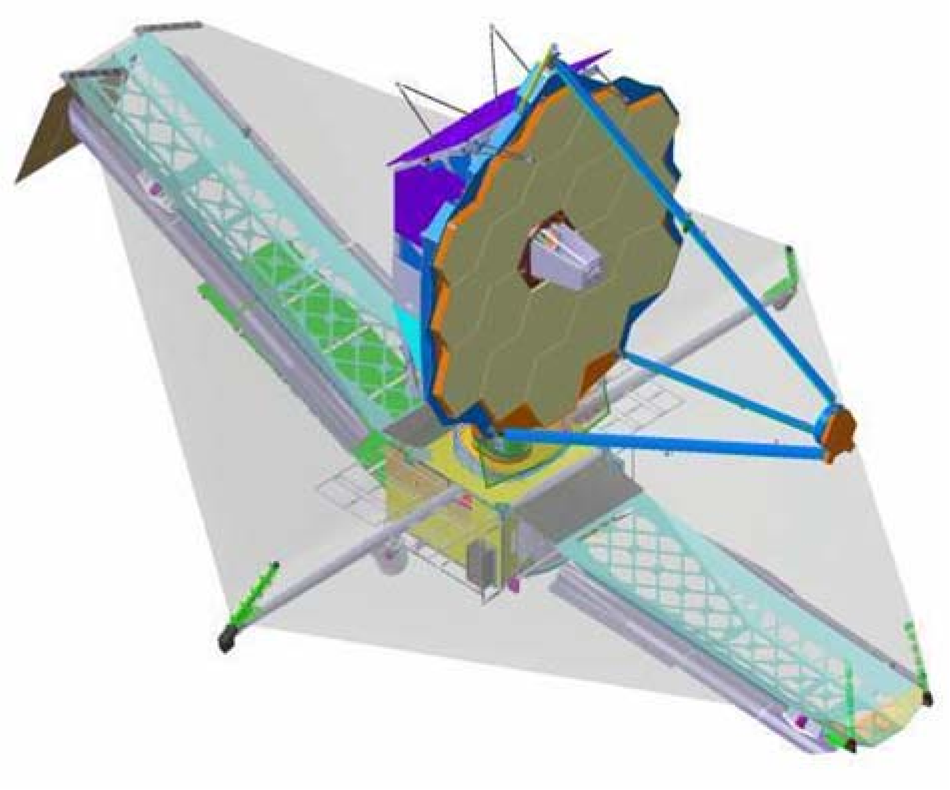
The Realities of Managing Complex Space Missions like the James Webb Space Telescope



Phil Sabelhaus
JWST Project Manager

John Durning
JWST Deputy Project Manager/Technical
June 2008

Who am I?

- Currently the James Webb Space Telescope (JWST) Project Manager
  - Graduated from the University of Maryland in 1978
  - Over 25 years of experience in the Aerospace business
    - Mostly at GSFC/NASA and as a manager (as apposed to engineering)
- Previous project or program management positions:
  - Total Ozone Mapping Spectrometer (TOMS) Project Manager
  - Geostationary Operational Environmental Satellite (GOES) Deputy Project Manager
  - Landsat 7 Project Manager
  - Earth Observing System (EOS) Deputy Program Manager plus
    - Aura Project Manager
    - Vegetation Canopy Lidar (VCL) Project Manager
    - Aqua Project Manager
  - Earth Observing System (EOS) Program Manager
- John Durning is Deputy Project Manager for Technical on JWST

Today's Topics

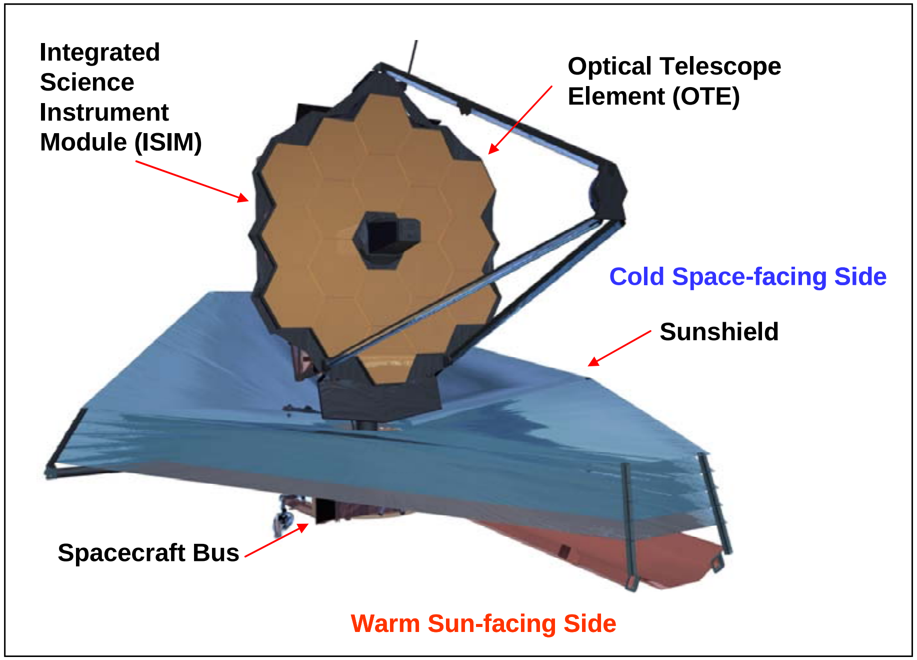
- JWST System Overview
- JWST Status
- JWST Project Management Approach
- Realities of Managing Complex Space Missions like JWST

JWST System Overview

James Webb Space Telescope (JWST)

Organization

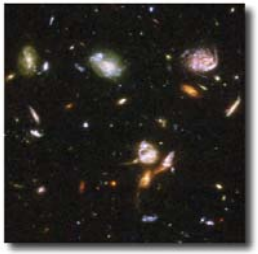
- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Space Technology
- Instruments:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - Fine Guidance Sensor (FGS) – CSA
- Operations: Space Telescope Science Institute



Description

- Deployable infrared telescope with 6.5 meter diameter segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch June 2013 on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)

JWST Science Themes



End of the dark ages: First light and reionization

The assembly of galaxies

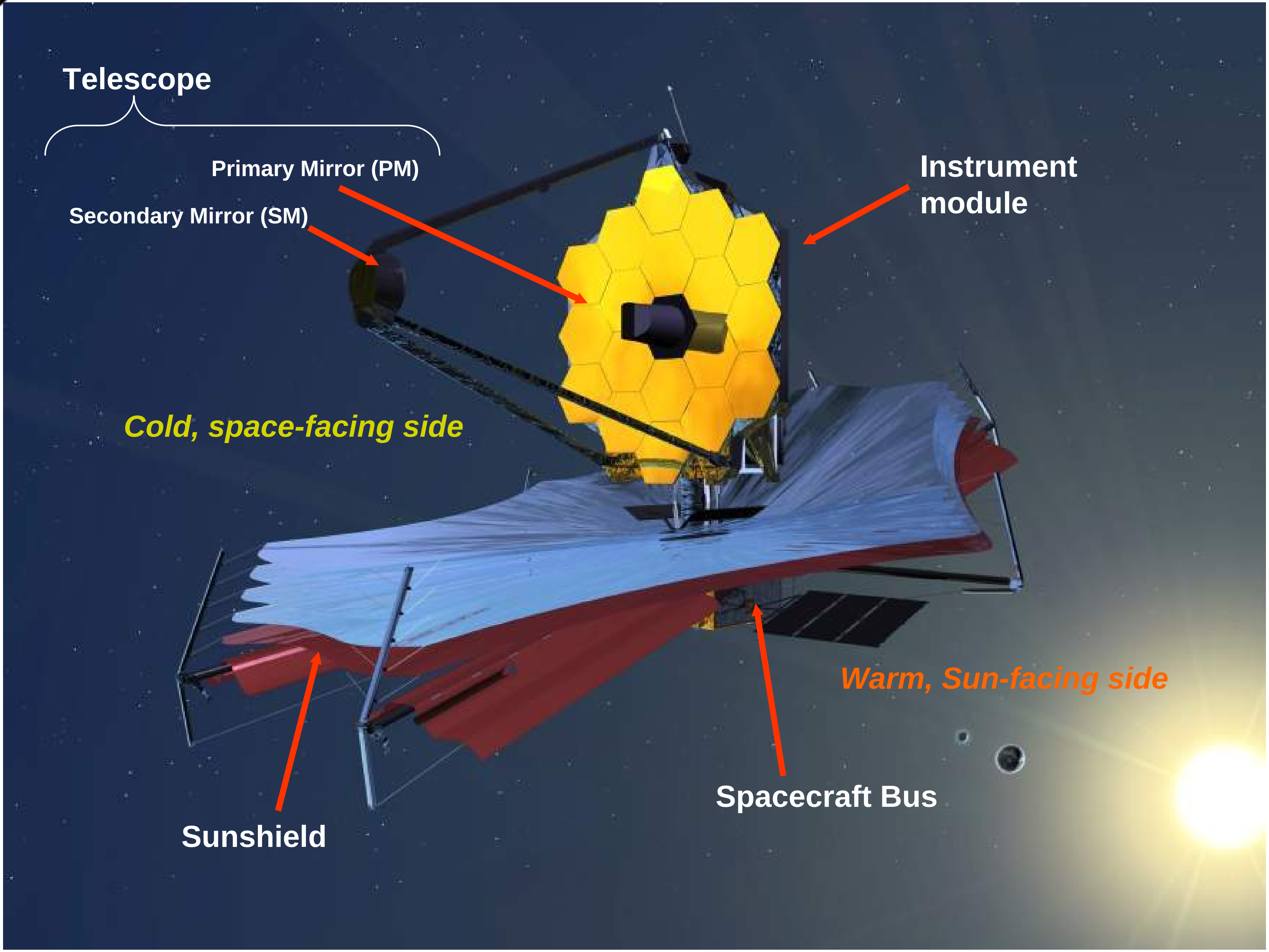
Birth of stars and proto-planetary systems

Planetary systems and the origin of life

www.JWST.nasa.gov

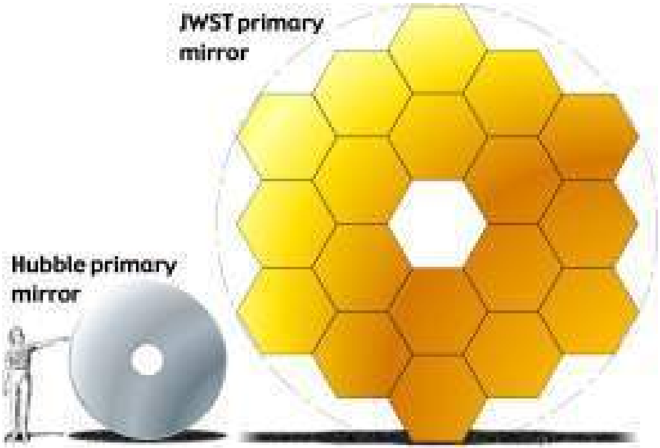
JWST Full Scale Model at the GSFC

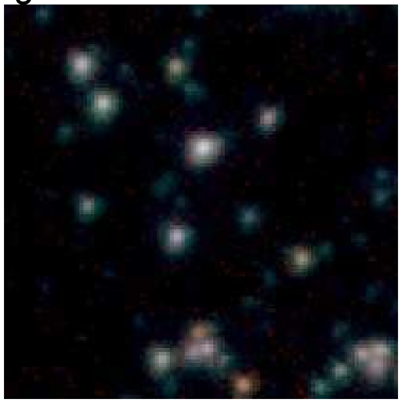
JWST Observatory is Optimized for the Science



JWST Compared with other Telescopes

- Hubble Space Telescope (HST):
  - 2.7 x diameter, 2.7 x longer wavelength
- HST NICMOS:
  - 189 x FoV,
  - 38 x better sensitivity at K band, 8 x at H band
- Spitzer:
  - 8 x Spitzer diameter
  - Diffraction limited at 2 microns vs. 6 microns
  - 8 to 24 x better angular resolution
  - 10 x lower dark current supports R ~ 1000 at high redshift
- Ground:
  - JWST and GSMT are complementary where capabilities overlap:
  - HST: Keck diameter ratio ~ JWST:GSMT
  - Background ~1,000,000 x larger on ground at 5 microns





Real data: Spitzer
25 hours

Simulated: JWST
3 hours

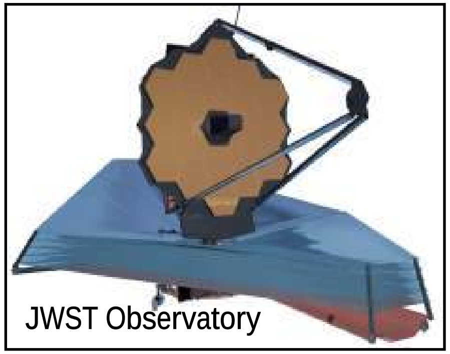
James Webb Space Telescope System

Launch Segment


Ariane Launcher

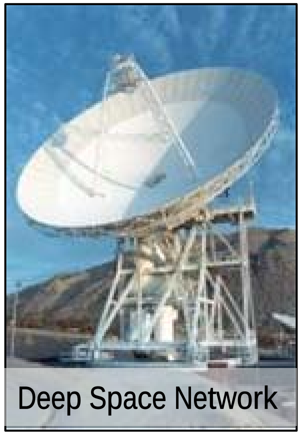
- Launch Vehicle
- Payload Adapter
- Launch Site Services

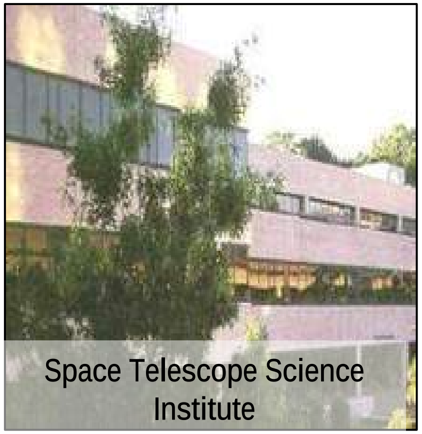
Observatory Segment


JWST Observatory

- Optical Telescope Element (OTE)
- Integrated Science Instrument Module (ISIM)
  - NIRCam
  - MIRI
  - NIRSpec
  - FGS
- Spacecraft Element (SE)
  - Spacecraft Bus
  - Sunshield

Ground Segment

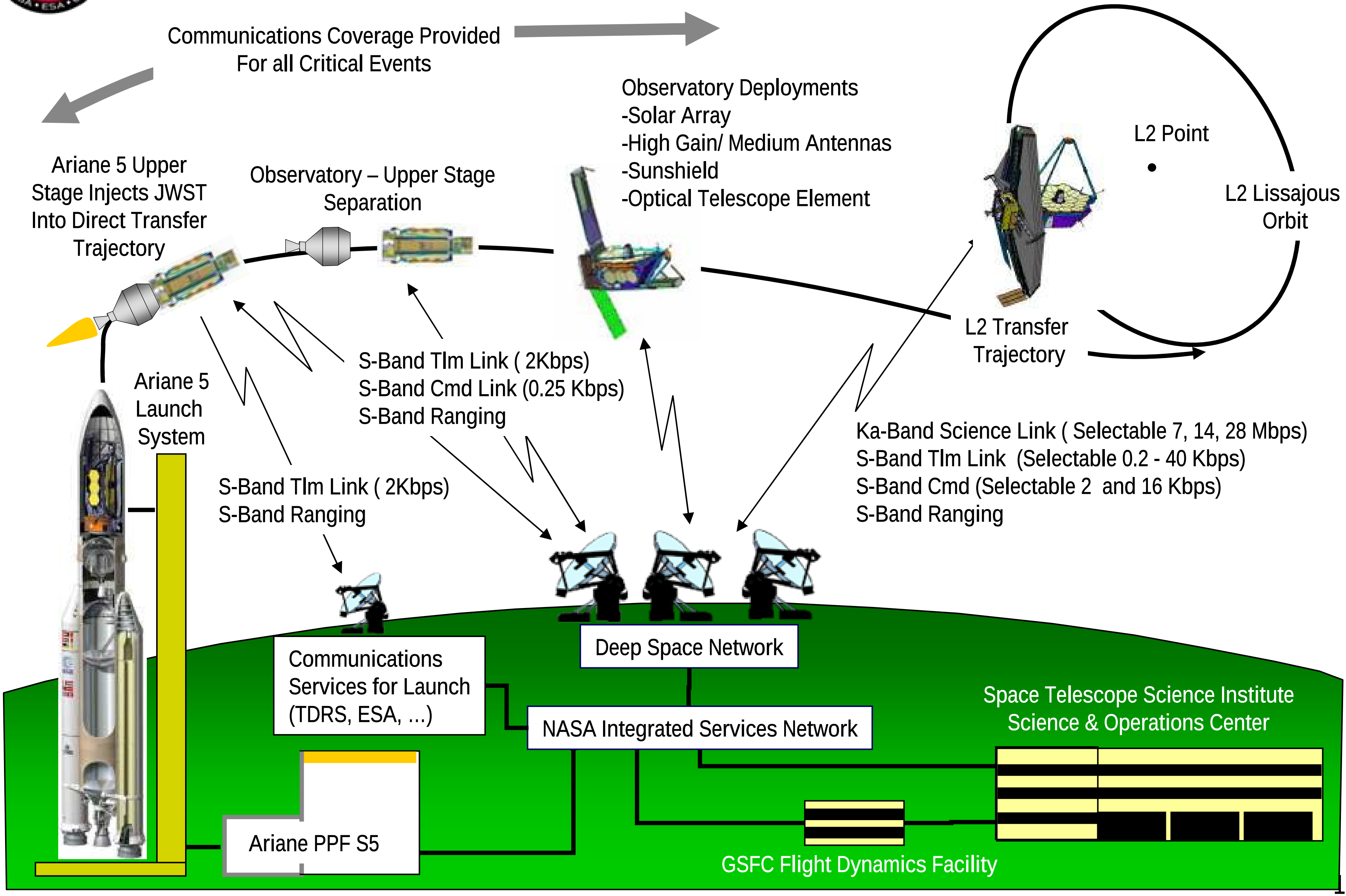

Deep Space Network


Space Telescope Science Institute

- Science and Operations Center (SOC)
- Institutional Systems
- Common Systems

🟦 Provided by NASA
🟩 Provided by NGST
🟧 Provided by STScI
🟪 Provided by ESA
🟨 Provided by CSA

JWST System Architecture



Communications Coverage Provided For all Critical Events

Ariane 5 Upper Stage Injects JWST Into Direct Transfer Trajectory

Observatory – Upper Stage Separation

Observatory Deployments
-Solar Array
-High Gain/ Medium Antennas
-Sunshield
-Optical Telescope Element

L2 Point

L2 Lissajous Orbit

L2 Transfer Trajectory

Ariane 5 Launch System

S-Band Tlm Link (2Kbps)
S-Band Cmd Link (0.25 Kbps)
S-Band Ranging

S-Band Tlm Link (2Kbps)
S-Band Ranging

Ka-Band Science Link (Selectable 7, 14, 28 Mbps)
S-Band Tlm Link (Selectable 0.2 - 40 Kbps)
S-Band Cmd (Selectable 2 and 16 Kbps)
S-Band Ranging

Communications Services for Launch (TDRS, ESA, ...)

Deep Space Network

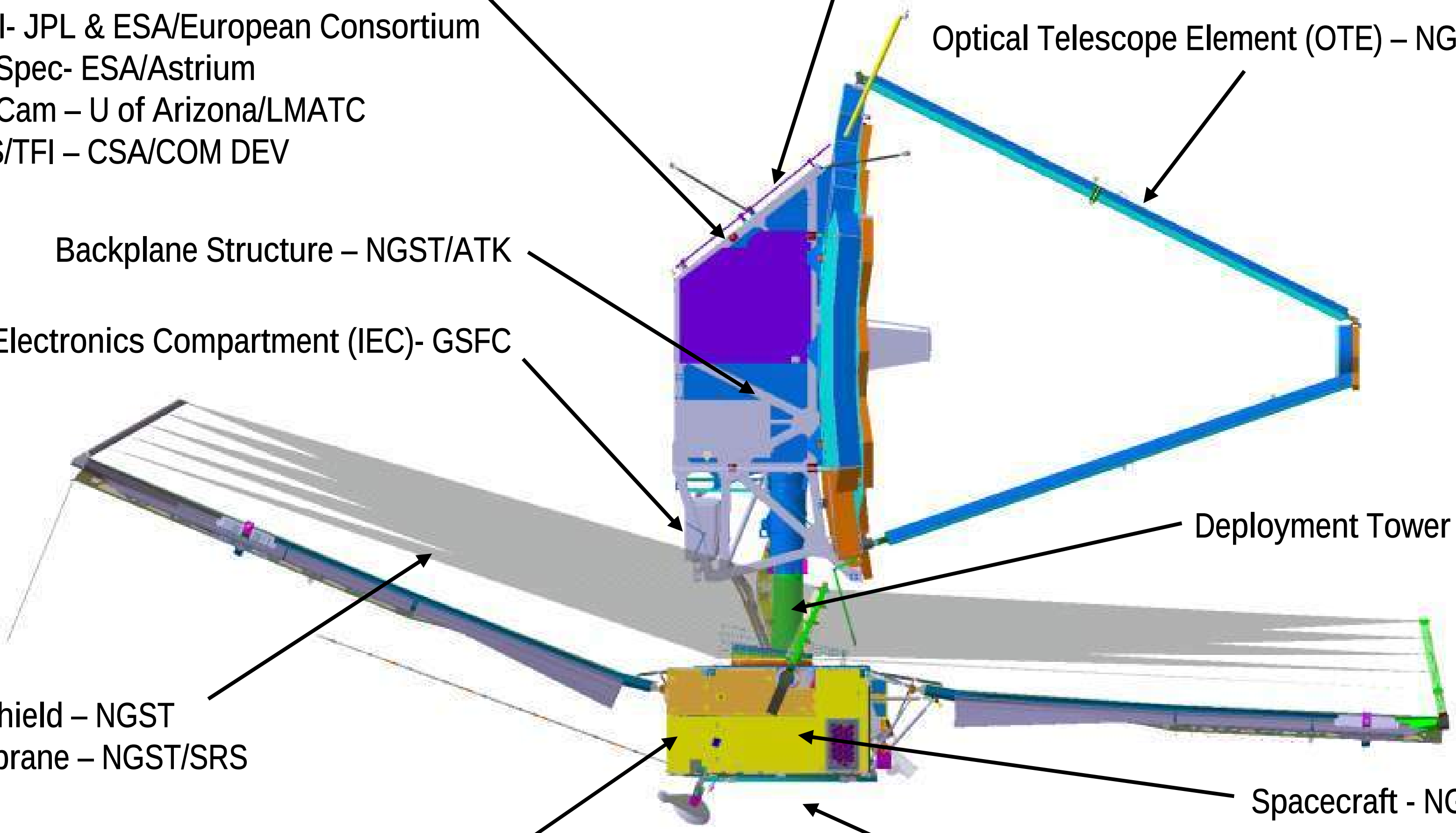
NASA Integrated Services Network

Space Telescope Science Institute Science & Operations Center

Ariane PPF S5

GSFC Flight Dynamics Facility

JWST Teams and Responsibilities



Integrated Science Instrument Module (ISIM) – GSFC
- Structure – GSFC/ATK
- MIRI- JPL & ESA/European Consortium
- NIRSpec- ESA/Astrium
- NIRCam – U of Arizona/LMATC
- FGS/TFI – CSA/COM DEV

ISIM Radiators- NGST/Ball

Optical Telescope Element (OTE) – NGST/Ball

Backplane Structure – NGST/ATK

ISIM Electronics Compartment (IEC)- GSFC

Deployment Tower - NGST

Sunshield – NGST
Membrane – NGST/SRS

Spacecraft - NGST

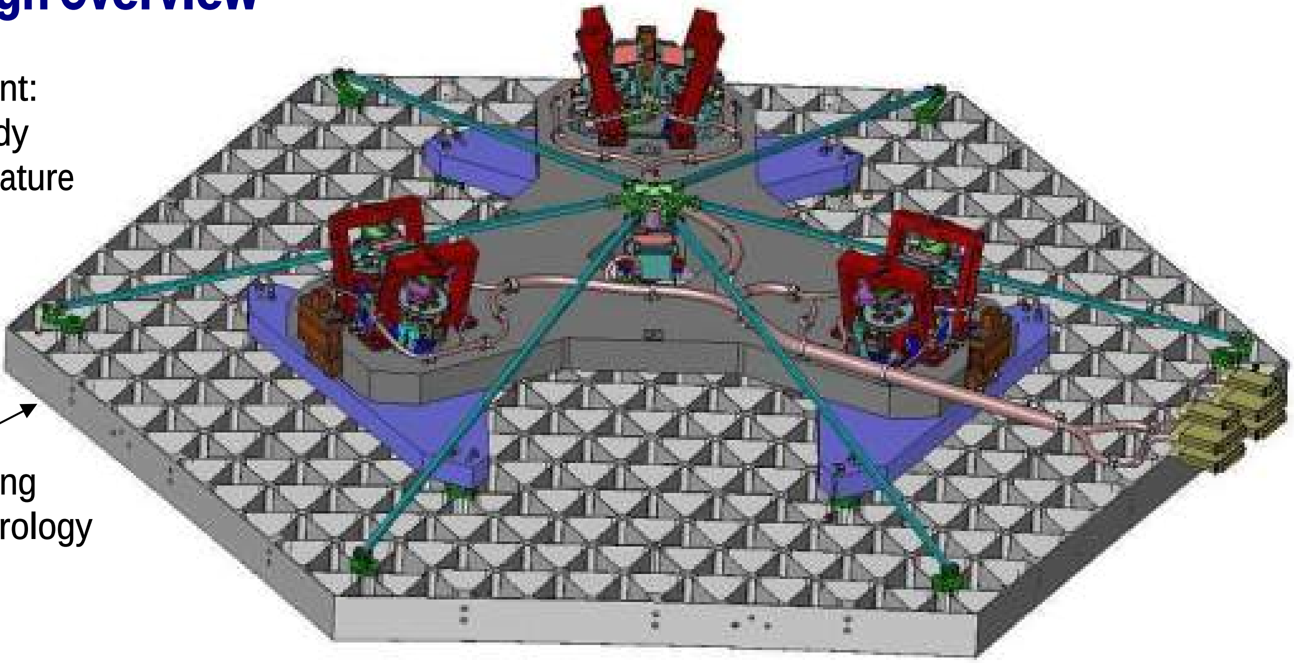
MIRI Cryocooler – JPL/NGST
Instrument C&DH - GSFC

Launch Vehicle & Adapter- ESA/Arianespace

Overall Observatory - NGST

Primary Mirror Segment Assembly and Secondary Mirror Assembly Design Overview

PMSA Adjustment:
- 6 DOF rigid body
- Radius of Curvature



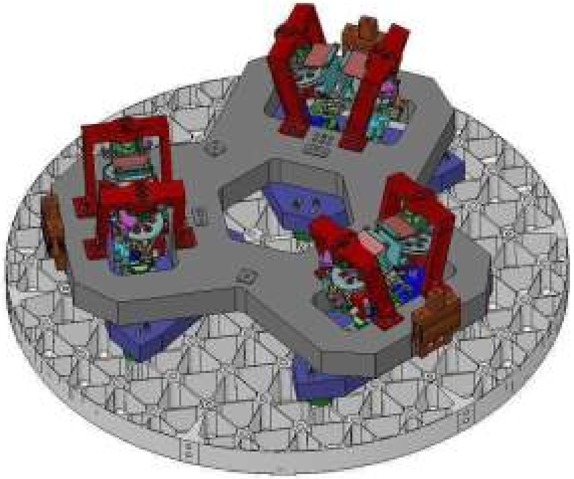
Inserts for tooling ball alignment metrology

Primary Mirror Segment Assembly

Common Design Features

Bipod Actuator

SMA Adjustment:
- 6 DOF rigid body

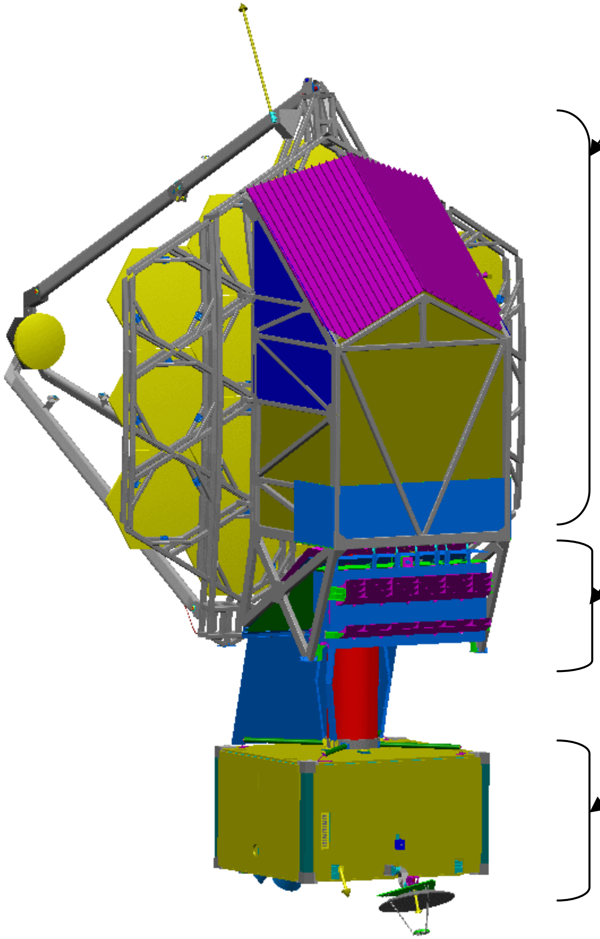


Secondary Mirror Assembly

The science payload is integrated to avoid duplication of common science instrument systems

ISIM is:

- **The JWST Science Instruments**
- **Associated Infrastructure: Structure, C&DH, & FSW**



Region 1

Science Instrument Optics Assemblies

Near Infrared Camera (NIRCam)
Near Infrared Spectrograph (NIRSpec)
Mid Infrared Instrument (MIRI)
Fine Guidance Sensor and Tunable Filter (FGS/TF)

Optical Bench Structure

Radiators and support structure (NGST-supplied)

Region 2

Focal Plane Electronics (FPE)

Instrument Control Electronics (ICE, MCE)

ISIM Remote Services Unit (IRSU)

Region 3

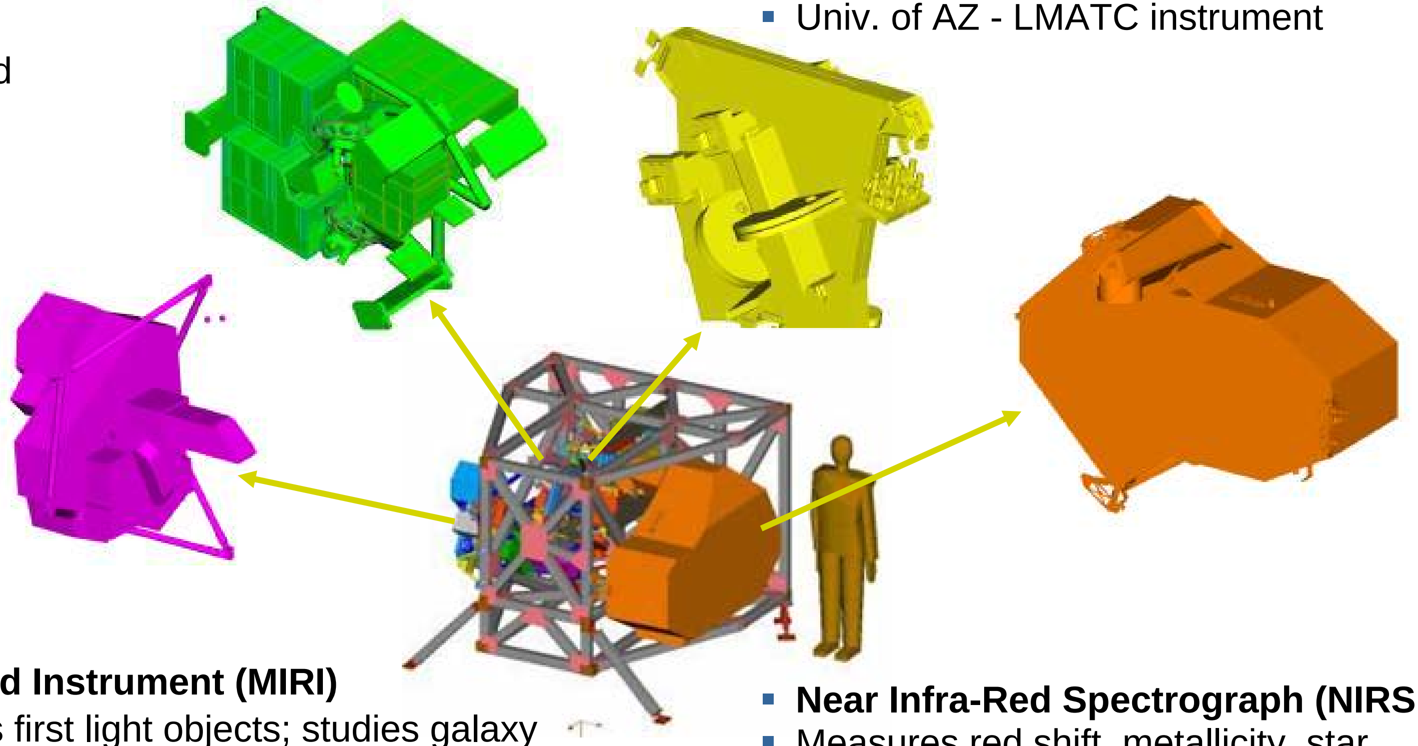
ISIM Command & Data Handling (ICDH) Electronics

MIRI Cryocooler Electronics

Instrument Overview

- **Fine Guidance Sensor (FGS)**
- Ensures guide star availability with >95% probability at any point in the sky
- Includes Narrowband Imaging Tunable Filter Module
- CSA provided

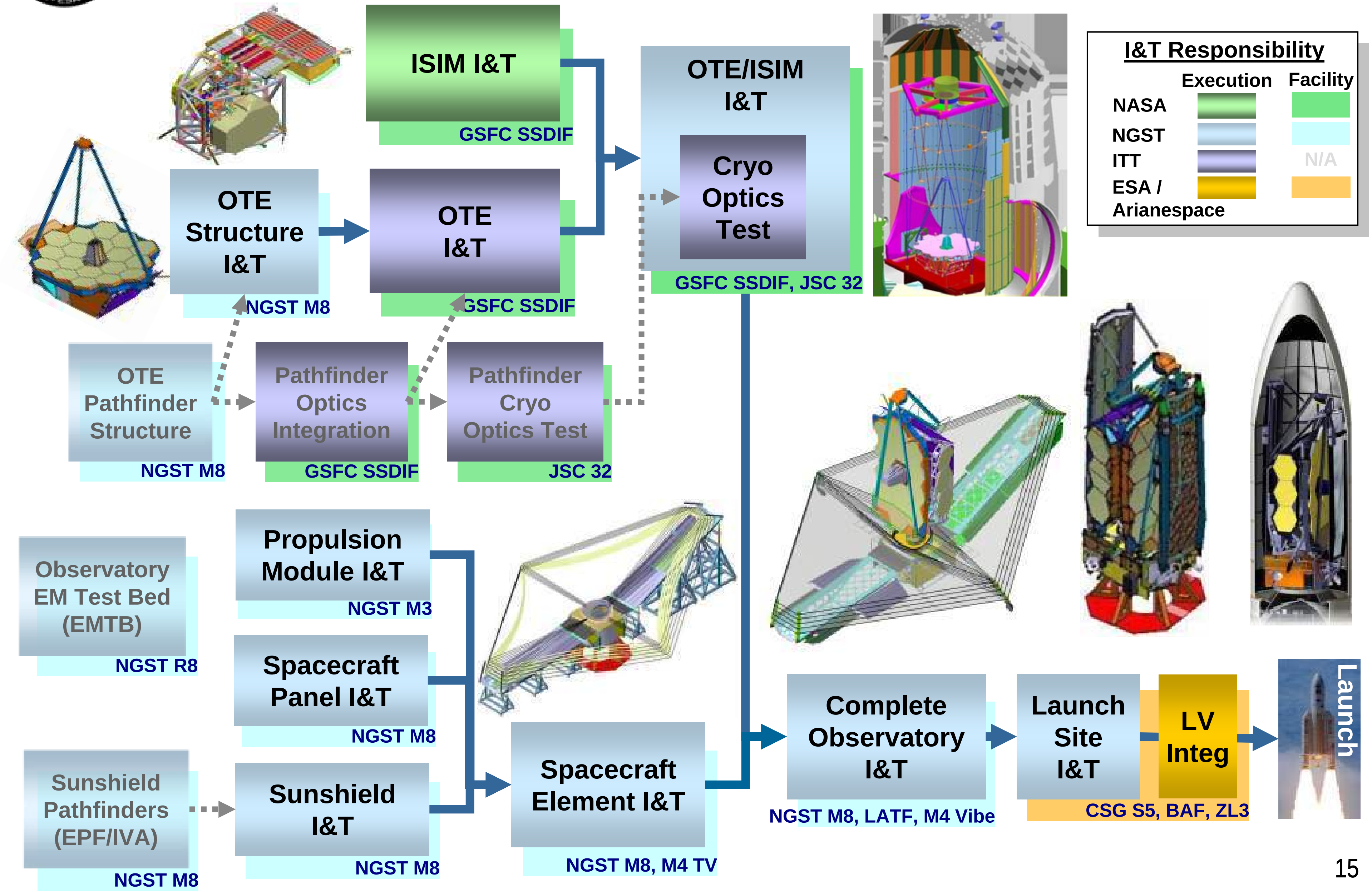
- **Near Infra-Red Camera (NIRCam)**
- Detects first light galaxies and observes galaxy assembly sequence
- 0.6 to 5 microns
- Supports Wavefront Sensing & Control
- Univ. of AZ - LMATC instrument



- **Mid-Infra-Red Instrument (MIRI)**
- Distinguishes first light objects; studies galaxy evolution; explores protostars & their environs
- Imaging and spectroscopy capability
- 5 to 27 microns
- Cooled to 7K by Cyro-cooler
- Combined ESA/JPL contributions

- **Near Infra-Red Spectrograph (NIRSpec)**
- Measures red shift, metallicity, star formation rate in first light galaxies
- 0.6 to 5 microns
- Simultaneous spectra of >100 objects
- Resolving powers of ~100 and ~1000
- ESA provided with NASA Detectors & Micro shutter

Integration &Test Flow Overview



OTE Structure I&T
NGST M8

ISIM I&T
GSFC SSDIF

OTE I&T
GSFC SSDIF

OTE/ISIM I&T
Cryo Optics Test
GSFC SSDIF, JSC 32

OTE Pathfinder Structure
NGST M8

Pathfinder Optics Integration
GSFC SSDIF

Pathfinder Cryo Optics Test
JSC 32

Observatory EM Test Bed (EMTB)
NGST R8

Propulsion Module I&T
NGST M3

Spacecraft Panel I&T
NGST M8

Sunshield Pathfinders (EPF/IVA)
NGST M8

Sunshield I&T
NGST M8

Spacecraft Element I&T
NGST M8, M4 TV

Complete Observatory I&T
NGST M8, LATF, M4 Vibe

Launch Site I&T

LV Integ
CSG S5, BAF, ZL3

Launch

I&T Responsibility

	Execution	Facility
NASA	🟩	🟩
NGST	🟦	🟦
ITT	🟪	N/A
ESA / Arianespace	🟨	🟧

The JWST deployment occurs en route to the L2 point

JWST Status

Program Status and Recent Progress

- General
  - Successful Mission PDR and Non Advocate Review held
- Science
  - NASA HQ SMD has decided to add moving target tracking capability to JWST
- Observatory
  - First spacecraft simulator delivered to the ISIM software lab at GSFC
  - Sunshield PDR held in February 2008
- Ground Segment
  - Completed deliveries of all Science Instrument Integrated Test Sets (SITSs) and Science Instrument Development Units (SIDUs) to SI teams in the US, Canada and Europe

Program Status and Recent Progress (Continued)

- **Mirrors and Optical Telescope Element (OTE)**
  - All 18 flight plus a spare and the EDU Primary Mirror (PM) segments, both flight and spare Secondary Mirrors (SMs) and the Tertiary Mirror (TM) are now out of the machine shop (Axsys) and are at the polishing shop (Tinsley)
    - Seven flight mirrors are in rough polishing, 10 mirrors are in smooth out grind, 1 flight and the pathfinder segment in figure grind
    - EDU is scheduled to be shipped to Ball in July to start PMSA processing
    - The Flight Secondary Mirror (SM), SM spare and Flight TM are in smooth out grind, even grind and figure grind respectively
  - Successful OTE PDR at NGST in November 2007
  - ATK continues manufacturing the center section billets for the pathfinder and flight backplanes
  - Preparations for PMSA testing at MSFC XRCF are going well

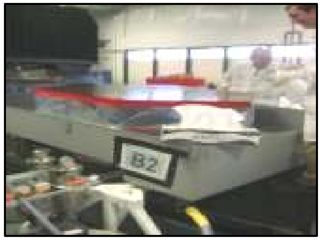
Flight PM, SM and TM Segments are in process at Tinsley

PMSA #1 (EDU-A / A1 / A1)

PMSA #2 (11 / B3 / B3)


PMSA #3 (12 / C3 / C3)

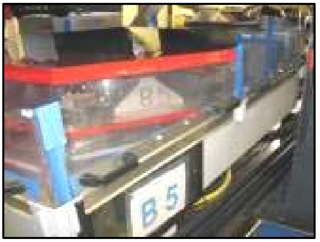

PMSA #4 (5 / A2 / A2)



PMSA #5 (6 / B2 / B2)

PMSA #6 (7 / C2 / C2)

PMSA #7 (13 / A4 / A4)



PMSA #8 (17 / B5 / B5)


PMSA #9 (4 / C1 / C1)


PMSA #10 (16 / A5 / A5)


PMSA #11 (20 / B6 / B6)

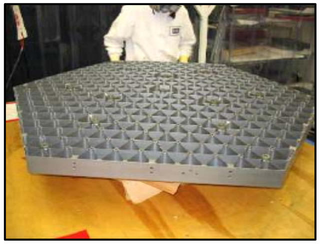
PMSA #12 (15 / C4 / C4)

PMSA #13 (8 / A3 / A3)

PMSA #14 (22 / B7 / B7)

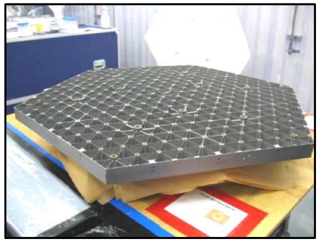
PMSA #15 (18 / C5 / C5)


PMSA #16 (19 / A6 / A6)


PMSA #17 (23 / B8 / B8)

PMSA #18 (21 / C6 / C6)


PM EDU (EDU-B / EDU / EDU)


PM PFL-C (24 / C7 / C7)


SM PFL (SM2 / SM1 / SM1)


SM Flight (SM1 / SM2 / SM2)


TM Flight (TM1 / TM1 / TM1)

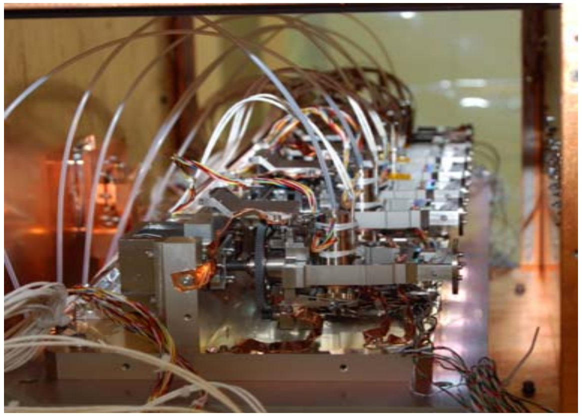
EDU Mirror after Smoothout Polishing

PMSA Flight Production Well Underway

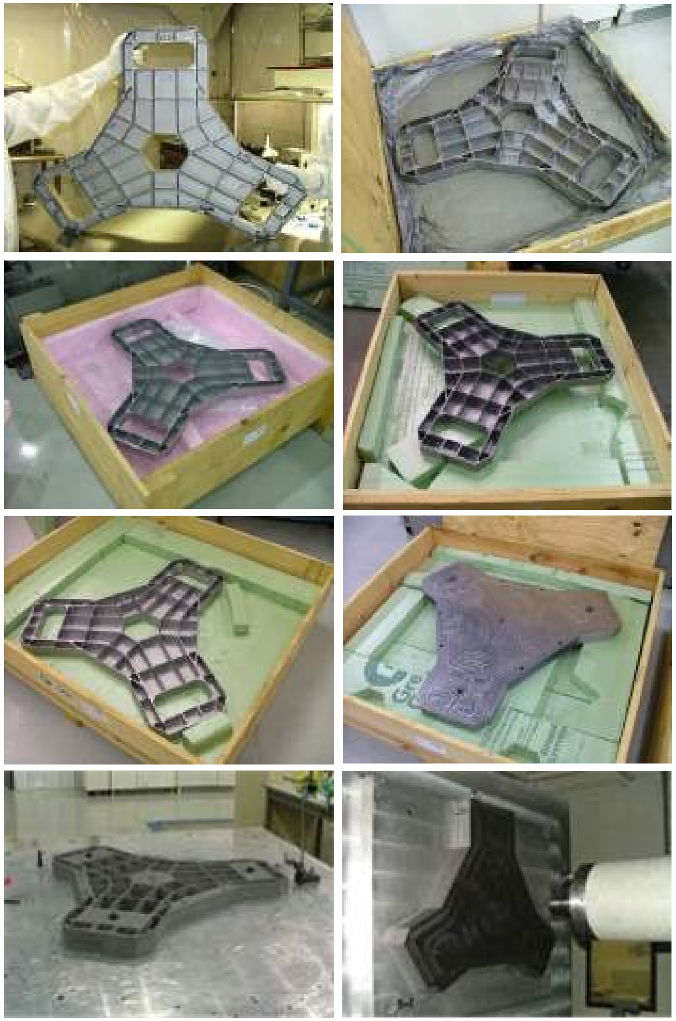

Launch Restraint Flexures


PM Bipod Mounting Brackets


Strongback Struts


Flight actuators under test

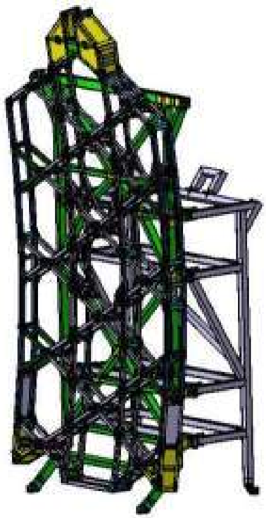

PM Whiffle Assemblies

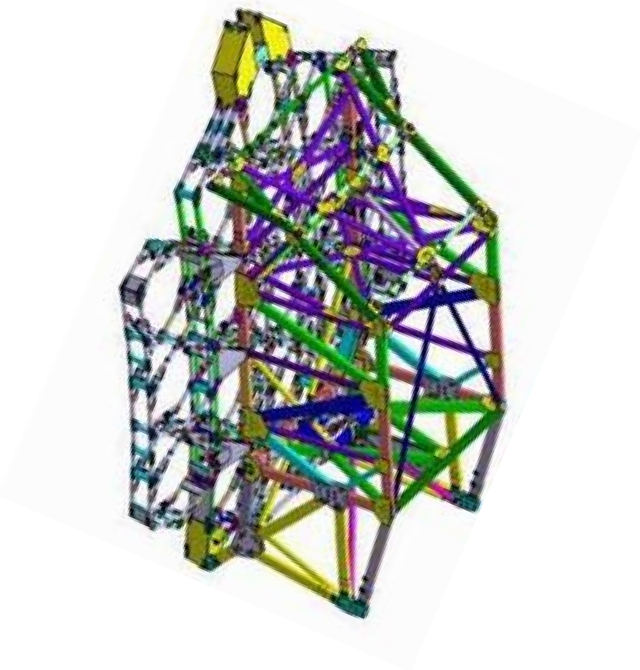

PM Delta Frames 1-8

Composite Piece Part Fabrication Summary

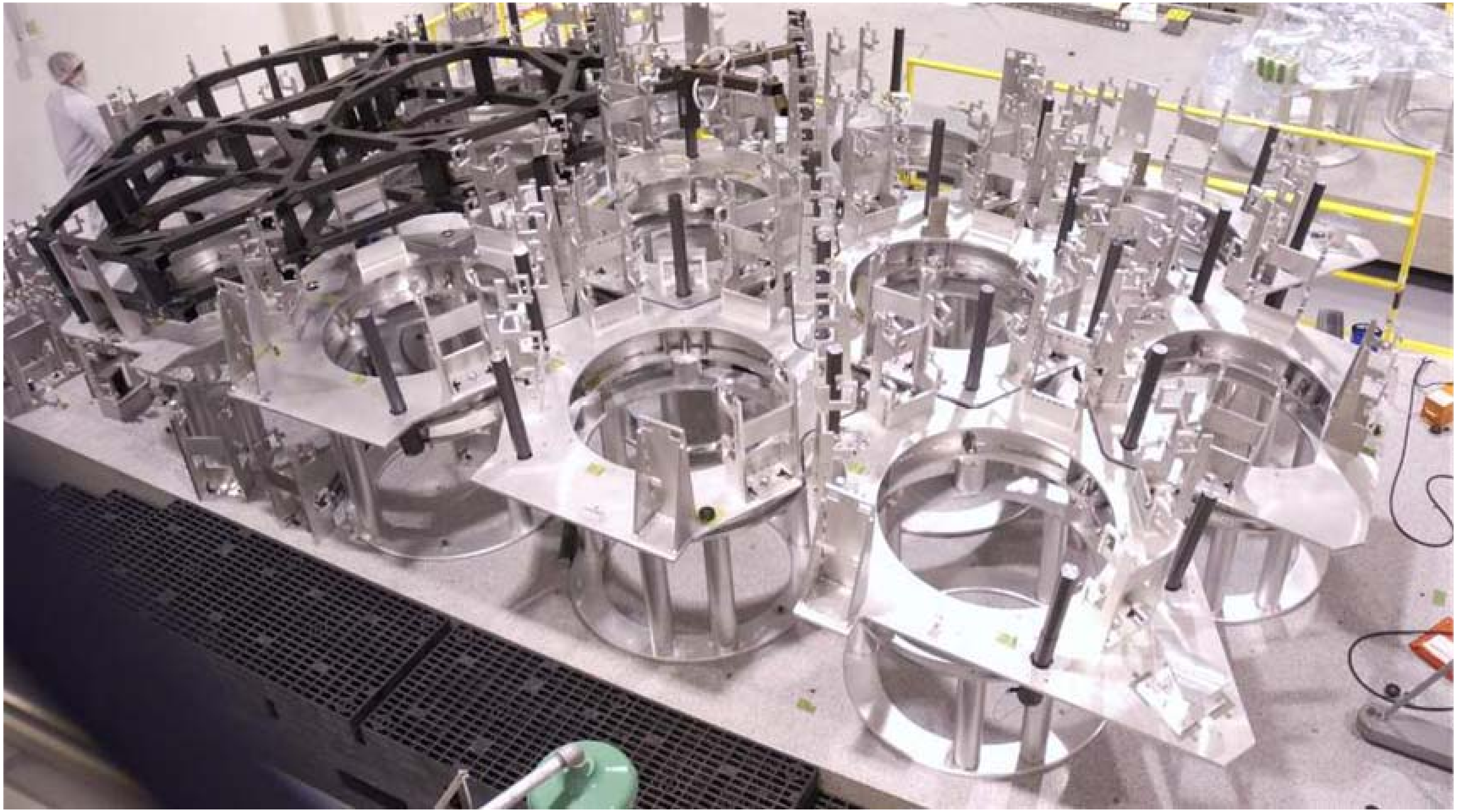
Pathfinder Billet Fabrication 90% complete, Flight Billet Fabrication 47% complete
Performance to Forecast Schedule (thru 5-6-2008)

Pathfinder (tube and flat plate billets)			% complete	Flight (tube and flat plate billets)			% complete
Composite Billet thru UT Inspection				Composite Billet thru UT Inspection			
Total	Scheduled	Complete		Total	Scheduled	Complete	
184	166	166	90%	453	214	214	47%
Composite Piece Part in Inventory				Composite Piece Part in Inventory			
	Total	Complete		Total	Scheduled	Complete	
CS	1185	520	44%				
BSF	230	0					
	1415	520	37%	2991	0	0	0%





Composite Piece Parts and Tooling at ATK

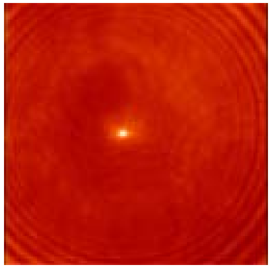


OTE Assembly Tooling

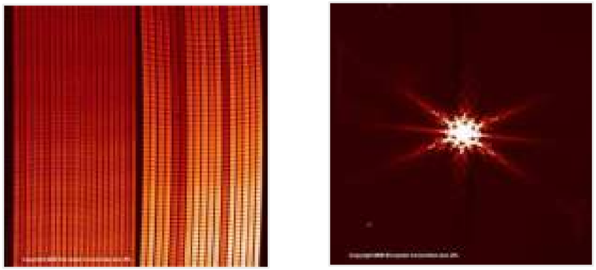
Program Status and Recent Progress (Continued)

- **Integrated Science Instrument Module (ISIM)**
  - **MIRI Verification Model achieved 6.2K operating temperature, completed cold functional test, and started first thermal balance**
    - Achieved first light!
  - **Completed CDR for NIRSpec Focal Plane Electronics and Software**
  - **Selected flight detectors for MIRI**
    - Held Cryo Cooler PDR
  - **Completed Microshutter CDR (part 1) covering Arrays and Quads**
    - ESA concurred with priority ranking of Microshutter Flight Candidates

Sample MIRI flight detectors



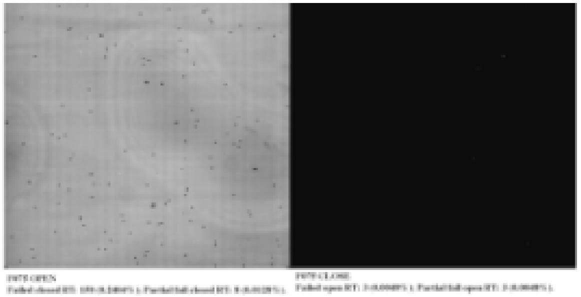
MIRI detectors 1st Light!



Spectrometer

Imager

Microshutter flight candidate



MIRI Verification Model prior to Cryo Vac Test

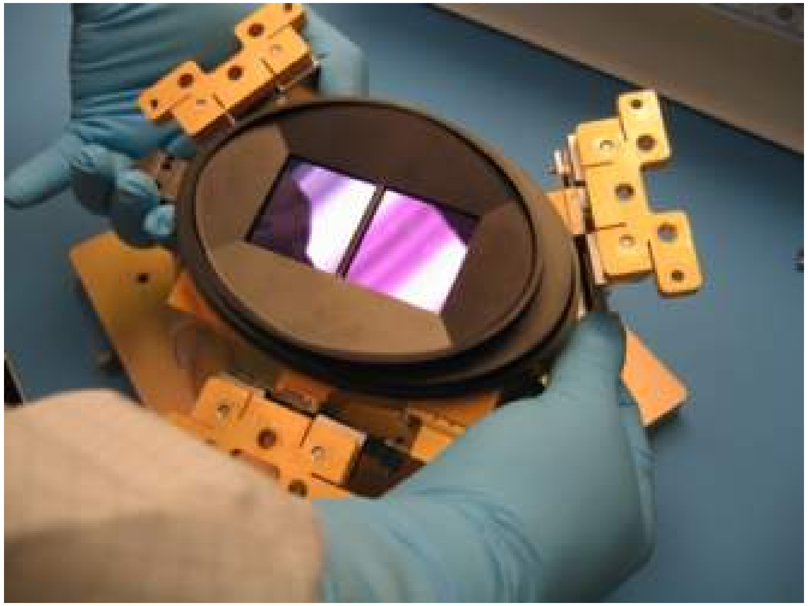
Program Status and Recent Progress (Continued)

- **Integrated Science Instrument Module (ISIM) Continued:**
  - **Successful ISIM Command and Data Handling (ICDH) CDR in October**
  - **ISIM, ISIM Electronics Compartment (IEC) and ISIM Remote Services Unit (IRSU) PDR's successfully completed**
  - **Harness Radiator breadboard in cryo-vac test**
  - **Held FGS TFI and System CDR at COM DEV**
  - **All flight tubes have been fabricated for the ISIM Structure**
    - Bonding scheduled to begin in late June
  - **Completed manufacturing of NIRSpec Qual Unit Optical Bench**
  - **Started bonding of the NIRCam ETU Optical Bench**

NIRCam ETU Optical Bench

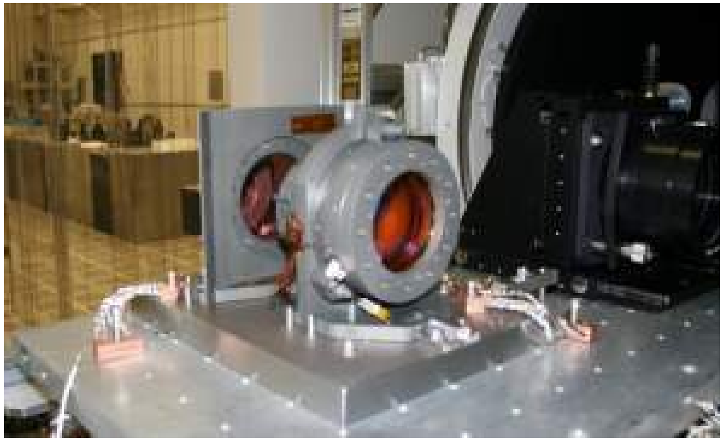
NIRSpec Qual Unit Optical Bench Ready for Delivery

ETU Hardware Queuing Up for Instrument I&T



NIRSpec Focal Plane Assembly

NIRCam PIL Mechanism



NIRCam Shortwave Camera Triplet & Beamsplitter

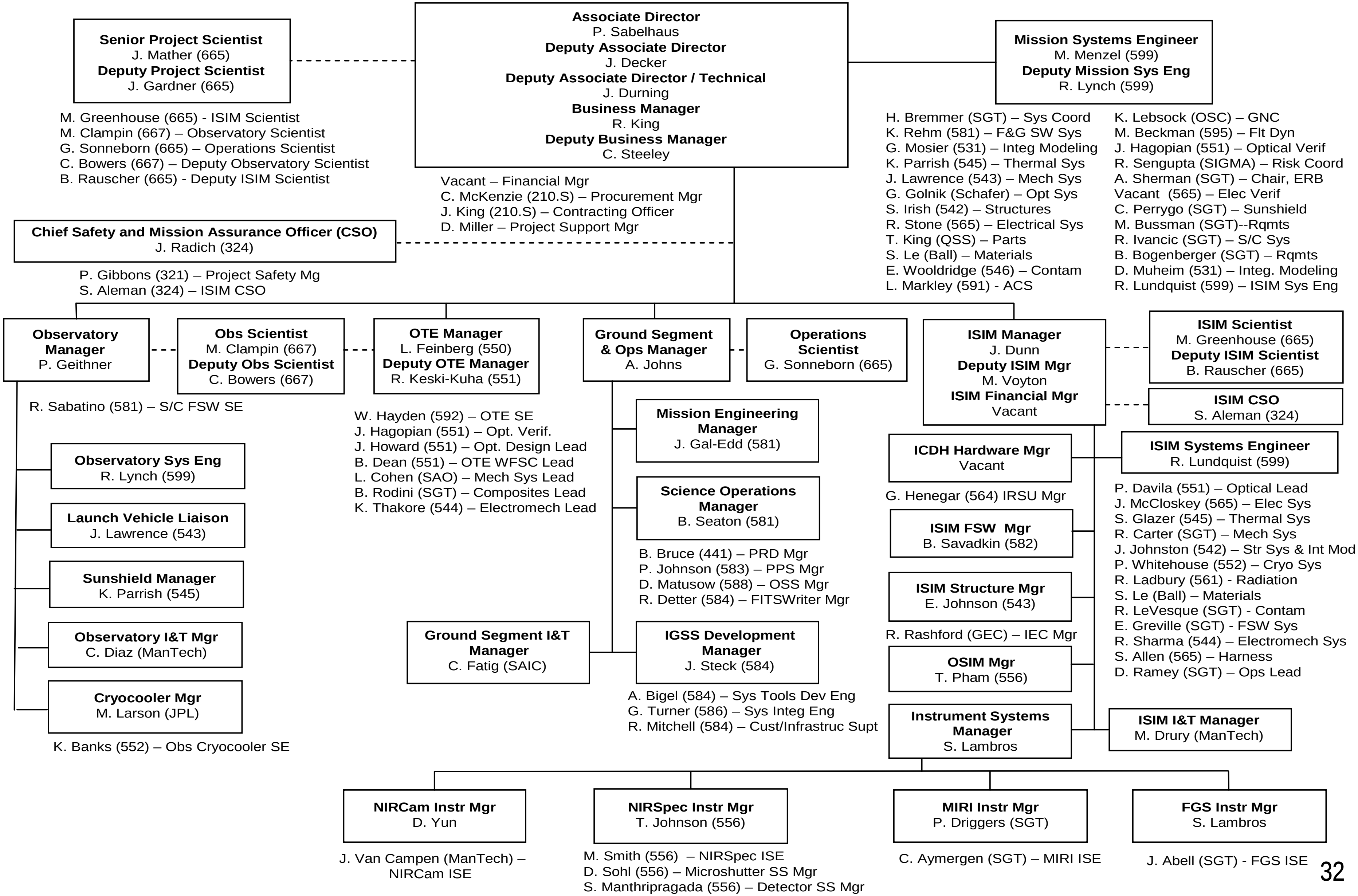
NIRSpec Fore Optics

JWST Project Management Approach

Program Management Summary

- Organizational structure is established
- Roles and responsibilities are well defined
  - All major contracts are in place
  - All foreign partners are in place, operating under signed Memoranda of Understanding (MOUs)
  - Partners include GSFC, NGST, Ball, ITT, ATK, STScI, ESA, CSA, UAz, LM, JPL, MSFC, ARC, JSC, etc.
- All enabling technologies are at Technical Readiness Level-6
- Earned Value Management is being applied to all major contracts consistent with Agency guidance
- Schedules are baselined and the project critical path is understood/managed
- Budget with reserves established
  - Liens and threats system in use
- Formal Configuration Management (CM) processes are in place
  - Project-level schedules are maintained within the CM system
- Formal Risk Management processes are in place
- Requirements are stable and flowed down
- Project metrics are established and tracked monthly
  - Includes technical as well as cost and schedule metrics
  - Changes as well as trends are reported each month

JWST Project Organization Chart



Associate Director
P. Sabelhaus
Deputy Associate Director
J. Decker
Deputy Associate Director / Technical
J. Durning
Business Manager
R. King
Deputy Business Manager
C. Steeley

Vacant – Financial Mgr
C. McKenzie (210.S) – Procurement Mgr
J. King (210.S) – Contracting Officer
D. Miller – Project Support Mgr

Senior Project Scientist
J. Mather (665)
Deputy Project Scientist
J. Gardner (665)

M. Greenhouse (665) - ISIM Scientist
M. Clampin (667) – Observatory Scientist
G. Sonneborn (665) – Operations Scientist
C. Bowers (667) – Deputy Observatory Scientist
B. Rauscher (665) - Deputy ISIM Scientist

Mission Systems Engineer
M. Menzel (599)
Deputy Mission Sys Eng
R. Lynch (599)

H. Bremmer (SGT) – Sys Coord
K. Rehm (581) – F&G SW Sys
G. Mosier (531) – Integ Modeling
K. Parrish (545) – Thermal Sys
J. Lawrence (543) – Mech Sys
G. Golnik (Schafer) – Opt Sys
S. Irish (542) – Structures
R. Stone (565) – Electrical Sys
T. King (QSS) – Parts
S. Le (Ball) – Materials
E. Wooldridge (546) – Contam
L. Markley (591) - ACS

K. Lebsock (OSC) – GNC
M. Beckman (595) – Flt Dyn
J. Hagopian (551) – Optical Verif
R. Sengupta (SIGMA) – Risk Coord
A. Sherman (SGT) – Chair, ERB
Vacant (565) – Elec Verif
C. Perrygo (SGT) – Sunshield
M. Bussman (SGT)--Rqmts
R. Ivancic (SGT) – S/C Sys
B. Bogenberger (SGT) – Rqmts
D. Muheim (531) – Integ. Modeling
R. Lundquist (599) – ISIM Sys Eng

Chief Safety and Mission Assurance Officer (CSO)
J. Radich (324)

P. Gibbons (321) – Project Safety Mg
S. Aleman (324) – ISIM CSO

Observatory Manager
P. Geithner

R. Sabatino (581) – S/C FSW SE

Observatory Sys Eng
R. Lynch (599)

Launch Vehicle Liaison
J. Lawrence (543)

Sunshield Manager
K. Parrish (545)

Observatory I&T Mgr
C. Diaz (ManTech)

Cryocooler Mgr
M. Larson (JPL)

K. Banks (552) – Obs Cryocooler SE

Obs Scientist
M. Clampin (667)
Deputy Obs Scientist
C. Bowers (667)

OTE Manager
L. Feinberg (550)
Deputy OTE Manager
R. Keski-Kuha (551)

W. Hayden (592) – OTE SE
J. Hagopian (551) – Opt. Verif.
J. Howard (551) – Opt. Design Lead
B. Dean (551) – OTE WFSC Lead
L. Cohen (SAO) – Mech Sys Lead
B. Rodini (SGT) – Composites Lead
K. Thakore (544) – Electromech Lead

Ground Segment & Ops Manager
A. Johns

Operations Scientist
G. Sonneborn (665)

Mission Engineering Manager
J. Gal-Edd (581)

Science Operations Manager
B. Seaton (581)

B. Bruce (441) – PRD Mgr
P. Johnson (583) – PPS Mgr
D. Matusow (588) – OSS Mgr
R. Detter (584) – FITSWriter Mgr

Ground Segment I&T Manager
C. Fatig (SAIC)

IGSS Development Manager
J. Steck (584)

A. Bigel (584) – Sys Tools Dev Eng
G. Turner (586) – Sys Integ Eng
R. Mitchell (584) – Cust/Infrastruc Supt

ISIM Manager
J. Dunn
Deputy ISIM Mgr
M. Voyton
ISIM Financial Mgr
Vacant

ISIM Scientist
M. Greenhouse (665)
Deputy ISIM Scientist
B. Rauscher (665)

ISIM CSO
S. Aleman (324)

ICDH Hardware Mgr
Vacant

G. Henegar (564) IRSU Mgr

ISIM FSW Mgr
B. Savadkin (582)

ISIM Structure Mgr
E. Johnson (543)

R. Rashford (GEC) – IEC Mgr

OSIM Mgr
T. Pham (556)

Instrument Systems Manager
S. Lambros

ISIM Systems Engineer
R. Lundquist (599)

P. Davila (551) – Optical Lead
J. McCloskey (565) – Elec Sys
S. Glazer (545) – Thermal Sys
R. Carter (SGT) – Mech Sys
J. Johnston (542) – Str Sys & Int Mod
P. Whitehouse (552) – Cryo Sys
R. Ladbury (561) - Radiation
S. Le (Ball) – Materials
R. LeVesque (SGT) - Contam
E. Greville (SGT) - FSW Sys
R. Sharma (544) – Electromech Sys
S. Allen (565) – Harness
D. Ramey (SGT) – Ops Lead

ISIM I&T Manager
M. Drury (ManTech)

NIRCam Instr Mgr
D. Yun

J. Van Campen (ManTech) – NIRCam ISE

NIRSpec Instr Mgr
T. Johnson (556)

M. Smith (556) – NIRSpec ISE
D. Sohl (556) – Microshutter SS Mgr
S. Manthripragada (556) – Detector SS Mgr

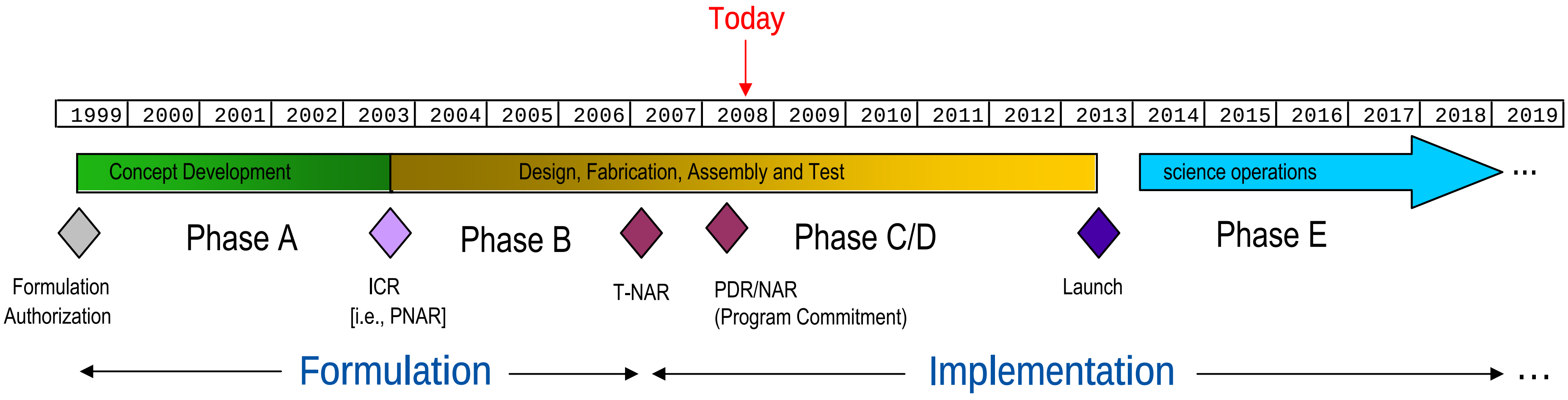
MIRI Instr Mgr
P. Driggers (SGT)

C. Aymergen (SGT) – MIRI ISE

FGS Instr Mgr
S. Lambros

J. Abell (SGT) - FGS ISE

Program Phases



- Currently in Formulation (Phase B)
- Early emphasis on vigorous technology development to retire risk
  - ~50% of Phase A through D total invested so far
  - Pacing items (primary mirror, detectors) already in Phase C/D and flight production per agreement with HQ at the Initial Confirmation Review (ICR)
  - Successful Technology-Non Advocate Review (T-NAR) in January 2007
- Mission PDR/Non-Advocate Review (NAR) completed last Spring
  - Confirmation Review schedule for July

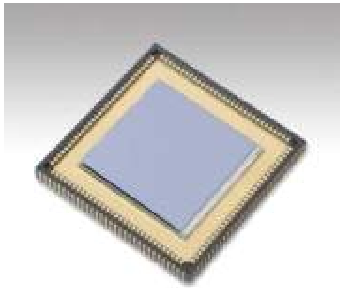
JWST Technology Status and TNAR Summary

- JWST identified ten “enabling” technologies required to achieve the performance needed to achieve the JWST science mission
  - NEAR INFRARED DETECTORS (NIR)
  - SIDECAR ASIC
  - MID INFRARED DETECTORS (MIR)
  - MIRI CRYOCOOLER
  - MICROSHUTTERS
  - HEAT SWITCH
  - SUNSHIELD MEMBRANE
  - WAVEFRONT SENSING & CONTROL (WFS&C)
  - PRIMARY MIRROR
  - CRYOGENIC STABLE STRUCTURES
- The Project made a significant early investment in these enabling technologies and pursued an aggressive development schedule to ensure that they would reach a technology readiness level (TRL) of 6 or higher prior to the Mission Preliminary Design Review/Non-Advocate Review
- At the Project’s request, NASA Headquarters chartered a non-advocate review team (NRT) to assess the readiness of these technologies in January 2007, more than a year before the Preliminary Design Review / Non-Advocate Review

NRT Assessment Report (April 2007) - TRL-6 success criteria met for all technologies

Near IR Detectors

Mid IR Detectors



Heat Switch

Sunshield Membrane

SIDECAR
ASIC

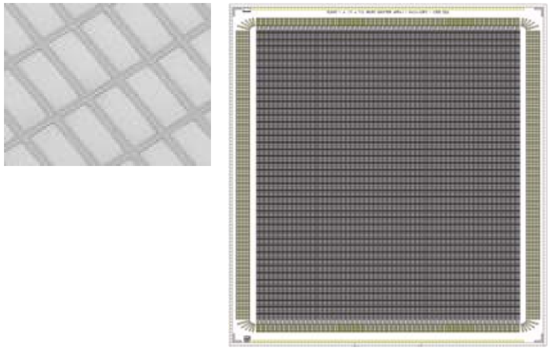
Stable Large Cryogenic Structures
Backplane Stability Test Article (BSTA)

MIRI Cryocooler

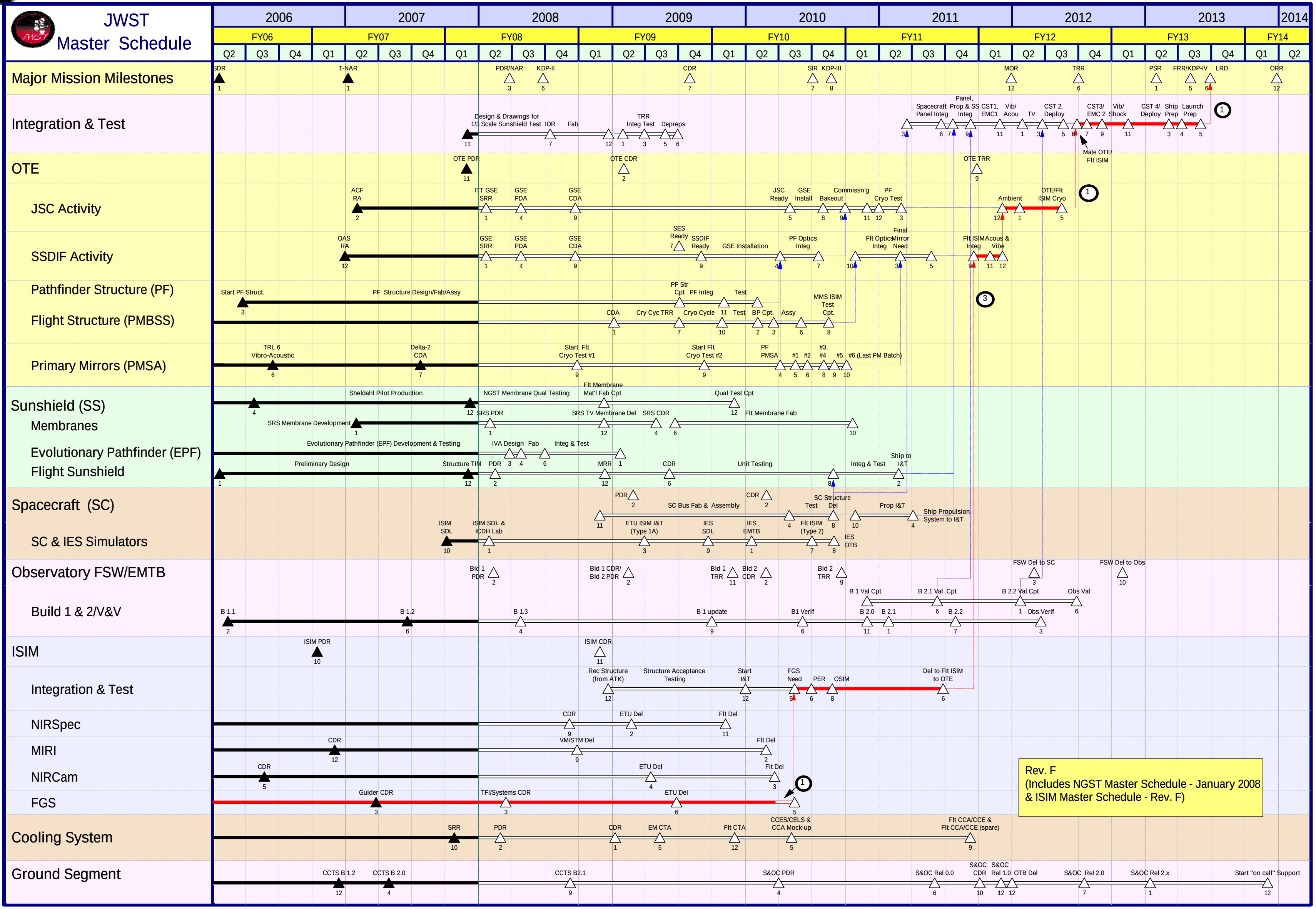
Wavefront Sensing & Control
Test Bed Telescope

Primary Mirror

Micro Shutter



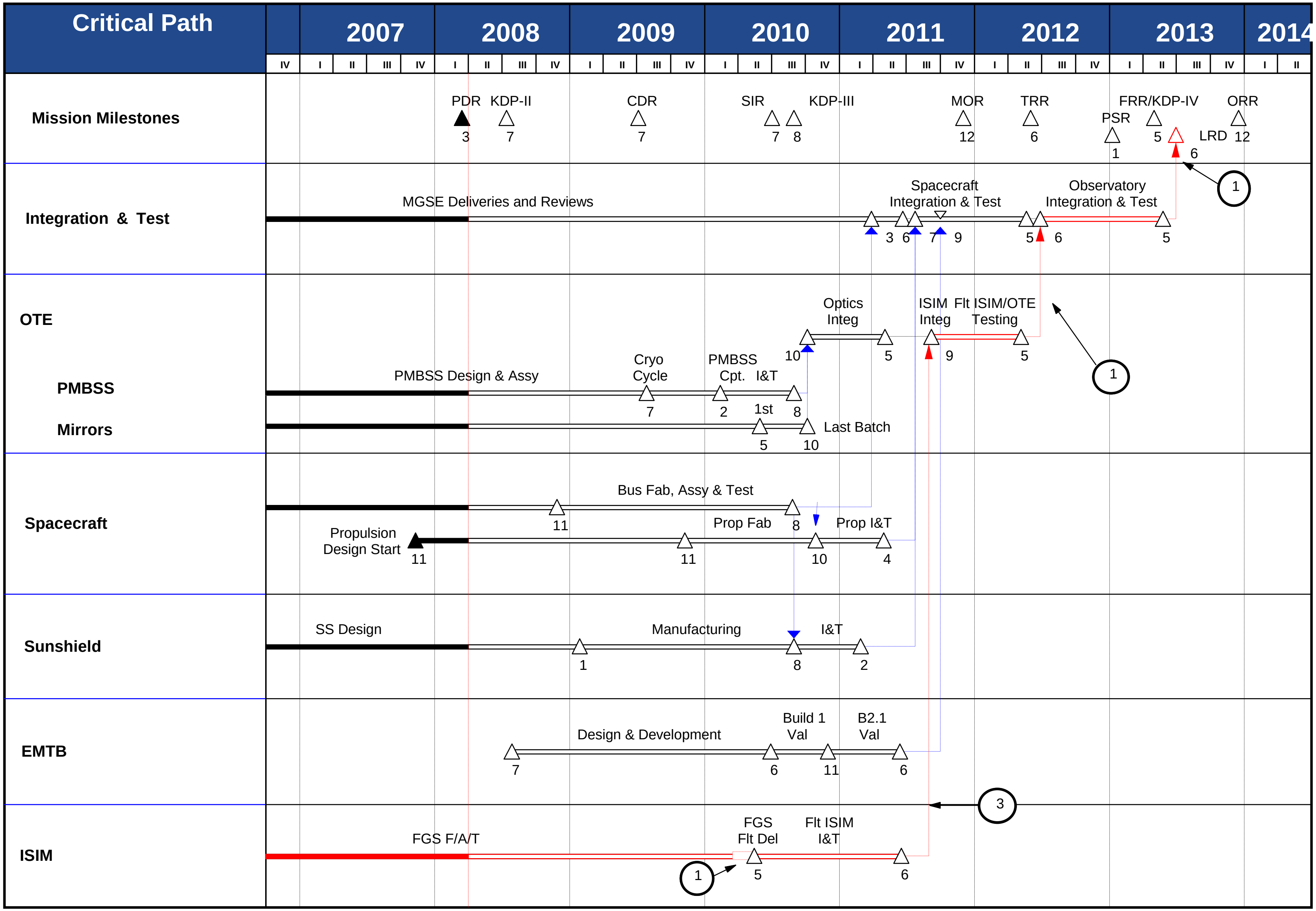
JWST Master Schedule



Rev. F
(Includes NGST Master Schedule - January 2008
& ISIM Master Schedule - Rev. F)

Project Critical Path Summary

3/31/08



The Realities of Managing Complex Space Projects

Obvious Project Management Tools

- Organization with clear lines of authority and accountability
- De-scope plan as a function of project life cycle
- Critical path schedule with identified and budgeted schedule contingency; manage the critical path
- Grass roots budget with adequate properly phased contingency
- Risk management process that is used. Process does not have to be complicated
- Understand your embedded margins
- Using the liens & threats system in conjunction with the risk system
  - Liens are resources needed but not yet budgeted
  - Threats are potential resource needs

Project Management – Set Up the Project Right

- Establish an organization with clear lines of authority and responsibility
  - Ensures who is responsible for what and establishes lines of accountability
- Ensure that requirements flowdown starts from the very top and that every lower level requirement has a parent
  - Requirement development must be completed during phase B and signed off by state holders and project prior to start of implementation phase (C&D)
  - This is crucial later on when working problems and understanding your trade space
- Start out with the best test program that, in theory, your budget can support
  - In the end, due to the problems that you will face, you will be force to focus on design & workmanship verification testing
  - The difference between these two test programs will be the program risk (primarily schedule) you have added to the program
- Be sure that any technology planned on is ready for prime time
  - Be sure the technology has been adequately demonstrated prior to beginning the developmental phase of the program (phases C&D). NASA targets technology readiness level 6
  - That was the death knell of the VCL mission – they tried to go, on the laser technology, from TRL-2/3 to TRL-8 during the development phase. Great progress was made but there was not enough time or money to complete the task.

Project Management – Set Up the Project Right (cont'd)

- Establish trust between the Project Science Team and the Project Management Team
  - The science team's primary focus is to ensure scientific success of the mission and they typically are conservative in their requirements to ensure this. The project team is focused on meeting budget & schedule. In the wrong environment this relationship can become adversarial which would be non-productive. If the cost and/or schedule blow up you may never get to launch (VCL) and if you focus primarily on cost & schedule you may never get the science (Mars '98). Trust will allow frank and productive discussions in dealing with development problems and understanding the full scope of the trade space and impacts.
- Make sure you establish the correct technical metrics to track
  - Get science team buy in on metrics
  - You don't want the tail to wag the dog

Project Management Objective

- Achieve mission success while looking for opportunities to share the blame for any additional required time and money
    - Share blame on factors not under the project's control, ie. budget cuts, launch vehicles, ground system, requirement changes, etc.
    - Ask for more money and time when you first take over a project, not after you have been there for awhile
- "The difference between a successful project manager and an unsuccessful project manager is recognizing and capitalizing on opportunity."
- "It's better to be lucky than good."
- It's even better to be lucky and good. You make your own luck by being good
- "Design to cost" – it is simple concept but one that is very foreign to many contractors and scientist. It is a mantra that needs to be bought into by the entire team. Typical contractors strive to give you the best product no matter what the cost and you need to adjust there thinking to giving you the best product your budget can buy and getting buy in by the science community along the way. Striking that balance is the key to mission success.

My Projects

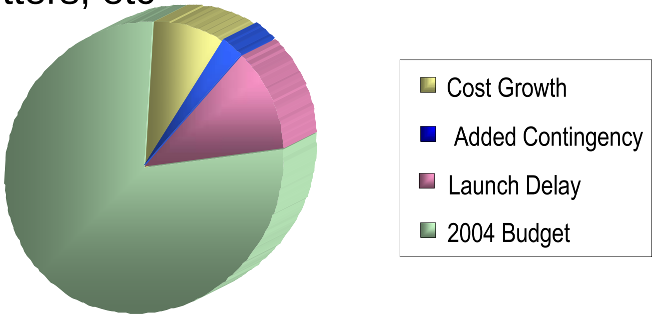
- TOMS-EP
  - Pegasus launch failures delayed the launch by 2 years. Some of that time was used to better train the FOT and fix latent satellite problems. We didn't need the 2 years, but a couple of months helped
- Landsat 7
  - ETM+ delays blamed on heritage design inherited from the Air Force. Detailed example of using schedule work arounds to reduce risk and minimize launch delays
- Aura
  - EOS Program office needed the Aura project's launch vehicle money for another project in FY01. The Aura project needed more time for instrument development. The program office got $12M loaned to them and the Aura project got 6 months of schedule slip and the loaned money paid back with interest. Everyone was happy
- VCL
  - Nothing seemed to work, the project was eventually cancelled due to immature laser technology
- Aqua
  - Asked for and received 5 months of schedule slip and $22M shortly after taking over the project. Used time to move up fault management testing while fixing latent problems with the satellite hardware. This reduced the over all risk to meeting the new LRD. Additional time became available due to the missions in front on the Delta II manifest slipping
- JWST
  - Used projected cost growth as the catalyst to simplify the I&T program. The technical team was able to come up with creative solutions to achieve almost all of the original testing requirements while reducing hardware interdependencies and moving the need date of some critical path hardware and money to the right

JWST Specifics

- Program Challenges
  - 2005 cost growth
  - 2007 Reformulation
- Understand and manage/fund critical path
  - Was absolutely critical when tough funding decisions had to be made
  - Our number 1 priority was completing our technology items to TRL-6 then the instruments then the OTE then the Sun Shade and wrapping it together with systems engineering
  - Since JWST was a phased development based on long leads, it was important to have a strong systems engineering team

JWST 2005 Cost Growth

- **Over the course of the formulation phase, the Project's estimate for completion of JWST increased**
  - Growth driven by both external and internal factors
- **Net life cycle cost growth from $3.5B in 2004 to $4.5B in 2006**
  - 30% growth ($1B)
- **Majority (2/3) of this increase due to external factors**
  - A 22 month launch delay:
    - Delay in approval for Ariane 5 launch vehicle
    - Fiscal year funding limitations, including previous years cuts, through 2007
  - Added budget reserves
- **Balance (1/3) of growth due to project internal changes**
  - Changes in requirements and growth in implementation
    - Cost increases in getting major suppliers under contract
    - Architecture changes: cryocooler, ASIC control of detectors, dedicated ISIM electronics compartment, added pupil imaging lens, etc
    - I&T reevaluation: test facility changes, added launcher-related testing, NIRCam-level wavefront sensing testing, cryogenic telescope simulator for ISIM testing, etc
    - Cost growth in instruments: detectors, microshutters, etc

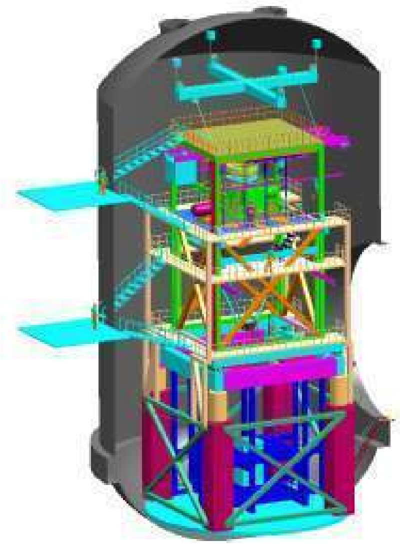


JWST 2007 Reformulation

- **Focused on simplifying the test program:**
  - Modified OTE Pathfinder
  - Eliminated the OTE/ISIM ETU test at JSC
  - Eliminated NOTES; added functionality to OSIM
  - Eliminated the OTE only test at JSC ; added a month to the flight ISIM/OTE test
  - Eliminated the ISIM Hybrid test
    - Current test program doesn't preclude adding back the OTE only or ISIM hybrid test depending on the availability of components
  - Completed a study last fall to further simplify the JSC test configuration addressing both cost risks and interface simplifications
    - This includes relying on phase retrieval instead of interferometry for optical testing and configuration changes that allow for less invasive interfaces
    - Simplified the ACF configuration
  - Added cryo photogrammetry at JSC and workmanship test of the flight backplane at the SES

Evolution of JWST Testing Approach

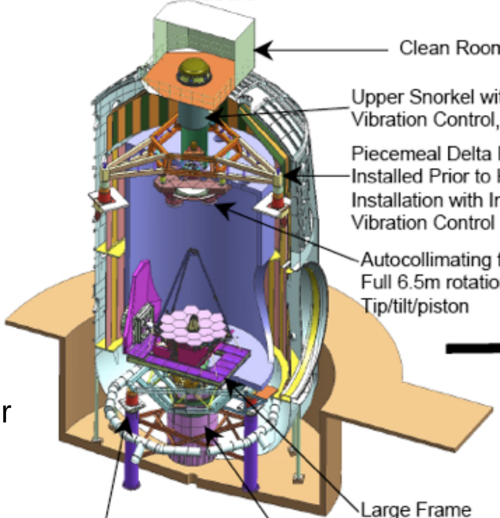
decreasing Cost/Risk increasing



“Cup-down” test configuration within Johnson Space Flight Center (JSC) cryogenic test chamber

JSC Test Configuration

“Was”



Clean Room Hut

Upper Snorkel with Vibration Control, Drift Control

Piecemeal Delta Frame Installed Prior to He Shroud Installation with Independent Vibration Control

Autocollimating flats with Full 6.5m rotation, spin, Tip/tilt/piston

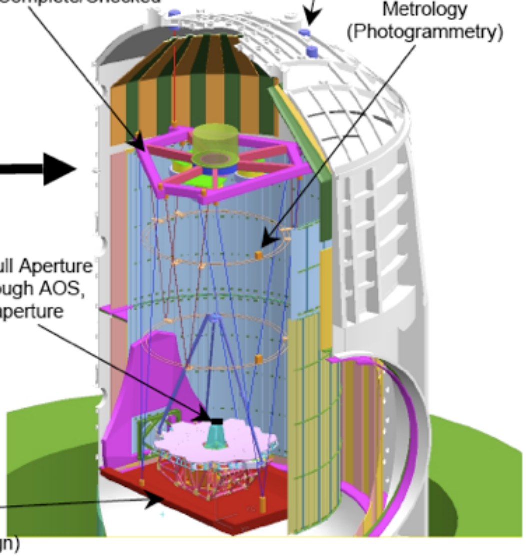
Large Frame Support for OTE Support Structure

Pillars and Independent Isolation System

Image Surface Optical Assembly (ISOA): Interferometers, Metrology Equipment, Upward Subaperture sources that inject through ISIM

OTE Alone Test Deleted but Not Precluded
Backplane Alone Test at SES Added

“Is”



Upper Delta Frame
- Holds COCOA
- ACF mirrors and Mechanisms (OSOA)
- Installed after Helium System Complete/Checked

Suspension System / Isolation System (6 places)

Cryo Position Metrology (Photogrammetry)

Downward Full Aperture Sources Through AOS, Upward Subaperture Sources

OTE Support Structure Hung on Hexapod Rod System (Heritage Design)

2003 **2005** **2007**

Final Thoughts

- Get good people and let them do their jobs
- Build good chemistry between all contractor and government team members. This ensures that everyone is a stakeholder in the success of the mission
- Never forget who is ultimately accountable
- Attack your problems early and aggressively. Don't put your head in the sand and hope things will get better. They don't!
- Always tell the truth, but do it at the right moment. Give your problems a little time to age. Follow the 24-48 hour gestation rule
- Don't constantly ask for direction or guidance. If you do, you will get it. It's your project, manage it
- Communicate communicate communicate. Can't over communicate
- Ignorance is never a good thing and timing of knowledge is important
  - Need time to work the problem
  - Stay on plan but understand fiscal realities at least 12-18 months into the future
  - Use the threat and lien system to capture your uncertainties
- Asking an engineer what it will take to get the job done is sure to break your bank. Telling an engineer "you have this much to do the job, what can you do with it?" and you more likely to get creative answers and stay closer to plan
- A test is worth a thousand analyses. Get operating time on the hardware and software. Test as you fly. Don't forget to test with the ground system. Can't do this on JWST
- Take care of yourself. Nobody else will. This means eat well and exercise. Project management is more of a marathon than a sprint
- The reward for doing a good job (at least at GSFC) is the opportunity to do it again
- Above all else "Mission Success". Make the right technical decisions. This achieves mission safety