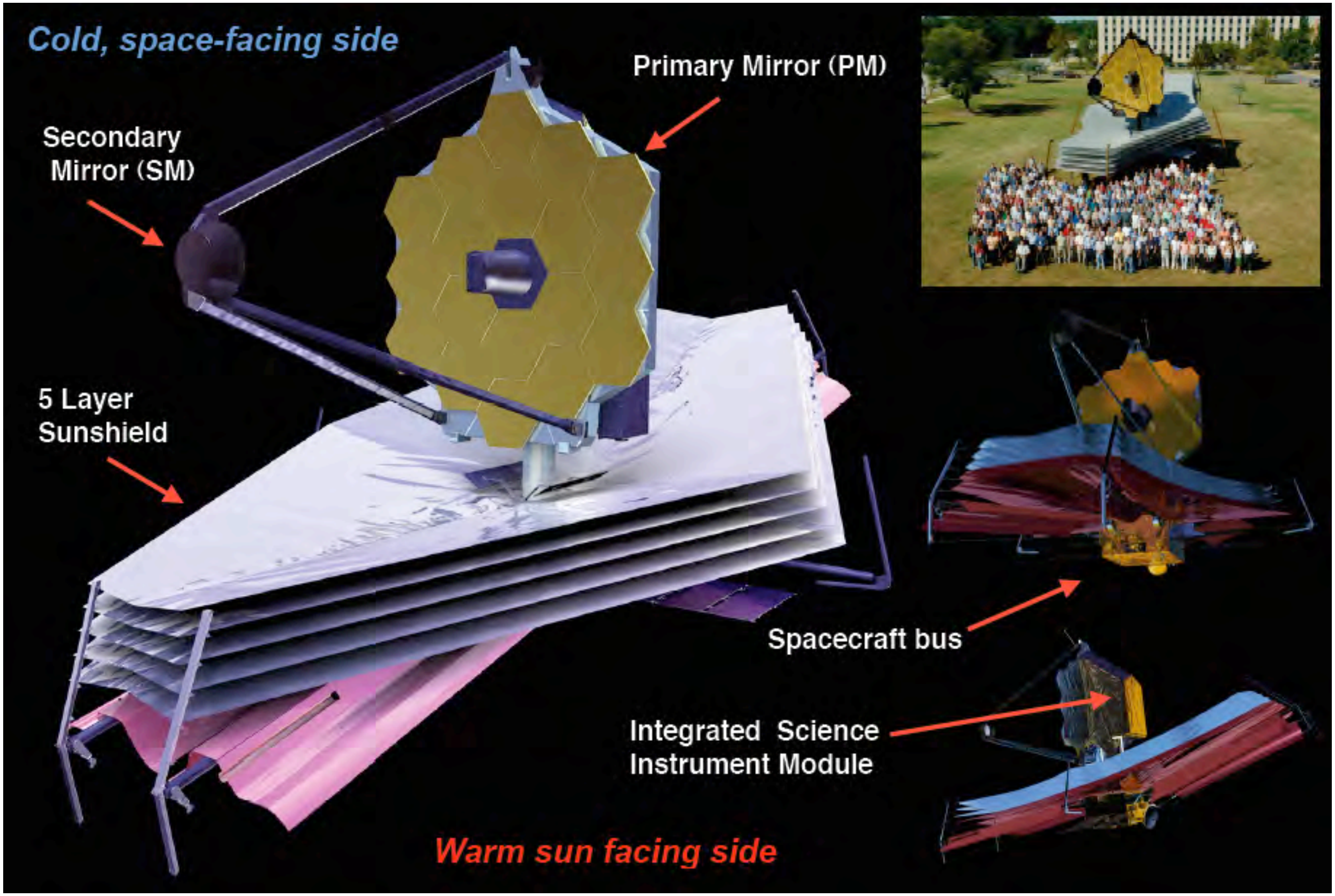
JWST Technology

May 20, 2006

Mark Clampin

JWST Observatory Project Scientist

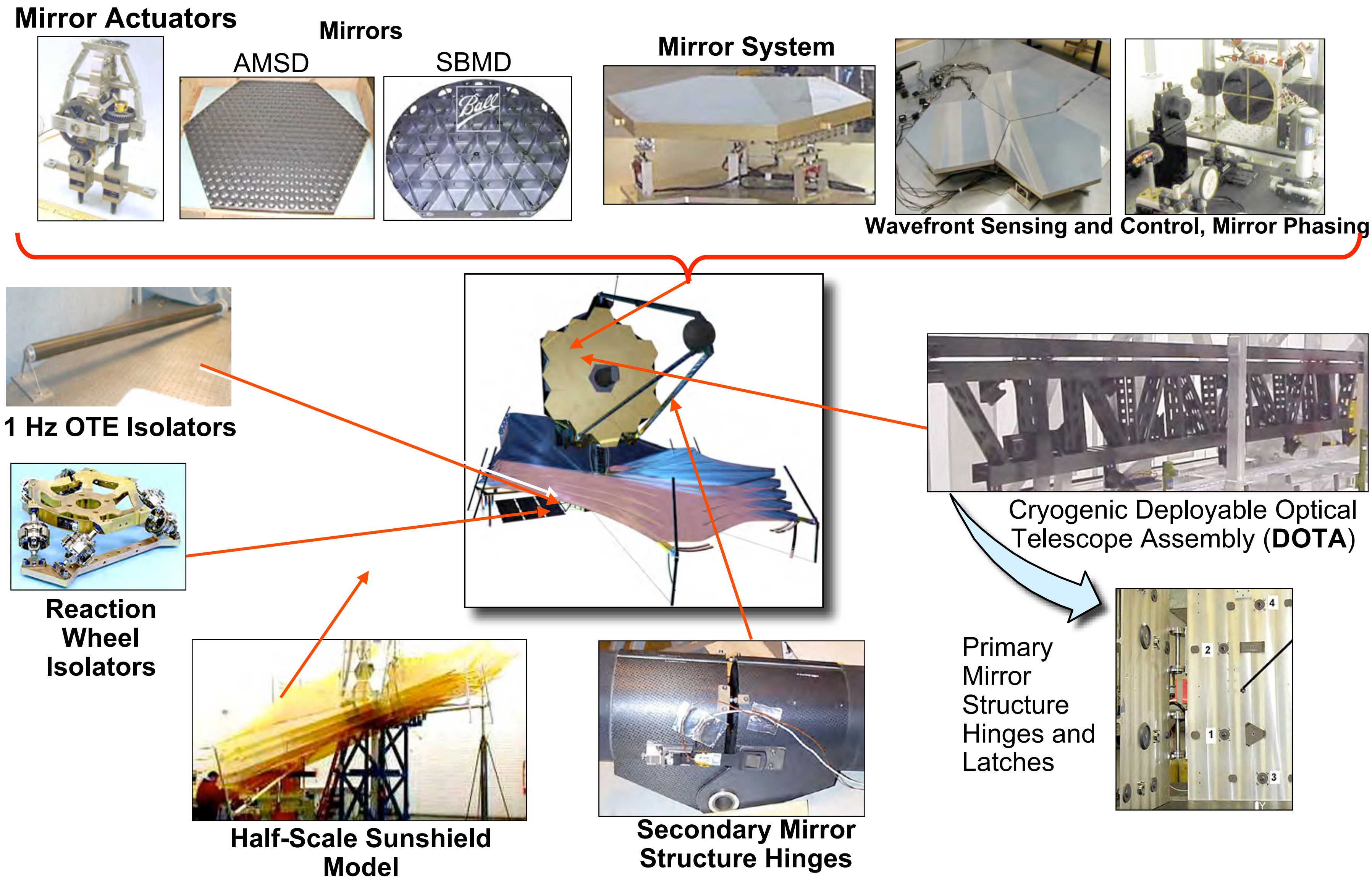
JWST Observatory



Early JWST Technology Investment: Reduces Risk and Contains Costs

- Based on HST, Spitzer, Chandra lessons learned, NASA invested early in JWST technologies:
  - Technologies started in 1997 and over $250M spent in Phase A
  - Unlike HST, technologies will be mature before Phase C/D lowering program risk
- NASA recognized early on that the critical lightweight mirror technology needed to be started early and was of mutual interest to DoD and NRO and formed a multi-agency collaboration to co-fund it
- Overall, technology developments have gone extremely well and all critical technologies will be at critical TRL-6 milestone (prototype tested in relevant environment) by January 2007
- JWST technology investments will enable future science missions and form the building blocks for future large and/or cryogenic telescopes
- All critical technologies will be at critical TRL-6 milestone (prototype tested in relevenat environment) by January 2007

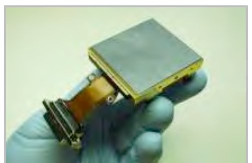
Early Investment in Technology



What is TRL 6

- TRL 6: System/subsystem model or prototype demonstration in a relevant environment (ground or space)

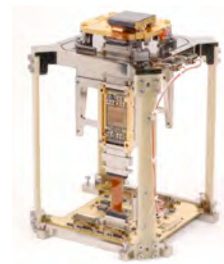
Example 1: Near-IR Detectors



√

TRL 4

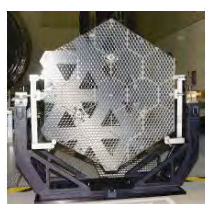
Radiation testing
Lifetime testing
Flight Packaging
Cryogenic Operation
Flight Controller



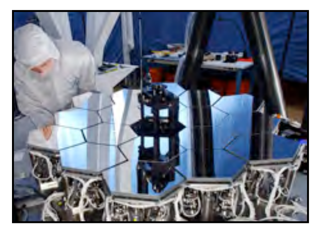
TRL 6

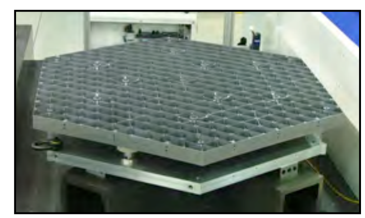
Example 2: OTE Control

Wavefront Control Brassboard



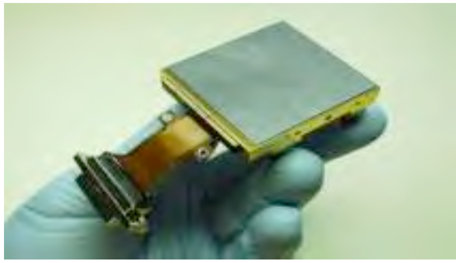
Advanced Mirror System Demonstrator



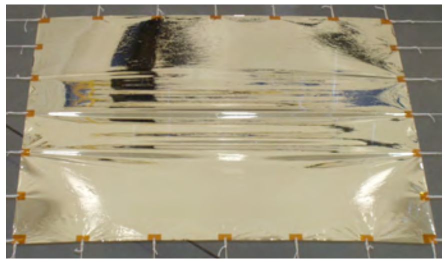


Flight mirrors and Test Bench Telescope

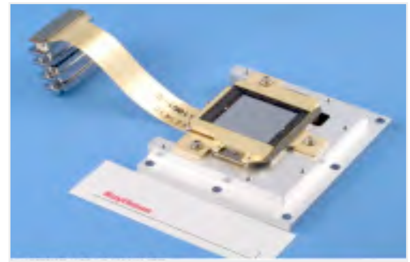
Technologies Demonstrated in 2006



Near Infrared Detectors √
April 2006

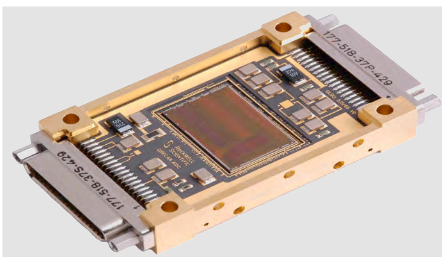


Sunshield Material √
April 2006

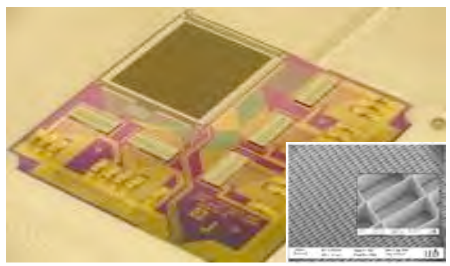


Mid Infrared Detectors
July 2006

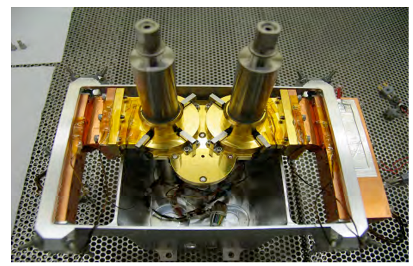
Primary Mirror
Segment Assembly
June 2006



Cryo ASICs
August 2006

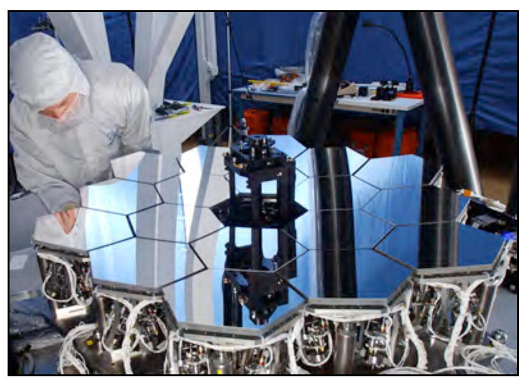


Microshutter Arrays
August 2006

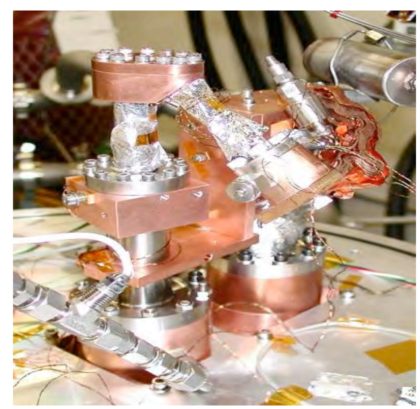


Heat Switches
September 2006

Large Precision Cryogenic Structure
November 2006

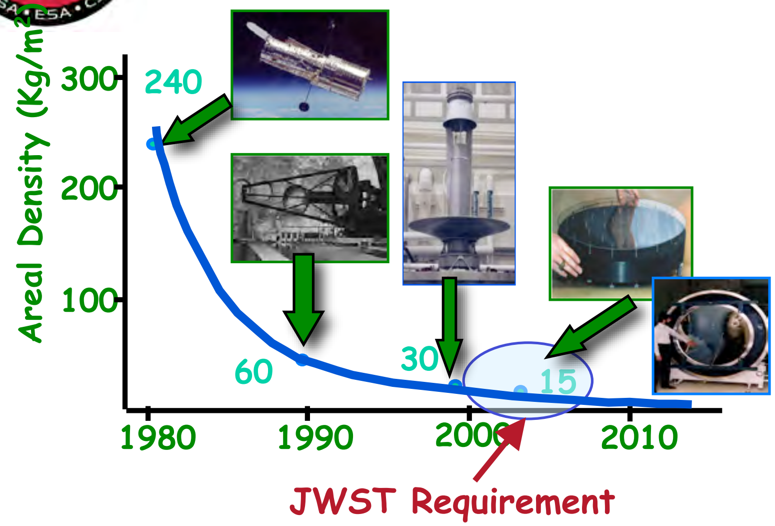


Wavefront Sensing & Control
November 2006



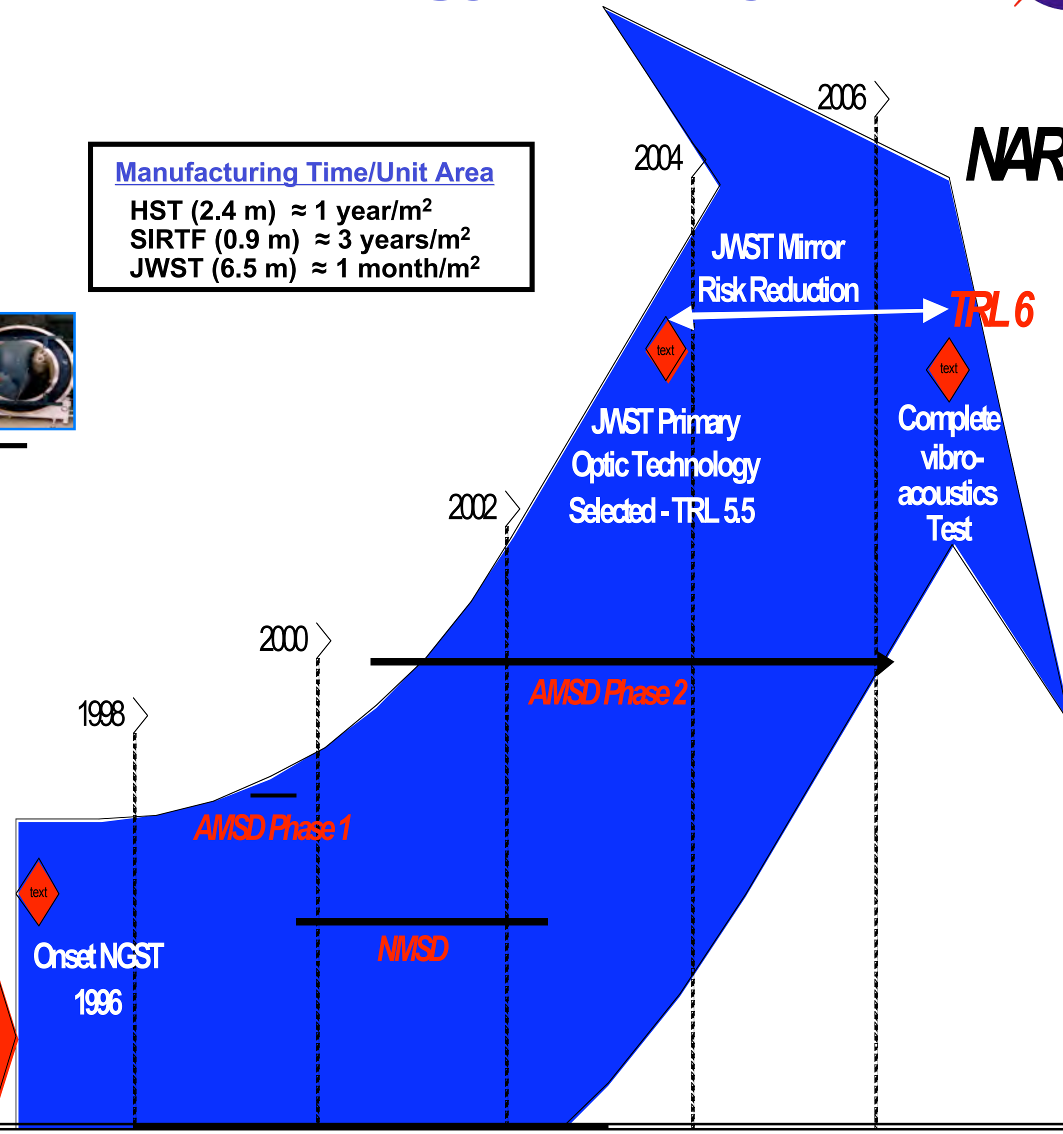
Cryocooler
December 2006

JWST Mirror Technology History



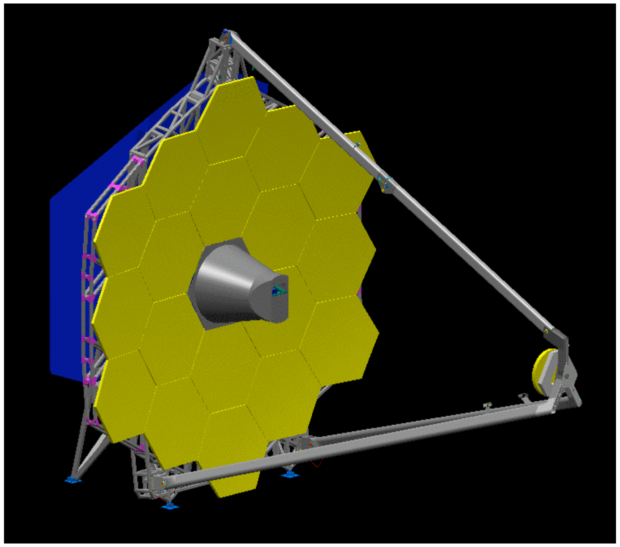
Manufacturing Time/Unit Area

HST (2.4 m) ≈ 1 year/m^2
SIRTF (0.9 m) ≈ 3 years/m^2
JWST (6.5 m) ≈ 1 month/m^2

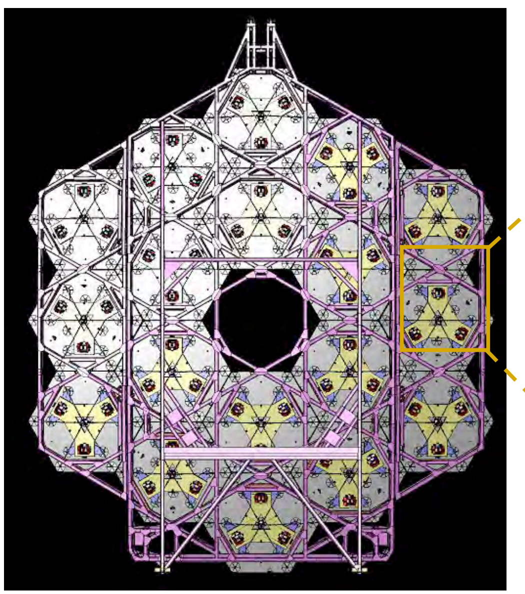


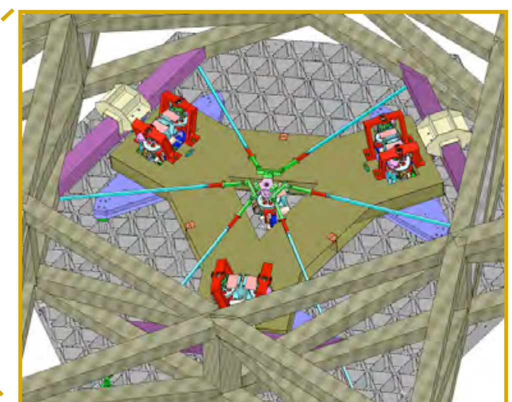
Based on lessons learned, JWST invested early in mirror technology and mirror production to address lower areal densities and manufacturing time

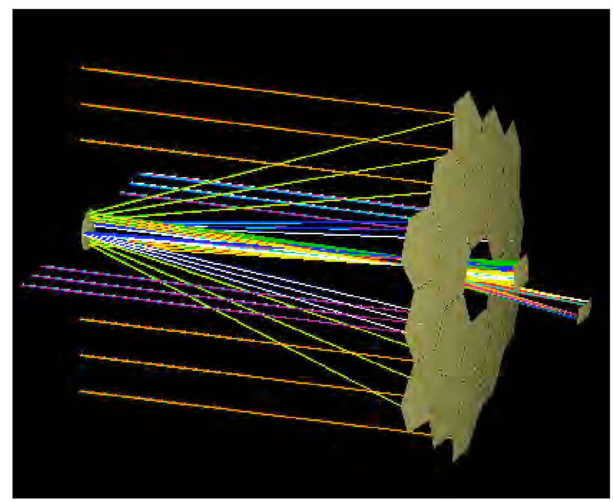
OTE Design



- Primary Mirror is comprised of eighteen (18) Primary Mirror Segment Assemblies (PMSA)
- PMSAs are mounted to a rigid, light-weight composite Backplane Assembly

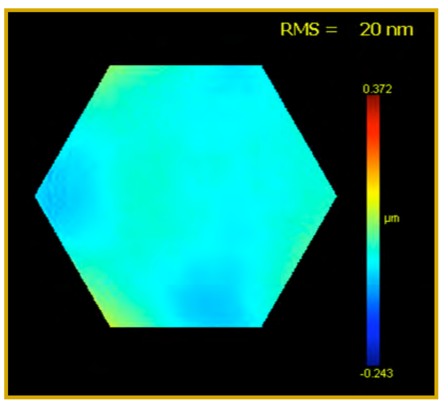




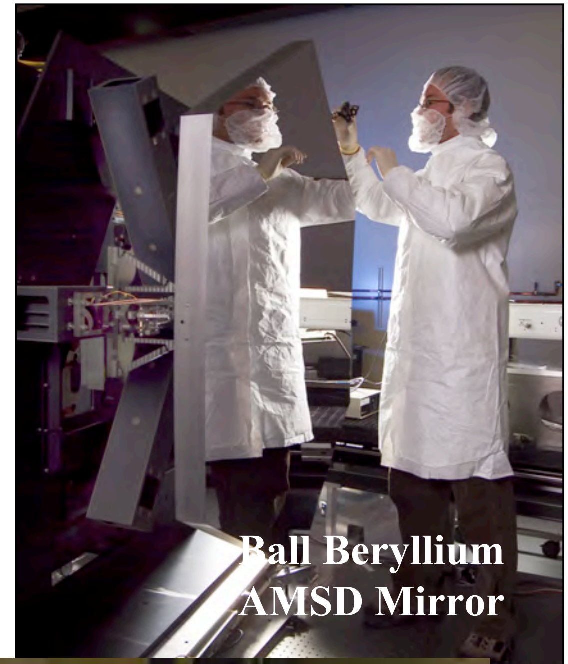


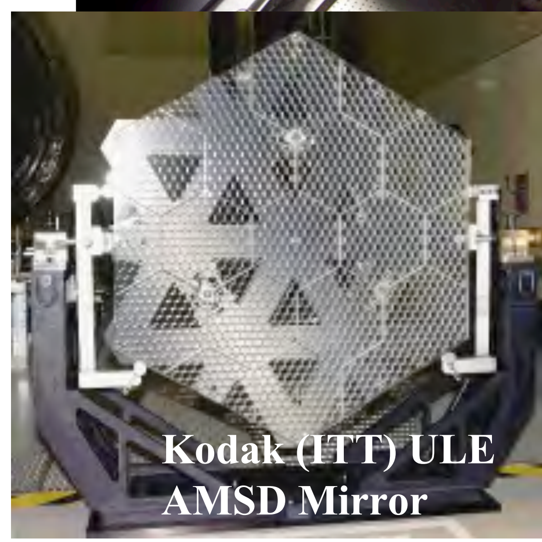
JWST Advanced Mirror System Demonstrator

- NASA, DOD, NRO $50M partnership funded 3 lightweight mirror technologies (right)
- Ball beryllium mirror technology completed and baselined for JWST in 2003
  - Ball beryllium mirror demonstrated all key aspects of JWST technology except for demonstration of vibro-acoustics survival which will be demonstrated this June on the Engineering Design Unit mirror
- Mirror manufacturing of flight mirrors started in September 2003

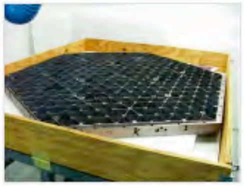


Final AMSD Beryllium mirror performance: 20 nm figure achieved on required schedule



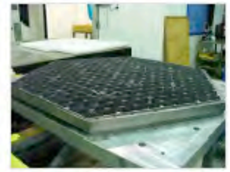


Flight PM Segments in Machining at Axsys


PMSA #1 (EDU-A / A1)


PMSA #2 (6 / B2)


PMSA #3 (4 / C1)

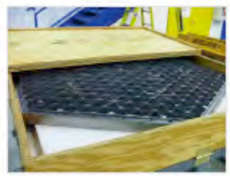

PMSA #4 (5 / A2)

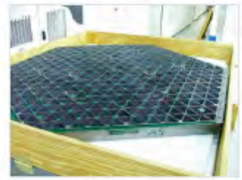

COMPLETE!!
PMSA #5 (3 / B1)


PMSA #6 (7 / C2)


PMSA #7 (13 / A4)


PMSA #8 (11 / B3)


PMSA #9 (12 / C3)

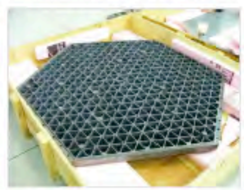

PMSA #10 (16 / A5)

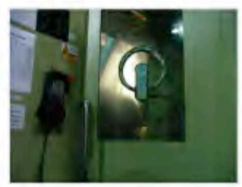

PMSA #11 (17 / B5)


PMSA #12 (15 / C4)


PMSA #13 (8 / A3)


PMSA #14 (20 / B6)


PMSA #15 (18 / C5)

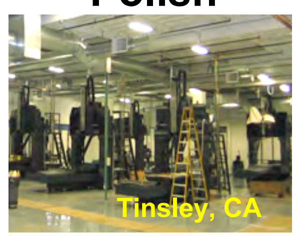

PMSA #16 (19 / A6)


PMSA #17 (22 / B7)


PMSA #18 (21 / C6)

Grind

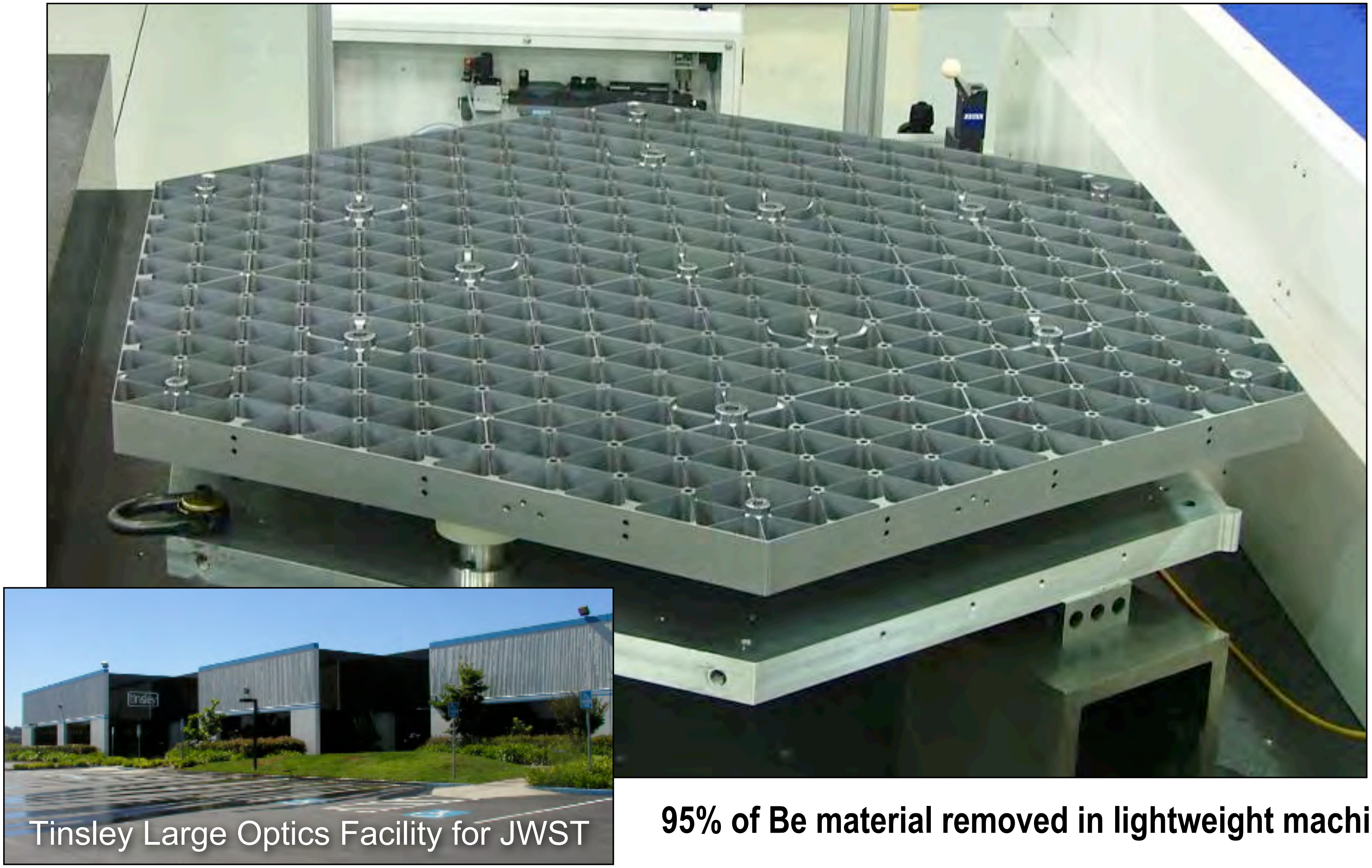
Polish



Cryo. Test

World's first production line for producing high precision cryogenic beryllium optics is up and running

Flight segment to be used for TRL-6 vibro-acoustics test this June



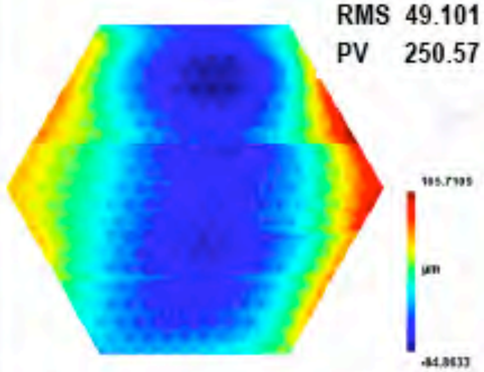
Tinsley Large Optics Facility for JWST

95% of Be material removed in lightweight machining

CCOS Grinding Progress on EDU

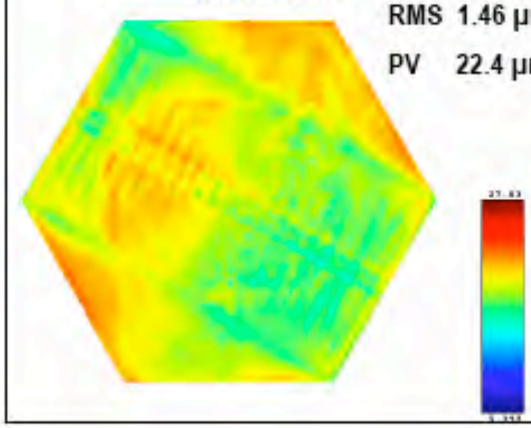
PRE CCOS PROCESSING FIGURE 1/10/2006

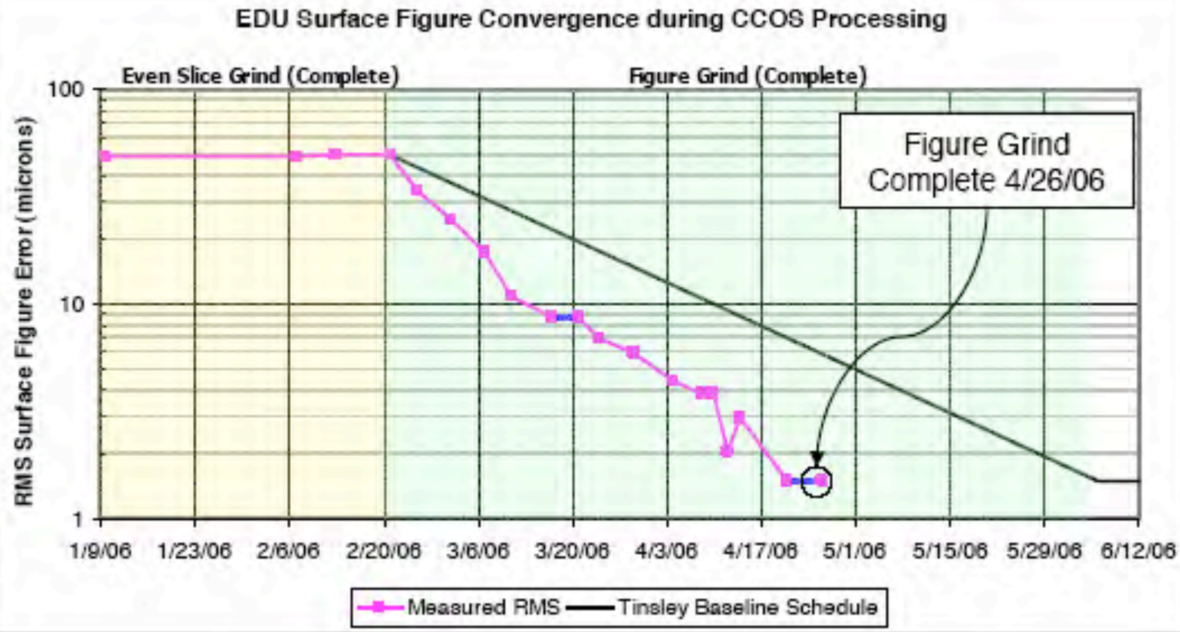
RMS 49.101 µm
PV 250.57 µm

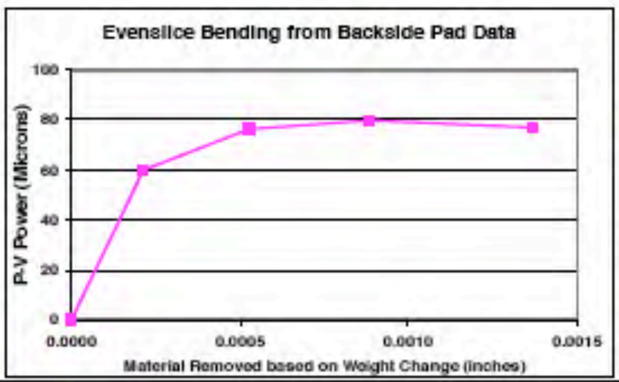


POST 15th GRIND ITERATION FIGURE 4/21/2006

RMS 1.46 µm
PV 22.4 µm



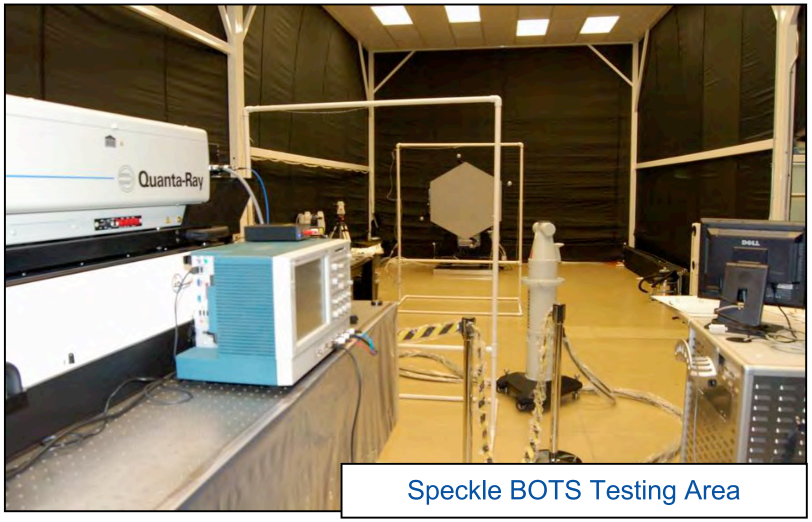




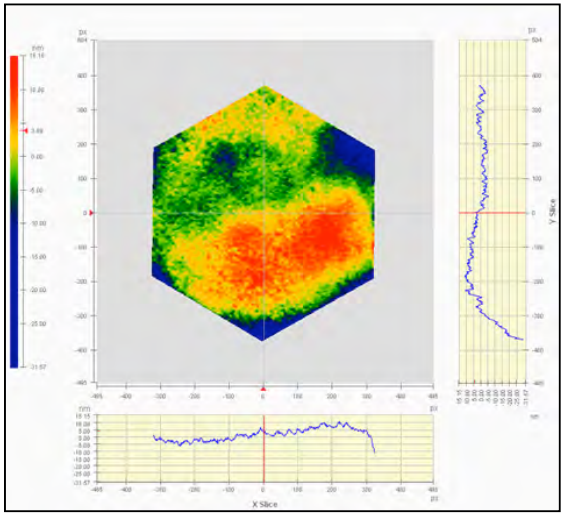
- Figure Grinding Operation converged faster than schedule baseline.
- Bending from stress flattened out during Even Slice Grinding just as predicted from Experiments after 0.0006" evenly removed.
- Segment B1 will start out the grinding process >2.5x BETTER than the EDU

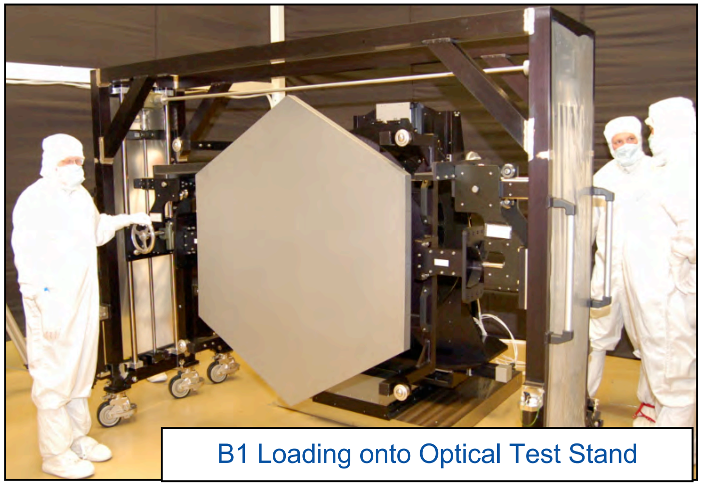
Flight Primary Mirror Segment Assembly

Speckle Interferometry Testing



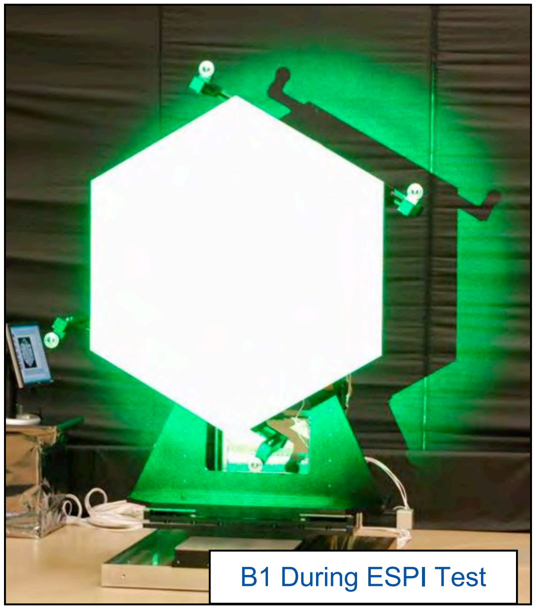
Speckle BOTS Testing Area





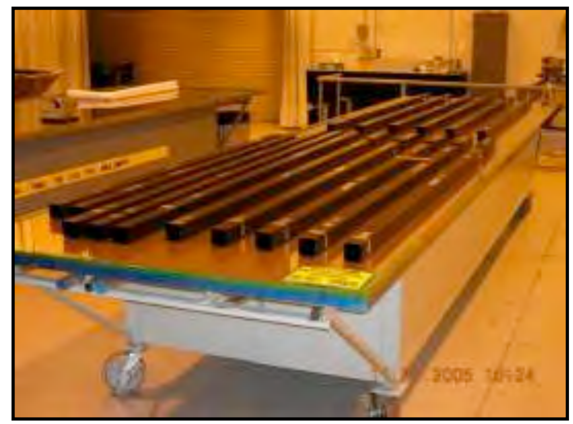
B1 Loading onto Optical Test Stand

6DOF Optical Test Stand



B1 During ESPI Test

Backplane Stability Test Article (BESTA)

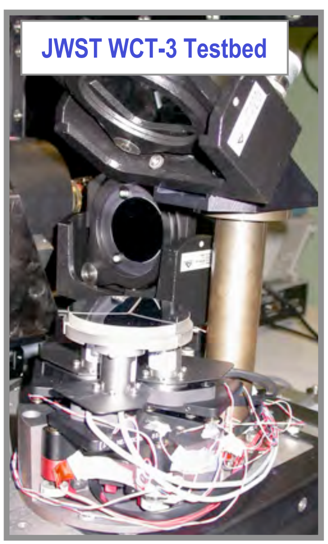


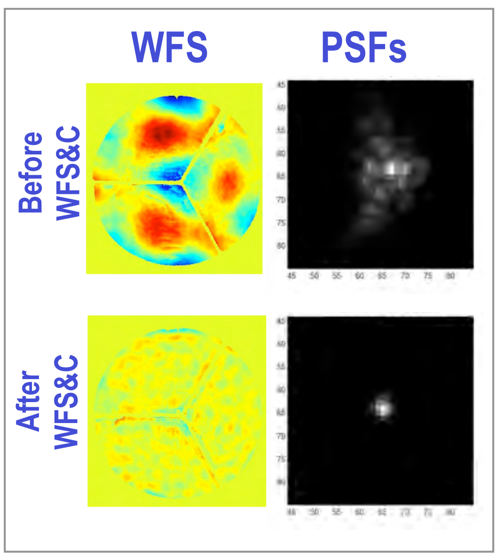
JWST Wavefront Sensing and Control

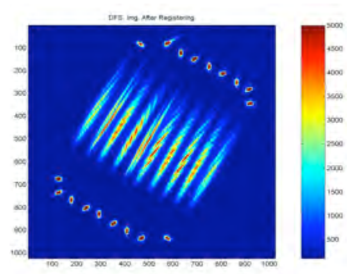
- Wavefront Sensing and Control (WFSC) provides the algorithms used to align the telescope
  - Techniques build on image based software and algorithms developed for HST Prescription Retrieval, ground telescopes, and on a large array of testbeds
  - Early investments in WFSC proved the basic feasibility of the JWST segmented mirror approach through modeling and hardware demonstrations

- WFSC testbeds at the Goddard Space Flight Center (the Wavefront Control Testbed) and at Ball were used to develop JWST-specific technologies to TRL 4/5

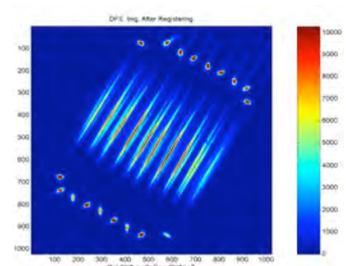
- An experiment last July on the inner 18 segments of the Keck Telescope demonstrated the specific coarse phasing portion to be used on JWST (coarse phasing now at TRL-6)





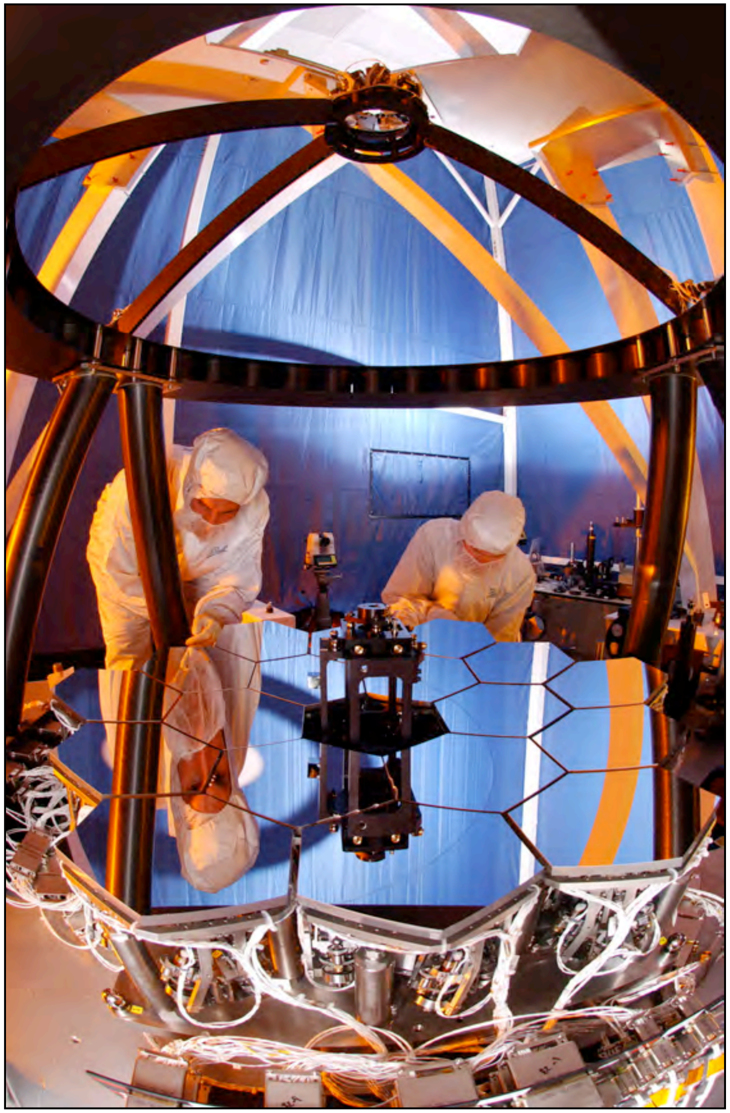


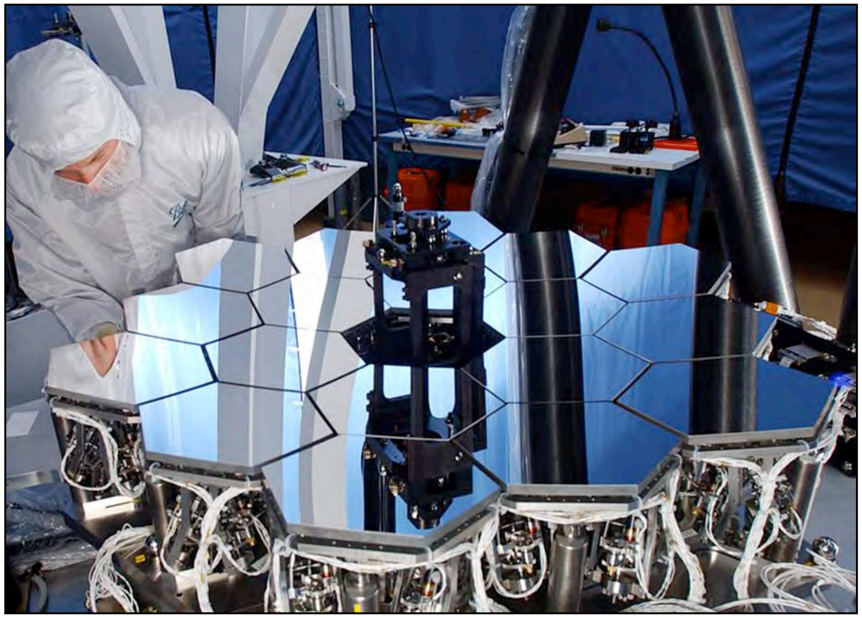
Initial errors
Max piston error=19 μm
Rms=5 microns



After correction
Max piston error=0.66 μm
Rms=0.18 microns

WFSC Testbed Telescope





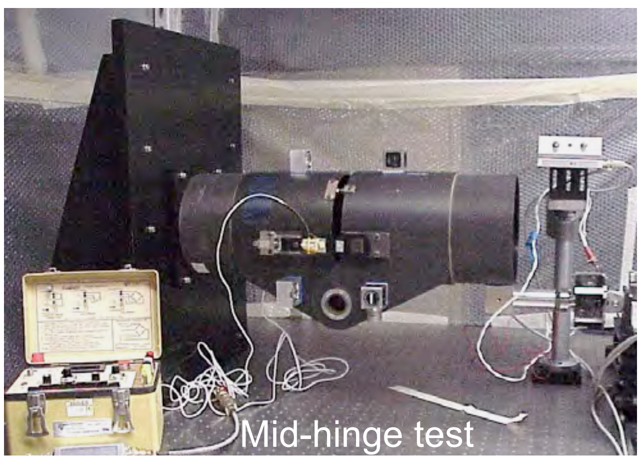
- WFSC Testbed Telescope is a 1/6th scale, fully functional model of the JWST telescope with performance traceable to JWST
- Testbed provides functionally accurate simulation platform for developing deliverable WFSC algorithms and software
- Algorithms are being checked out on the testbed
- Remaining WFSC TRL task is to demonstrate end-to-end wavefront sensing and control through final alignment

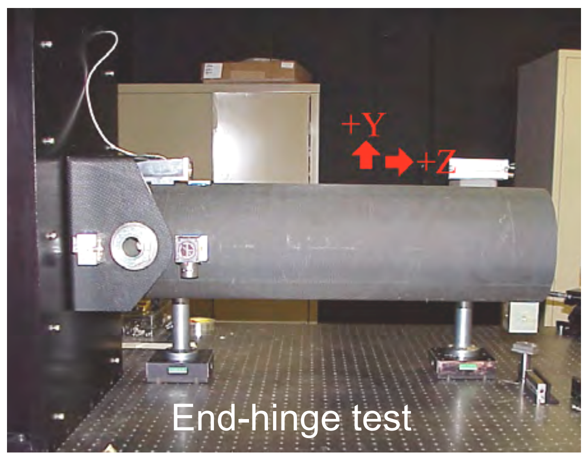
Observatory Oversight

- JWST key technology areas have rigorous oversight from Product Integrity Teams (PIT) with extensive large optics and flight experience e.g. OTE PIT
  - **James Wyant, University of Arizona, Co-chair**
  - **Duncan Moore, University of Rochester, Co-chair**
  - **Bob Gehrz, University of Minnesota**
  - **Bob Shannon, University of Arizona**
  - **John Mangus, Private/Ex-GSFC**
  - **Robert Laskin, JPL**
  - **Roy Frieden, University of Arizona**
  - **Jim Burge, University of Arizona**
  - **Mark Kahan, ORA**
  - **Jim Fienup (University of Rochester)**
  - **Gary Chanan, UCI**
  - **George hartig (STScI)**
  - **John Hayes, 4D Technologies**
  - **Mike Krim, Private/Ex-Goodrich**
  - **Greg Forbes, QED**
  - **Matt Mountain, Gemini Observatory**
  - **Larry Step, Gemini Observatory**
- Wavefront Sensing and Control PIT
- Deployment Review Team
- Sunshield PIT

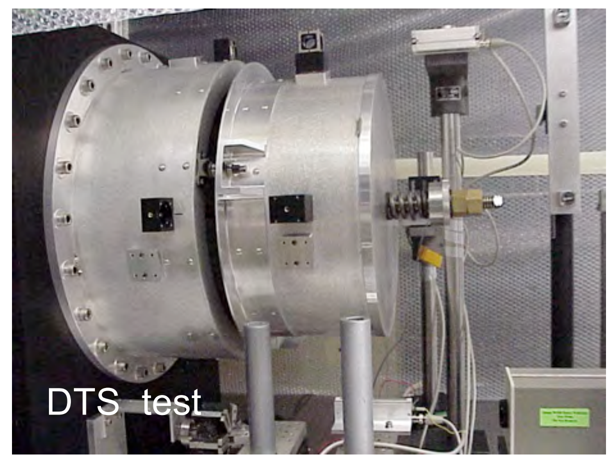
Microdynamic testing of all Deployment latches

- Two types of SMSS hinge/latches and DTS testing completed
  - Wing latch was tested in 2000 (see 5179-28)
- In all cases, no “nano lurches” were observed (with a noise floor of about 10nm) when loads were applied that were at least 10x greater than will be seen operationally

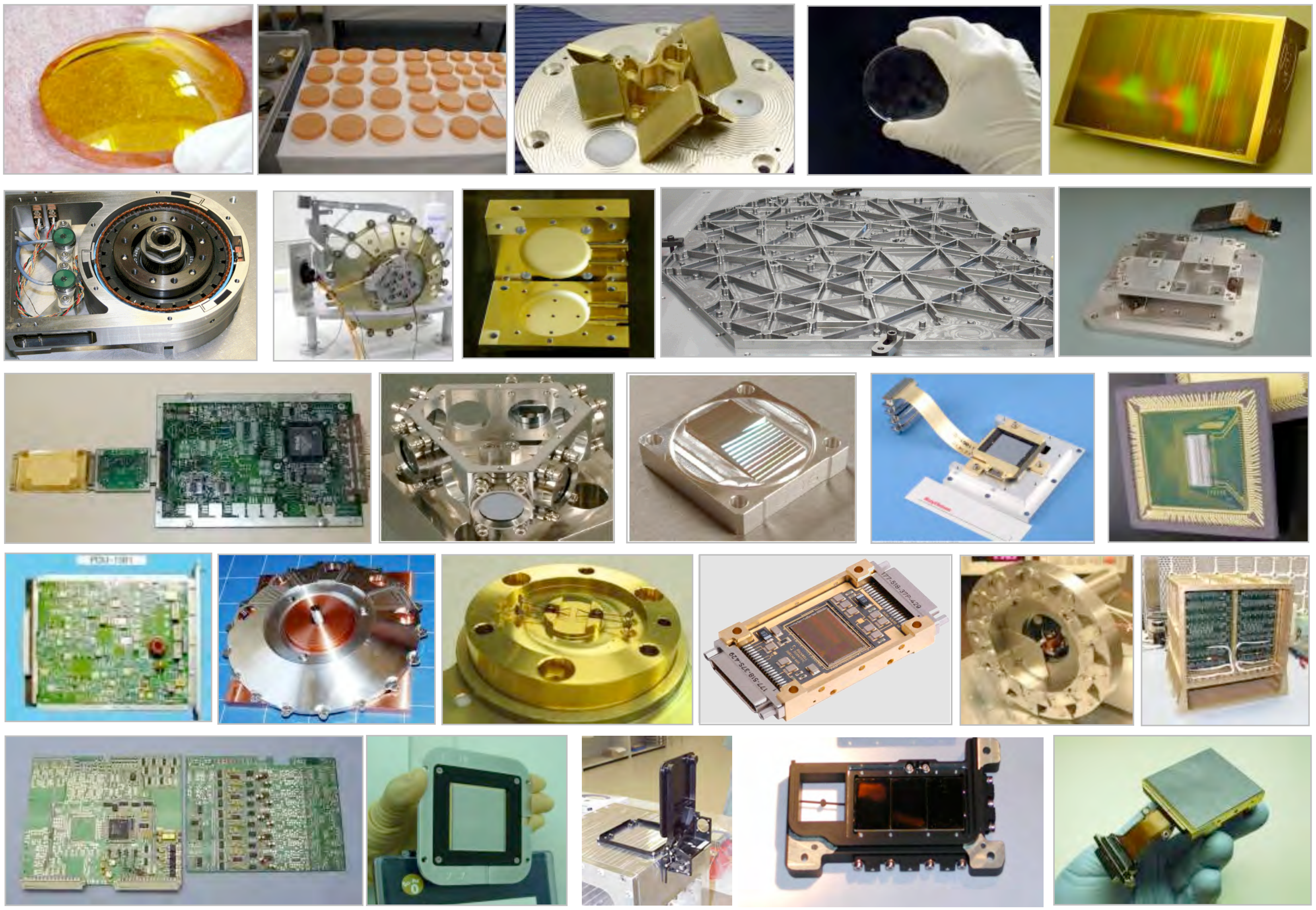

Mid-hinge test



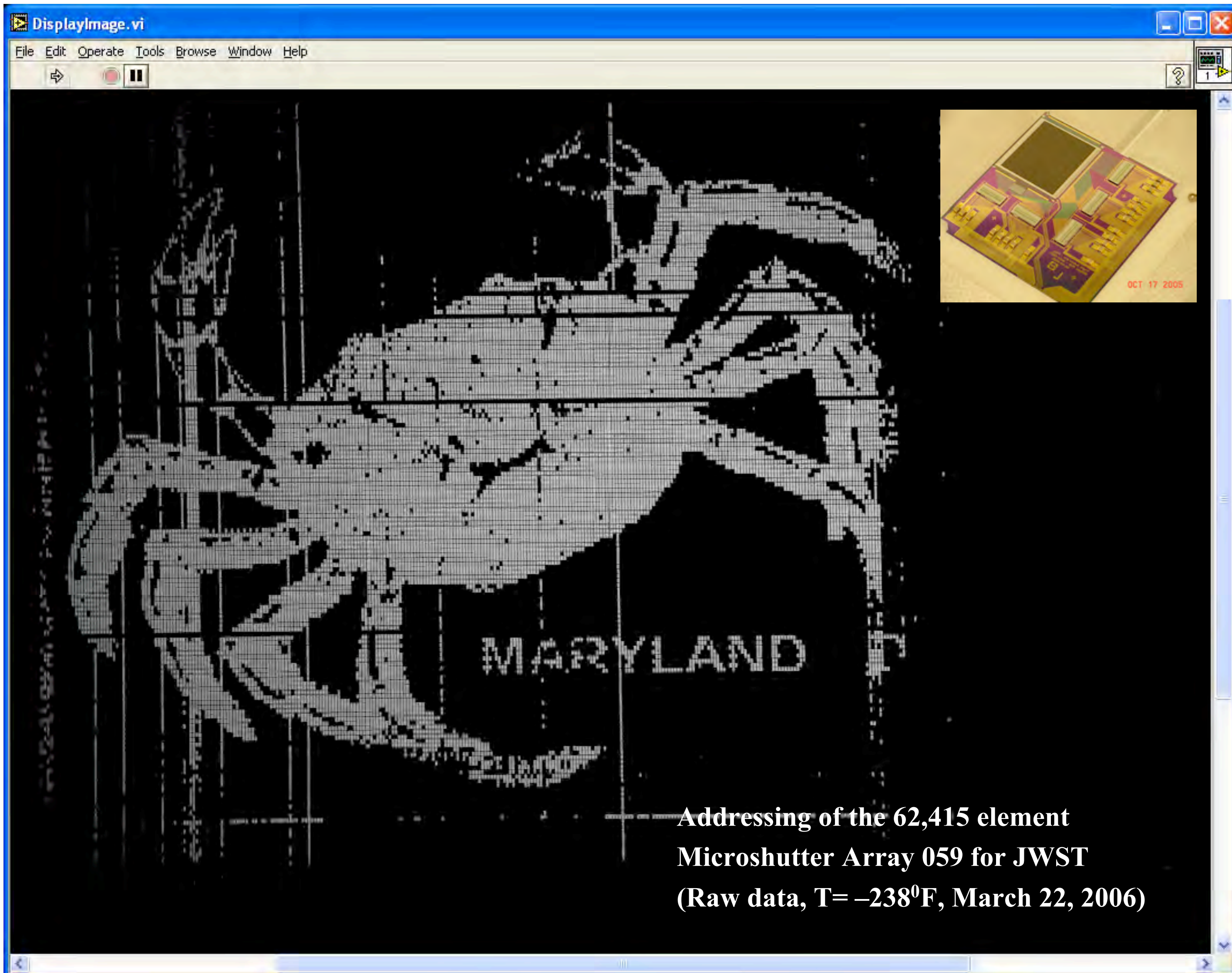
End-hinge test


DTS test

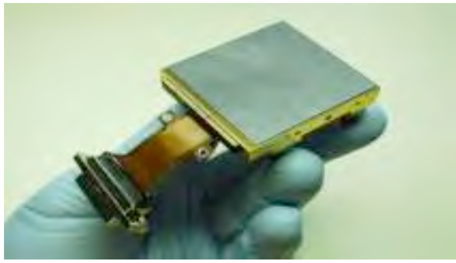
Instrument Hardware in Production



Microshutter Array for JWST



Technologies Demonstrated in 2006



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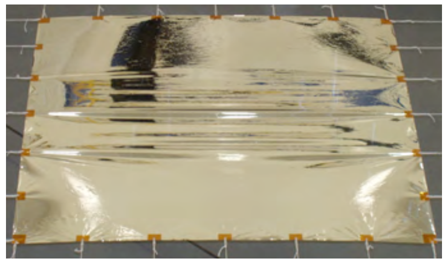
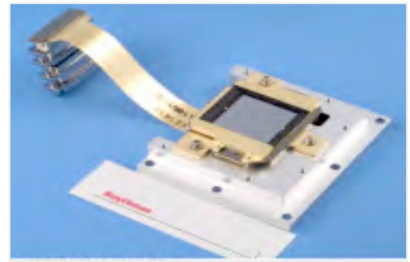
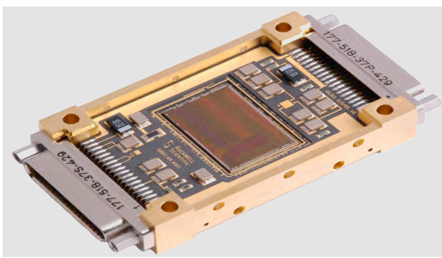


Sunshield Material √
April 2006



Mid Infrared Detectors
July 2006

Primary Mirror
Segment Assembly
June 2006



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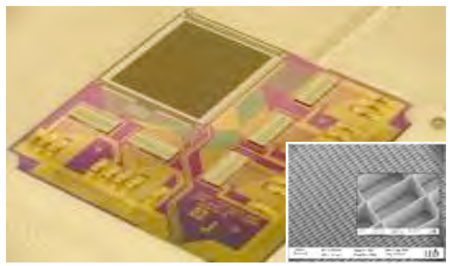

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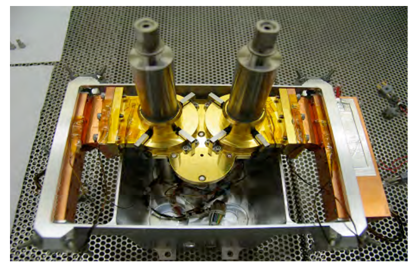

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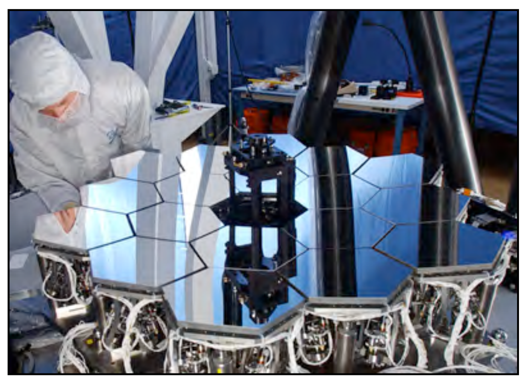
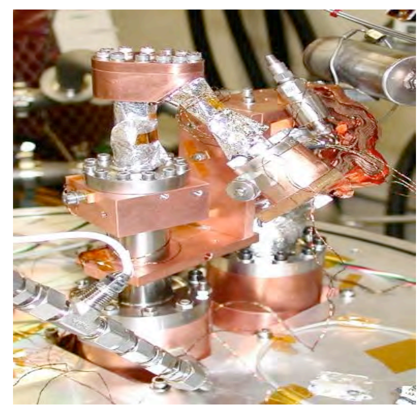
Large Precision Cryogenic Structure
November 2006



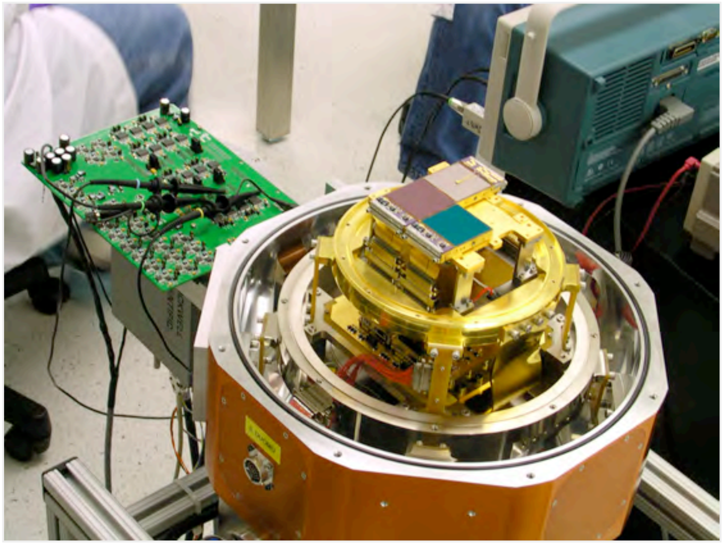
Wavefront Sensing & Control
November 2006



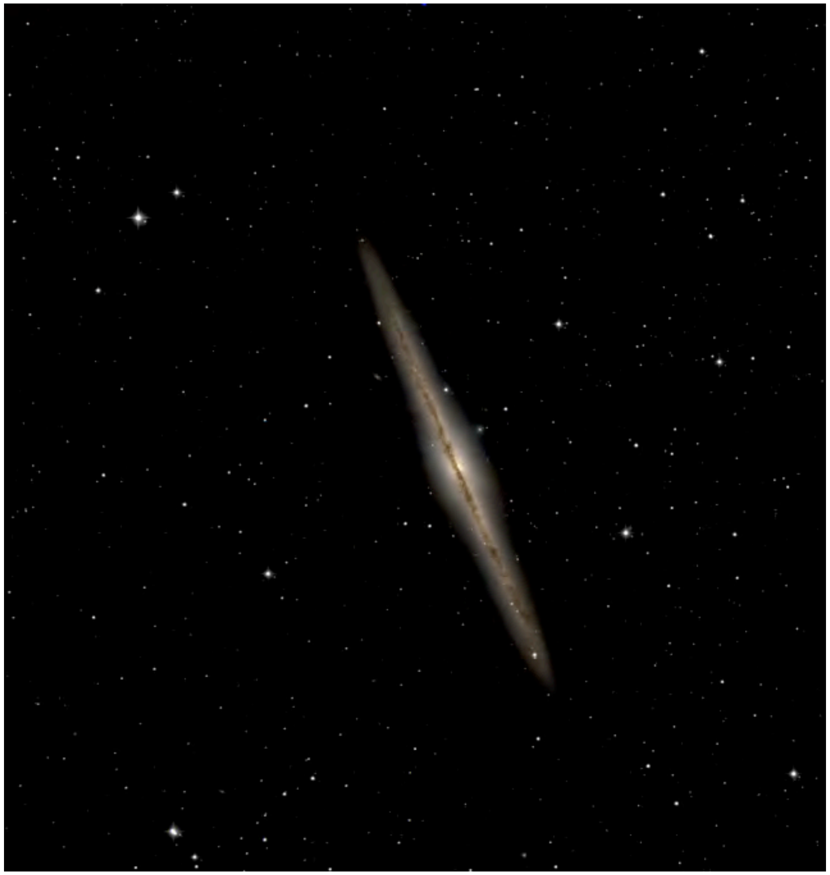
Cryocooler
December 2006

First Astronomical Image With HGR2 Detector

Near-infrared image of the galaxy NGC-891 obtained using a NIRCam prototype 16 Mpixel H2RG array



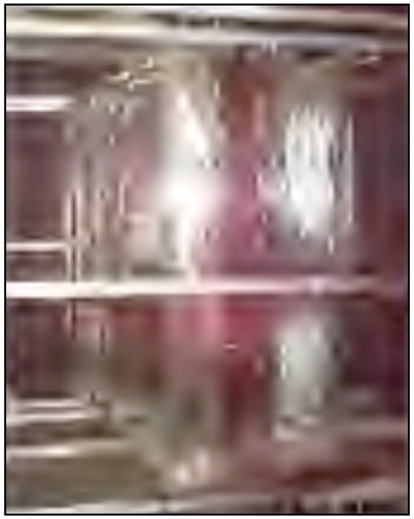
Eng Model 2Kx2K HgCdTe Detectors

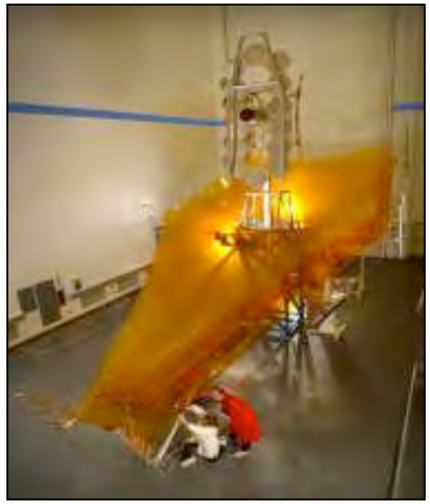


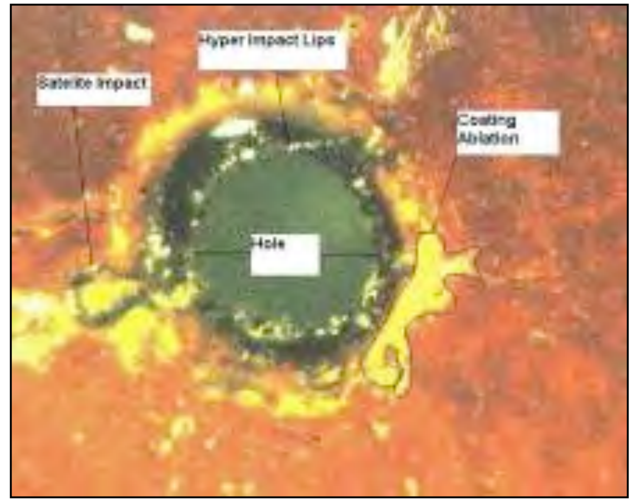
Similar detectors have flown on HST and Spitzer and have been used in ground observatories. Key challenge for JWST was flight qualified large format (4Kx4K)

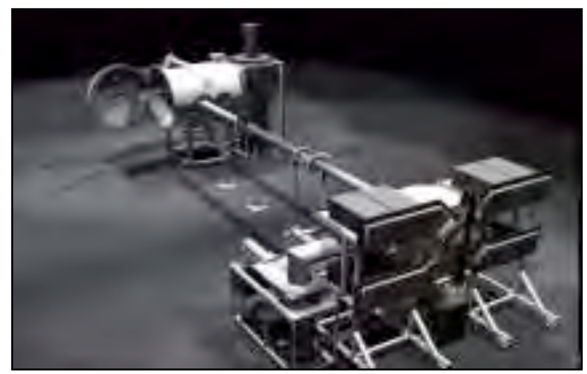
- **TRL-6 completed!**

Sunshield Progress









- NGST have had 2200 successful mechanism deployments with no failures

Summary

- Early investment in technology expected to significantly reduce the program risk in Phase C/D
  - Many potential risks discovered and mitigated

- Technology development is far along and will be complete by January 2007

- Primary mirror manufacturing is progressing as planned,
  - JWST’s primary mirror has been “cast”
  - Pathfinder polishing started

- Experience in large flight programs shows that understanding true cost and mitigation of risks requires real designs, and design trade studies (Phase A/B)