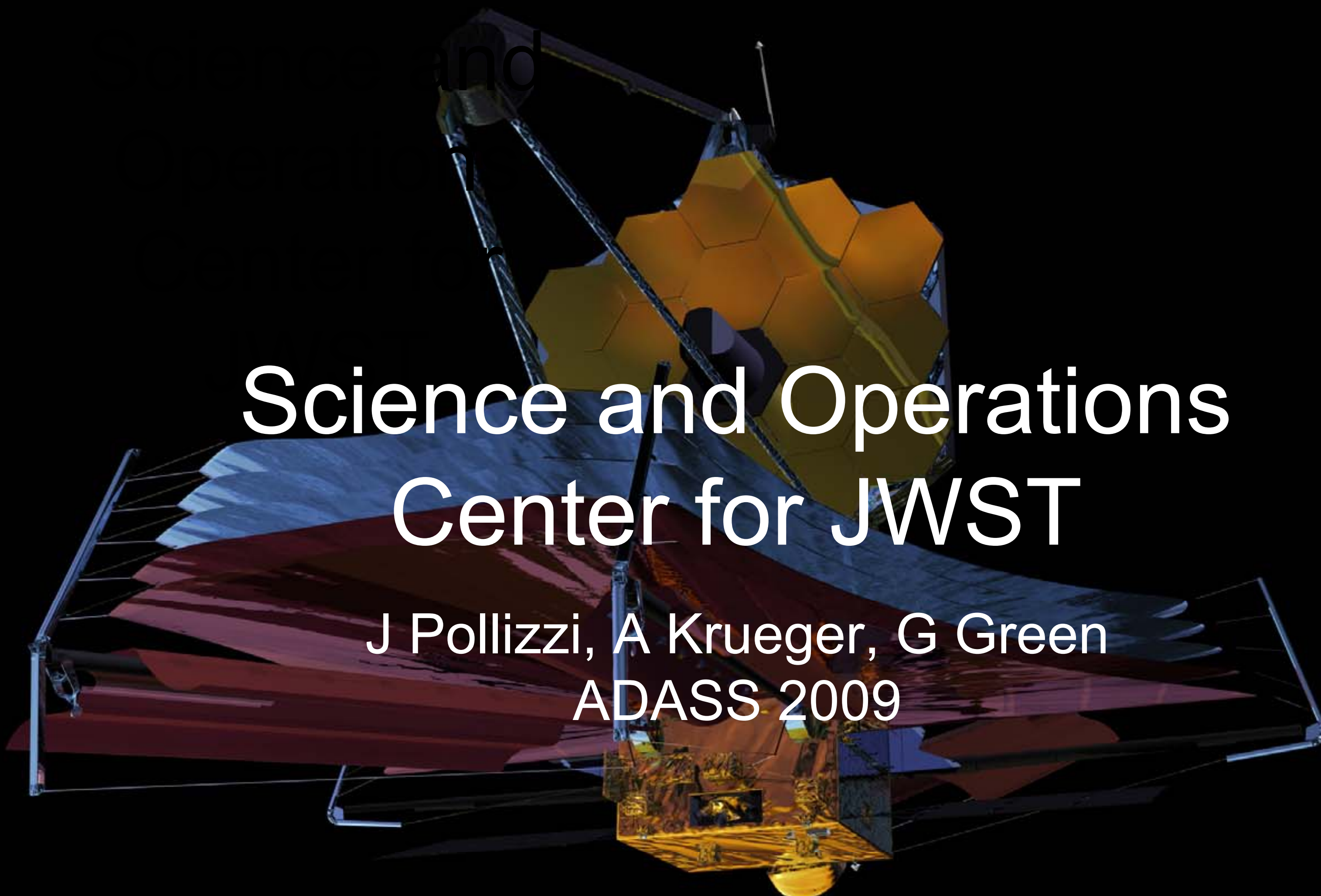
Science and Operations Center for JWST



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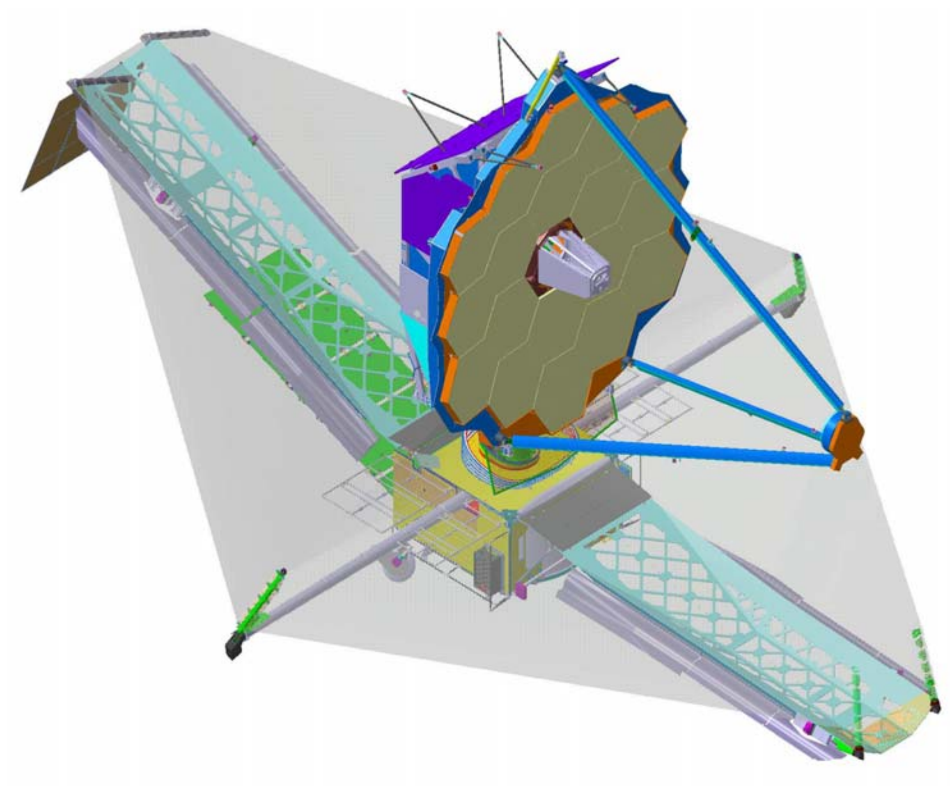
ADASS 2009

Space Telescope Science Institute

S&OC for the JWST

- Agenda
  - Brief background of the satellite and mission
  - Lessons learned from operating the HST that we plan on applying to JWST
  - Challenges we face in developing the S&OC

The James Webb Space Telescope



Effective Mirror Size: 6.5m; 18 segments

Sunshield Size: 14.6 m x 21.1 m

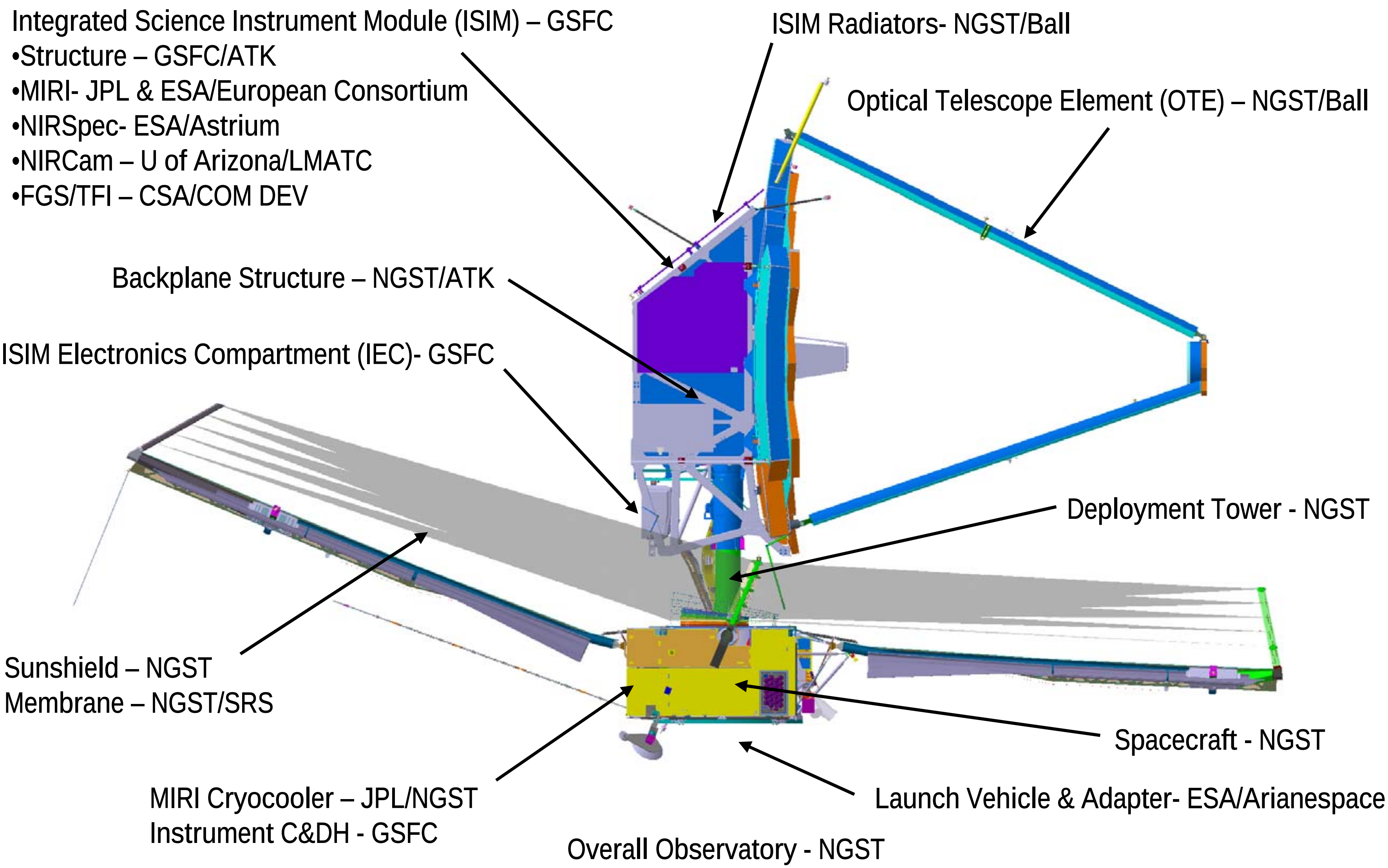
Payload Weight: 6500 kg (estimated)

Cold Side Operating Temp: -233C

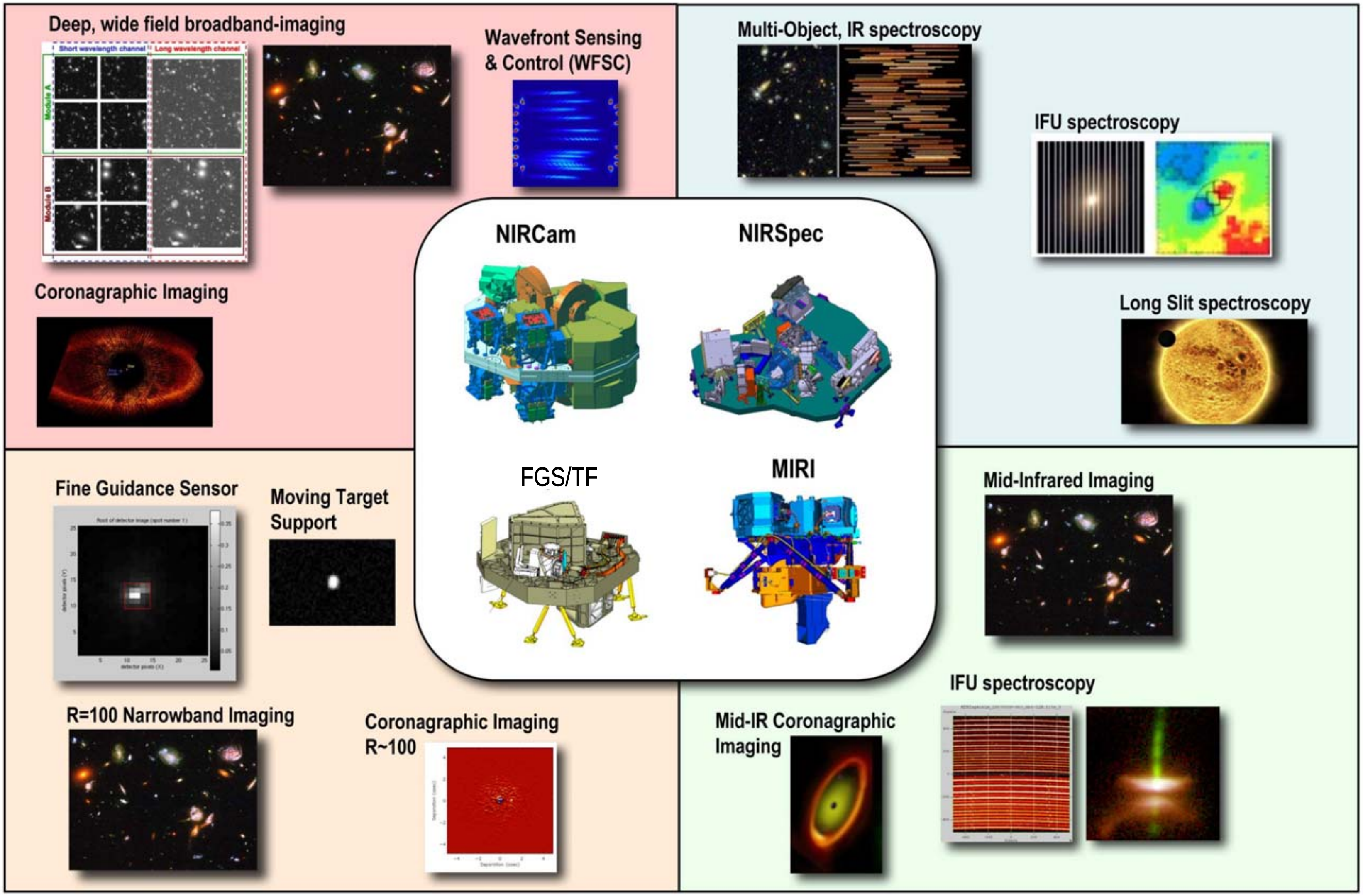
Hot Side Operating Temp: +85C

Planned Consumables Lifetime: 10 years

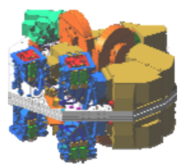
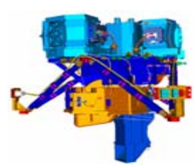
JWST Teams and Responsibilities



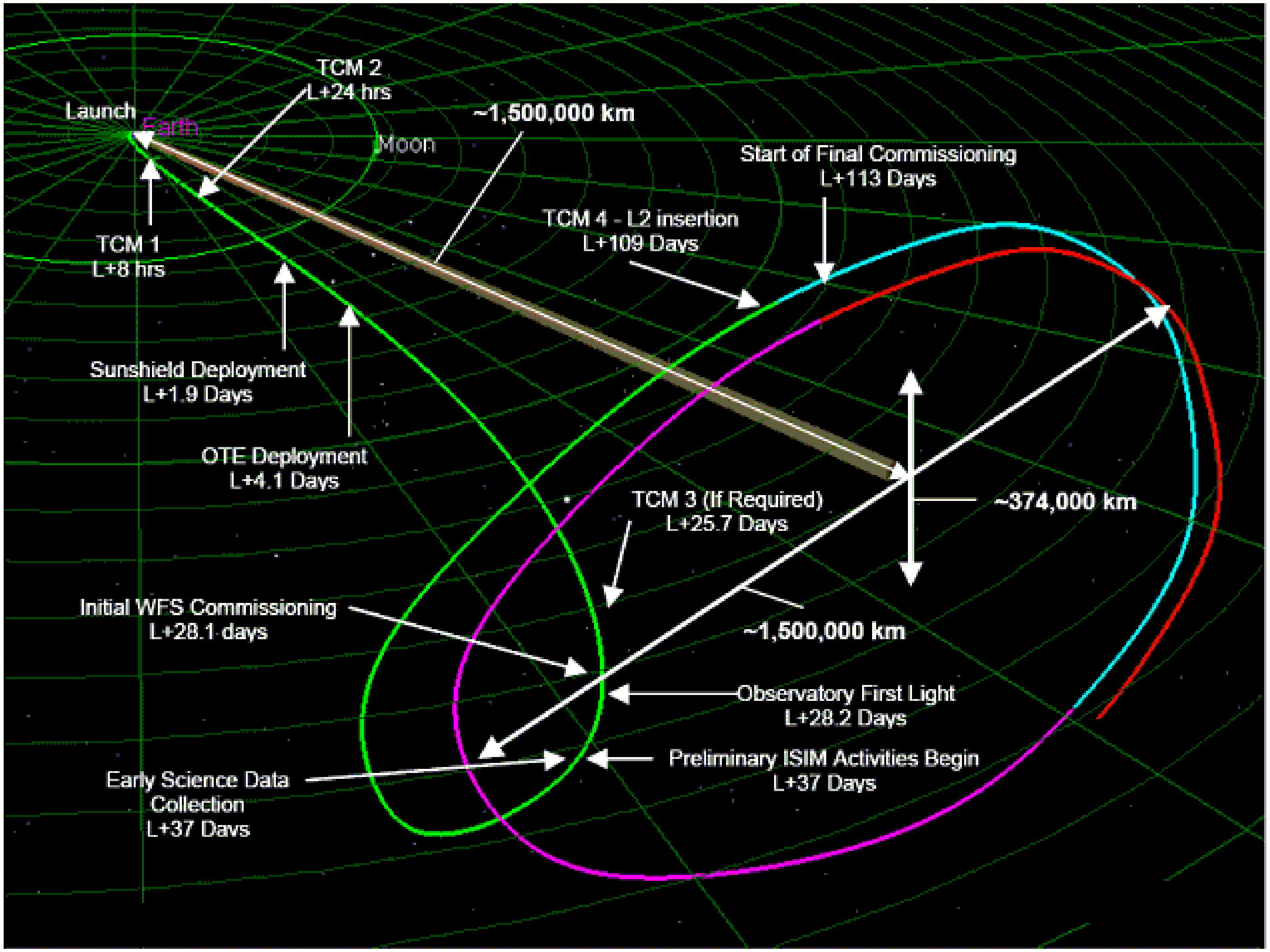
JWST Science Instruments



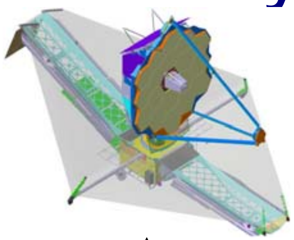
JWST Instruments

Instrument		Science Goal	Key Capability
NIRCam Univ. Az		*Wide field, deep imaging* ➲ 0.6 µm - 2.3 µm (SW) ➲ 2.4 µm - 5.0 µm (LW)	Two 2.2’ x 2.2’ SW Two 2.2’ x 2.2’ LW
NIRSpec ESA		*Multi-object spectroscopy* ➲ 0.6 µm - 5.0 µm	9.7 Sq arcmin Ω 100 selectable targets R=100, 1000
MIRI ESA/JPL		*Mid-infrared imaging* ➲ 5 µm - 27 µm *Mid-infrared spectroscopy* ➲ 4.9 µm - 28.8 µm	1.9’ x1.4’ 3.7”x3.7” - 7.1”x7.7” R=3000 - 2250
FGS/TFI CSA		*Fine Guidance Sensor* ➲ 0.8 µm - 5 µm *Tunable Filter Imager* ➲ 1.6 µm - 4.9 µm	Two 2.3’ x 2.3’ 2.2’ x 2.2’ R=100

JWST Orbit Transfer



Key Operations Concepts



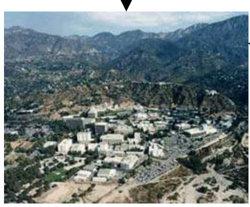
JWST Observatory
- L2 Orbit - thermal stability, stay light avoidance, stable communications
  - Orbit Determination & Maintenance
  - Momentum Management
- Event-Driven Operations - efficient and flexible operations
  - Parallel SI Calibrations - Darks, Sky Flats
- Wavefront Sensing & Control

Goldstone

Madrid

Canberra

JPL Deep Space Network (DSN) Ground Stations
- CFDP File Transfer Protocol
- Ranging
  - Alternating hemispheres
- Clock Correlation
- Downlink rate
  - 458 gbits/day over 2x 4 hour passes
  - All science and engineering is recorded for downlink
    - Engr also downlinked real-time during pass



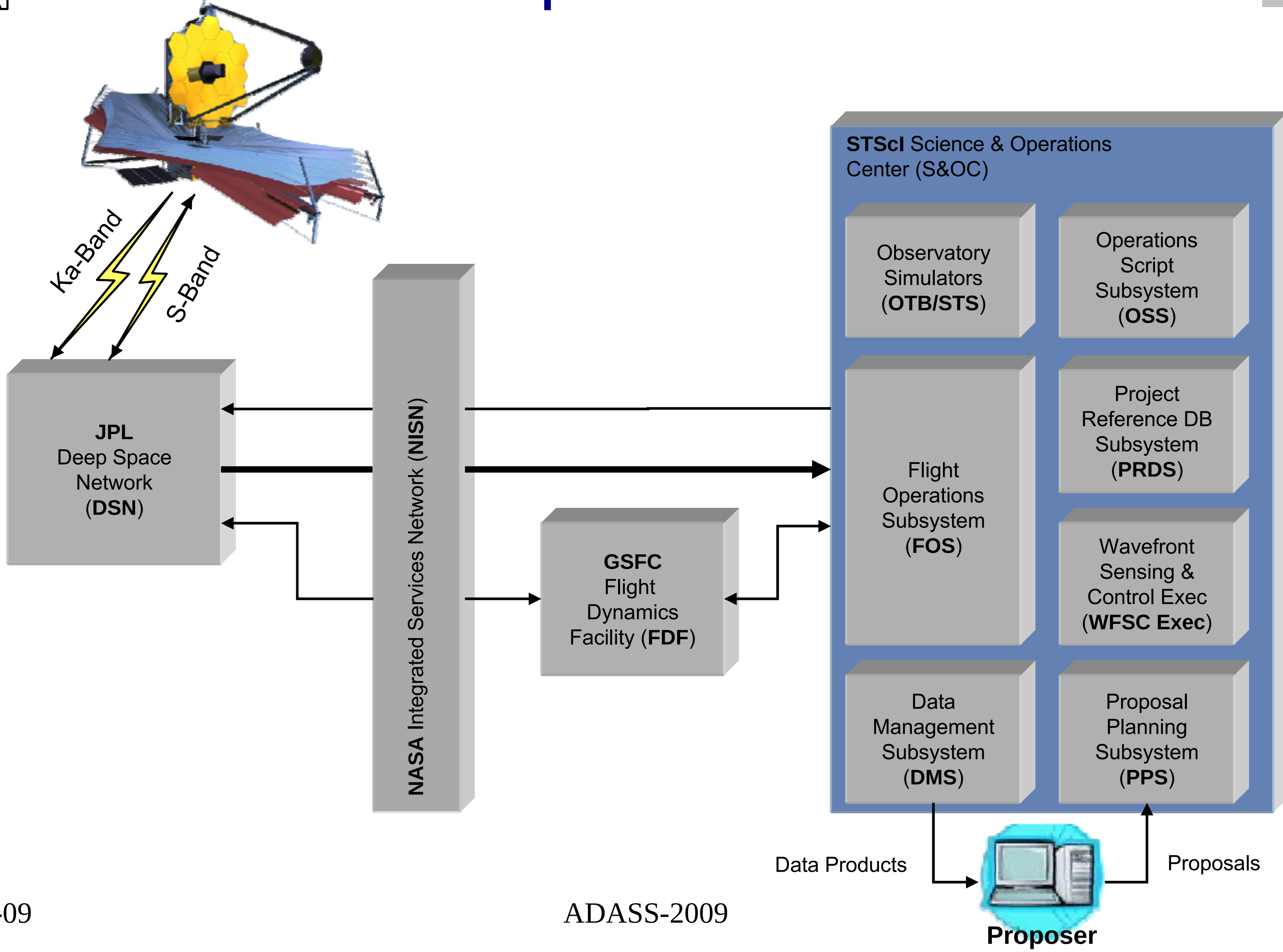
JPL Deep Space Network (DSN) - Pasadena CA
- Launch Support
- Commissioning Support - continuous coverage
- Normal Operations Support - 4 hour contact / day

NASA Integrated Services Network (NISN) - MSFC - Huntsville AL
- Ground Network & Voice Communications

Goddard Space Flight Center (GSFC) - Greenbelt
- Flight Dynamics Facility (FDF)
- Flight Software Maintenance Facility

Space Telescope Science Institute (STScI) - Baltimore
- Science Operations
  - Proposal Selection, Planning & Scheduling
  - Event-Driven Operations
  - Data Archive & Calibration
- Mission Operations
  - Real-Time Operations, Health & Safety Monitoring
  - Anomaly Resolution, Trending Analysis
- Normal Operations 8 x 5
  - Automated Contacts

Science and Operations Center



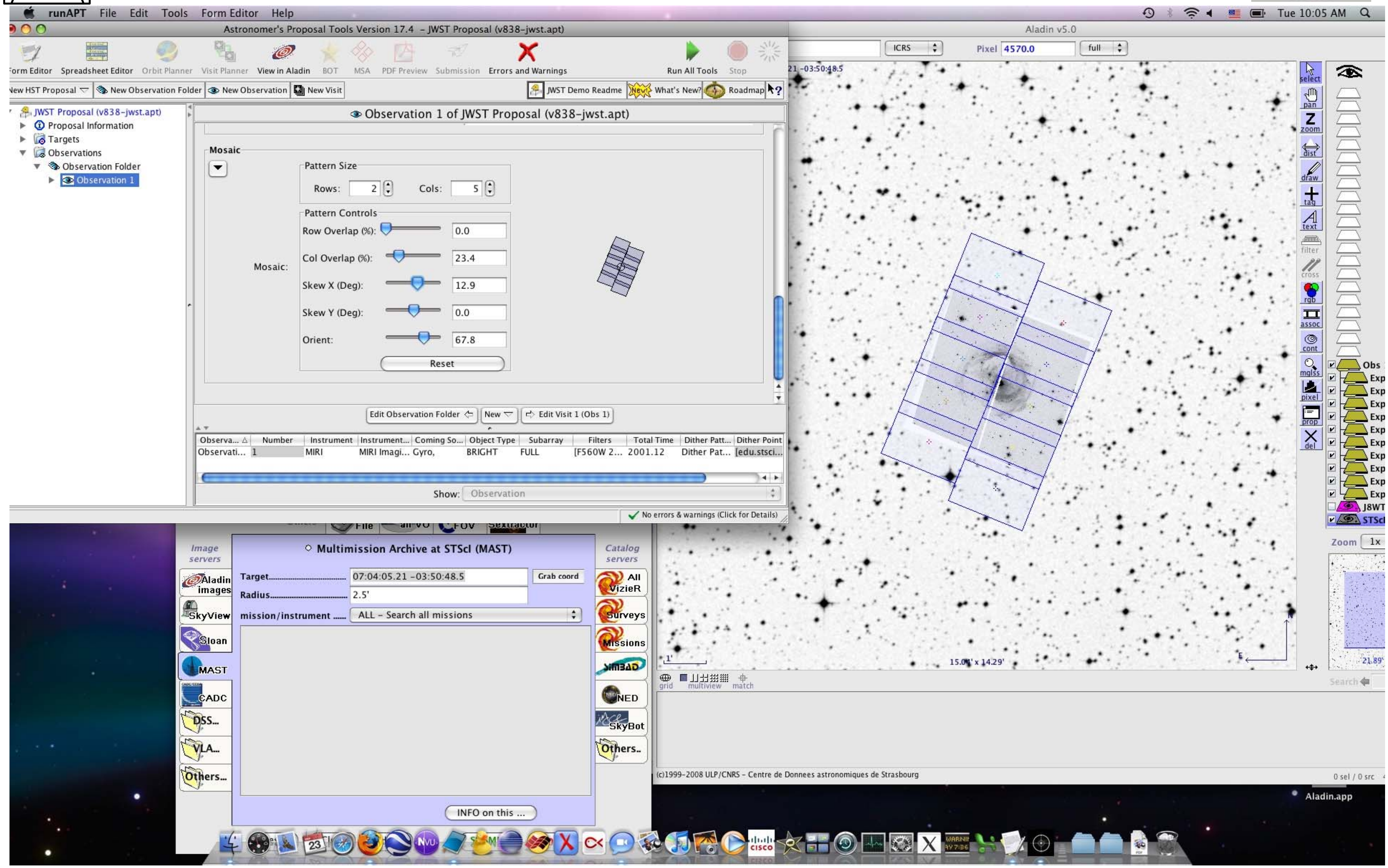
Lessons Learned from HST(1/3)

- Test as you fly
  - Use every opportunity and system used during I&T to work out flight operations concepts and approaches
    - Use testing as training events for eventual flight staff
- Take best of legacy systems – but not without true competitive analysis – and certainly not with any leftover baggage
  - E.g. keeping APT, SPIKE and some GSS –but not rest of planning
  - Likewise will use MAST, and our Storage Architecture (NSA), but not DADS and likely not OPUS
- Use an iterative design approach – but do a good requirements analysis upfront
  - The requirements gives both a list of what needs to be done as well as can drive the testing

Lessons Learned from HST(2/3)

- Have a uniform mechanism for users to interact with Institute regardless of mission
  - Using APT as "the" proposal entry tool for both HST and JWST
  - Using MAST as the "front door" to the archive for all mission data held by STScI
  - Will use GMS as a consistent means for working with Grant submissions and reporting across missions

Example JWST APT Input



Lessons Learned from HST (3/3)

- Maximize efficiency by having onboard event driven operations
  - HST uses only absolute timing actions. Looses opportunities for more exposure time due to incurred overheads (i.e. waiting a fixed amount of time for a mechanism to move)
  - JWST uses event driven actions – i.e. can proceed with next step once a mechanism has reported motion completion
  - Event concept applies to visits as well. A succeeding visit can start as soon as its earlier visit successfully completes or fails (within some no-earlier-than constraints)
    - i.e. should a guide star acquisition fail, then that visit is canceled and the succeeding one can start. The science program can continue even in the wake of failed visits

Challenges(1/5)

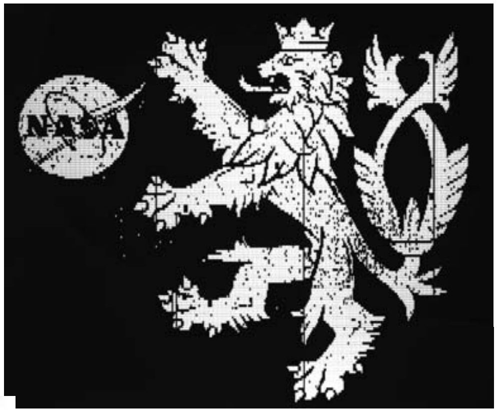
- Funding for Ground Segment components delayed
  - Defers startup of key aspects to ground system to different times
    - Impinges on “Test as you fly” since the software is not ready when the hardware is
    - And defers integration problems effectively till last major system comes online (will be years after the first system is ready)
      - Will have to rely more on intra-subsystem simulators/stubs to check out components

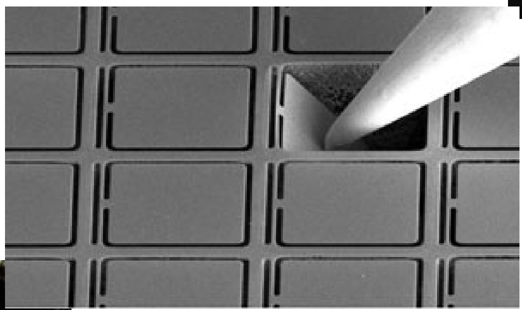
Challenges(2/5)

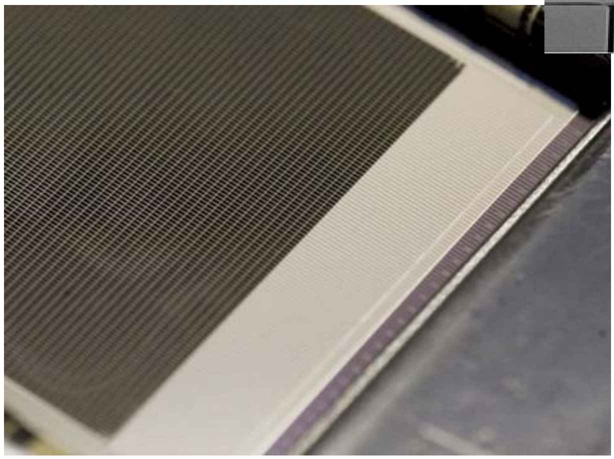
- Complexity of the Instruments and nature of the data
  - NIRSpec has a micro shutter array of 798 x 350 shutters (detector is 2 arrays of 2k x 2k); NIRCAM has 10 sensor arrays, each 2k x 2k
  - Data is downlinked as a cube holding successive read-outs as the sensors accumulate charge
  - Early indications imply a persistence effect on the detectors
    - Will require new approaches to doing the calibration pipelines

- Environment of the satellite
  - Solar wind applies a torque to the spacecraft
    - Momentum management requires an ongoing and active response
    - Factored into both the planning systems and onboard scripting system
      - Is complicated by the event driven nature of the visits
    - An autonomous system will issue a burn to unload momentum if not otherwise reduced

NIRSpec Micro Shutter Array







Challenges(3/5)

- Nature of the data taken
  - As planned design factored in a 2:1 compression of science data for recording and downlink
    - Realized nature of the data did not lend itself to suitable compression strategies
    - Initial response was/is to double the number of contacts/day; Was originally 1x 4 hour pass – now 2x
    - Now considering compressing a series of delta images (readouts) taken against some initial baseline image.
      - Since the delta's only reflect what's changed from read-out to read-out – they are much more suitable to compression approaches

Challenges(4/5)

- Dealing with the obsolescence of planned legacy systems
  - Original plan from 5 years ago cited the usage of then existing systems.
  - In the 5 years since the plan – several of the planned systems are no longer sustainable for another 5 – 15 years for JWST
    - OPUS, ETCs, use of the Sunfire/Symetrix, MOSS, use of Sybase, STSDAS/IRAF
  - Hardware-wise JWST is basing its architecture on new standard configurations
    - All servers 64-bit Intel based; most using RHEL5; Databases using MS SQL Server

Challenges(5/5)

- Dealing with the obsolescence (continued)
  - Some systems can be re-implemented using a more sustainable approach
    - MOSS from Fortran to C++; ETCs and necessary STSDAS/IRAF routines being redone in Python
  - Others require trade studies and evaluations of new approaches
    - i.e. considering LSST’s and NOAO’s pipeline systems as replacements for OPUS

Summary

- Use of Legacy systems is beneficial to a new project, but …
  - Beware not to freely adopt all aspects of the legacy components
    - Use only what works for the new mission
  - Recognize the lifetime potential of the legacy software/hardware
    - Will it last for the duration of the new mission?
- An iterative development approach works well – but don't ignore the benefit of having up-front baselined requirements and interface specifications
  - You will always find new functions to incorporate though the development phase – but having a strong base set of requirements up-front will help assure you don't miss anything on the way
  - Particularly useful if you need to rephase your development efforts
- Whenever possible – Test as you fly
  - Exercise the system in an operational mode up front (during nominal testing) then you'll be less surprised and better trained when operating for real

JWST Full Scale Model

JWST Links

- STScI page http://webbtelescope.org/webb_telescope/
- NASA page http://www.jwst.nasa.gov/index.html
- ESA page http://www.esa.int/esaSC/120370_index_0_m.html
- Canadian Space Agency: http://www.asc-csa.gc.ca/eng/satellites/jwst/default.asp
- Northrop Grumman: http://www.as.northropgrumman.com/products/jwst/index.html
- U of Arizona page on NIRCAM: http://ircamera.as.arizona.edu/nircam/
- JPL page on MIRI: http://www.jpl.nasa.gov/missions/missiondetails.cfm?mission=Webb