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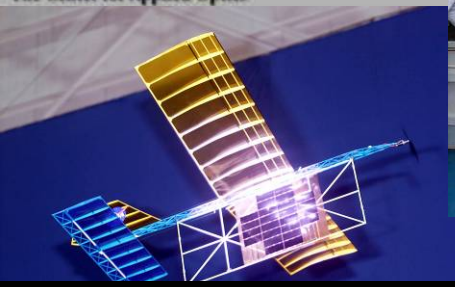

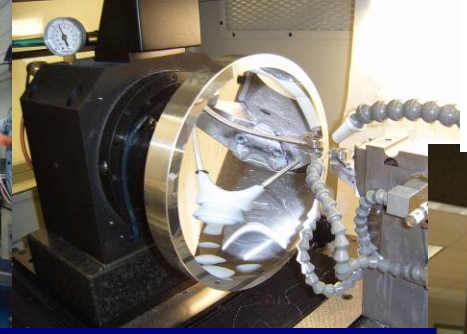

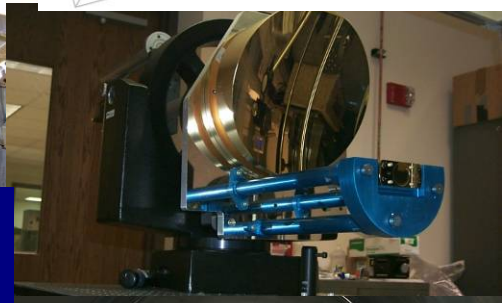

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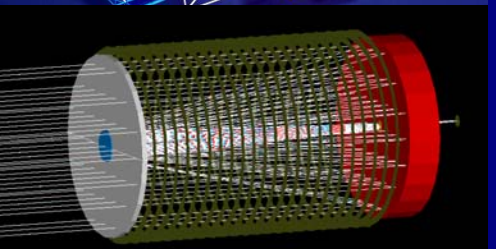
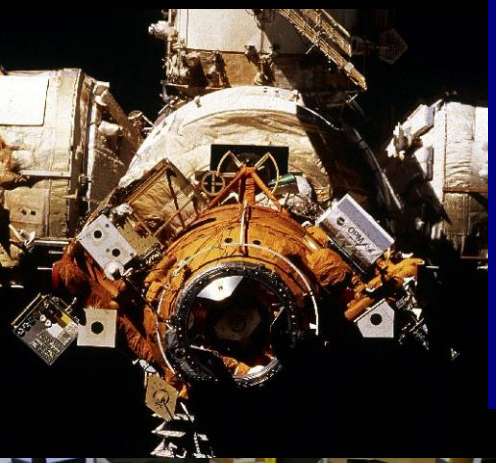
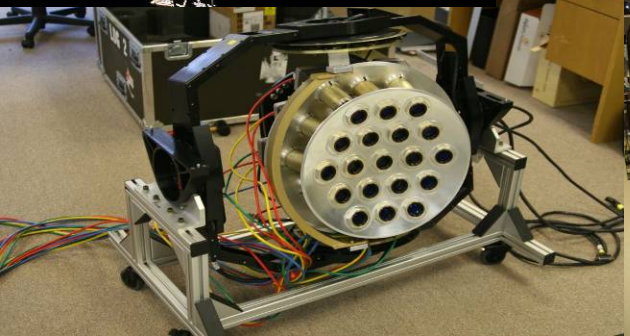
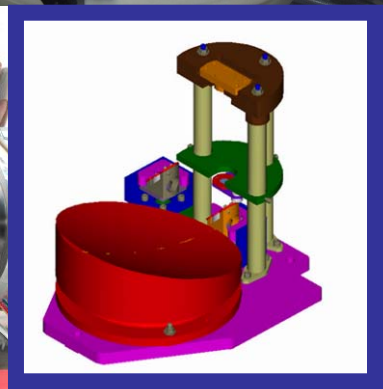
Research advancing optical science, optical design, fabrication and testing

Building complex optical systems and components for environments from the lab to space









CAO Background

- Established in 1985 as a focal point of optics at UAH & in Alabama.
- Primary mission: advance research and education in applied optics and optical engineering.
- Primarily Research Staff with many affiliated faculty and graduate students.
- 110,000 ft2 Optics Building completed in 1991 with vibration-isolated laboratory core, including numerous clean rooms.

Center for Applied Optics Nano & Micro Devices Center

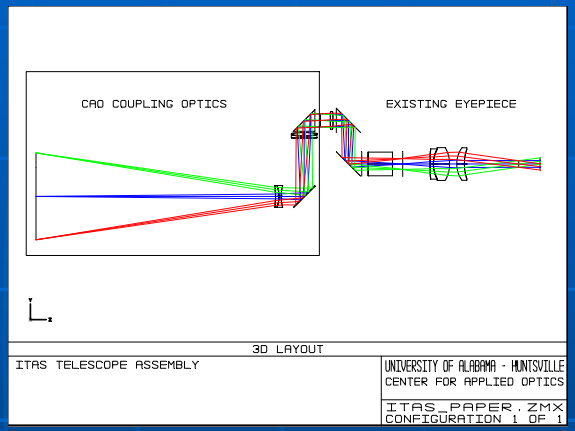
- CAO and NMDC Merged in 2008
  - CAO: Research Staff
    - Dr. Patrick J. Reardon, Interim Dir., CAO
    - Dr. James Hadaway
    - Dr. Brian Robinson
    - Mr. Darell Engelhaupt (OC)
    - Dr. Joe Geary
    - Dr. Lisa Blackwell (OC)
    - Mr. Dave Pollock (OC)
    - Mr. Ken Pitalo (OC)
    - Mr. Ted Rogers
    - Mr. Chris Underwood
  - NMDC; Faculty
    - Dr. John Williams, Assoc. Dir, NMDC
    - Dr. Yongbin Lin, NMDC staff
    - Frank Berisford, NMDC staff
    - Dr. Robert Lindquist, ECE
    - Dr. Junpeng Guo, ECE
    - Dr. Emanuel Waddell, Chem.
    - Dr. Jeffrey Weimer, ChE
    - Dr. Jennifer English, ECE
    - Dr. David Coe, ECE
    - Dr. Seyed Sadeghi, Physics

CAO: Classical Optics

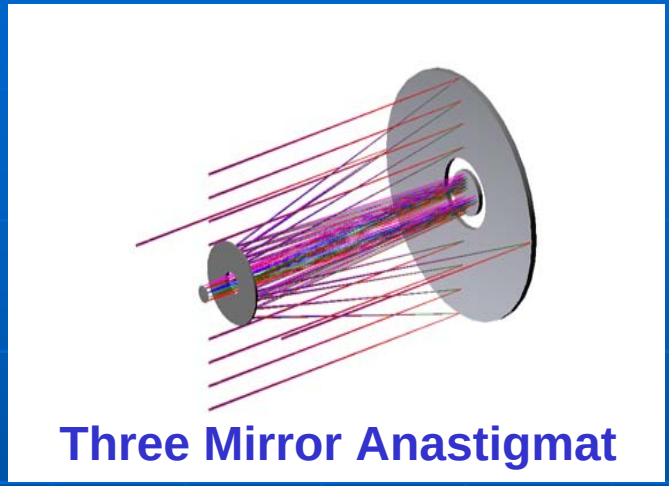
- **Research Areas**
  - Optical and Opto-mechanical System Design
  - Optical Fabrication, Testing, Integration and Deployment
  - Laser Technology, Power Beaming and Lidar
  - Adaptive Optics and Wavefront Sensing
  - Radiometry, Radiometric Calibration & Polarimetry
  - Optics for UAS's
- **Experience**
  - Gamma-ray to THz
  - Meter-class to micro-optics
  - DoD, NASA, NSF and commercial customers
  - Basic research through product development
  - Education

Optical and Optomechanical Design

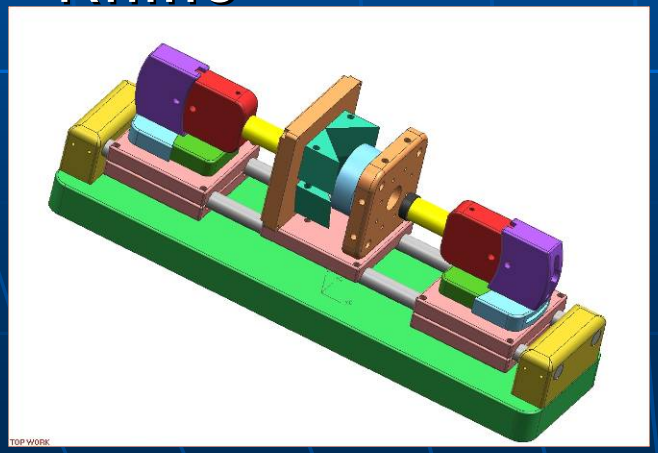
- ZEMAX
- CODE V
- Pro E
- UG
- Rhino



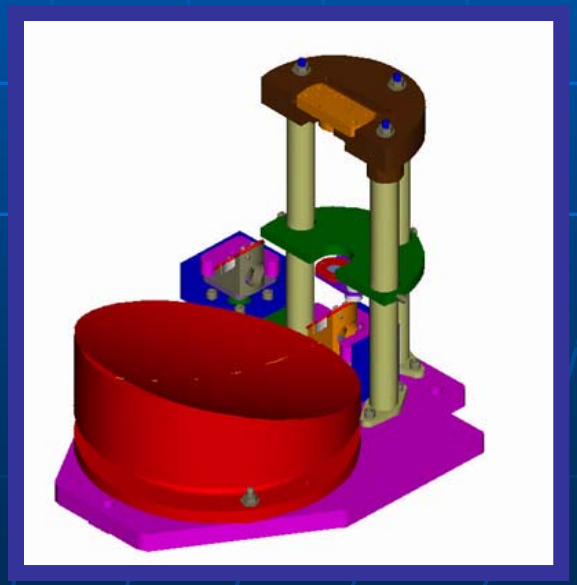
ITAS



Three Mirror Anastigmat



Thin Disk Laser



SPARCLE

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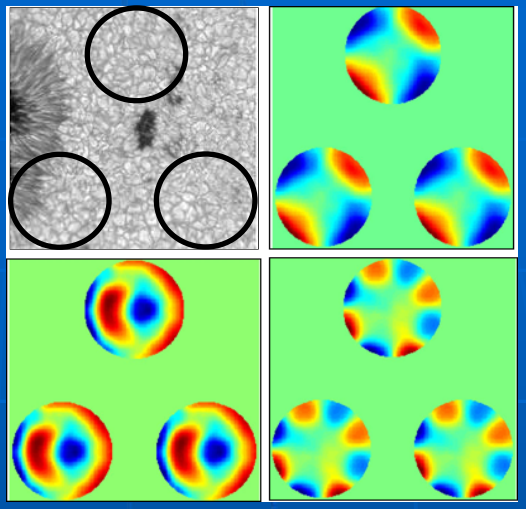
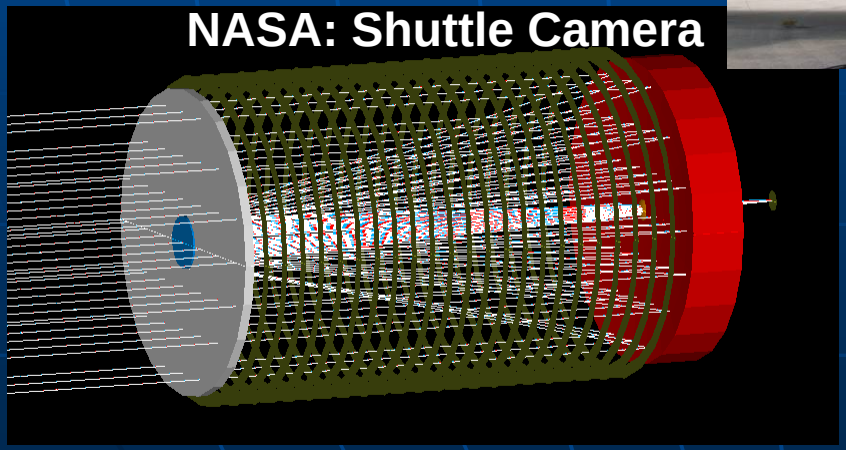
NSO: MCAO Modeling

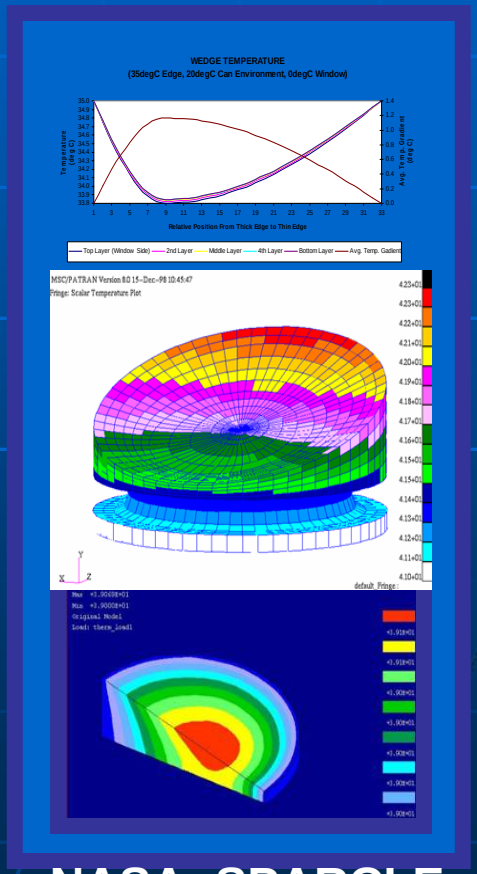


- **Analysis**
  - ZEMAX
  - CODE-V
  - ASAP
  - FRED
  - NASTRAN

NASA: WAVE

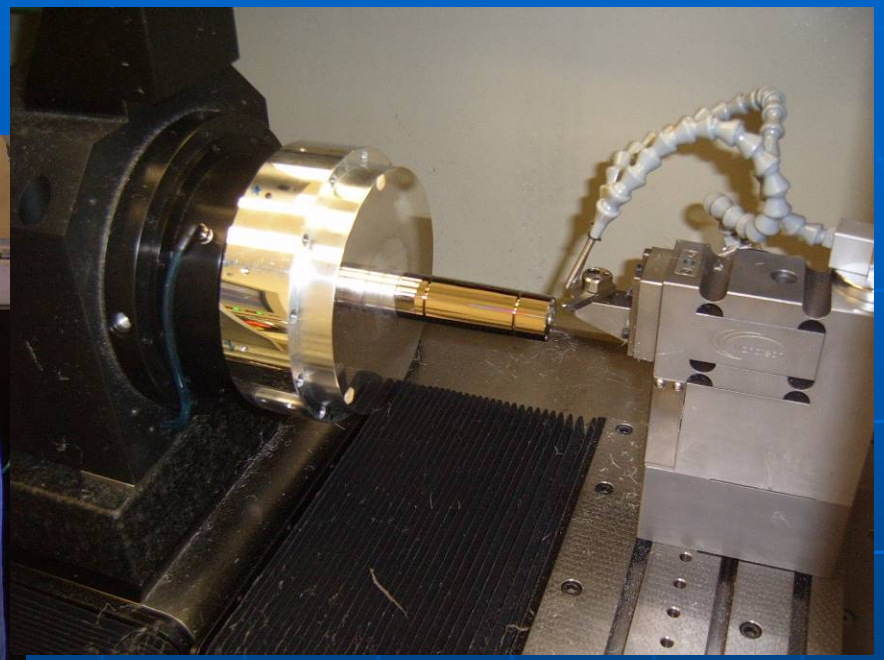


NASA: Shuttle Camera

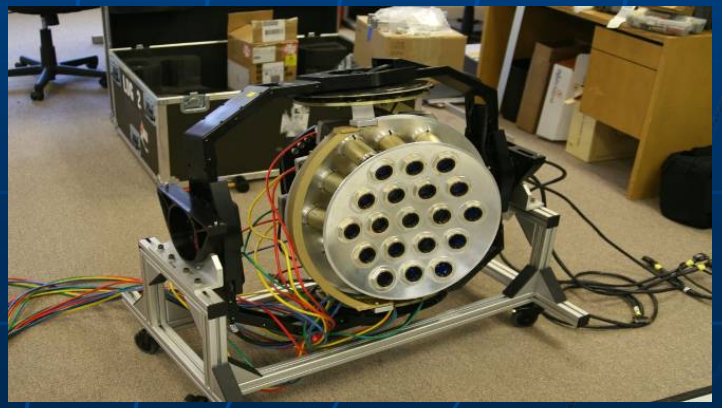


NASA: SPARCLE

Fabrication



Components to Systems



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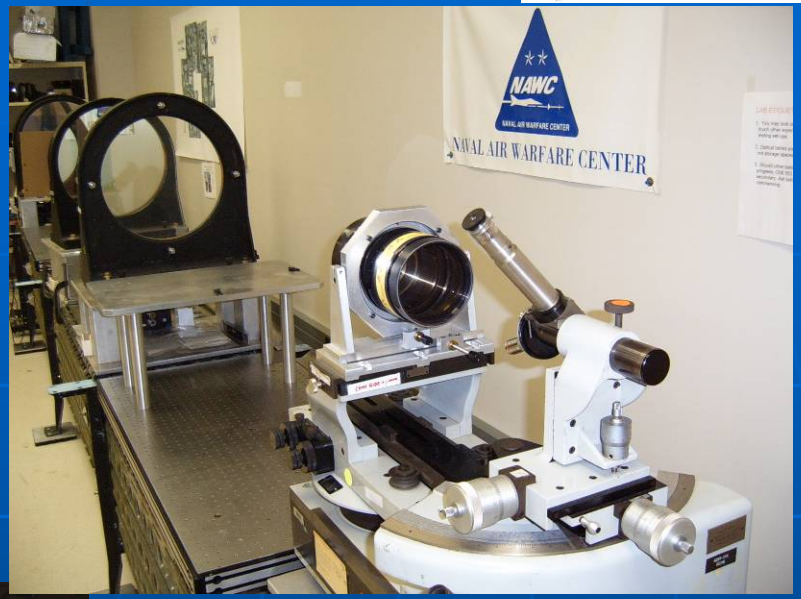
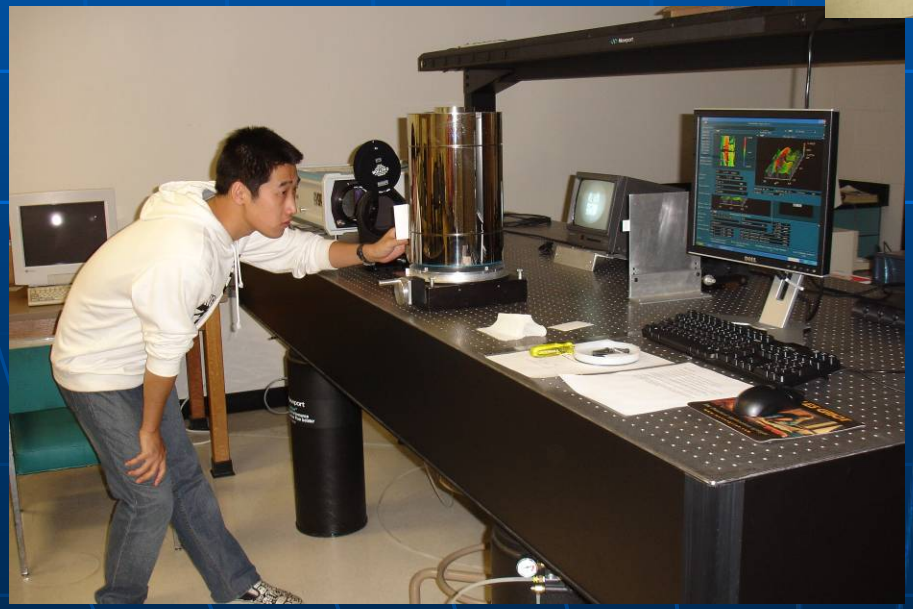
Optical Testing

- Surface Metrology
- Component Quality
- Optical System Performance





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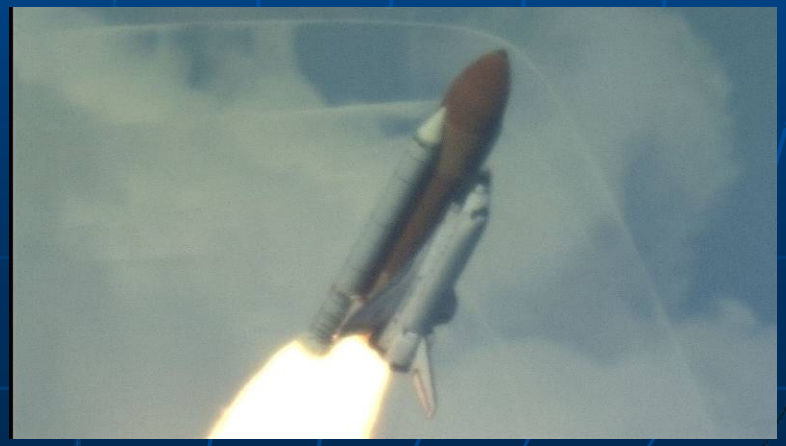
CAO Example Programs

WAVE : Response to Columbia Accident Investigation Board

A collaboration with NASA MSFC to design and build a telescope

on a mobile platform

to observe the Shuttle launch as never seen before.



Gigapixel Camera Program

- UAH-CAO Role
  - Provide Optics Expertise to Ipix, Inc
    - Ipix Inc. provided virtual tour technology to the real-estate industry
    - Won DARPA proposal in 2005 to build Gigapixel Camera
  - Program Goals
    - Persistent daylight surveillance at 25kft, 10km diameter area, 0.5m resolution, for a forensic tool

Gigapixel Camera Program Technology Readiness

Development

9/18/05
Knoxville, TN
7.6° x 7.6°

3/30/06
Milwaukee, WI
> 21°

2007 - 2009
Springfield, IL – FW, Gimbal
Yuma, AZ – FW & Rotary
> 34°

Fully
Operational
Data Collection

2005 2006 2007 2008 2009.....

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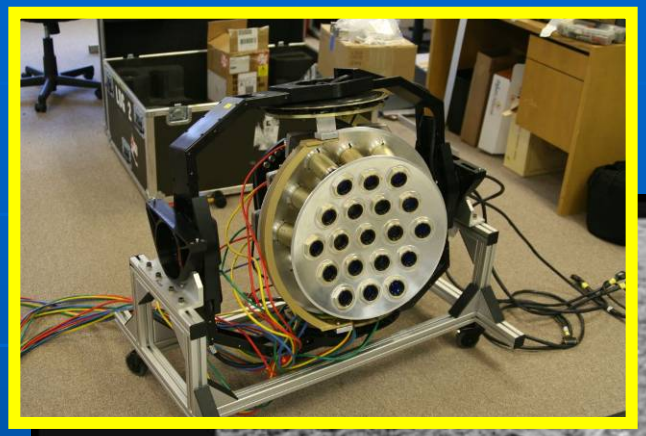
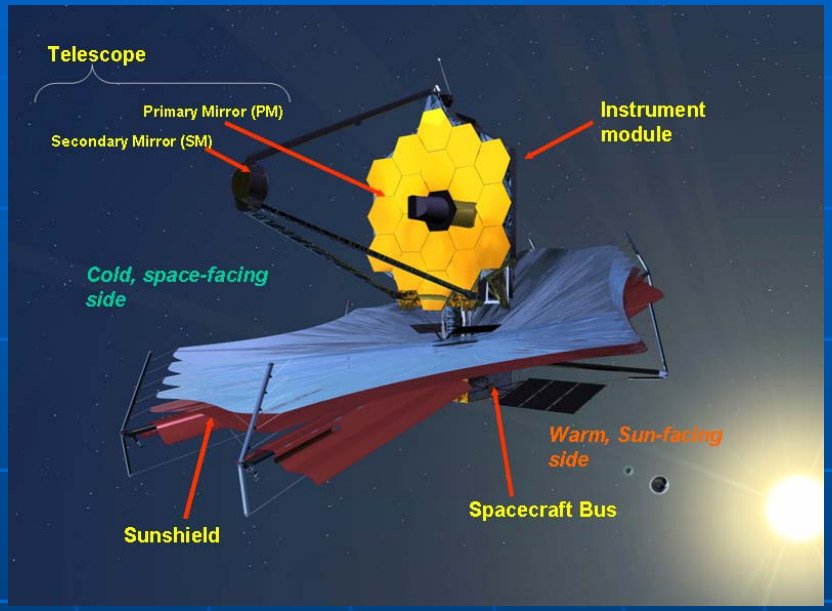
76MPix Movie Camera over Springfield, IL
35 degree FoV, 3500ft, Stabilized gimbal
~5” resolution, ~0.5mile diameter



James Webb Space Telescope Support



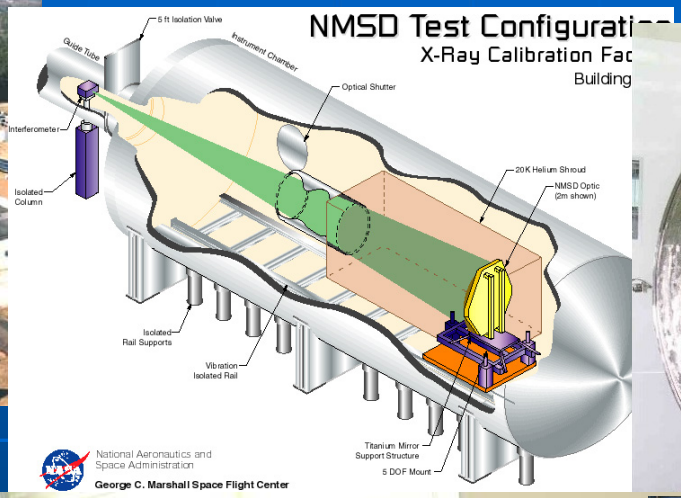
Primary Mirror Segment Assemblies

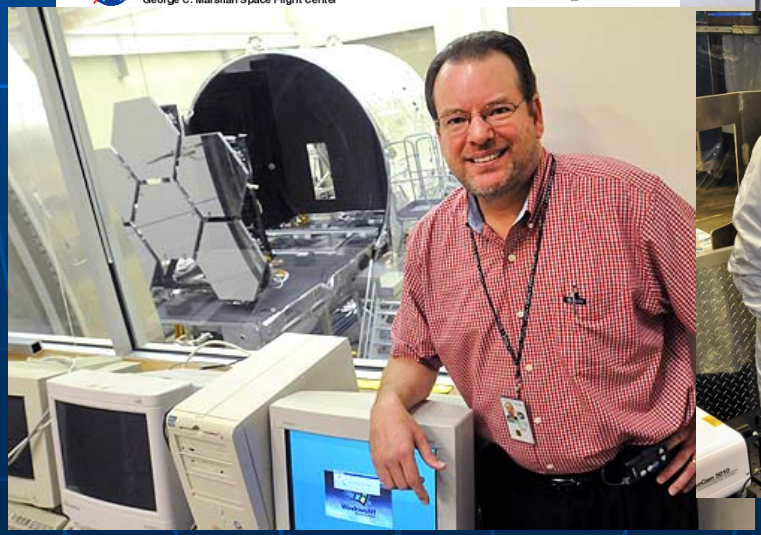
- **Ball/UAH: lead; design; actuators; integration; cryo testing.**
- **Brush-Wellman: Blank manufacture**
- **Axsys: Blank machining**
- **Tinsley: Mirror surface figuring.**
- **Denton: Gold coating.**
- **MSFC: Cryo testing facility.**

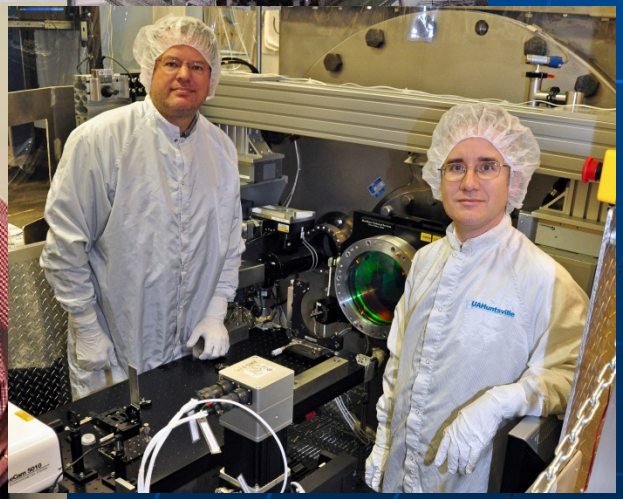
The NASA X-Ray Calibration Facility (XRCF)

For UAH testing of the JWST

Modified to test JWST mirror segments.

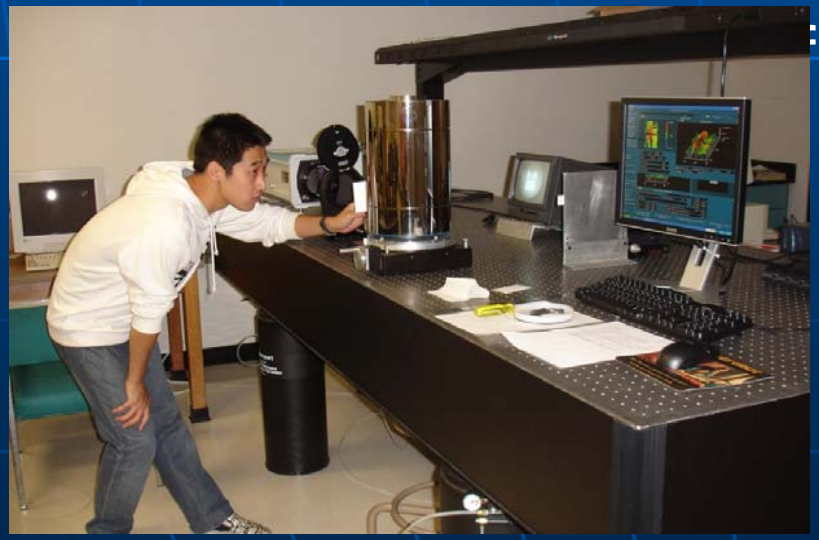




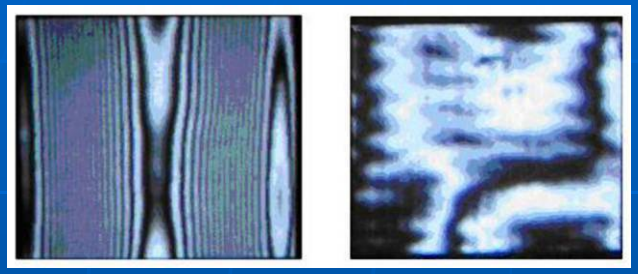


SiC Polishing Project

- MSFC – Xray Mirror Fabrication
  - Produce a precision mandrel in aluminum
    - Diamond turned and polished
  - Plate on a nickel replica

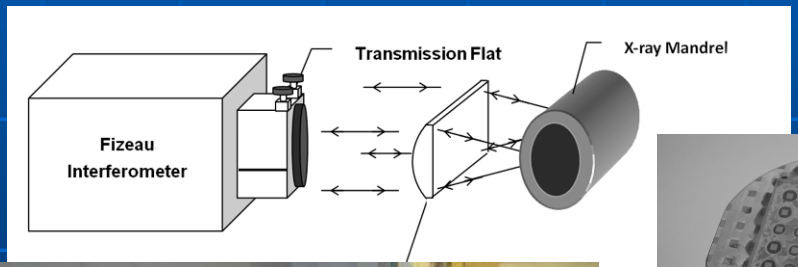


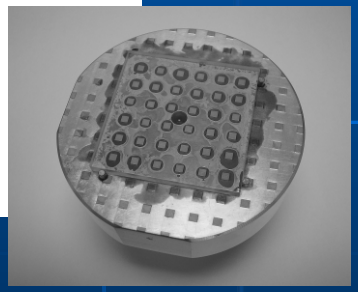
SiC X-ray Mandrel Metrology and Polishing

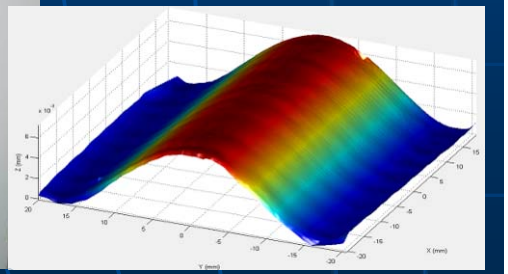


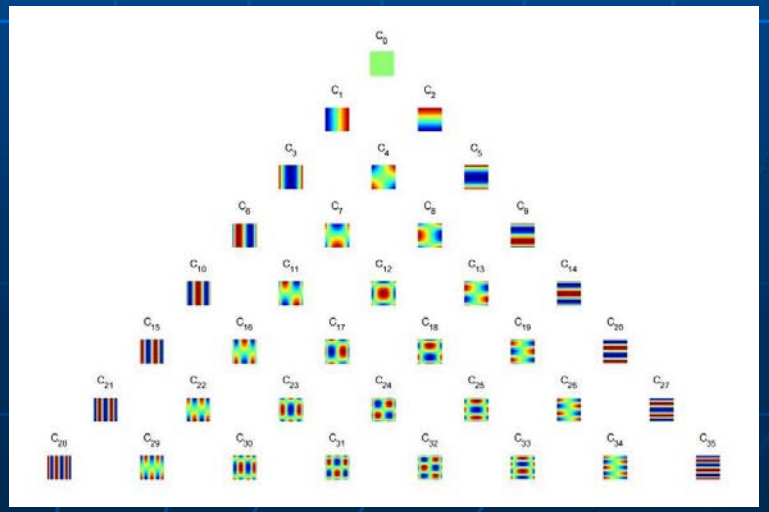
Before and after Corrector

- Developed
  - New metrology approach for testing a near-cylinder with cylindrical wavefronts
  - New optic yielding 20X improvement in metrology
  - New process for figuring SiC on Zeeko polisher
  - New surface analysis for rect. apertures



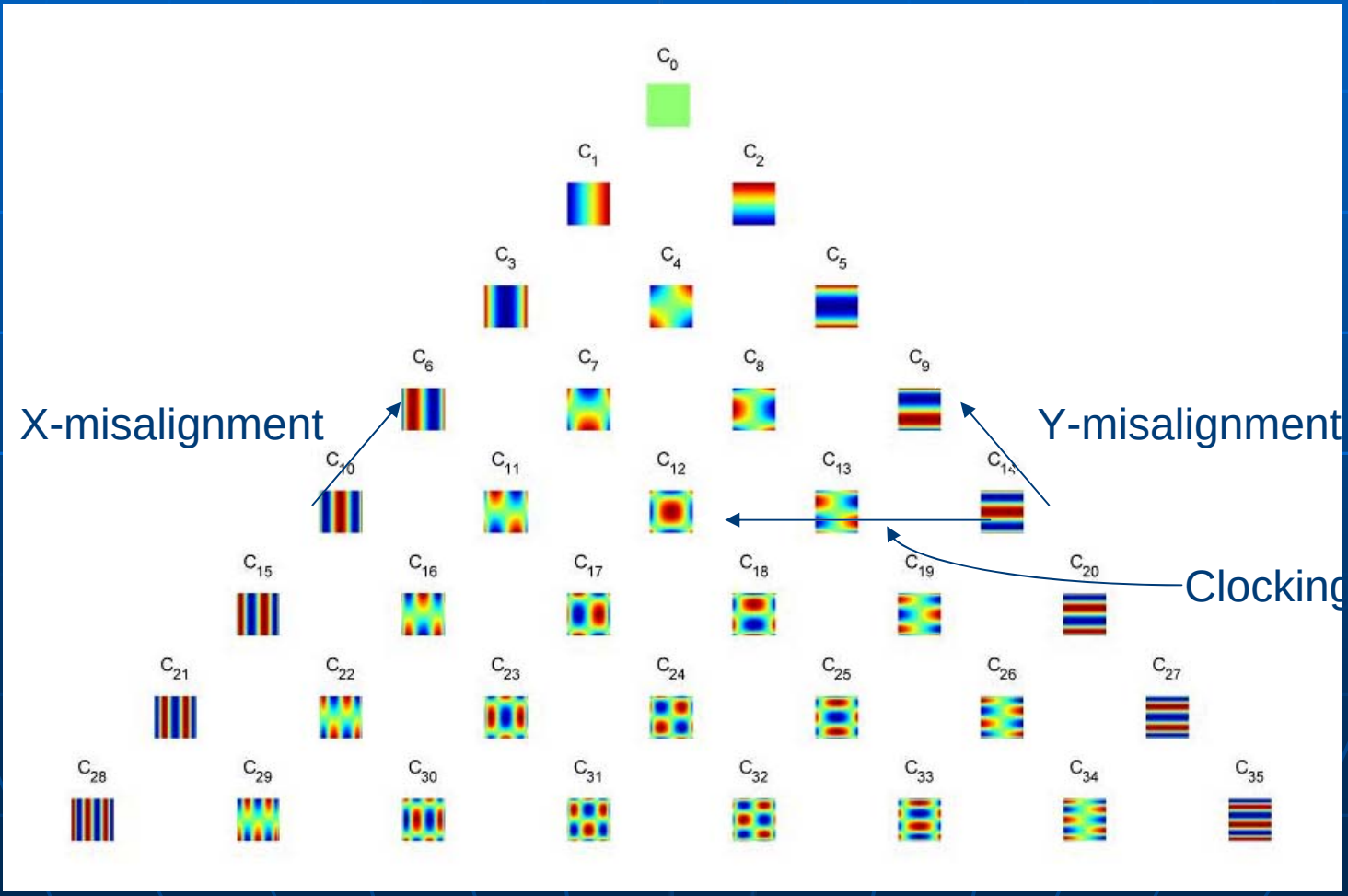






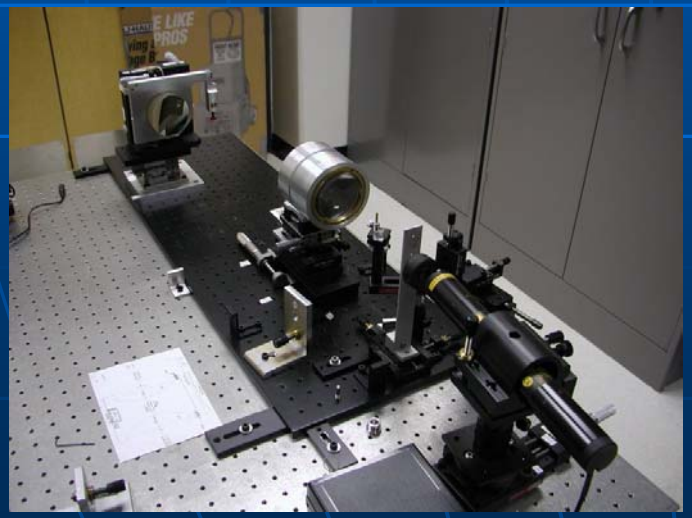
Misalignment or Misfigure: X-ray testing

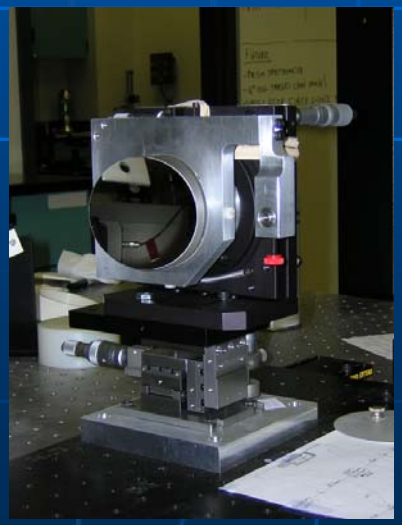
2-D Chebychev decomposition reveals misalignment errors



Dissertations

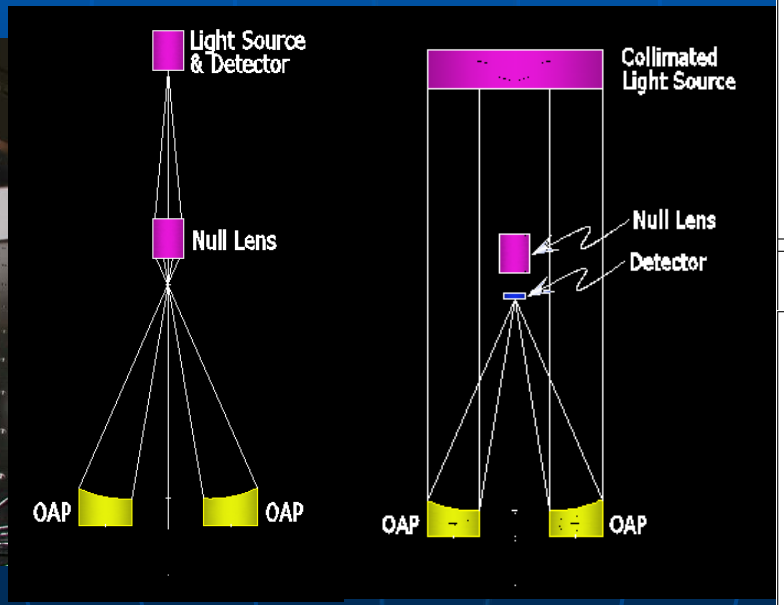
- Differential metrology
  - Regressing surface shape from many known misalignments
  - Brian Robinson, Ph.D.

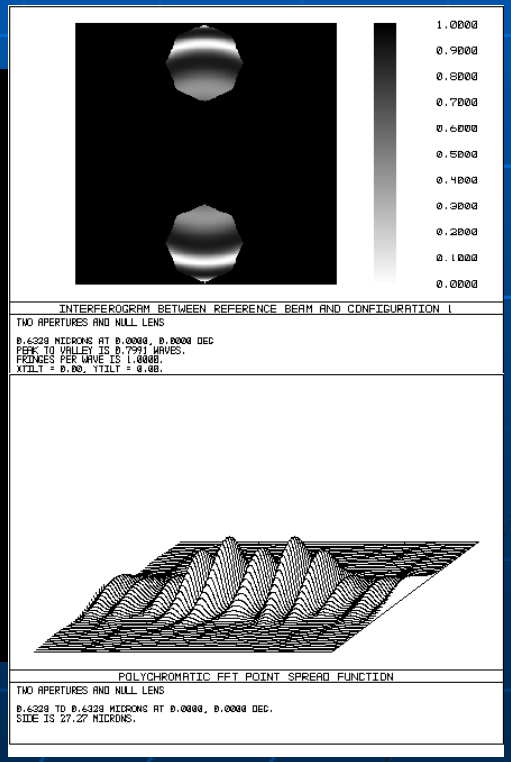




Dissertations

- Interferometric Phasing of Segments
  - William Lightsey, Ph.D.





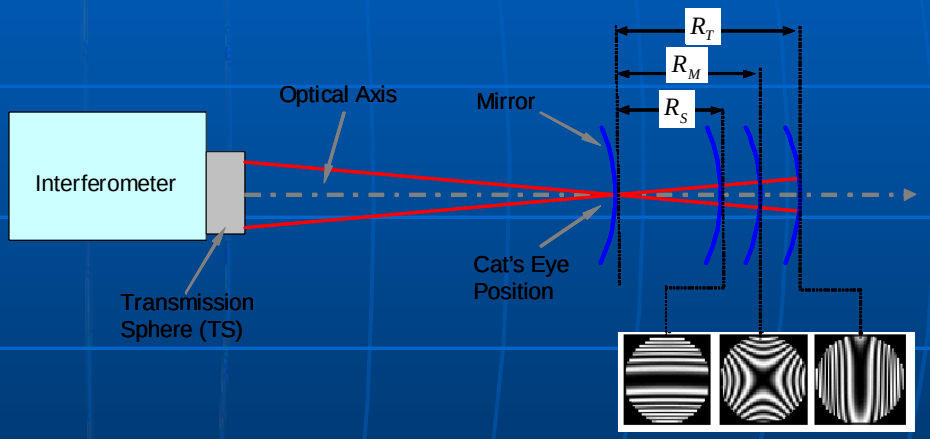
Dissertations

- Parent Radius and Conic Constant with a Spherical Reference Wave
  - No null optics required,
  - Ying Pi , Ph.D.

$$R_S = \sqrt{R^2 - Ky^2}$$

$$R_T = \frac{\sqrt{\left(R^2 - Ky^2\right)^3}}{R^2} \qquad \left(R_T = \frac{{R_S}^3}{R^2}\right)$$

$$\Delta R_{TS} = R_T - R_S = -Ky^2 \frac{\sqrt{R^2 - Ky^2}}{R}$$

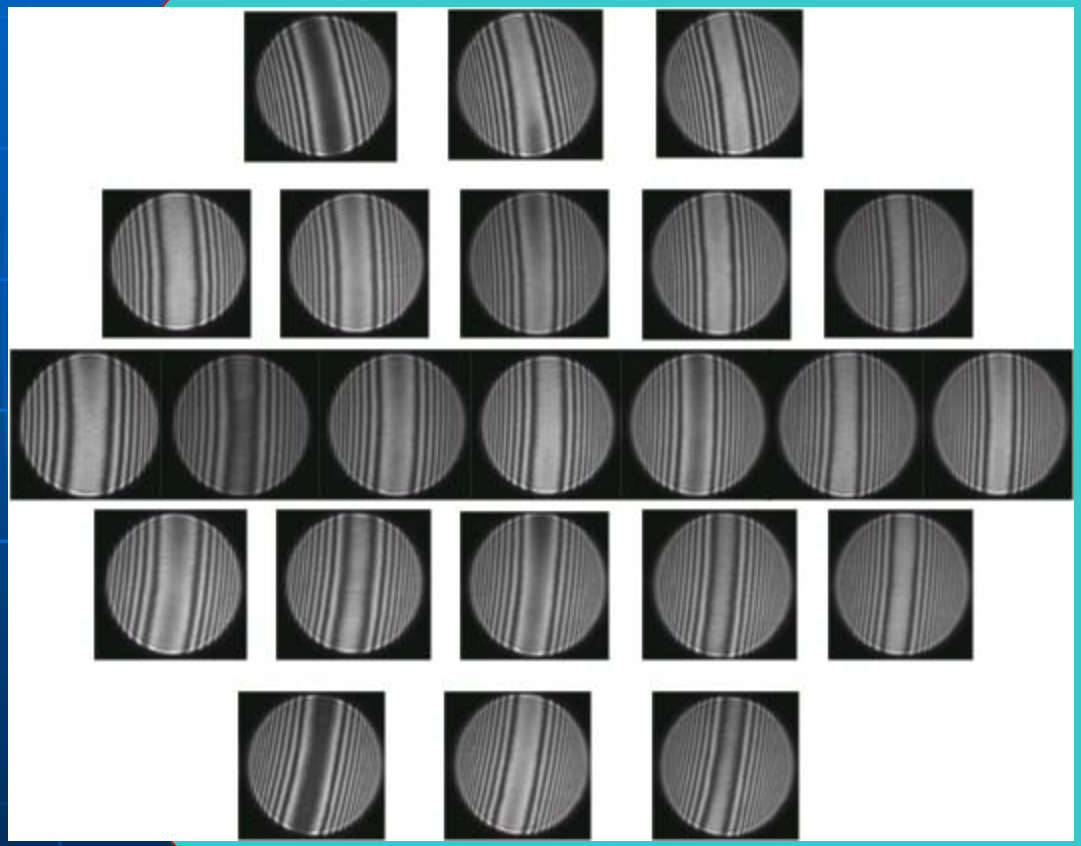


$$R = \sqrt{{R_S}^2 + 8(f/\#)^2 R_S w_{22-S}} \qquad \text{when} \quad R_{rs} = R_S$$

$$K = \frac{Q^2}{P^2 - 1} + P^2 - 1$$

$$\begin{cases} Q = \dfrac{32(f/\#)^3 w_{31\_S}}{R_S\left(3P^2 + 1\right)} \\ P = \dfrac{R}{R_S} \end{cases} \qquad \text{when} \quad R_{rs} = R_S$$

Interferograms of Off-Axis Paraboloid



Parent Vertex

Ying Pi

New Fabrication Equipment

- NSF-MRI
  - Zeeko IRP-600X Free - form Polisher
    - Any shape or material
    - 600mm diameter
    - Operational, August 2011

- NASA Grant
  - Nanotech 250UPL Diamond Turning Lathe
    - Free form surfaces
    - 350mm diameter
    - Rotary B-axis

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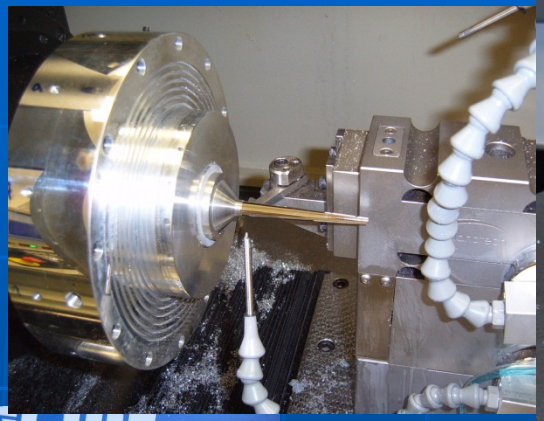
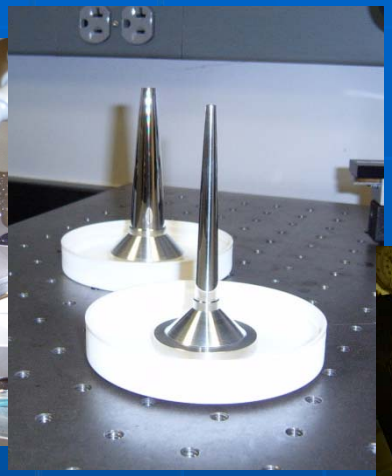
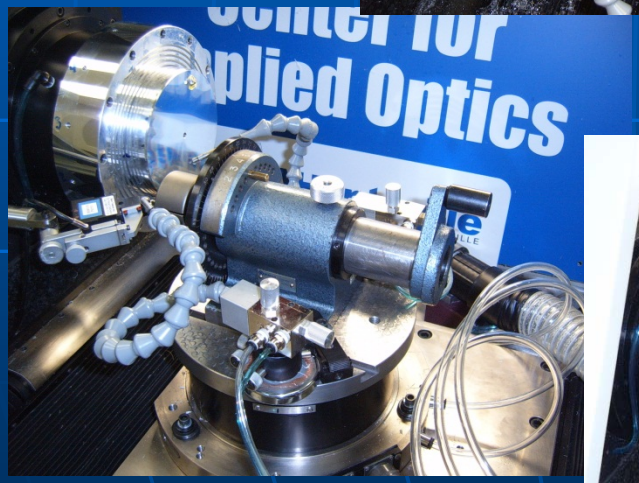
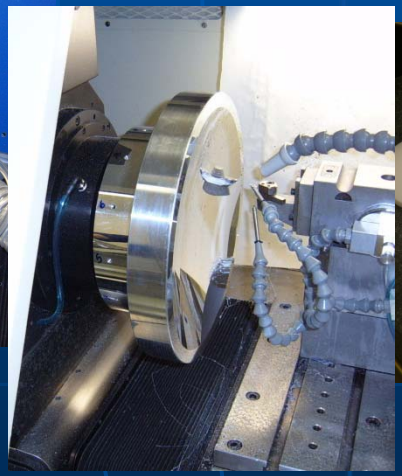
Nanotech Activities



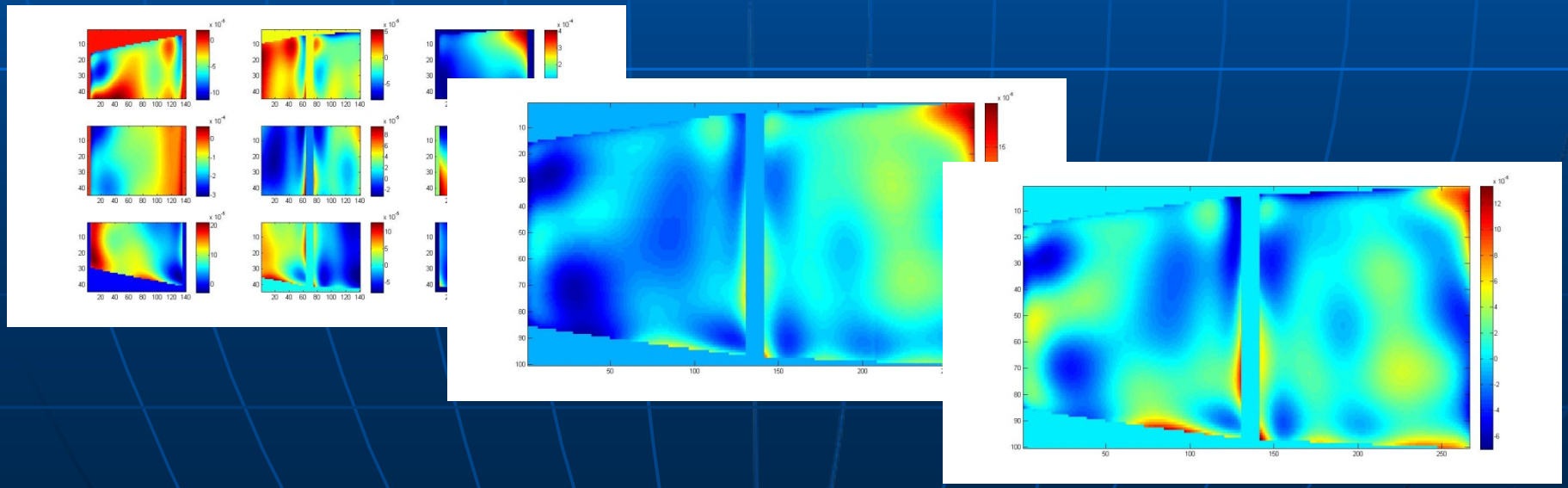






Current Zeeko Activities

- X-ray mirror stave (MSFC)
- Process development for new optical materials (Industry x 3)
- Optical testing calibration tools

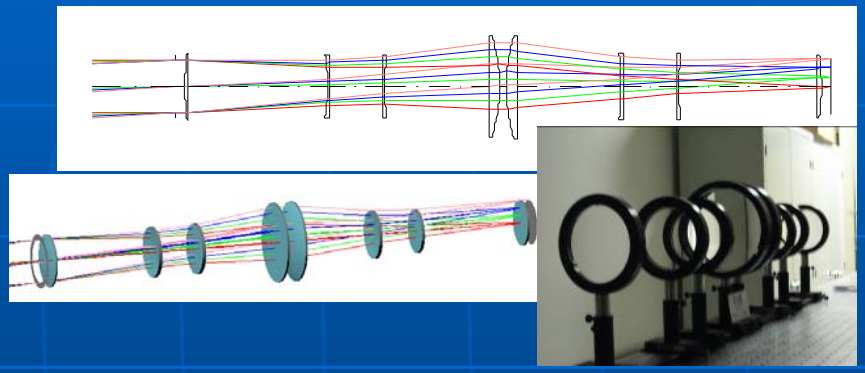


Rapid Optical System Results

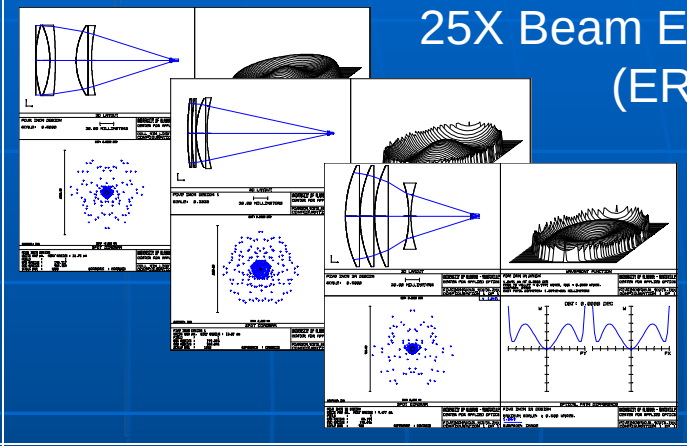
- Optical Systems from COTS Optics
- Diamond turned mirrors and plastics
- Modify COTS glass optics with Zeeko Free-form polisher

Optical Design/COTS

High Speed Wavefront Sensor



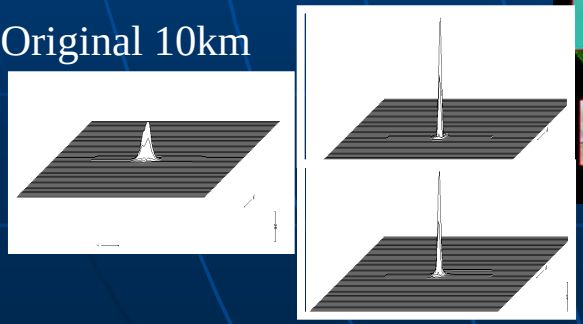
25X Beam Expander (ERC)



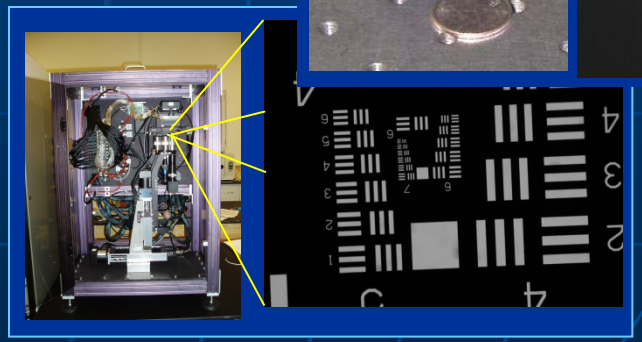
AMOR Zoom Optics

Optimized 10km

Original 10km



LOCAD (MSFC)



Current Fabrication / Testing Research Efforts

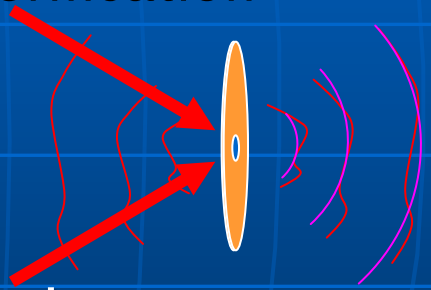
- MaGIXS (NASA-MSFC, Robinson)
  - Fabricate an x-ray telescope stave in Zerodur
    - 3 Diffractive Nulls
      - Paraboloid, Hyperboloid, Both for relative alignment
    - Stitching multiple interferograms
  - Parallel, non-critical path student research
    - Use a cylindrical null
    - Use differential measurements
      - Despace, tilt,
    - Use Chebyshev decompositions

Future Research

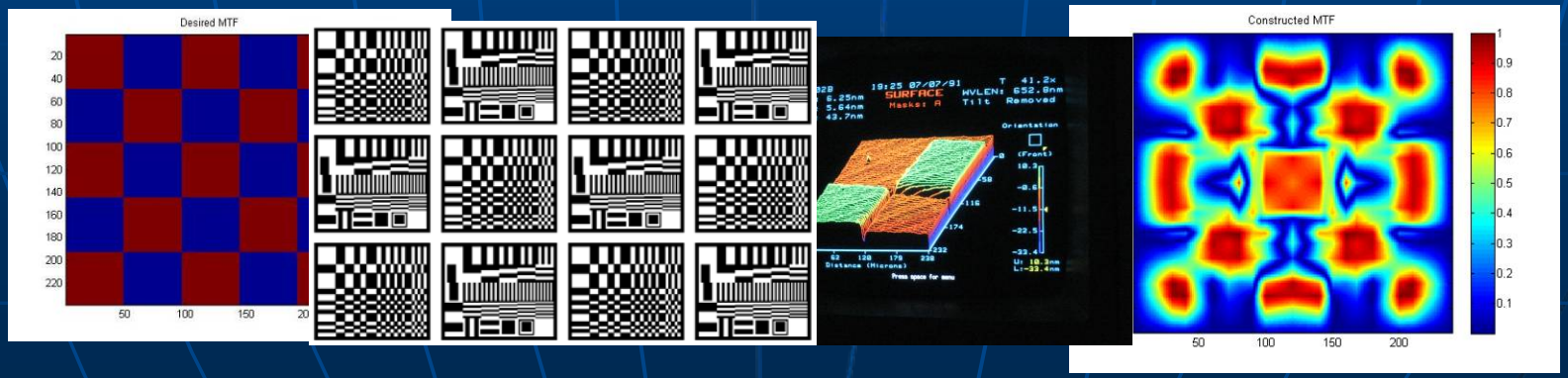
- Optical instrument design, fabrication, test, assembly, deployment
  - Enhanced by new fabrication capabilities
- Zeeko/Nanotech based
  - Free form metrology
    - Interferometer test plates for calibration
  - Generic Null
- Zeeko based
  - ZeekoJet Process Development
  - Process optimization
    - SiC
  - Extend Freeform diameter range

CAO / Nano Micro Devices Center: Collaborations

- Infrared Point Diffraction Interferometer (PDI)
  - Vendors provide IR optics to customers who can not test them
  - PDI allows simple interferometric verification
  - Many made on a single ZnSe plate
  - Covers broad spectrum and quality



- Computational Imaging: Thin optics



CAO/NMDC Summary

- Optical design, analysis, fabrication, assembly and testing
- THz, IR, visible, UV, X-ray, Gamma-ray
- Meter class to microoptics
- Advanced photonics and microwave modeling and fabrication
- Basic research, rapid prototype, deployed systems
- Experience in delivering results

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