James Webb Space Telescope (JWST)

Engineering the Beginning
US Frontiers of Engineering Conference

Amy S. Lo
JWST System Engineering
Space-Based observation has enabled giant leaps in our understanding of the universe.

- Chandra
- HEAO
- GRO
- Hubble
- OGO

Approved for public release; NGAS Case 15-1471 dated 7/27/15
Looking back in time
The Webb Telescope will build on Hubble’s observations and answer the questions:

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

- Targets are anywhere in the sky
- Very far away = faint = high sensitivity
- Very far away = small = high resolution
- Infrared objects = cool telescope

Even with 25 m², JWST will only collect 1 photon/s from prime targets
For reference, stray light from solar system (dust) = 3 photons/s
Challenges of Building JWST: “New Technology” list in early 2000’s

JWST Enabling Technologies “At a Glance”

- Near IR Detectors
- Mid IR Detectors
- Heat Switch
- Sunshield Membrane
- SIDECAR ASIC
- Stable Large Cryogenic Structures Backplane Stability Test Article (BSTA)
- Wavefront Sensing & Control Test Bed Telescope
- MIRI Cryocooler
- Micro Shutter
- Primary Mirror
Challenges of Building JWST: All early challenges are TRL 6 and beyond
Major JWST Observatory Elements

- **Science Instruments**
- **Telescope**
- **Spacecraft**
- **Sunshield**

- Warm, sun-facing side
- Cold, space-facing side

Approved for public release: NGAS Case 15-1471 dated 7/27/15
Unfolding the Sunshield

Movie can be found at: https://www.youtube.com/watch?v=PVAe9Ovca5Q
Aligning the Sunshield

• What’s at stake
  – Telescope is shielded from direct sunlight
  – Upper layers, which are cold, do not get illuminated, and let stray light into the telescope
  – Lower layers, which are hot, do not get any stray light into the telescope

§ Sunshield Alignment
  – 14m x 22m Sunshield, tips of the deployed Sunshield structure must be within a few cm of nominal over all nominal on orbit conditions

Approved for public release; NGAS Case 15-1471 dated 7/27/15
Extensive Analysis, Test Planning, and Modeling

• Identify and quantify all major contributors and form a detailed error budget
  – Perform analysis to quantify the items in the error budget
    • E.g. tolerance analysis, the mechanical design
    • E.g. finite element analysis of the parts: deflection, thermal distortion, outgassing
    • E.g. deployment mechanisms, deployed position, repeatability

• Plan a test program to verify everything
  – Define the tests, major analysis, models, we need
  – Define the inputs to test, analysis, models
  – What measurements are needed? How do we measure such precision? What are the references? How do we ensure they remain stable? What are the measurement uncertainties?
  – Fight gravity every step of the way

• A team of four experienced engineers took two years to perform the analysis, detail out the test program and complete the planning
James Webb Space Telescope Current Status

• Optics
  – All mirrors are complete
JWST Current Status

- **Optics**
  - All mirrors are complete

- **Instruments**
  - All instruments installed
  - Detector swap out complete
JWST Current Status

• Optics
  – All mirrors are complete

• Instruments
  – All instruments installed
  – Detector swap out complete

• Telescope
  – Structure complete
  – Ship to GSFC

• Spacecraft
  – Structure completed
  – Undergoing testing
JWST Current Status

• Optics
  – All mirrors are complete

• Instruments
  – All instruments installed
  – Detector swap out complete

• Telescope
  – Structure complete
  – Ship to GSFC

• Spacecraft
  – Structure completed
  – Undergoing testing

• Sunshield
  – Test unit completed
  – 2/5 layers complete
  – Major structures being manufactured
JWST Current Status

• Optics
  – All mirrors are complete

• Instruments
  – All instruments installed
  – Detector swap out complete

• Telescope
  – Structure complete
  – Ship to GSFC
Steps to JWST Launch

• Telescope structure, instruments, mirrors get integrated at GSFC and tested in Chamber A at JSC

• Spacecraft complete structure testing, electronics and equipment gets installed, more testing

• Sunshield completes manufacturing and testing, and integrated

• Bus + Sunshield with Telescope simulator under extensive tests and deployments

• Assembly of Telescope + Instruments with Bus + Sunshield into the complete Observatory at Space Park, final pre-flight testing

• Oct. 2018 Launch
JWST Transit Spectra For Exoplanet

See radiation from star transmitted through the planet’s atmosphere

Secondary Eclipse
See thermal radiation and reflected light from planet disappear and reappear

Orbital Phase Variations
See cyclical variations in brightness of planet

Transit

2 R_{Earth} super Earth, a smaller GJ 1214b analog

Beichman, 2014
Potential Exoplanet Spectra from JWST

Seager et al., 2009
Deployment Video of JWST

Movie can be found at: https://www.youtube.com/watch?v=bTxLAGchWnA
THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN