James Webb Space Telescope

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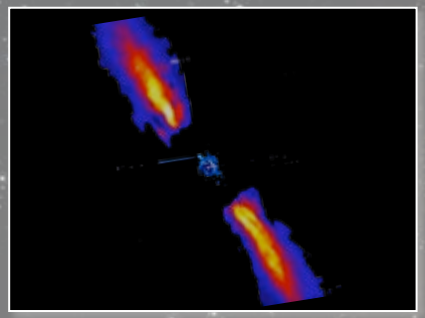
Science Goals

James Webb Space Telescope (JWST) goes beyond Hubble and other space telescopes by seeing things that they cannot see…

- How did the universe make galaxies?
- Are there other planets that can support life?
- How are stars made?

JWST is about beginnings: the beginning of galaxies, the beginning of stars, the beginning of planets and life.

First Light



Planets and the Origins of Life

The Assembly of Galaxies

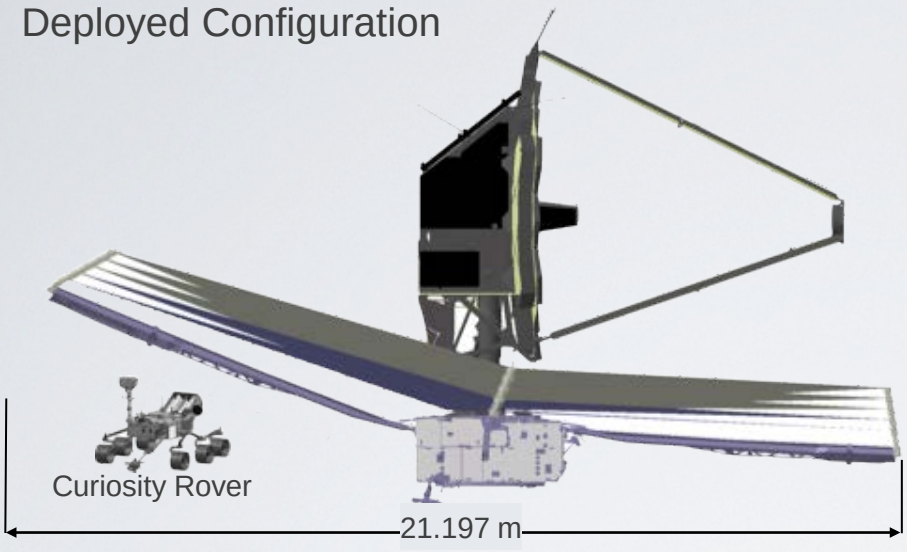
Birth of Stars and Planets

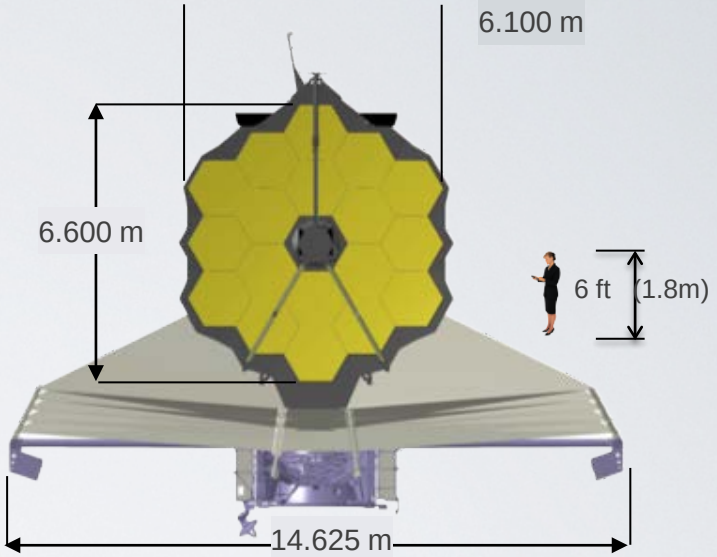
Organizations Involved

- Mission Lead Center: Goddard Space Flight Center
- International Partners: European Space Agency (ESA) & Canadian Space Agency (CSA)
- Major Contractor: Northrop-Grumman Aerospace Systems
- Science Instrument Providers:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - Fine Guidance Sensor (FGS) + Near Infrared Imager and Slitless Spectrograph (NIRISS) – CSA
- Operations: Space Telescope Science Institute

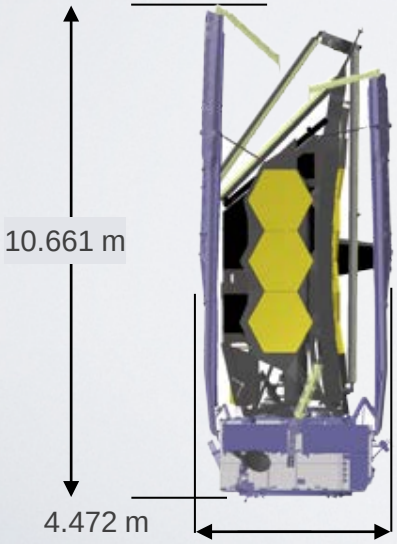
Observatory Design

Deployed Configuration



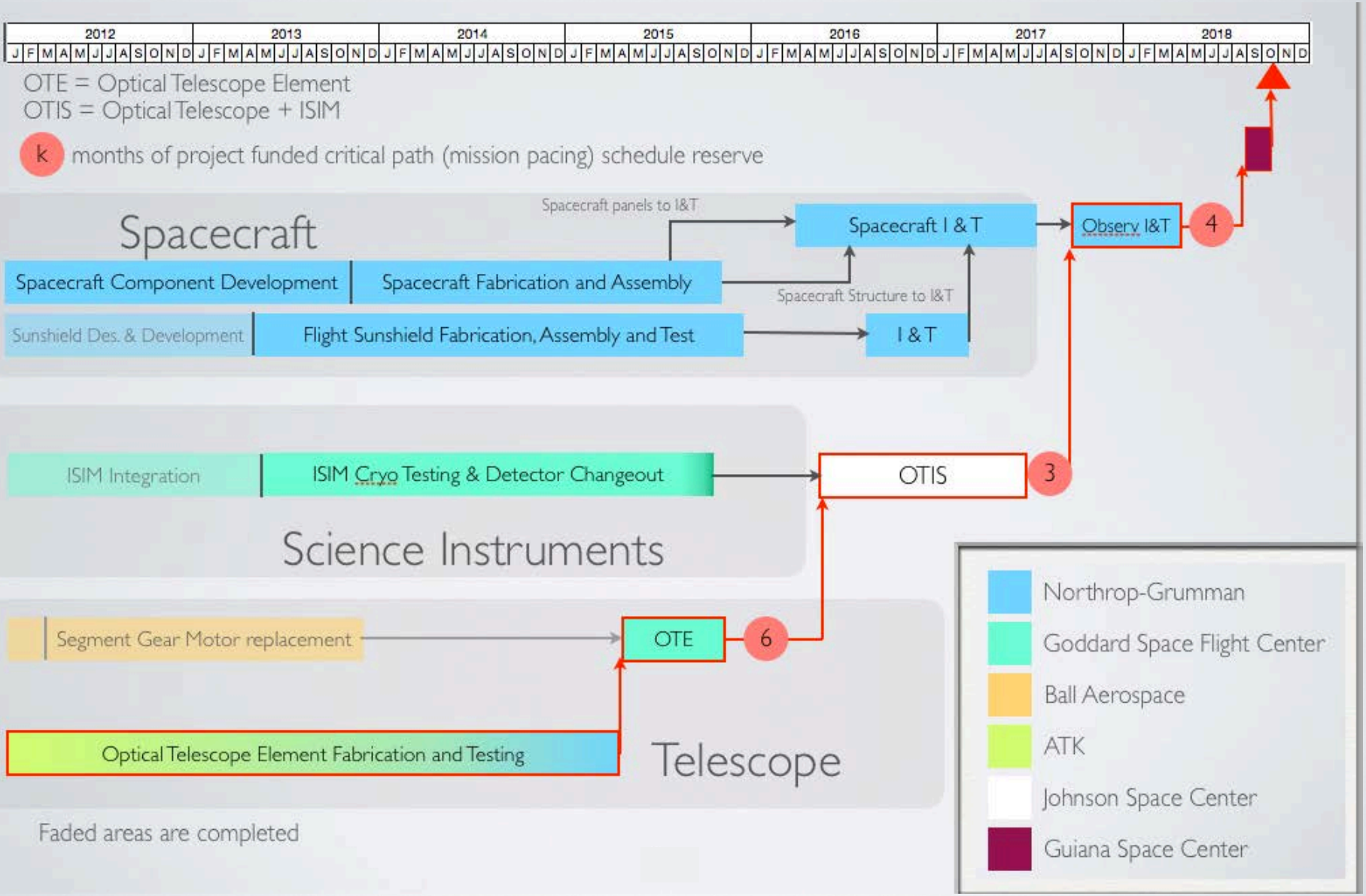


Stowed Configuration



- Telescope diffraction limited at 2 micron (2×10^{-6} meters) wavelength.
  - $25\ m^2$, 6.35 m average diameter aperture.
  - Instantaneous Field of View ~ 9 arcminutes X 18 arcminutes.
  - 18 Segment Primary Mirror with 7 Degrees-of-Freedom adjustability on each.
- Integrated Science Instrument Module containing near and mid infrared cryogenic science instruments
  - The Near-infrared camera functions as the on-board wavefront sensor for initial telescope alignment and phasing and periodic maintenance.
  - Instruments from University of Arizona, European Space Agency, and Canadian Space Agency
- Deployable sunshield for passive cooling of Telescope and Science instruments.
- Mass: $\leq$ 6620 kg.
- Power Generation: 2000 Watts Solar Array.
- Data Capabilities: 471 Gigabits on-board storage, 229 Gigabits/day science data.
- Life: 5 years [Designed for 11 years (goal) of operation].

JWST Simplified Schedule



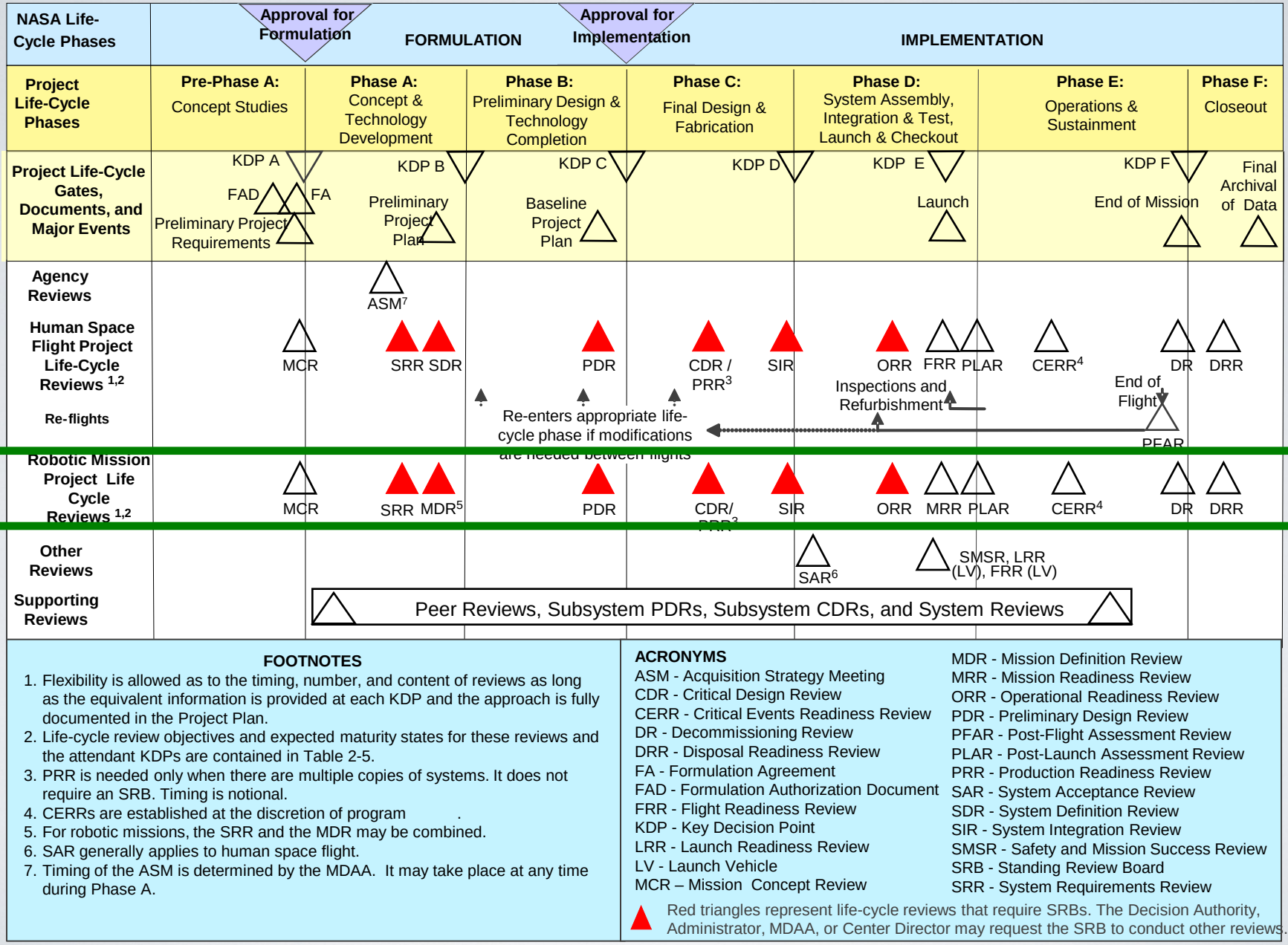
NPR 7120.5e

“Space flight programs and projects flow from the implementation of national priorities, defined in the Agency's Strategic Plan, through the Agency's Mission Directorates…”

“A program implements a strategic direction that the Agency has identified as needed to accomplish Agency goals and objectives.”

A project is “a specific investment identified in a Program Plan having defined requirements, a life-cycle cost, a beginning, and an end.”

Figure 2-5 NASA Project Life Cycle



FOOTNOTES

1. Flexibility is allowed as to the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan.
2. Life-cycle review objectives and expected maturity states for these reviews and the attendant KDPs are contained in Table 2-5.
3. PRR is needed only when there are multiple copies of systems. It does not require an SRB. Timing is notional.
4. CERRs are established at the discretion of program .
5. For robotic missions, the SRR and the MDR may be combined.
6. SAR generally applies to human space flight.
7. Timing of the ASM is determined by the MDAA. It may take place at any time during Phase A.

ACRONYMS

ASM - Acquisition Strategy Meeting
CDR - Critical Design Review
CERR - Critical Events Readiness Review
DR - Decommissioning Review
DRR - Disposal Readiness Review
FA - Formulation Agreement
FAD - Formulation Authorization Document
FRR - Flight Readiness Review
KDP - Key Decision Point
LRR - Launch Readiness Review
LV - Launch Vehicle
MCR – Mission Concept Review
MDR - Mission Definition Review
MRR - Mission Readiness Review
ORR - Operational Readiness Review
PDR - Preliminary Design Review
PFAR - Post-Flight Assessment Review
PLAR - Post-Launch Assessment Review
PRR - Production Readiness Review
SAR - System Acceptance Review
SDR - System Definition Review
SIR - System Integration Review
SMSR - Safety and Mission Success Review
SRB - Standing Review Board
SRR - System Requirements Review

Red triangles represent life-cycle reviews that require SRBs. The Decision Authority, Administrator, MDAA, or Center Director may request the SRB to conduct other reviews.

Program/Mission Definition

- NASA Science Mission Directorate (SMD) Process
- Strategic Programs/Missions
  - Goals & methods defined through National Academy of Sciences Decadal Surveys
  - Costs exceed $1B typically
  - NASA Center led
- Competed Programs/Missions
  - Explorers, Discovery, New Frontiers, Earth Venture, sounding rockets, balloons
  - Principal Investigator led

Pre-formulation Lesson

- Externally defined goals (*e.g.*, by National Academy of Science) can provide quantitative, stable and resilient requirements upon which programs can be structured and subsequently defended to stakeholders.

- But, should these goals prove difficult to achieve, the process to change them (*i.e*., a Level 1 requirements change) could involve a dialog with the science community rather than a simple intra-agency decision.

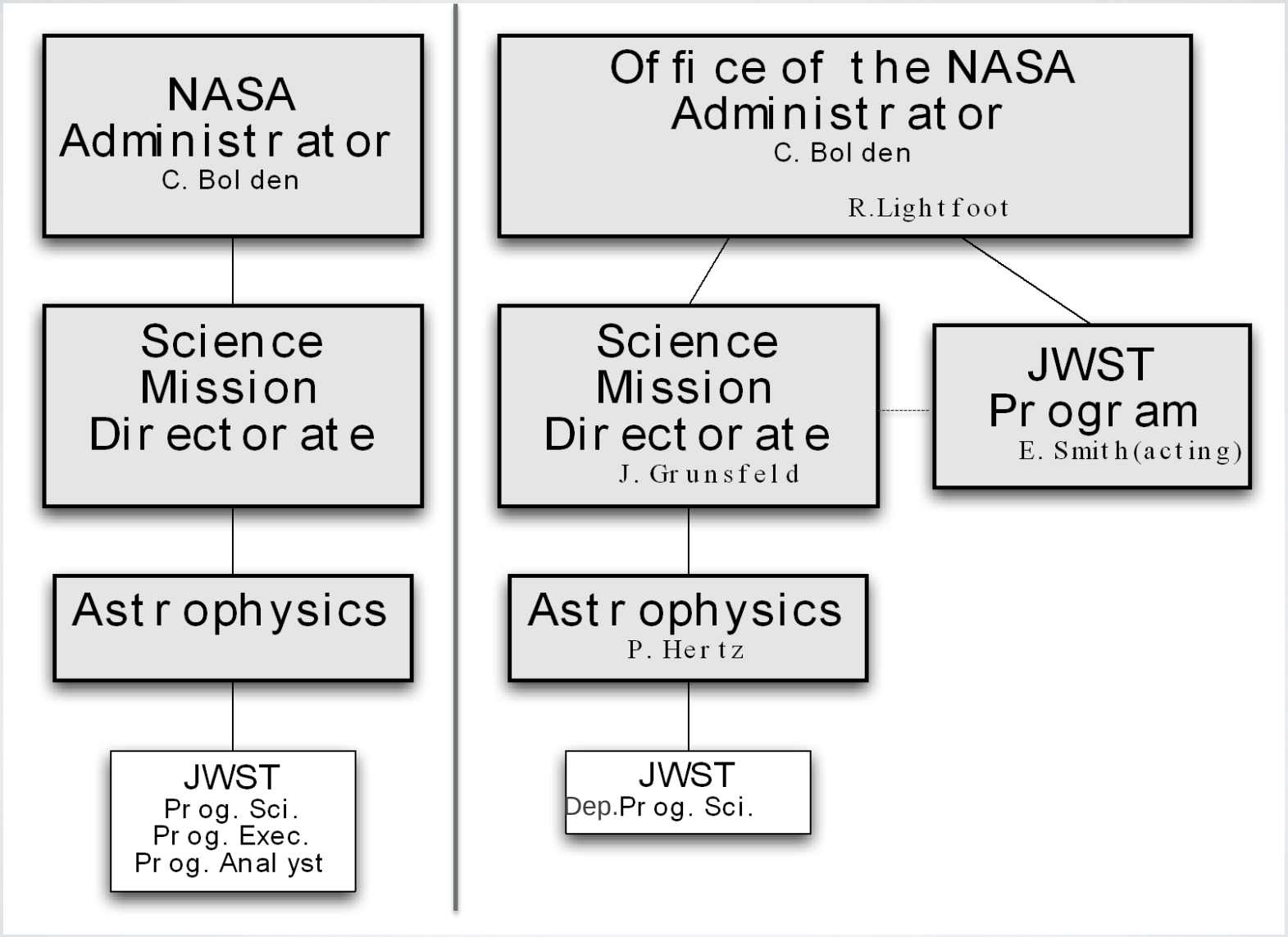
Acquisition Lesson

- International partnership for JWST led NASA to choose acquisition/management model with two major centers of hardware responsibility, Northrop-Grumman as lead industry partner (telescope and spacecraft) and GSFC (science instrument integrator).
- Generated difficulties on who was system engineering lead, ultimately resolved during 2011 replan (government is systems engineering lead)

Program Management Lesson

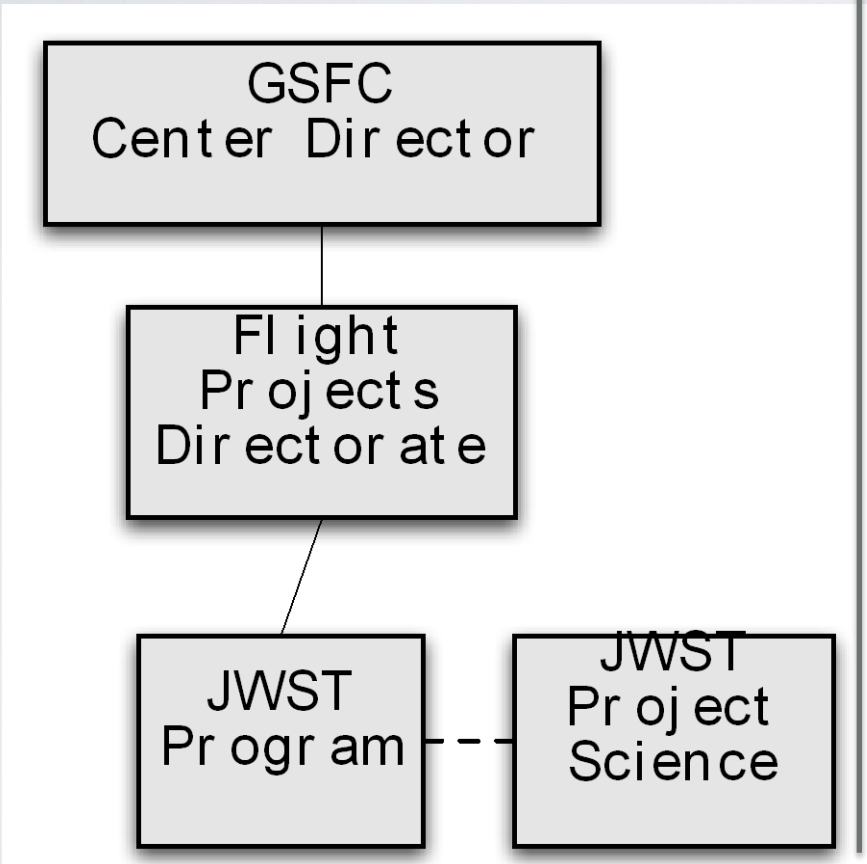
- Lines of programmatic and project authority were unclear
- Project/Mission grew to a size unmanageable in its host organizational structure, but “can do” nature of the business inhibits the inclination to request help.
- Because of this lack of management clarity there was inadequate analyses of project performance trends

HQ Organization

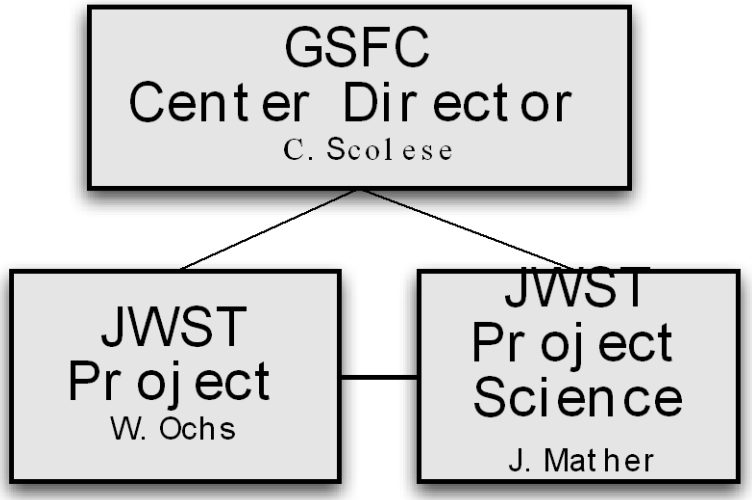


GSFC Organization

Pre 2010 replan

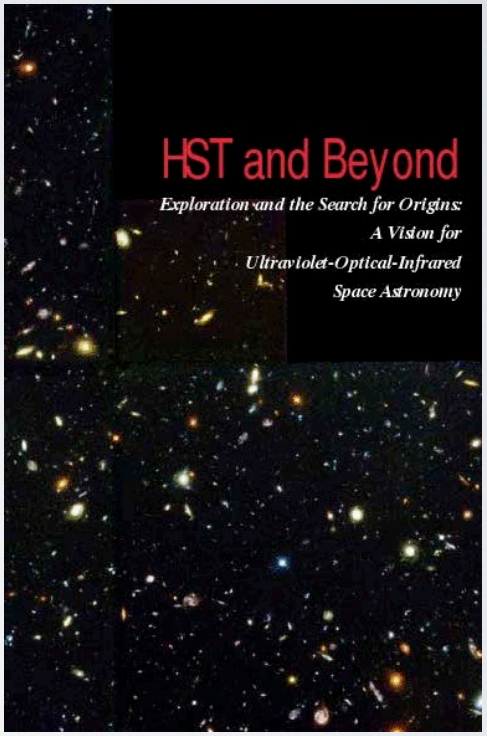


Current



Cost Estimation History

- First Estimates (1995): *HST & Beyond* [Not NASA]
  - Mission specification different from ultimate mission (4m, single instrument)
  - Technical specifications changed without appropriate change in estimate and resources
- KDP-C (2008) cost estimate factor of ~4 higher.
- Replan (2011) using extensive project history and realistic estimating practices methodology additional factor of ~2



Program Control Lesson

- Realistic estimating practices, including adequate internal reserves at NGAS and GSFC, and reserves held at HQ, used to create a more robust program profile
  - Other tools used for active program control
- In depth (subsystem-level) monthly analysis by project and program and center resource personnel
  - Use contractor Earned Value data, among other sources, as input
  - Use schedules and costs for non-profits to measure estimate-at-complete
- Monthly risk, schedule control board meetings

Communication Lesson

- Keeping stakeholders well informed has been a key component of the JWST replan
  - Quarterly briefings with OMB/OSTP, Congressional staffers
  - High-level milestones discussed publicly
  - High-bandwidth interactions with science community, top agency officials, GAO

Keeping our Partners and Stakeholders Informed

- Daily tag-ups with the Project Manager (Program Manager)
- Weekly or more meetings with NASA AA and SMD AA (Director/Deputy Program Director)
- Weekly meetings/telecons with GSFC Project Manager (Program Director/Program office)
- Weekly meetings/telecons with GSFC Center Director (Program Director)
- Weekly tag ups with APD Director (Director/Deputy Director)
- Weekly telecons with project science team (Deputy Director)
- Monthly Flight Program Review with SMD (Program Office)
- Monthly meetings with AURA, Inc. (Director/Deputy Program Director)
- Monthly presentations to OMB/OSTP with more detailed quarterly briefings (Director/Deputy Program Director)
- Quarterly briefings to House authorization committee staff, House appropriations staff, Senate authorization committee staff, Senate appropriations staff (Director/Deputy Program Director)
- Quarterly presentations to the NAC Science Committee, and scientific groups such as; SWG, AAAC, STIC, JSTAC, etc. (Director/Deputy Program Director)
- Senior Executive Quarterly meetings with Center Director, NGAS VP, LM VP, other senior members of industrial team (NASA AA, Director/Deputy Program Director, Program Manager)
- Quarterly (or as needed) telecons/meetings with ESA and CSA directors (Program

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 April, resolving parts issues, 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	
	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	
	21	Sunshield Membrane Cover Assembly Manufacturing Readiness Review	
	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	
	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")	Delayed to 6/2014 [shutdown]
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	
	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	
	30	Proprosal Planning Subsystem build 9 complete	
Aug-14	31	Sunshield Mid-boom and Stem assembly Manufacturing Readiness Review	
	32	Spacecraft Flight Software Build 2.2 Test Readiness Review	
	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]

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	15	7	11*	4

*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.