Managing Capital Investments and Resources for Large, Complex Satellite Development Efforts

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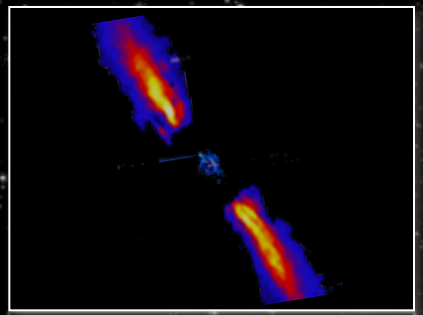
THE JAMES WEBB SPACE TELESCOPE ADDRESSES "ETERNAL QUESTIONS"

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



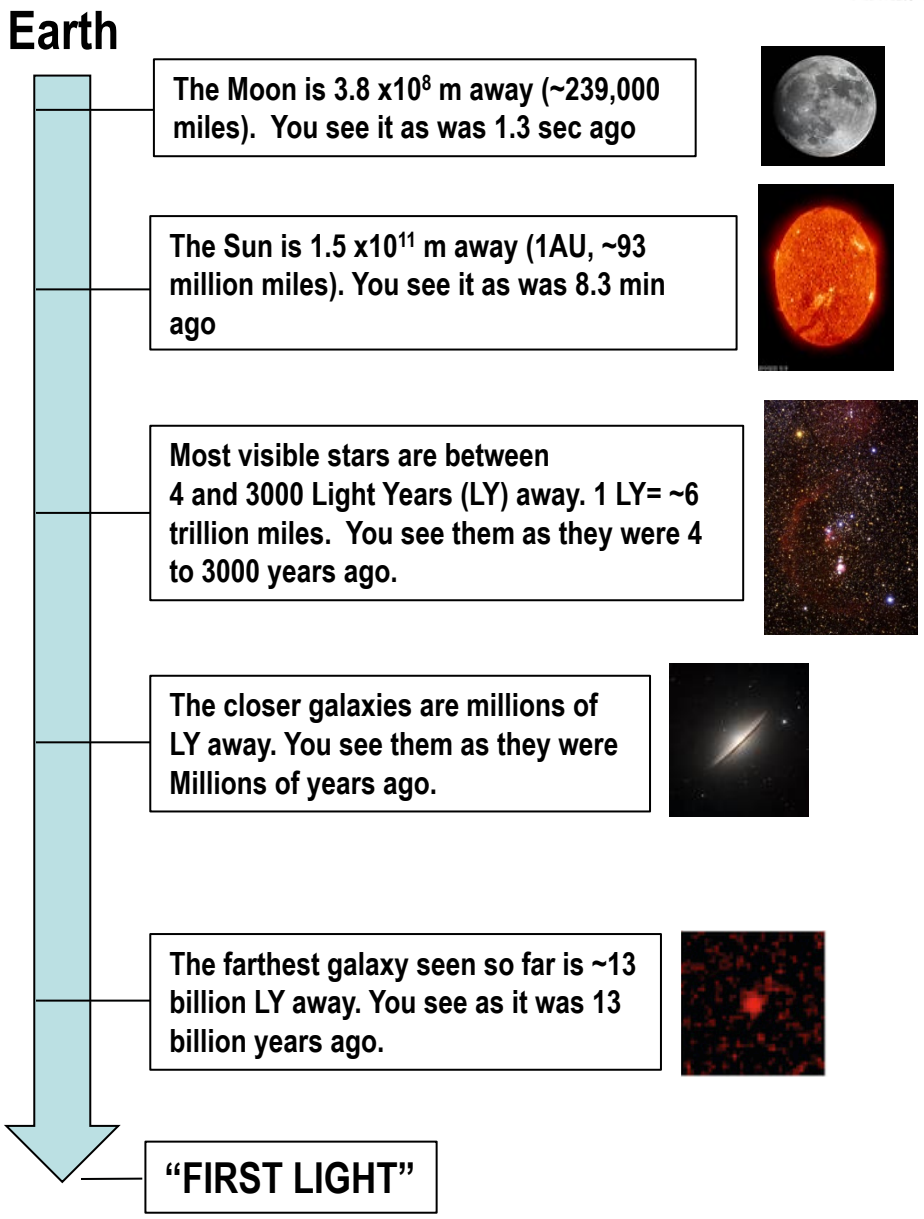
Planets and the Origins of Life

The Assembly of Galaxies

Birth of Stars and Planets

The Successor to the Hubble Space Telescope: "A Time Machine"

- **Scientists considered what telescope would replace the HST in 1989, and in 1995 the "HST and Beyond Committee" recommended a large Infrared telescope.**
- **Scientists wanted to address fundamental questions of NASA's Origins Program, which considers how the fundamental components of the universe came to be and evolved over time.**
- **A "Time Machine" to look back in time was required.**
  - Since light travels at 3 x 10^8 m/s, the farther an object is, the farther back in time you see it.
- **A telescope sensitive enough should be able to look far enough back in time to the first objects in the universe.**



Largest On-Orbit Cryogenic Telescope Ever Constructed

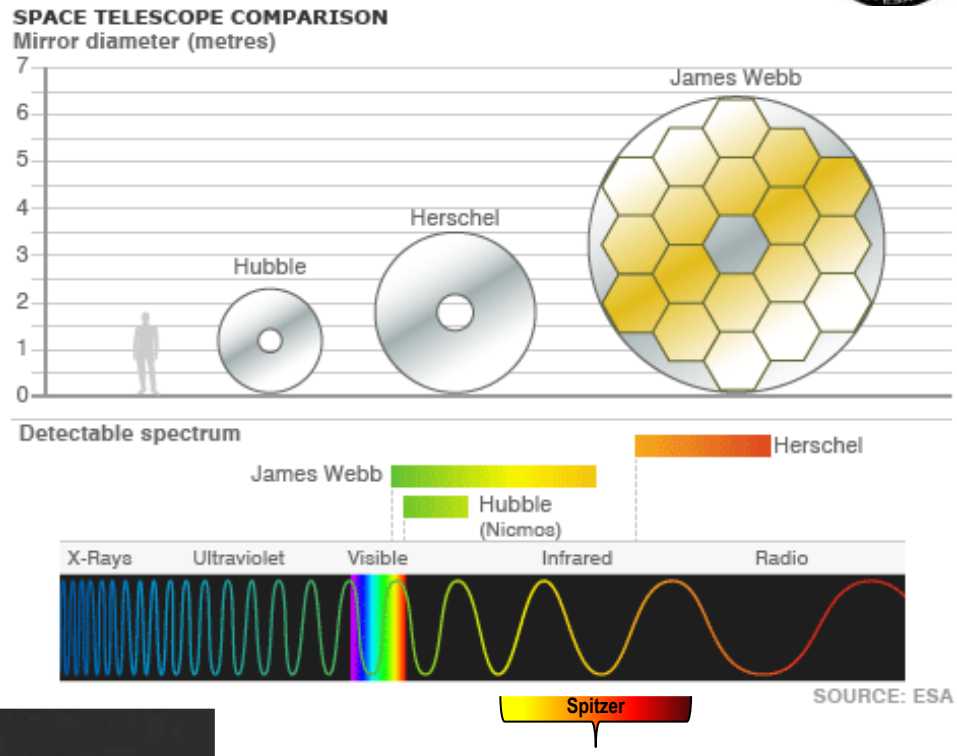
To observe the early universe, the JWST mission requires:

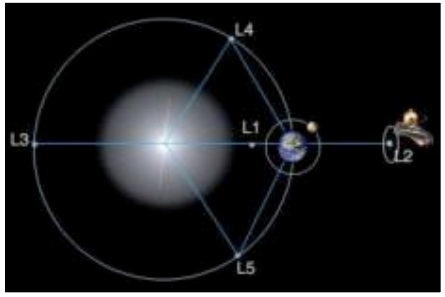
- 7X the light gathering capability of the Hubble Space Telescope
- Wavelength coverage spanning the optical to mid-infrared spectrum

As a consequence, the observatory requires:

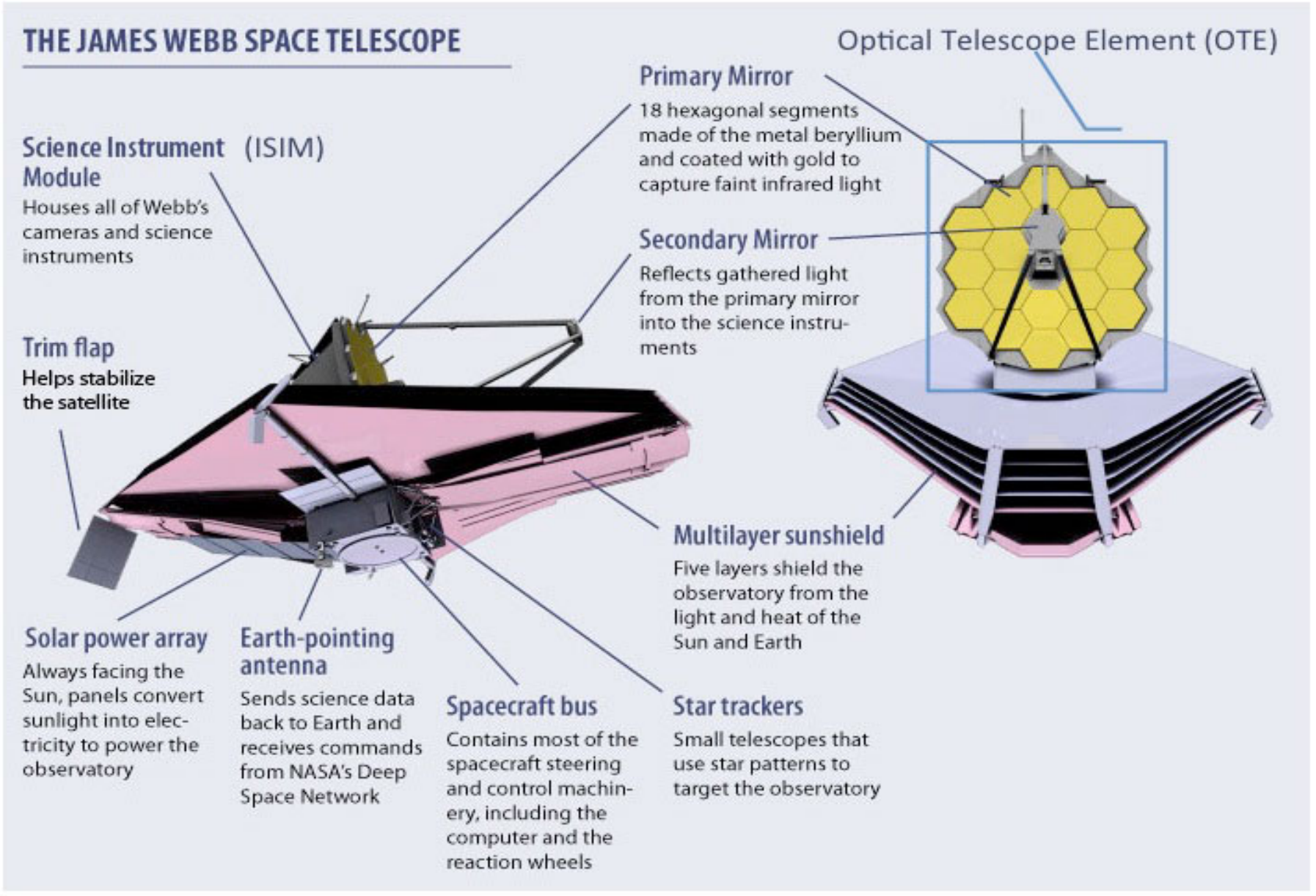
- A primary mirror that is larger in diameter than available rocket fairings
- A high stability 40-50K cryogenic operating temperature

Poses complex testing challenges





MAJOR JWST COMPONENTS



JWST Full Scale Model

"Whose Doing What – Major Players"

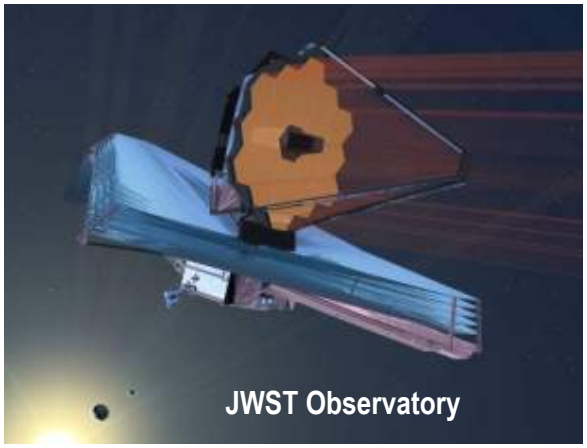
James Webb Space Telescope

- Mission Systems Engineering

Launch Segment

- Launch Vehicle
- Payload Adapter
- Launch Site Services

Observatory Segment



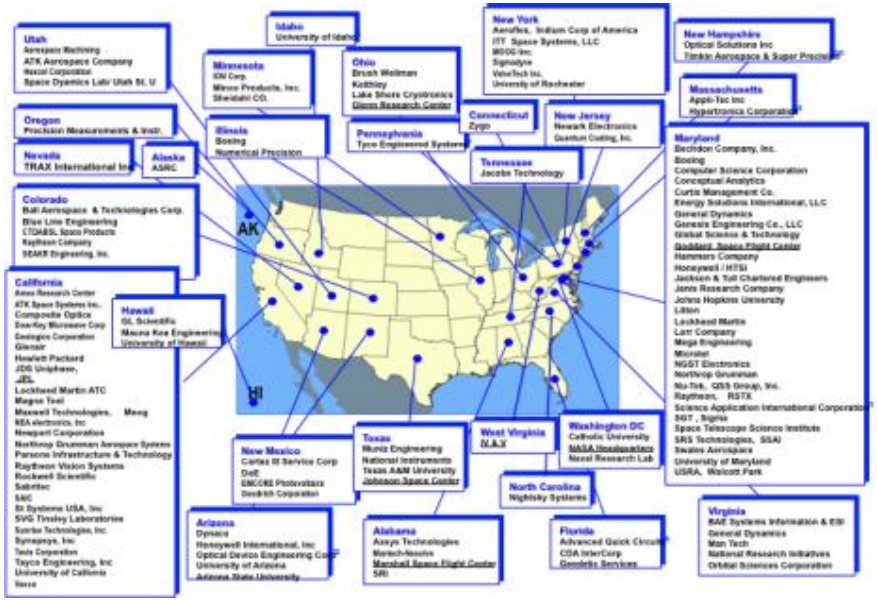
- Optical Telescope Element (OTE)
- Integrated Science Instrument Module (ISIM)
  - NIRCam
  - MIRI
  - NIRSpec
  - FGS
- OTIS – Integrated OTE & ISIM
- Spacecraft Element (SE)
  - Spacecraft Bus
  - Sunshield
- Observatory I&T

Ground Segment

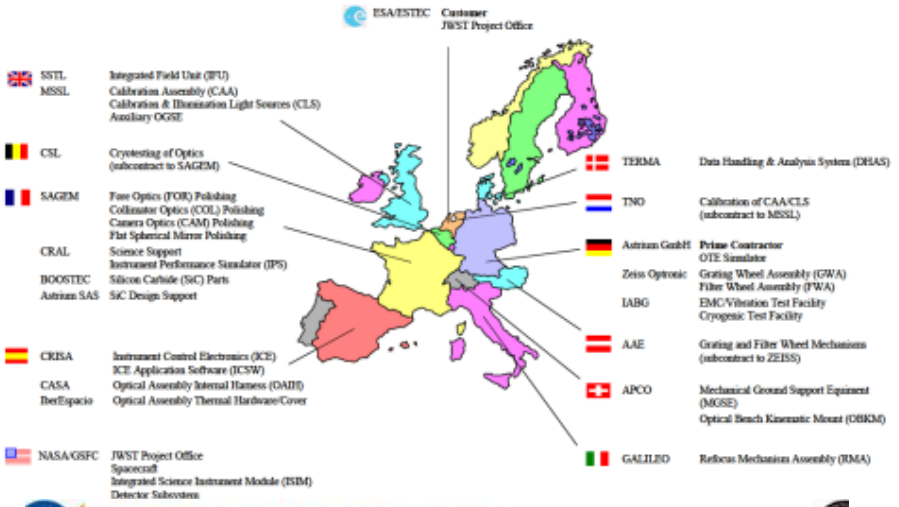
- Science and Operations Center (S&OC)
- Institutional Systems
- Common Systems

Provided by NASA/GSFC
Provided by NGAS
Provided by STScI
Provided by ESA
Provided by CSA

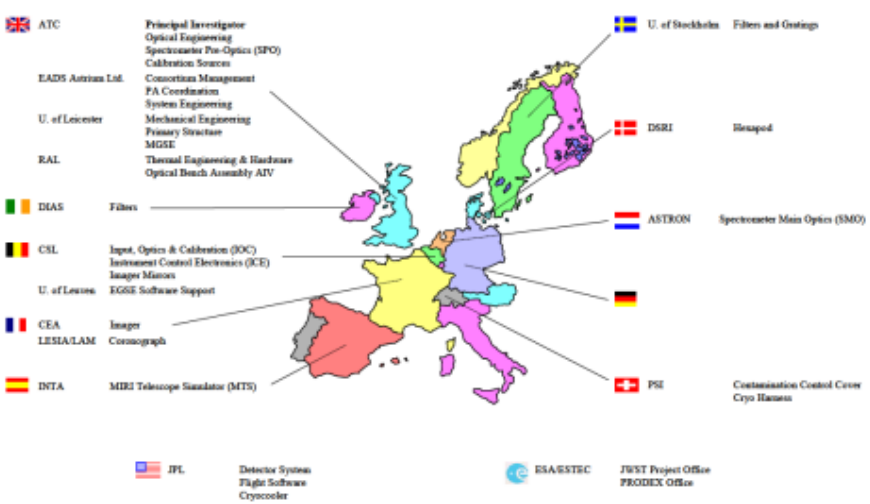
JWST – A Product Of The United States, Europe, and Canada



JWST Team Members – Europe / NIRSpec



JWST Team Members – Europe / MIRI



JWST Team Members – FGS

Where We Are Now

JWST Is Fully Immersed In Integration And Test, But Testing JWST Is A Formable Challenge

JWST's Size, Complexity, And Cryogenic Characteristics Require A Multifaceted Test Plan To Verify Mission Readiness

Each Of These Tests Are Opportunities To Uncover Issues Which Must Corrected To Be Able To Move Forward

OTIS - Optical Telescope Element/ Integrated Science Instrument Module

OTIS Integration & Test @ NASA- GSFC

OTIS I&T @ GSFC – Deployments / Sys Func WGs

OTIS Moved from the Dolly/Vibe Fixture to the HCROF [2017.03.08]

Photo courtesy of Chris Gunn and/or Desiree Stover

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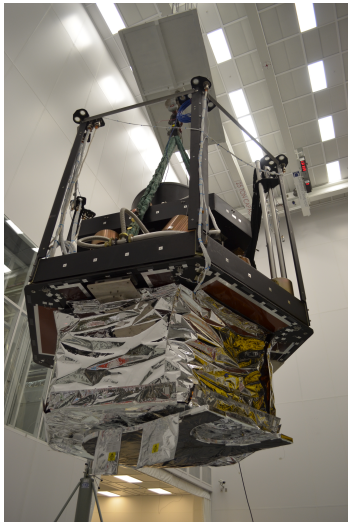
Spacecraft Element (SCE)= Spacecraft + Sunshield

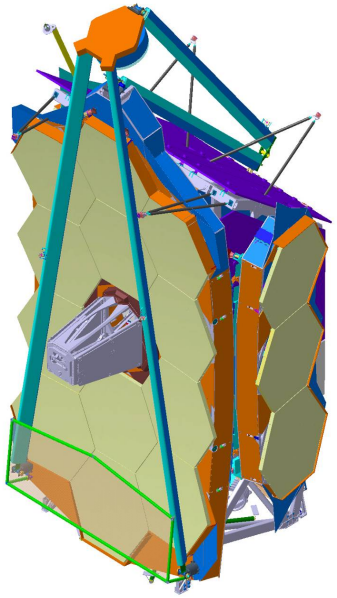
Cryogenic Testing of OTIS At Johnson Space Center

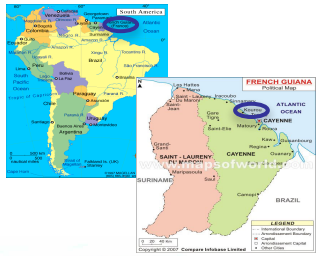
- **15 Years In The Planning!**
- **Preparations for OTIS Testing included**
  - Development of Worlds Largest Cryogenic Chamber
    - 55’ in diameter, 90’ tall

- **Development, installation, and test of complex optical ground support equipment**



Transportation Comes In All Types





Origami On Steroids
(Over 3 Stories High and As Wide As A Tennis Court When Deployed)

73 Consecutive Successful Ariane 5 Launches To Date!

Managing the JWST Baseline

Schedule Reserve Management

- **Once the schedule was baselined and the primary, secondary, and tertiary critical paths (at least) were established:**
  - Identified what entity control which portion of the schedule reserve
  - Dollarized the time associated with the schedule reserve and segregated it off from other budget reserves – authorization to spend only came when authorization to utilize the time was given
  - Created a process to manage the control of these resources
- **This process was above and beyond the typical schedule controls used to monitor and maintain the day-to-day schedules**

Other Schedule Products & Analyses

- IMS – Integrating ~22 detailed MS Project schedules
- Oversight of detailed MS Project schedules
- ~ 39,000 + Total Tasks & Milestones
- Development and coordination of intermediate schedules, tracked to detailed MSProject schedules
- Development and tracking of slack charts/trends
- Perform weekly detailed schedule review
- Last Week, This Week, Next Week, In Progress activities
- Schedule Reserve Control Board
- Controls use of schedule reserves
- NASA HQ Milestone Tracking
- Key Milestone Program Performance Status and Trend
- Key Milestone 90 day look ahead
- Open Task Completion Plan
- Giver/Receiver Hand-offs
- Priced Slack Status/Liens
- Cost Performance Report
- NGAS Program Head Count
- SPI and CPI Metrics
- Current Period Primary Schedule/Cost Drivers
- Schedule Variance Recovery Plans
- Identification of Schedule Threats
- DCMA 14 Point Assessment
- GSAT Metrics – HMI, BEI, CEI
- STAT Tool Assessments
- Monthly Schedule Book Production
- Subsystems Status/Issue Tracking
- Special program and subsystem schedule visibility
- Facility usage schedules
- Schedule Risk Analysis

Managing the JWST Baseline Plan

- Tools & Processes used to manage project resources
  - Monthly Programmatic Status & Trending
    - Technical, cost, schedule, risk, issues, reserve trending, performance measurement trending
    - Capital investment status, including IT infrastructure and assets
    - Project reserve details (each threat, lien, encumbrance) provided in for transparency
  - NASA 533M and 533Q Cost & Forecast Reports
    - Although a schedule performance element is not part of the 533 reporting process, actual costs at the lower WBS levels are used as a 'sanity' check to EVM Contractor Performance Reports (CPRs)
  - Monthly Contractor Performance Reports (Raw Earned Value Management (EVM) data analysis).
    - EVM & EAC analysis & trending, schedule trending analysis (DCMA and NASA schedule health metrics)

Managing the JWST Baseline Plan (Continued)

- Tools & Processes used to manage (continued)
  - Monthly Secondary EAC analysis
    - Performed by independent consultant (not Government cost/resources analyst)
    - Also uses contractor raw EVM data, but different methodology than primary IEAC
    - Incorporates Monte Carlo simulation on NGAS risk/threat database
    - Any delta between IEAC pessimistic forecast and current budget is threated against project cost reserves
  - Monthly In-House Performance Analysis (for work within NASA)
    - NASA GSFC JWST Project generated and analyzed monthly Estimate-at-Complete for Integrated Science Instrument Module (ISIM)
  - Monthly Schedule Analysis
    - NASA GSFC project office conducts monthly independent schedule analysis and Health Metric Analysis
  - Schedule Risk Assessments
    - NASA JWST Project conducted statistical analysis of major elements of JWST with current risks to ensure appropriate schedule reserve exists to element delivery

Management Lessons Learned

JWST Pre-Replan Challenges & Post-Replan Opportunities

Pre-replan Challenges (Prior to 2011)

- Back-loaded budget profile
  - No funding reserve of any consequence in near years
- Significant lag time between “agreement” on funding augmentation and funding showing up
- Contractor not transparent with fiscal state of their operations
  - Communications with prime were not very productive
- On-orbit performance incentives had negative effect on contractor cost and schedule performance
- Technology development program caught the big ticket items – mirror processing, sunshield material, wavefront sensing, etc – but missed smaller things – detector yield, cooler architecture subtly, etc. – that drove schedule primarily but cost as well

Post 2011Replan Opportunities

- Proper budget profile
- Communications and coordinate between HQ and project in lock step
- GSFC took over “prime contractor” responsibilities
  - NASA took over SE leadership role
  - Vastly improved overall project team coordination
  - Added much needed management flexibility to address various technical/schedule challenges occurring in multiple “swim lane” activities
  - Provides cleaner path to contract changes and technical direction
- Restructured the incentive and award fee pools to emphasize execution
  - Added schedule incentive (above award fee to increased the fee % on contract which got contractor very motivated)
  - Balanced the schedule incentive pool with large award fee pool that focused on collaborative working arrangement, technical execution and cost performance
  - Bi annual performance evaluation places strong emphasis on collaboration and communication with NASA systems and technical teams.
- Allowed major contractor PM’s to hold budget reserve

MANAGEMENT LESSONS LEARNED

INTER-CENTER AND INTERNATIONAL PARTNERSHIPS

Experience and Culture at NASA Centers

- Different NASA centers have different origins, different experiences, so have different cultures
- Showing a little respect gets people off the defensive and facilitates trust and communication, which of course facilitates a highly-functioning relationship
- Spend some time in person and in very small group with your counterparts at your partner center to discuss details and build a rapport

Lessons:

- Each center has a history that is a source of pride and outlook that is reflected in process and procedure emphasis
- Center history and experience is context and is a big part of why they are the way they are. Know it and appreciate it.
- Find common ground in rules and practices to bridge understanding
- Review existing Memorandum Of Understandings (MOUs) or create MOUs to document understanding

JWST International Partnerships

- JWST has refined our partner relationships over many years to gain trust and to enhance collaboration and efficiency
  - Open communication is crucial
  - Documenting expectations, with single responsible parties from each side
  - Feeling of ownership across agencies, participants
  - Team approach, regardless of disparity in contributions

- Multiple opportunities to overcome obstacles in foreign partnerships
  - Contractual challenges
  - ITAR issues
  - Communication pathways
  - Different ways of doing business
  - Language barriers

James Webb Space Telescope Fun Facts

- Webb telescope will be the premier space observatory for astronomers worldwide, extending the tantalizing discoveries of the Hubble Space telescope
- An international collaboration among NASA, the European Space Agency, and the Canadian Space Agency
- The largest telescope ever placed in space, Webb will be ~100 times more powerful than Hubble
- It is so big it has to fold origami-style to fit in the rocket and will unfold like a transformer once in space
- The 5-layer sunshield protects the telescope from the Sun, Earth, and Moon's infrared radiation. It's like having sun protection of SPF 1 million
- Unprecedented infrared sensitivity will peer back in time over 13.5 billion years to see the first galaxies born after the Big Bang
- Hubble orbits ~350 miles above the Earth; Webb will orbit the sun ~1 million miles from Earth
- Launch from French Guiana in 2018