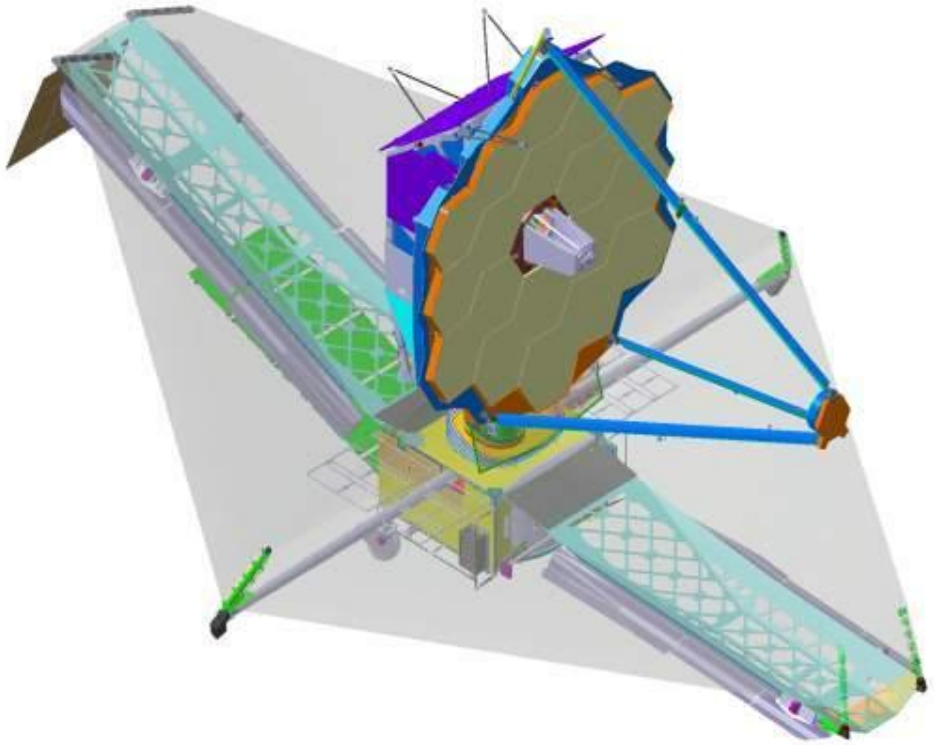
Managing Complex Space Missions like the James Webb Space Telescope
Paper Number 7738-23



Phil Sabelhaus
JWST Program Manager
June 28, 2010

Who am I?

- **Currently the James Webb Space Telescope (JWST) Program Manager**
  - Graduated from the University of Maryland in 1978
  - 32 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

Today's Topics

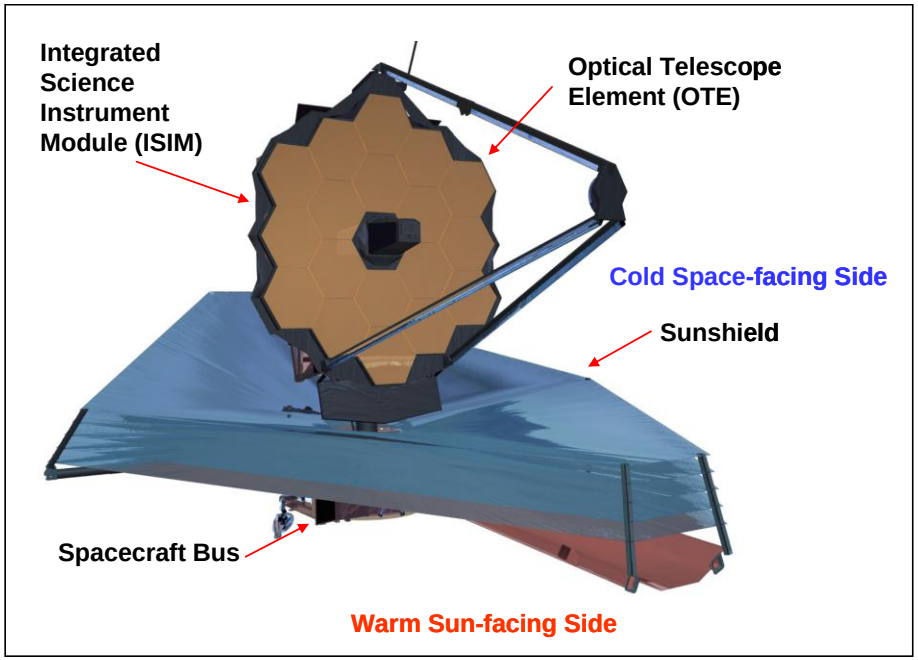
- JWST System Overview
- NASA Project Management Process
- JWST Project Management Approach and Challenges
- What hasn't been working and what does

JWST System Overview

James Webb Space Telescope (JWST)

Organization

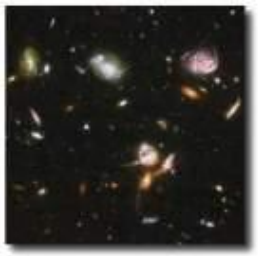
- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Aerospace Systems
- Instruments:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - 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 2014 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 is a general astrophysics mission for use by the international astronomical community

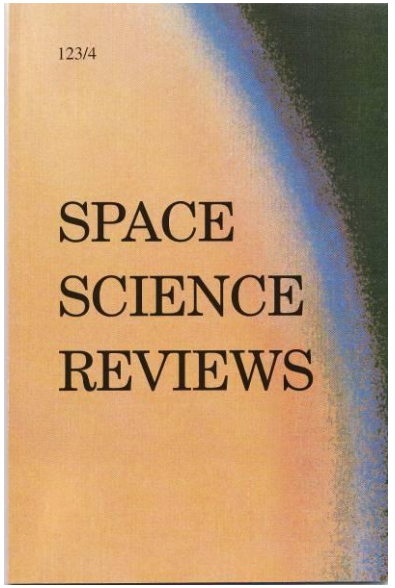
- **Often described as the successor to the Hubble Space Telescope, the JWST will serve astronomers world-wide in much the same way:**
  - Science & mission operations managed by the Space Telescope Science Institute
- **The science investigations performed by the JWST will be determined by the General Observer community.**
  - Observing time allocated through annual peer-reviewed proposal cycles
- **Four science themes have been defined by a succession of international community working groups to guide engineering development of the JWST:**

Identify the first bright objects that formed in the early Universe, and follow the ionization history.

Determine how galaxies and dark matter, including gas, stars, metals, overall morphology and active nuclei evolved to the present day.

Observe the birth and early development of stars and the formation of planets.

Study the physical and chemical properties of solar systems (including our own) and where the building blocks of life may be present.



The JWST Program is a Multi-Agency Partnership

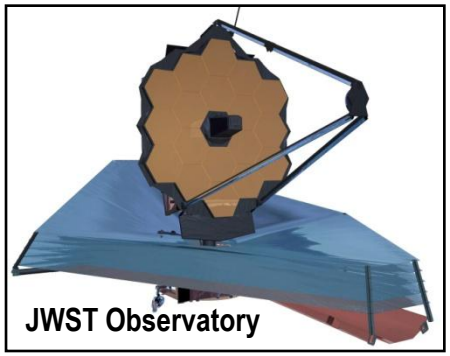
James Webb Space Telescope System

Launch Segment


Ariane Launcher

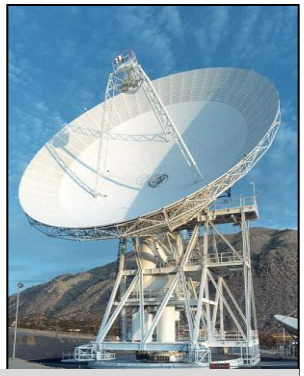
- Launch Vehicle
- Payload Adapter
- Launch Site Services

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

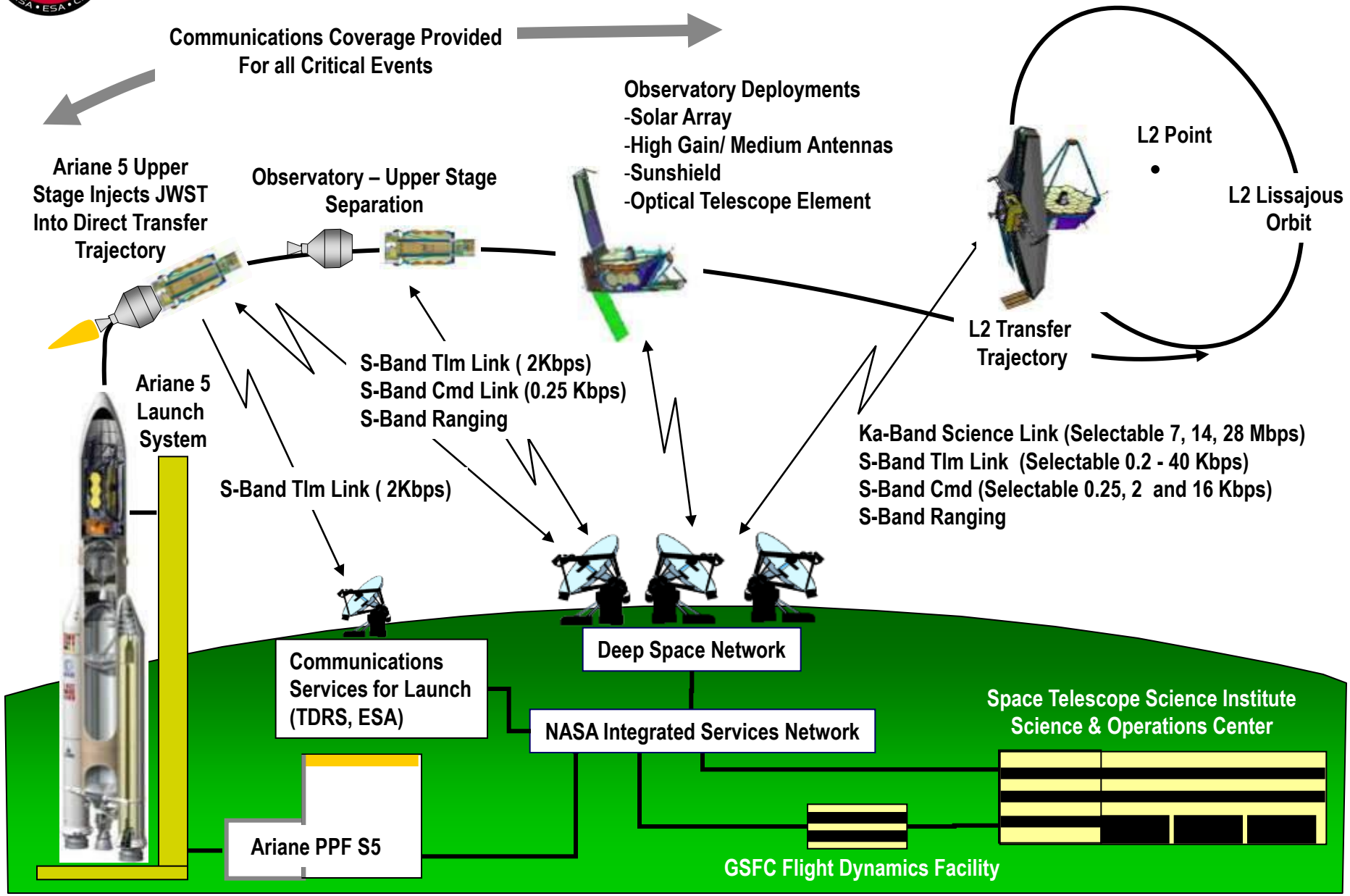

Deep Space Network


Space Telescope Science Institute

- Science and Operations Center (SOC)
- Common Systems

Provided by NASA
Provided by ESA
Provided by CSA

JWST System Architecture



Ariane 5 Launch Vehicle

Ariane 5 ECA

- JWST is designed for launch on an Ariane 5 launch vehicle with a 5 m diameter fairing
- Launch from Kourou Launch Center (French Guiana) with direct transfer to L2 point
- Payload launched at ambient temperature with on orbit cooling to 50 K via passive thermal radiators
- JWST payload: 6330 kg

JWST Team and Responsibilities

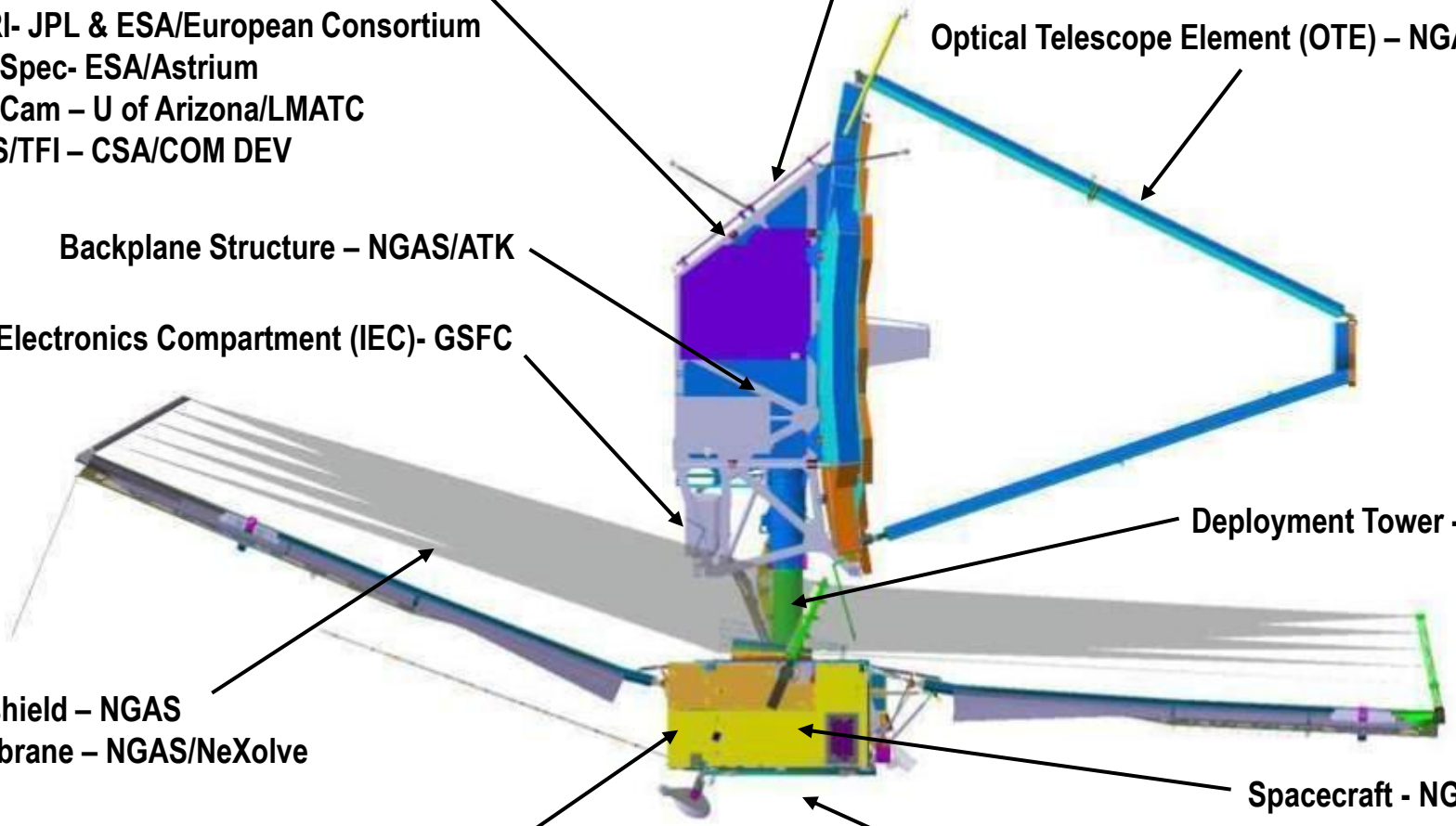
Integrated Science Instrument Module (ISIM) – GSFC
- Structure – GSFC/ATK
- MIRI- JPL & ESA/European Consortium
- NIRSpec- ESA/Astrium
- NIRCam – U of Arizona/LMATC
- FGS/TFI – CSA/COM DEV

ISIM Radiators- NGAS/Ball

Optical Telescope Element (OTE) – NGAS/Ball

Backplane Structure – NGAS/ATK

ISIM Electronics Compartment (IEC)- GSFC



Deployment Tower - NGAS

Sunshield – NGAS
Membrane – NGAS/NeXolve

Spacecraft - NGAS

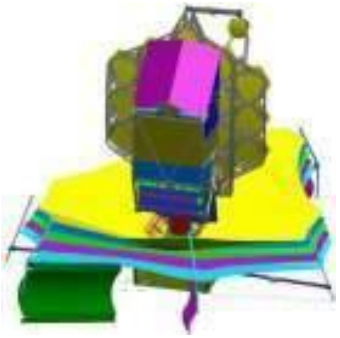
MIRI Cryocooler – JPL/NGAS
Instrument C&DH - GSFC

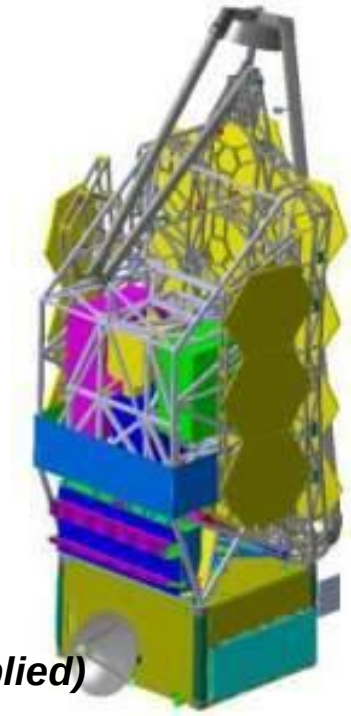
Launch Vehicle & Adapter- ESA/Arianespace

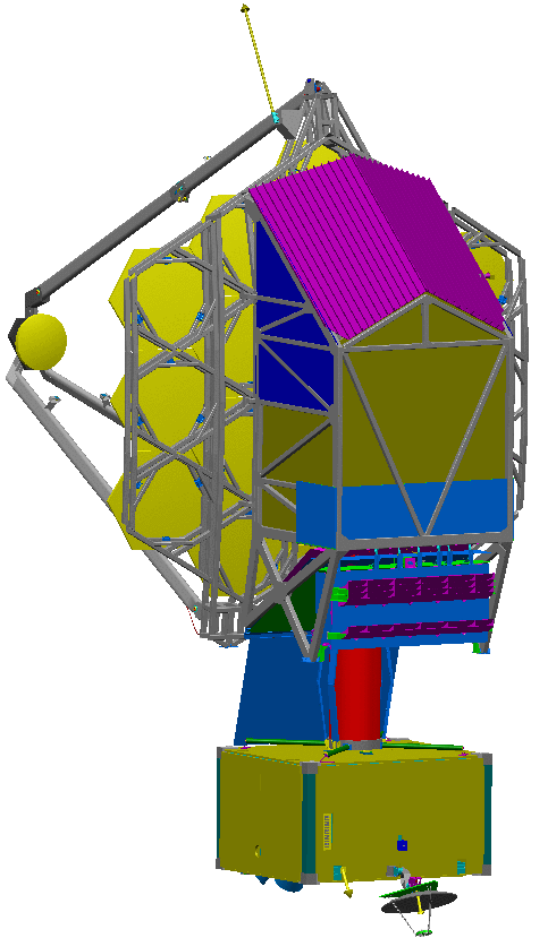
Overall Observatory - NGAS

ISIM Overview

ISIM is:
- **The JWST Science Instruments**
- **Associated Infrastructure: Structure, Thermal Subsystem, C&DH, & FSW**







Region 1:

Science Instrument Optics Assemblies

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

Optical Bench Structure

Radiators and support structure (NGAS-supplied)

Region 2:

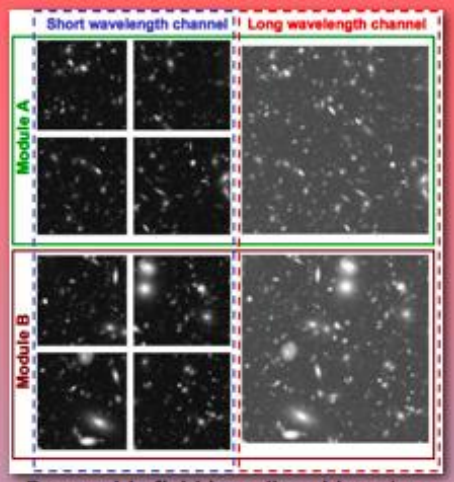
ISIM Electronics Compartment

Focal Plane Electronics (FPE)
Instrument Control Electronics (ICE, MCE)
ISIM Remote Services Unit (IRSU)

Region 3

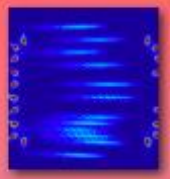
ISIM Command & Data Handling (C&DH) Electronics

JWST Science Instruments



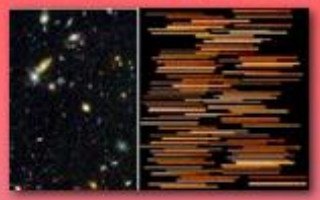
Deep, wide field broadband-imaging

Wavefront Sensing & Control (WFSC)

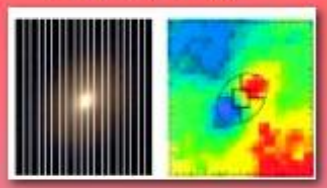


Coronagraphic Imaging

Multi-Object, IR spectroscopy



IFU spectroscopy



NIRCam

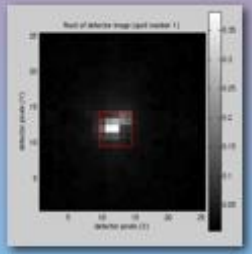
NIRSpec

Long Slit spectroscopy

FGS/TF

MIRI

Fine Guidance Sensor

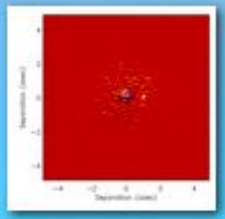


Moving Target Support

Mid-Infrared, wide field Imaging

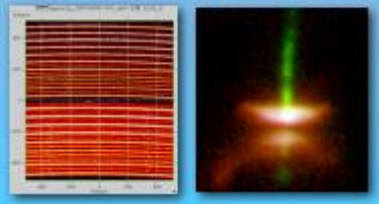
R=100 Narrowband Imaging

Coronagraphic Imaging R~100

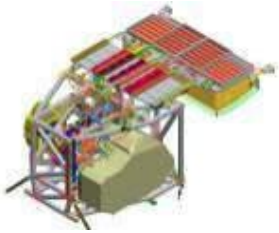


Mid-IR Coronagraphic Imaging

IFU spectroscopy



Integration &Test Flow Overview



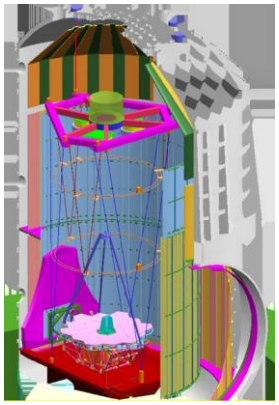
ISIM I&T

GSFC SSDIF

OTE/ISIM I&T

Cryo Optics Test

GSFC SSDIF, JSC 32



OTE Structure I&T

NGST M8

OTE I&T

GSFC SSDIF

OTE Pathfinder Structure

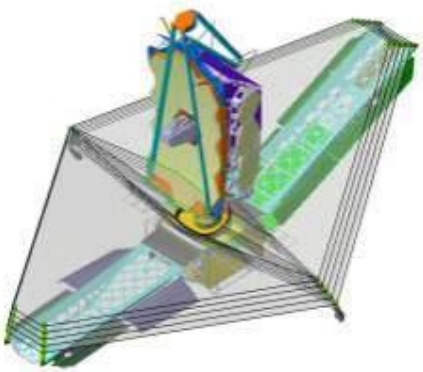
NGAS M8

Pathfinder Optics Integration

GSFC SSDIF

Pathfinder Cryo Optics Test

JSC 32



Observatory EM Test Bed (EMTB)

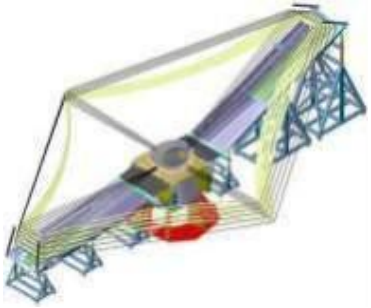
NGAS R8

Propulsion Module I&T

NGAS M3

Spacecraft Panel I&T

NGAS M8



Sunshield Pathfinders (EPF/IVA)

NGAS M8

Sunshield I&T

NGAS M8

Spacecraft Element I&T

NGAS M8, M4 TV

Complete Observatory I&T

NGAS M8, LATF, M4 Vibe

Launch Site I&T

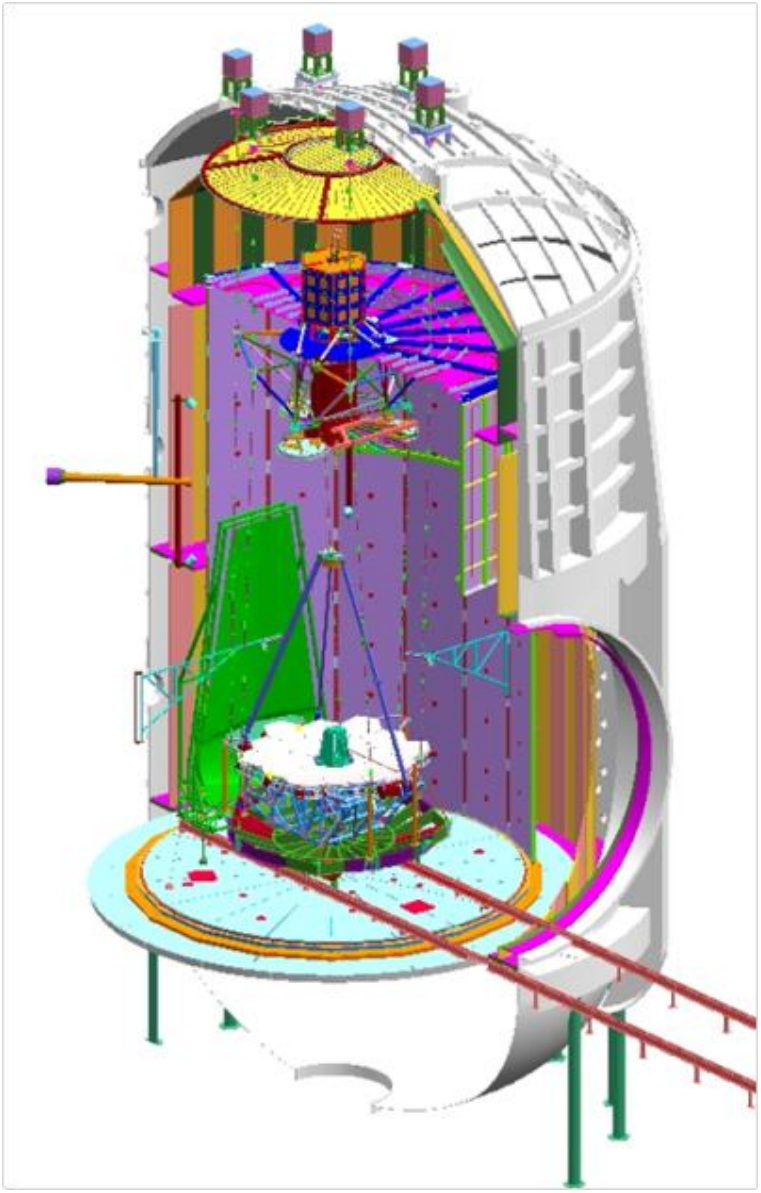
LV Integ

CSG S5, BAF, ZL3

I&T Responsibility

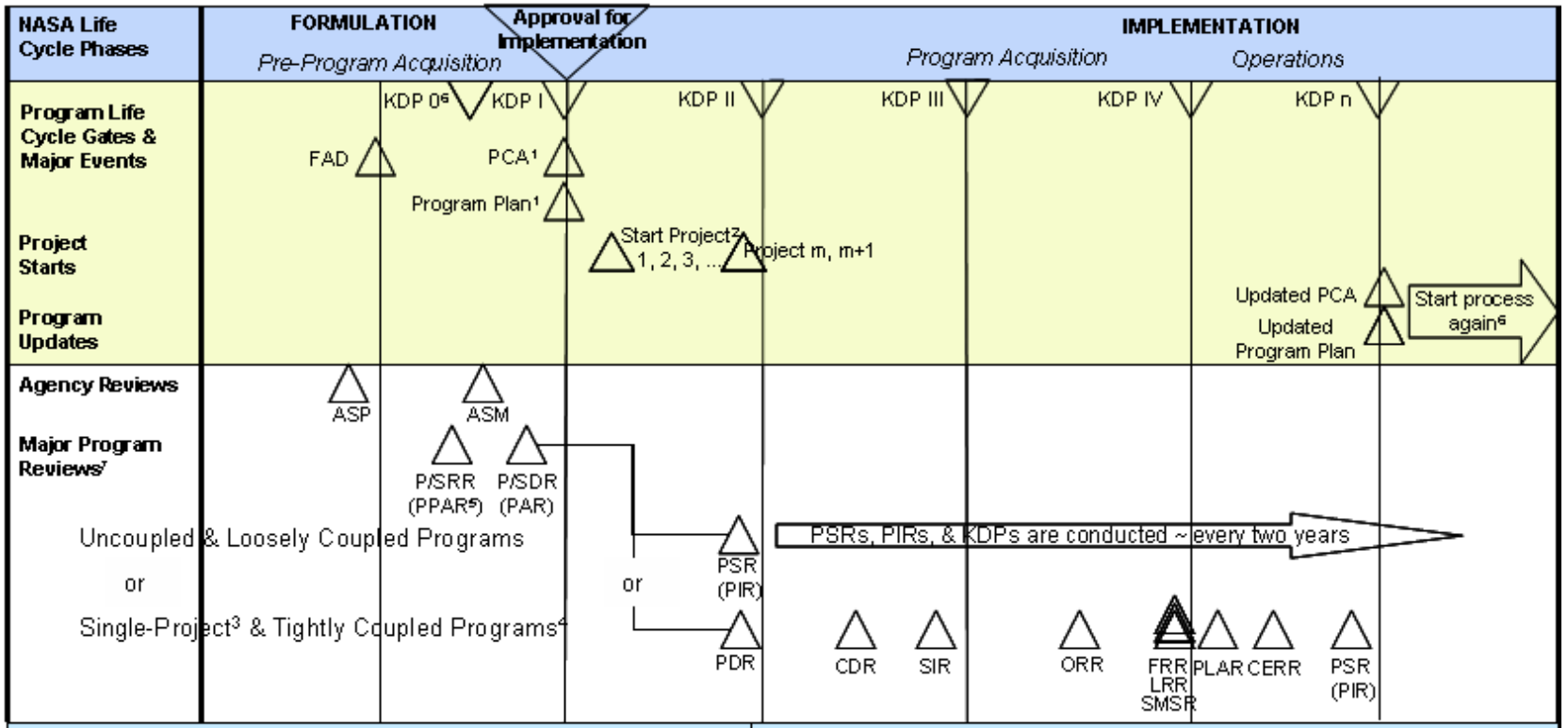
	Execution	Facility
NASA		
NGAS		
ITT		N/A
ESA / Arianespace		

The OTE + ISIM will be tested in a larger space simulation chamber at JSC



NASA Project Management Process

NASA Program Life Cycle



FOOTNOTES

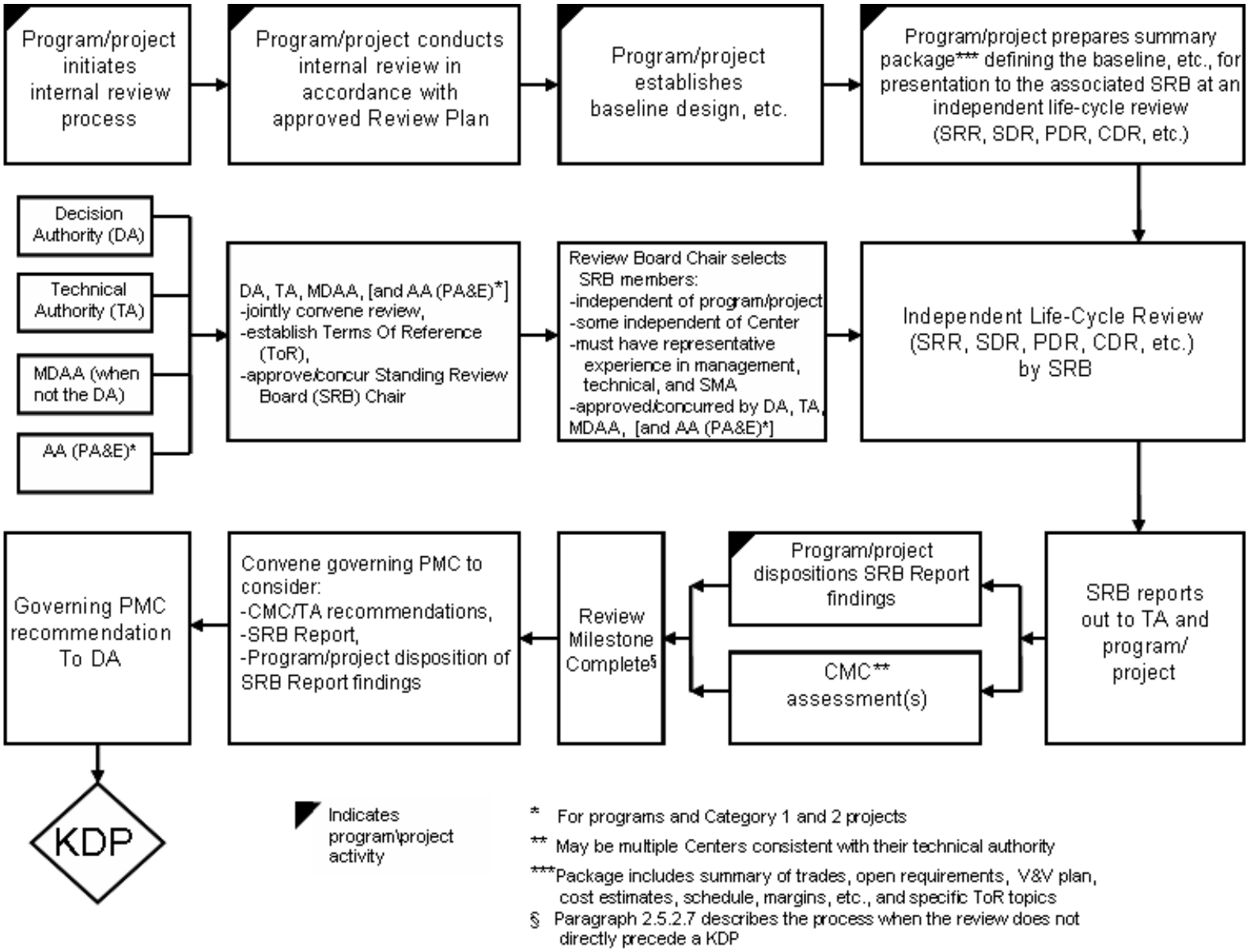
1. PCA and Program Plans are baselined at KDP I and reviewed and updated, as required, to ensure program content, cost, and budget remain consistent.
2. Projects, in some instances, may be approved for formulation prior to KDP II. Initial project pre-formulation generally occurs during program formulation.
3. Single-project program reviews from PDR until operations are the same reviews as the project reviews (not duplicates). Single-project programs are approved at KDP II.
4. Tightly coupled program reviews generally differ from other program types because they are conducted to ensure the overall integration of all program elements (i.e., projects). Once in operations, PSRs/PIRs are conducted ~ every two years.
5. KDP 0 and the PPAR may be required by the Decision Authority to ensure major issues are understood and resolved prior to formal program approval at KDP I.
6. When programs require upgrades (e.g., new program capabilities), the life-cycle process will be restarted when directed by the AA, i.e., the program's upgrade will go through the same formulation and implementation steps as originally done.
7. These reviews are conducted by the program for the independent SRB (with the exception of the FRR and SMSR). See Section 2.5 and Table 2-5.

ACRONYMS

ASP—Acquisition Strategy Planning meeting
ASM—Acquisition Strategy Meeting
CDR—Critical Design Review
CERR—Critical Events Readiness Review
FAD—Formulation Authorization Document
FRR—Flight Readiness Review
KDP—Key Decision Point
LRR—Launch Readiness Review
ORR—Operational Readiness Review
PAR—Program Approval Review
PCA—Program Commitment Agreement
PDR—Preliminary Design Review
PIR—Program Implementation Review
PLAR—Post-Launch Assessment Review
PPAR—Preliminary Program Approval Review
P/SDR—Program/System Definition Review
P/SRR—Program/System Requirements Review
PSR—Program Status Review
SIR—System Integration Review
SRB—Standing Review Board
SMSR—Safety and Mission Success Review

(Figure 2-3 from NPR 7120.5D)

Independent Life-Cycle Review Process



(Figure 2-5 from NPR 7120.5D)

NASA Project Cost and Schedule Visibility

- **Watchdogs: Standing Review Board (SRB), IPAO, PA&E,GAO and Congress**
  - NASA must make program and project cost and schedule commitments at Key Decision Points
  - Following KDP-C comes Project confirmation and authority to proceed to Phase C. With this comes the signed PCA and the project's formal commitment to Congress for Cost and Schedule
  - Deviations from this commitment will result in future visits to Congress and/or potential cancellation
  - Forms basis for any "Congressional Notification" threshold actions

Cost and Schedule Validation Required at KDP-C

- Grass root budgets and BOE's must be supported by parametric cost models (Independent Cost Estimates (ICE), Joint Confidence Level Estimates (JCL))
- Schedule flows and durations must be supported by independent analysis and probabilistic risk assessments
- NASA has committed to funding programs and projects at a 70% confidence level based on Independent Cost Estimates

Cost and Schedule Guidelines from GPR 7120.7

- **Cost Reserves**
  - At the time of Initial Confirmation (Key Decision Point-B [KDP-B]), flight projects should have a budget reserves level of 30% or higher through Phase D. This is a goal, not a requirement
  - At the time of Confirmation (KDP-C), flight projects shall have a budget reserves level of 25% or higher through Phase D. Deviations from this level of budget reserves shall require concurrence of the CMC at the Confirmation Readiness Review
  - At the time of delivery to the launch site, flight projects should have a budget reserves level of 10% or higher through Phase D. This is a goal, not a requirement
- **Schedule Reserves**
  - From Confirmation to the beginning of Observatory Integration and Test (I&T): 1 month of funded schedule reserve per year
  - From start of I&T to shipment to launch site (or to planned storage): 2 months of funded schedule reserve per year
  - From delivery to launch site to launch: 1 week of funded schedule reserve per month

JWST Project Management Approach and Challenges

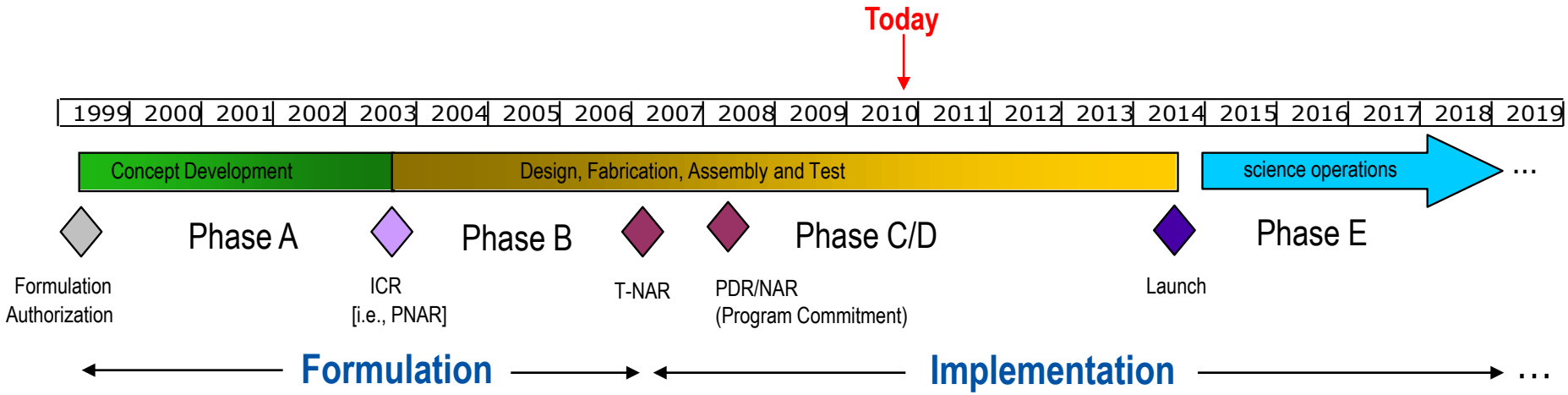
Project Management Tools

- **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

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

Program Phases



- **Mission PDR/Non-Advocate Review (NAR) completed in Spring 2008**
  - Confirmation Review successfully held in July 2008
- **Mission Critical Design Review (MCDR) held in April 2010**
  - Currently in Development (Phase D)
- **Early emphasis on vigorous technology development to retire risk**
  - Greater than 50% of Phase A through D total invested so far
  - Pacing items (mirrors, detectors, instruments, etc) in flight production
  - Successful Technology-Non Advocate Review (T-NAR) in January 2007

How do we manage cost and schedule on JWST?

- **It's more than just having a good baseline and adequate reporting**
  - Early warning systems are a must. You must stay ahead of the "game"
- **No project is static. The baseline is only the baseline until it changes. And that happens a lot**
- **The key is flexible use of your reserves and margins; this includes cost, schedule and technical reserves and margins**
- **You must understand your reserve and margin posture**
  - This includes embedded margins and reserves as well as the explicate ones
  - Fiscal year carry out, sub-system level schedule slacks and contractor fees are examples of embedded cost and schedule reserves
- **Early warning systems are in place to identify potential cost growth including EVM as well as process controlled systems for identifying and resolving cost risks, i.e. liens and threats (L&T's)**
  - EVM applied to prime as well major subcontractors
  - EVM data reviewed monthly
  - EVM is a lagging indicator; L&T's are more current indicator
  - Prime's L&T's include their subs
  - L&T's are reviewed internally on a weekly basis and with the prime monthly
- **Award fee scores send a strong messages to contractors**
- **GSFC Quarterly Executive Dialogs (QED's) with contractors reinforce award fee concerns on cost and schedule**

Critical Path Management

- **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
- **ISIM deliveries (in house activities/ foreign partner deliverables) have high priority**
  - Need to get products delivered and marching army costs off the books; close out contracts ASAP
  - Meet commitments to international partners
  - Has highest funding priorities
- **Near term Observatory deliverables given high priority (Keep them off the critical path)**
  - Mirrors
  - Sunshield
  - Critical analyses

What hasn't worked out so good

- **Cost Reserves**
  - Timely cost phased reserves are absolutely required but rarely available. This has huge leverage on the run out cost of the program. Without them there is a realistic chance, when problems arise, the project will be forced to defer some work to later years which has a compounding effect of at least doubling the cost of the deferred work and reducing the available reserves in the out years
  - Maturing the JWST technologies into flight hardware took longer and costed more that planned. We probably needed 35-40% reserves in those years
- **TRL's:**
  - Achieving TRL-6 is necessary but not always sufficient for building the flight hardware. The technology development activity on JWST was absolutely necessary but we also realized, in some cases, the engineering proved to be harder than we thought as well
    - Detectors: I believe that the definition of TRLs fails to address a key issue for this technology which is accounting for production yield of the device. In addition to demonstrating the detector technology, the TRL 6 definition should mandate that the predicted yield of producing the device be demonstrated so that the flight project can properly plan
    - ASICs: a similar argument as for the detectors can be made for the ASICs
    - TRL scope: I think the TRL activity works for discrete components – ensures the component as a stand alone item is ready for integration to a flight program – but misses the integrated effect of that technology in the overall system. The interaction between systems is never fully appreciated and the cross system requirements drivers are missed or under-estimated. I also think this is a major reason why cost estimation gets thinks wrong in the phase-A cost estimation

What does work

- **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 completely test JWST as you fly. It's too big**
- **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**