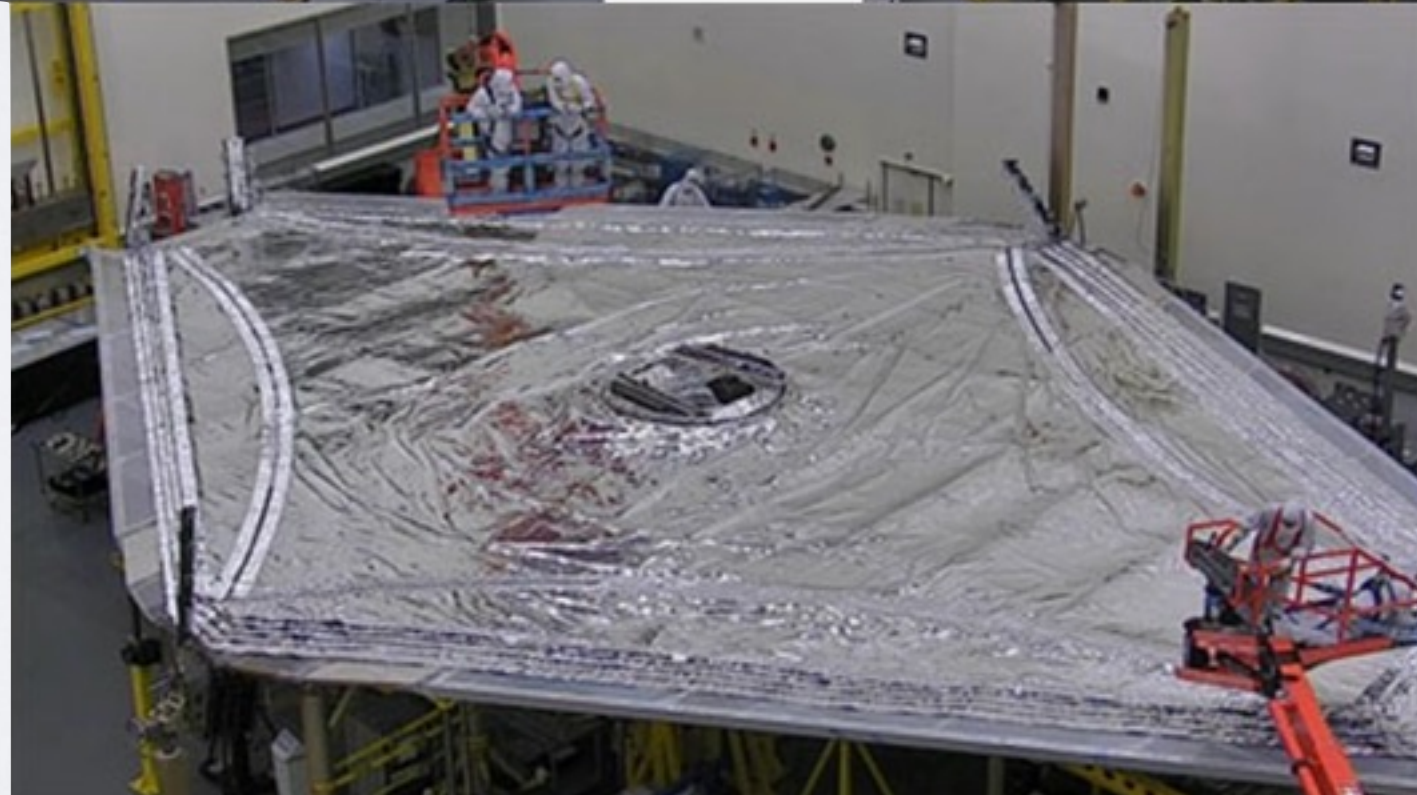
OTIS TEST TIMELINE



SPACECRAFT ELEMENT



- Spacecraft and sunshield membrane integration complete
- All elements of sunshield delivered



HQ WATCH LIST

- FY 17 budget reserves
 - FY17 is a year of significant integration and test activities, where UFE likely to be needed to address any issues that arise
 - NGAS workforce remains high, now beginning to decrease
- 3.5 months funded critical path schedule reserve
 - No critical path reserved used in the past month
 - Critical path goes through spacecraft element
 - Current and potential additional schedule liens on spacecraft element might require use of critical path reserve.
- Propulsion subsystem - Leaks in thrusters, under review, will require replacement
- OTIS 18 Hz mode – Design, manufacturing, installation of particle dampers on aft optics assembly after cryovacuum testing
- Schedule risk assessment – Project conducting schedule assessment to support ESA decision on launch sequence in Kourou (BepiColombo is targeting Oct 2018 launch).

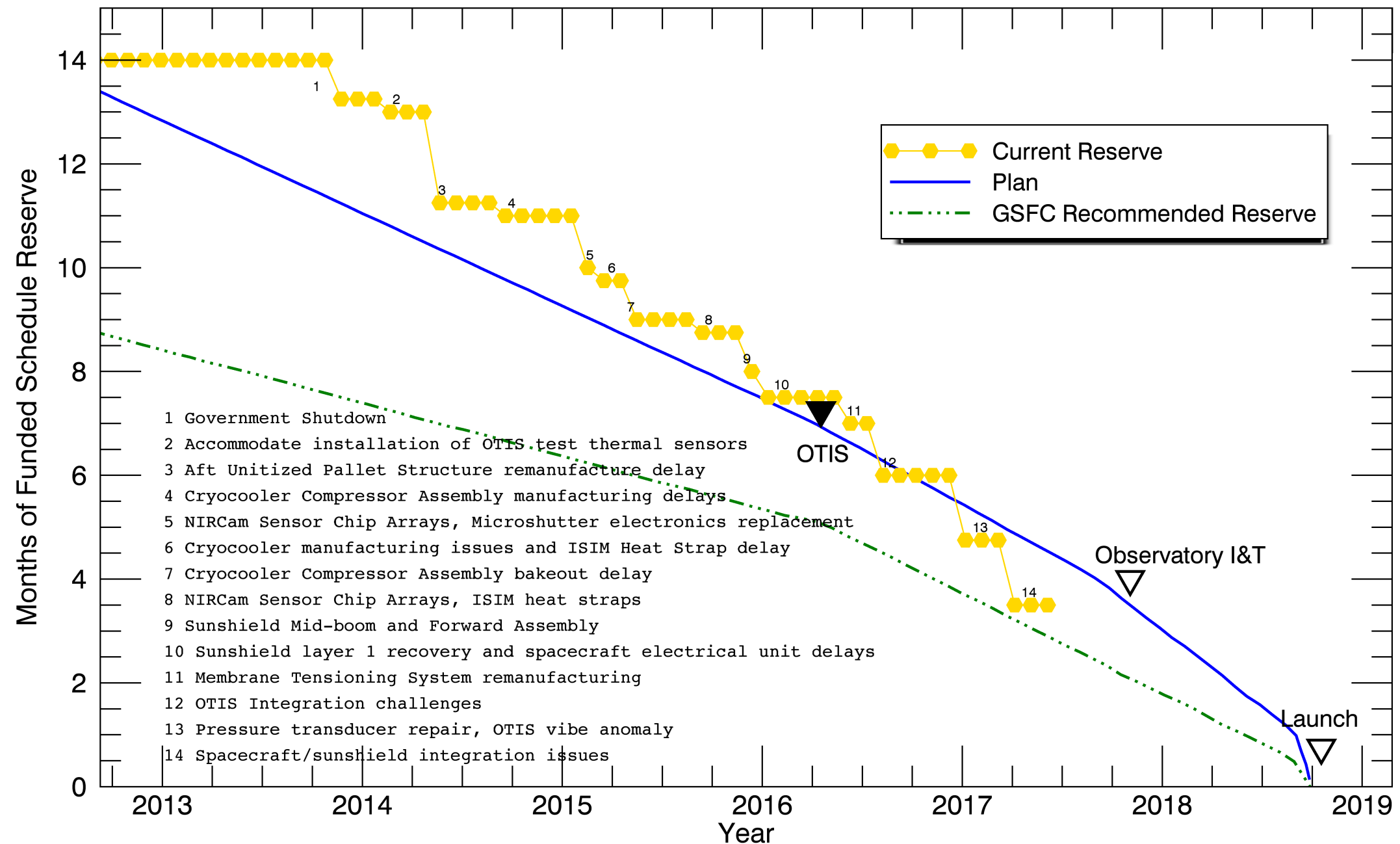
Fiscal Year 2017 JWST HQ Milestones

Month	Milestone	FY2016 Deferral	Comment
Oct-16	1 Complete portable clean room for Telescope and Science Instruments (OTIS)		<u>Completed 10/13/16</u>
	2 Complete final checkout of new shaker tables at Goddard Space Flight Center		• <u>Completed 10/13/16</u>
	3 Begin making electrical connections between spacecraft panels		<u>Completed 10/7/16</u>
	4 Complete Sunshield Mid-Boom Assembly #2 functional test		• <u>Completed 12/5/16</u>
Nov-16	5 Start optical measurements of OTIS prior to vibration and acoustic tests		<u>Completed 10/24/16</u>
	6 Deliver Science and Operations Center release 1		<u>Completed 9/30/16</u>
	7 Perform Cryocooler installation into the spacecraft bus and begin functional testing		<u>Completed 10/29/16</u>
	8 Complete Aft Unitized Pallet Structure assembly		• <u>Completed 10/29/16</u>
	9 Deliver Aft Unitized Pallet Structure to Observatory I&T		• <u>Completed 3/14/17</u>
Dec-16	10 Deliver Forward Sunshield Pallet Structure to Observatory Integration and Test (I&T)		• <u>Completed 3/28/17</u>
	11 Start OTIS vibration and acoustic testing program		<u>Completed 11/19/16</u>
	12 Complete final test of engineering model of telescope center section at Johnson Space Center (JSC)		<u>Completed 10/31/16</u>
	13 Deliver sunshield flight membranes to Observatory I&T		<u>Completed 12/15/16</u>
Jan-17	14 Complete OTIS vibration and acoustics testing		<u>Completed 3/2/17</u>
	15 Deliver observing proposal and planning subsystem software build that supports launch		<u>Completed 1/12/17</u>
	16 Complete electrical testing of the spacecraft at Northrop-Grumman		<u>Completed 3/7/17</u>
Feb-17	17 Complete OTIS optical measurements after vibration and acoustic tests		<u>Completed 3/31/17</u>
	18 Deliver wavefront and control software that supports launch (controls telescope mirror shape)		<u>Completed 1/20/17</u>
	19 Deliver horizontal deployable radiators to Observatory I&T		<u>Completed 7/13/17</u>
Mar-17	20 Deliver OTIS to the Johnson Space Center		<u>Completed 5/7/17</u>
	21 Deliver the pre-launch Flight Operations System software build		<u>Completed 2/17/17</u>
	22 Delivery of sunshield extension boom #2 membrane attachment assembly to Observatory I&T		<u>Completed 4/13/17</u>
Blue font(<u>underline</u>) denotes milestones accomplished ahead of schedule, orange font denotes milestones accomplished late. "*" denotes 2016 milestones carried forward.			

Fiscal Year 2017 JWST HQ Milestones

Month	Milestone	FY2016 Deferral	Comment
Apr-17	23 Conduct first test of the Ground System (communications and data handling)		Completed 6/20/17
	24 Install the deployable horizontal radiators onto the Observatory		Delayed to <u>September</u> due to delay in #19
	25 Conduct the Observatory Deployment Review #2		Completed 6/13/17
May-17	26 Complete room temperature integration of OTIS and test equipment at JSC		Delayed to <u>July</u> for OTIS vibration and other issues
	27 Conduct the Mission Operations Review		<u>Completed 4/7/17</u>
	28 Perform Spacecraft Acoustic Testing		Delayed to <u>September</u> for several factors
Jun-17	29 Start OTIS thermal vacuum test At JSC Chamber A		Delayed to <u>July</u> due to post environmental testing
	30 Deliver Operations Scripts Subsystem software build that supports launch		<u>Completed 3/30/17</u>
	31 Issue final release of call for proposals for Early Release Science Programs		<u>Completed 5/19/17</u>
	32 Begin spacecraft thermal vacuum test		Delayed to <u>November</u> for propellant system re-welding
Jul-17	33 Deliver vibration test results to support the combined analysis of the rocket and the observatory		Delayed to <u>November</u> due to delay in environmental te
	34 Conduct second Flight Operations Team Operational Readiness Exercise		
Aug-17	35 Tension sunshield membranes while they are mounted on the spacecraft		Delayed to <u>January</u> for numerous issues
	36 Deliver final report describing spacecraft influence on observatory optical alignment		Delayed to <u>September</u> for later OTIS test start
Sep-17	37 Complete OTIS thermal vacuum test		Delayed to <u>October</u> due to post environmental testing
	38 Deliver the results of the combined analysis of the rocket and the observatory		
Blue font(<u>underline</u>) denotes milestones accomplished ahead of schedule, orange font denotes milestones accomplished late. "*" denotes 2016 milestones carried forward.			

FUNDED SCHEDULE RESERVE



S&OC SUBSYSTEMS

S&OC & Subsystem Status						
Subsystem	Build	Development completion date	I&T completion date	Status	% of requirements delivered to date	% of requirements verified to date
Data Management Subsystem (DMS)	7*	December 2016	June 2017	In I&T	89%	78%
	7.1	November 2017	February 2018	In Development		
Proposal Planning Subsystem (PPS)	14*	December 2016	June 2017	In I&T	97%	90%
	14.1/14.2	October 2017	January 2018	In Development		
Wavefront Sensing & Control (WFS&C) Software Subsystem	6.1*	November 2017	February 2018	In Development	100%	100%
Flight Operations Subsystem (FOS)	6.1*	August 2017	December 2017	In Development	83%	48%
Operations Scripts Subsystem (OSS)	6*	March 2017	October 2017	In Level 2 certification testing	73% Level 2 certified	58% Level 3 certified
	7*	October 2017	March 2018	In Development		
Project Reference Database Subsystem (PRDS)	4.13*	April 2017	April 2017	Latest Sustaining Engineering release	100%	100%

*Flight Build

SUMMARY

- Program remains within replan budget and on time for October 2018 launch readiness date
- Project is well into integration & test. There are and will be many new, first time challenges associated with this phase
- We are regularly monitoring the schedule of the remaining activities prior to launch, and its assessment will allow NASA and ESA together to discuss and identify the best launch window for Webb

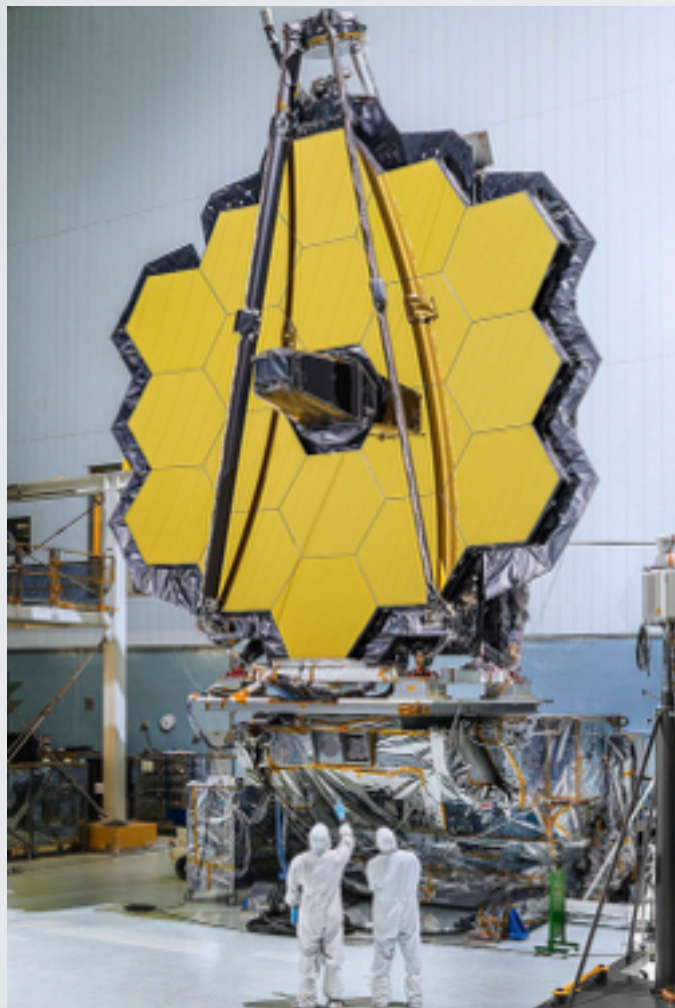


BACKUP

THE JWST TESTING PROGRAM

How do we check that the telescope we design...

will result in this?



+



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WHY WE TEST

- NASA missions push the boundaries of industry and government technical capabilities
 - New technologies need to be verified before launch
 - Extreme environment of space provides a unique challenge for spacecraft and instrument designers
- Testing and Verification serve to demonstrate that our missions will meet their objectives with an acceptable level of risk – no NASA mission is 100% guaranteed
 - More new technology involved = more testing required
 - More extreme the mission environment = more testing required
 - Number of tests increases with time as the agency applies lessons learned from previous missions too (e.g., OTIS test in part from HST legacy)

WEBB HARDWARE VERIFICATION DOMAINS

- Optics – Do the mirrors and instruments work?
- Deployments – Will the observatory open as planned?
- Cryogenics – Can we achieve the needed sensitivity?
- Launch – Can we survive our ride to space?
- Commissioning – Are we ready to begin the science mission?

MUST VERIFY THE OPTICS...

- Return Good Images

- Using Segmented Optics

- All elements must have combined Wave Front Error of 150 nm (diff. lim. @ 2 μ m)

- Surface figure accurate to the width of a bacterium

- Control of optics via actuators

- Avoid the Hubble Problem

- Telescope cryo test

- Are Big Enough to See the First Stars and Galaxies

- Largest space telescope ever built

- Are Super Clean

- Exposed Optics

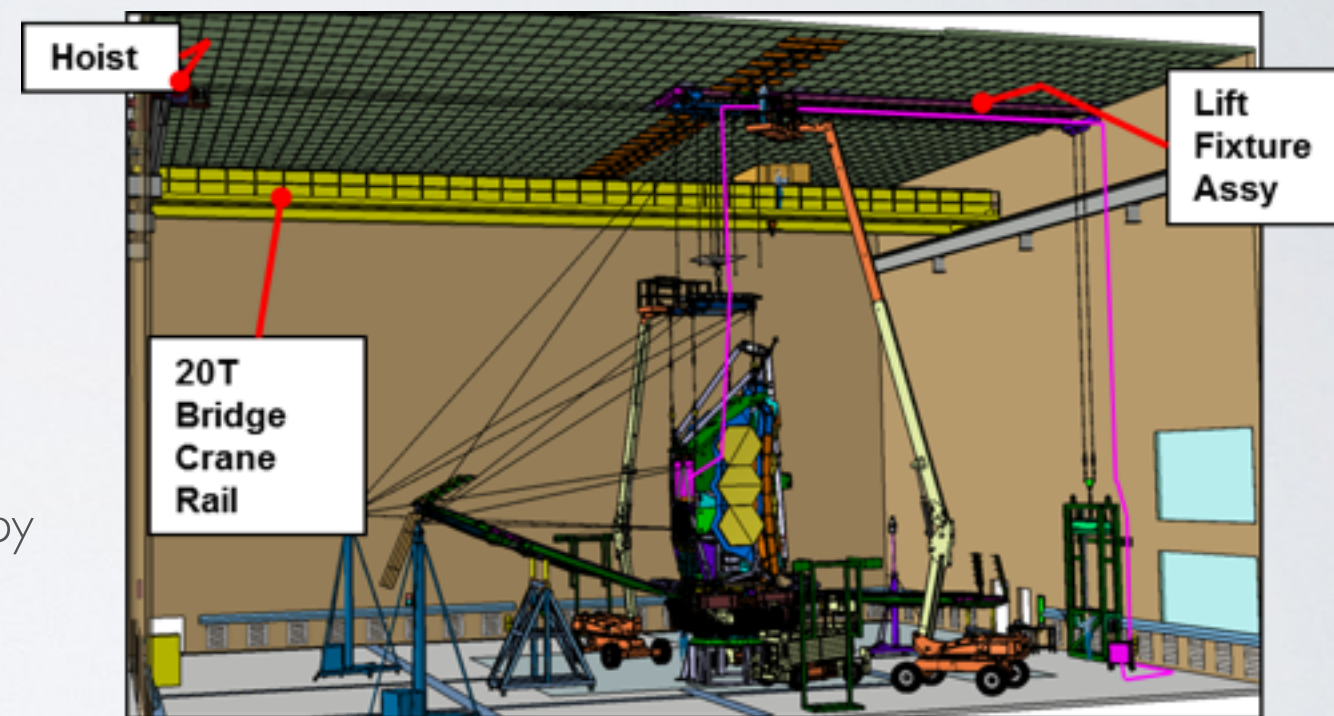
- H₂O is a contaminant for JWST! (A mere 1 oz. of water ice spread over the aft sunshield will interfere with mid-infrared observations)



JWST mirror being tested at GSFC

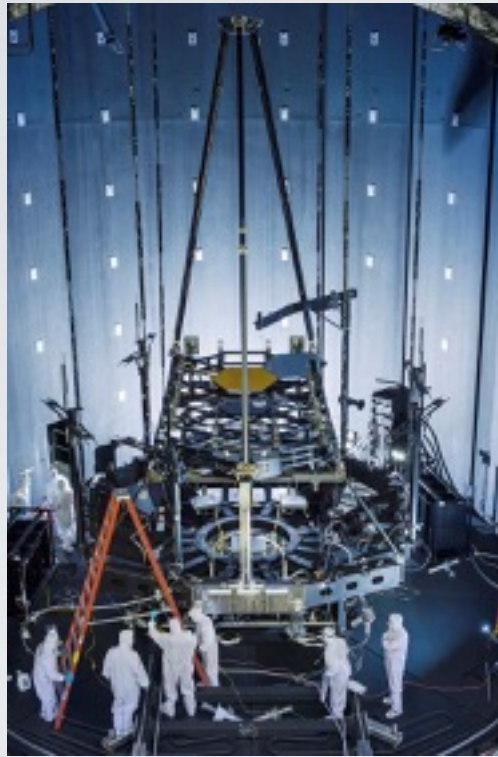
MUST VERIFY DEPLOYMENTS...

- All work
 - All spacecraft have deployments (e.g. solar panels, antennae)
 - Because of its size, JWST has over 300 deployments (counting mechanisms in a similar way, the Mars Curiosity mission had about 70 deployments)
- Work in zero-gravity
 - Mechanisms must work in zero gravity, but must be tested in Earth's gravity requiring often complex off-loading machinery to “counter” the acceleration felt by part when tested on the ground
- Work in extreme cold temperatures
 - Some parts must move while extremely cold – How would you uncoil a garden hose when it's frozen?
- Can Survive Launch
 - These mechanisms parts must be strong to withstand the vibrations and sound waves from the launch, yet moveable or in some cases separable for deployment.

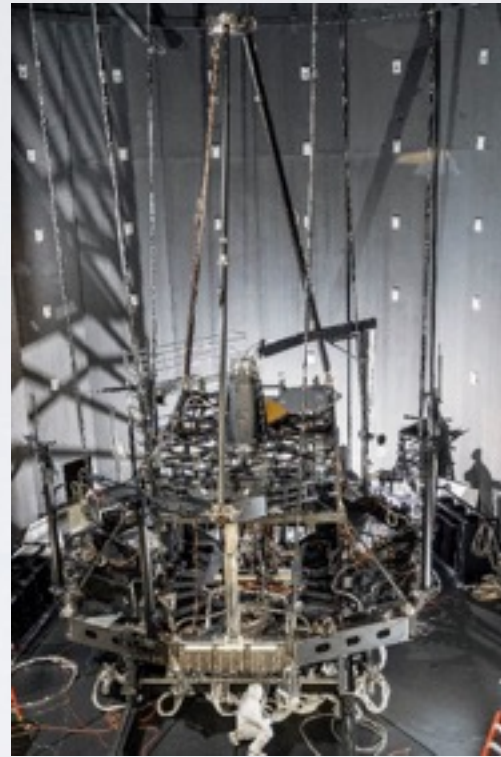


Deployment rigging at Northrop-Grumman

CRYOGENIC TESTING STEPS



Pathfinder test 1

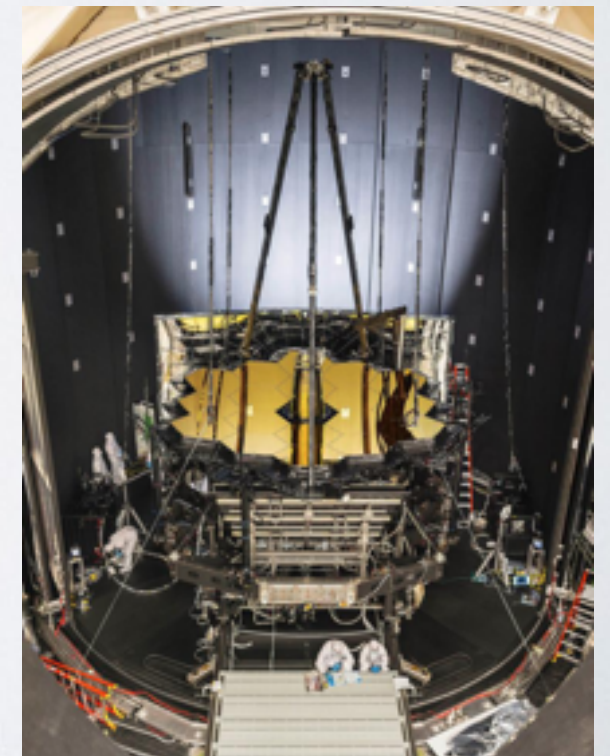


Pathfinder test 2
Aft Optics Installed



Pathfinder test 3
Thermal hardware installed

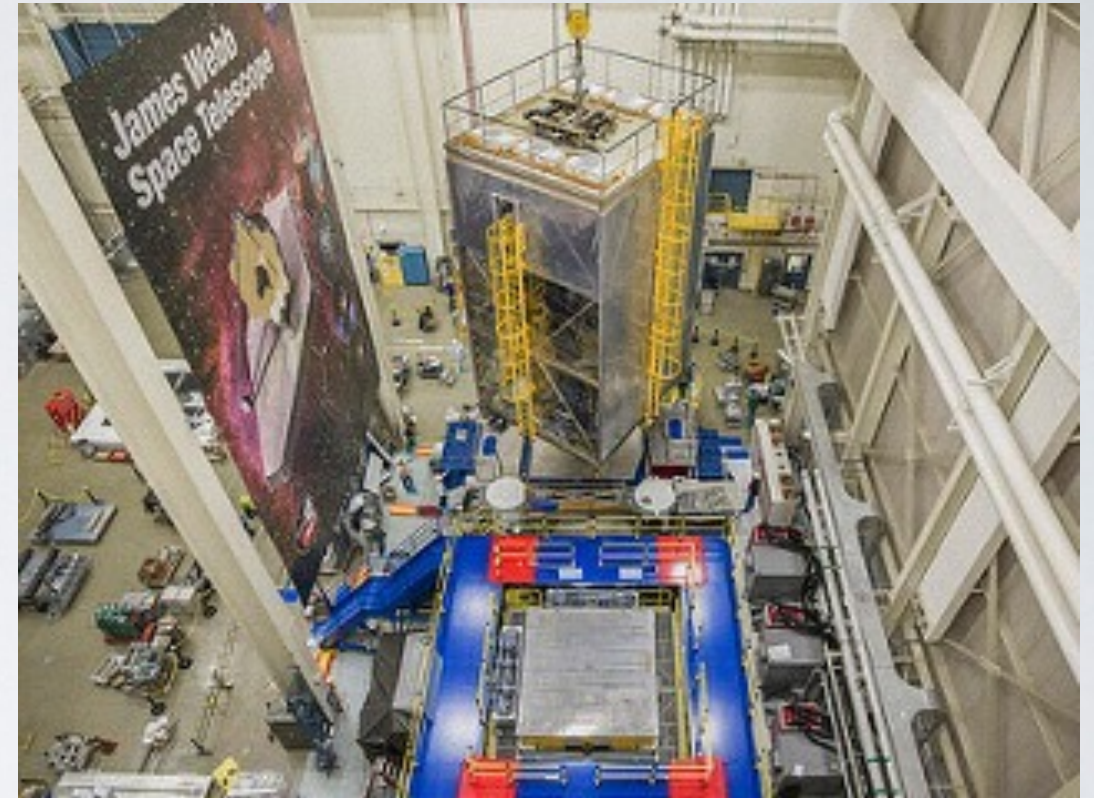
OTIS test configuration



MUST VERIFY LAUNCH SURVIVAL...

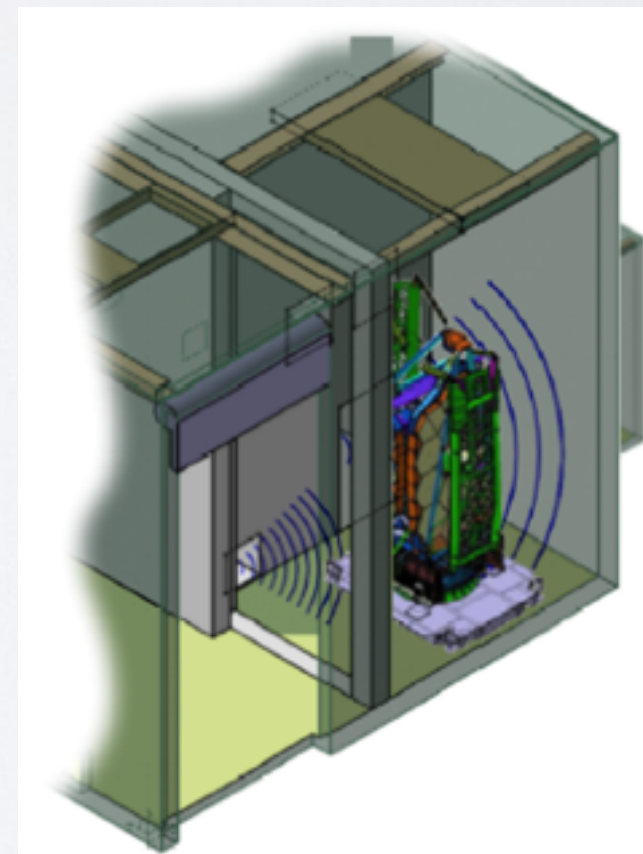
- By Vibration Testing

- Size – largest payload ever vibration-tested at GSFC
- Load Carrying deployments – key areas of the payload must carry large stress yet deploy after launch



- By Acoustics Testing

- Payload is blasted with the sound of launch
- All structures including very thin ones (e.g., sunshield membranes, microshutters) must survive



Observatory at Vibration
Tables

Observatory in Large
Acoustic Test Facility

JWST PRE-LAUNCH HARDWARE TESTS

- ✓ Telescope Vibration (3 axes)
- ✓ Telescope Acoustics
- ✓ Telescope Deployment (7 different deployments)
- Telescope Cryogenics (93 day cryo-vacuum test) [Underway]
- ✓ Spacecraft Electrical test
- Spacecraft Thermal Vacuum test
- Spacecraft Deployment (7 tests)
- Observatory Vibration (3 axes)
- Observatory Acoustics
- Observatory Deployment (all deployments retested)

COMMISSIONING IN SPACE

- Observatory, Telescope, Science Instrument operability demonstrated and calibrated
- JWST's many moving parts and operational modes demand a lengthy commissioning period (6 months)
 - Some functions cannot occur until the the telescope is very cold (~ 40 days after launch)
- Product of commissioning is a scientific facility ready to execute the planned observing program solicited from the science community

COMMISSIONING TIMELINE

- Soon after launch the spacecraft is controlled from the Mission Operations Center at STScI
- OTE commissioning will take almost 3 months
- Commissioning of the science instruments will start 4 months after launch and is completed in 1.5 months.
- 0.5 months are held on reserve to the nominal start of Cycle 1 science in April 2019

