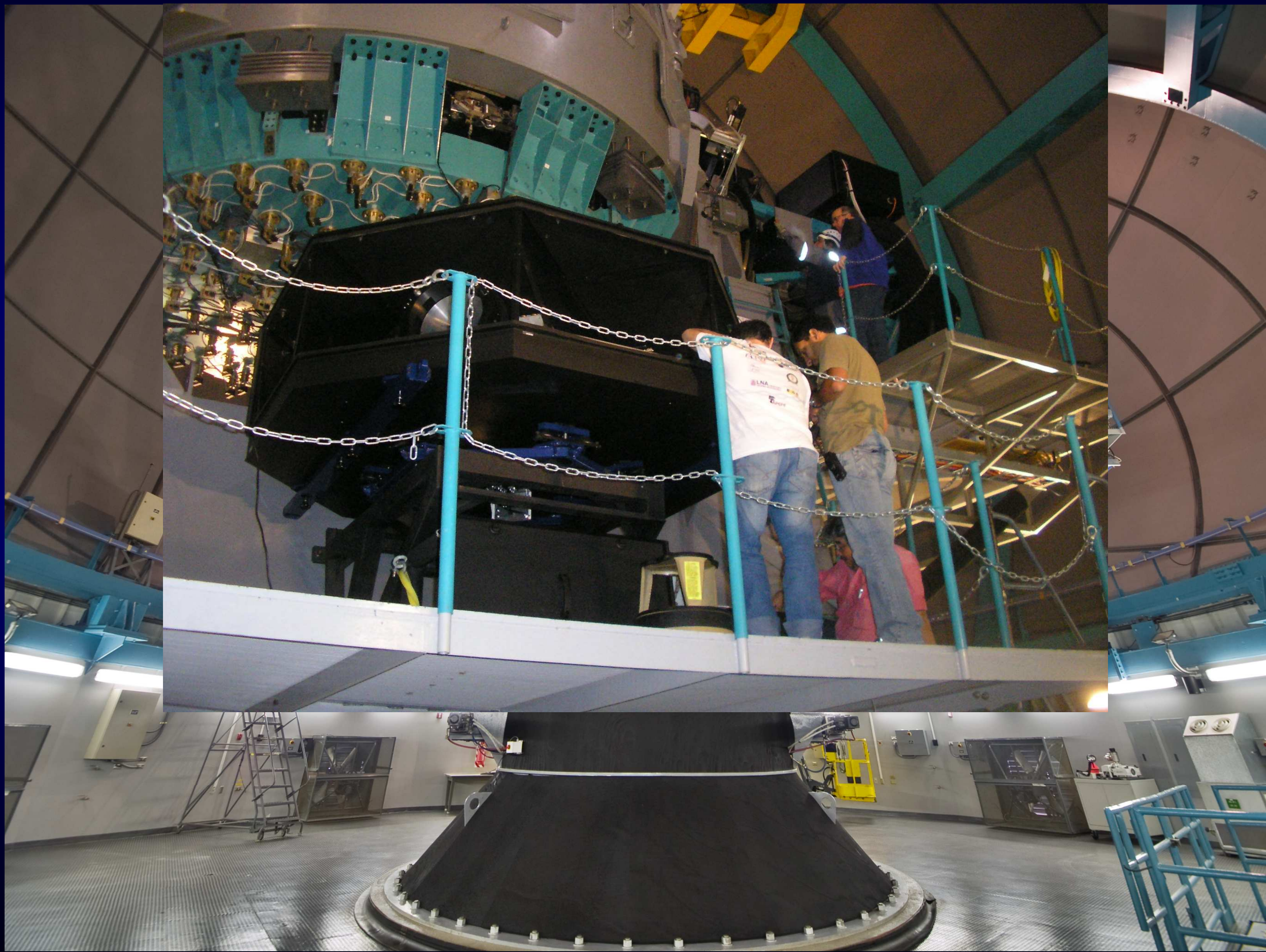
SOAR Telescope Status

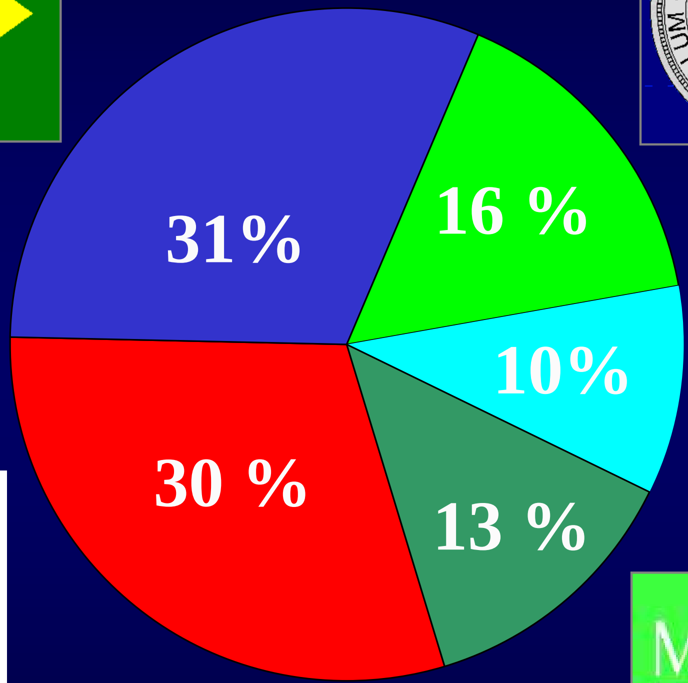
Workshop OPD, SOAR E Gemini – *Passado, Presente e Futuro*



The SOAR Consortium

BRAZIL

U. North Carolina



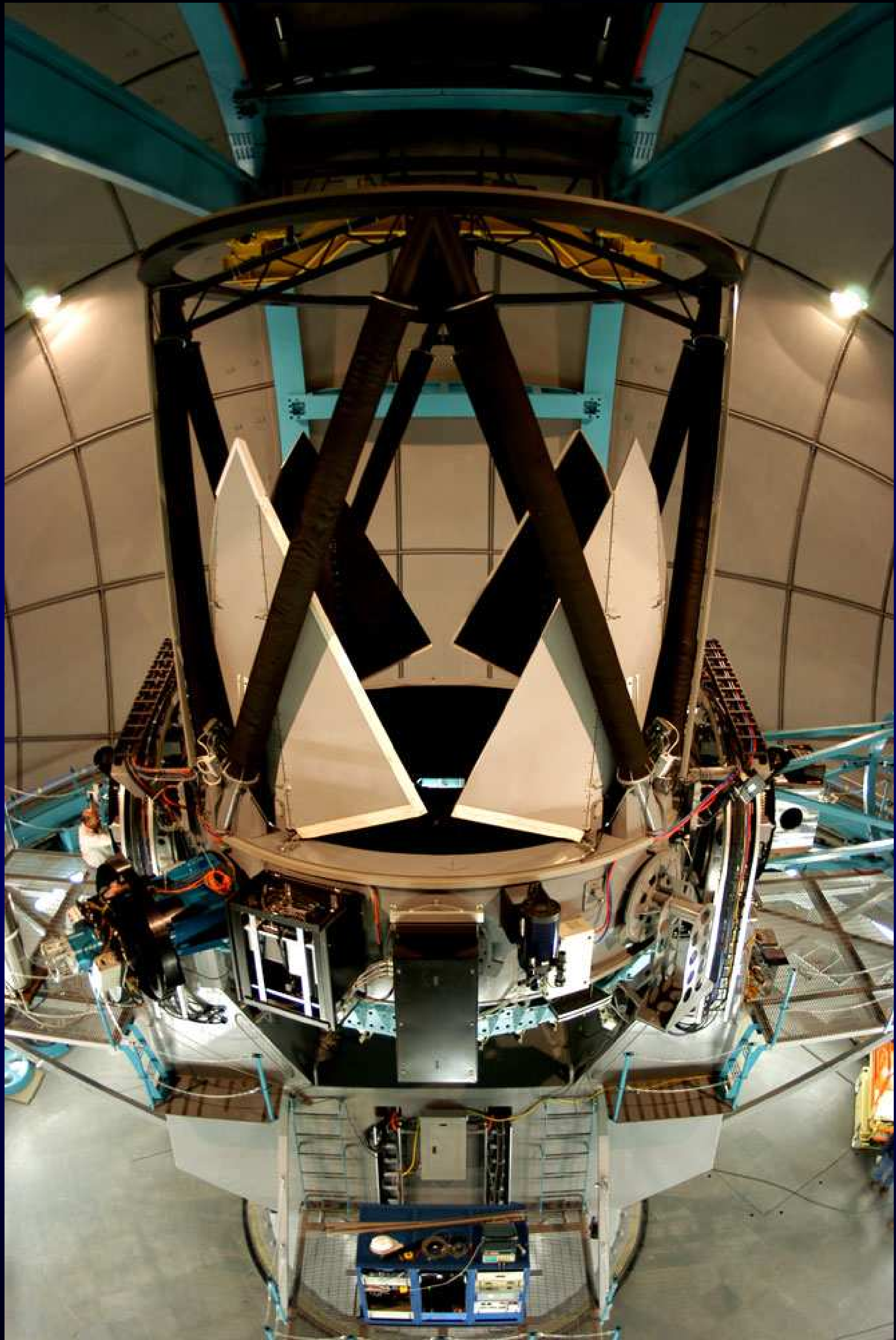
Chile

NOAO

Partner Time Share

MICHIGAN STATE UNIVERSITY

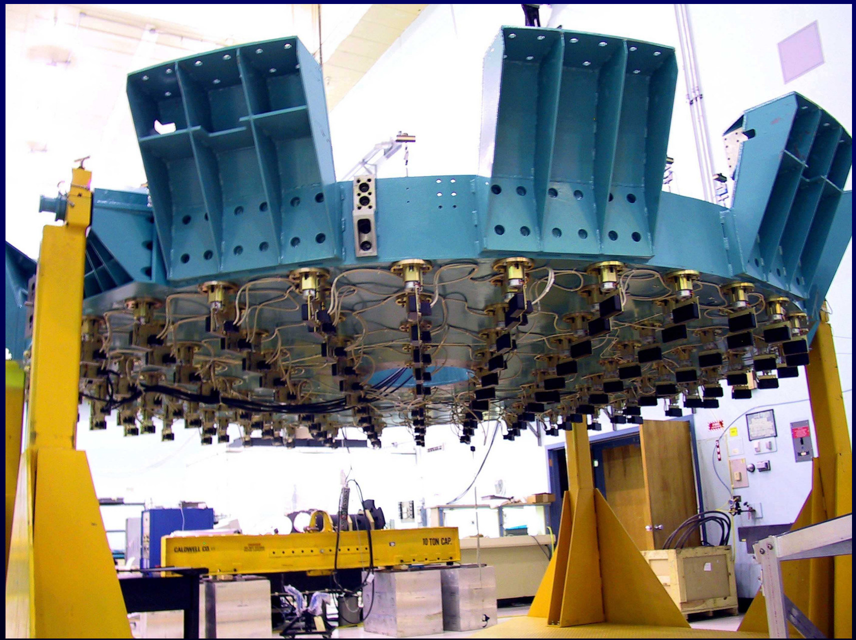
Michigan State University



The Telescope

- 4.1 m clear aperture
  - f/16 Ritchey-Chrétian
  - Active control of M1 & M2
  - 30Hz Tip-Tilt correction using M3
- Best possible images over Isokinetic Patch
  - 8.5 arcmin Science field
  - 10x10 arcmin guide field
- Large Instrument Payload
  - 2 Nasmyth ports
    - 3 instruments on each
  - 3 Bent Cass
    - Facility wavefront sensor
    - 2 instruments
  - Rapid switching between instruments

Active Optics System



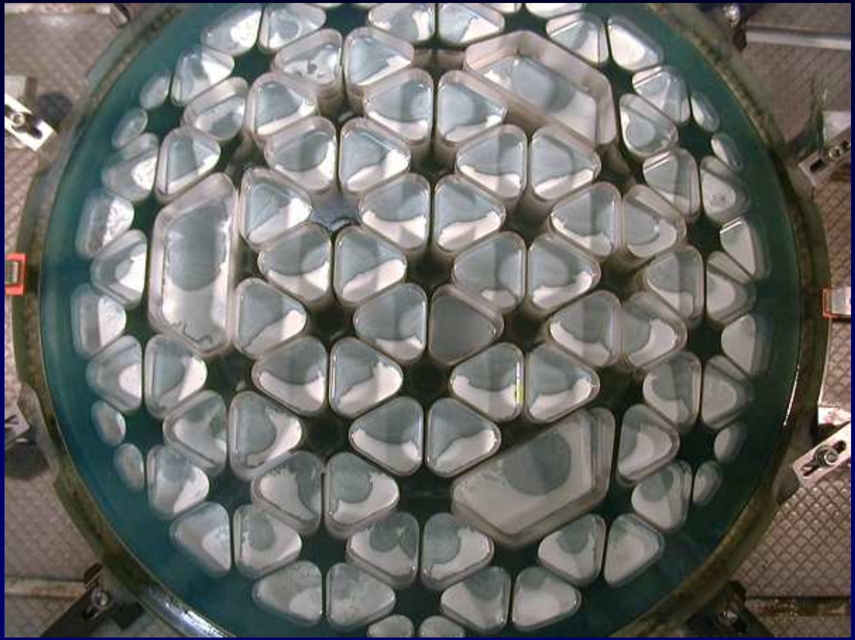
M1

- 4.3m diameter (4.1m C.A.) 10cm thick (3,200Kg) ULE face sheet

Support System

- Steel “honeycomb” reaction structure
- 120 axial actuators
  - Electromechanical with force feed back
  - 3 designated as fixed “hard points” define position & tilt
- 6 actuated tangential links in a pinwheel arrangement
  - Act together as two triangles emulating a kinematic support
    - One set holds position and measure forces
    - The other set “mirrors” the measured forces
- Replaces original <u>defective</u> passive system
  - Severely impacted early science operation

Active Optics System



M2

- 0.615m diameter, 80% light weighted (20Kg) ULE mirror
- 6-axis Hexapod positioning system

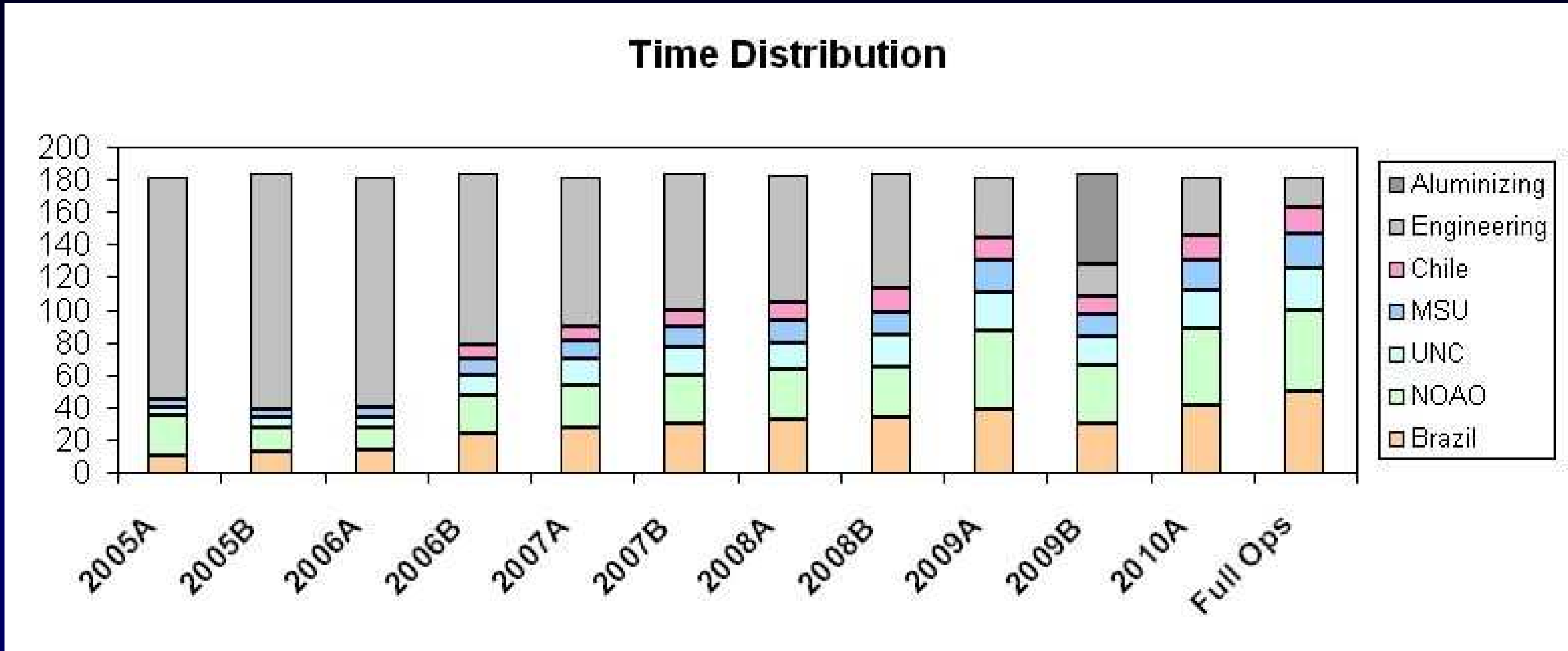
M3

- 0.655 x 0.470 m, 80% light weighted (30Kg) ULE Mirror
- Fast Tip-Tilt Gimbal
  - Provides Tip-Tilt correction @ ~30Hz closed loop bandwidth
    - Original Specification was 50Hz
  - Rotates to direct light to 2 Nasmyth, and 3 Bent Cass instrument ports

A Brief History

- Aug 1997 Project initiated
- Jan 2000 Construction starts on site
- Oct 2002 Telescope mount installed & completed
- Jan 2004 Optical system delivered to Chile & installed
- April 2004 1st light and dedication ceremony
  - Serious problem with lateral support system identified
  - Severely limits ability to do science
- Feb 2005 (2005A) “early science” starts using telescope “as is”
  - ~20% science time with SOI and OSIRIS
- June 2006 Installation & test of new lateral supports completed
- August 2006 (2006B) Effective start of science operations
  - Science time ramps up from ~40% in 2006B to 80% in 2009A
  - Balance of time used for engineering, mostly instrument commissioning
- Oct/Nov 2009 major shutdown for recoating of all optics
- Feb 2010 (2010A) onward
  - 80% science fraction
  - 20% instrument commissioning

An Even Briefer History



- 1997 – 2004 Building the telescope
- 2004 – 2006 Making it work
- 2006 – 2011 Instrument commissioning & Science use
- 2010 – Onward Fully Exploiting SOAR's potential

Instrument Availability

- SOI
  - Available for science since 2005A, Working reliably
- OSIRIS
  - Available for science since 2005A, showing its age, but mostly reliable
- Goodman
  - Available for single slit & broad band imaging since 2008B
  - Work continues at UNC to implement multi-slit mode with science use anticipated by the end of 2010
  - ADC delivered to Chile and ready for commissioning
- Spartan
  - Available for science starting in 2010A
- SIFS
  - Delivered in Dec 2009 & installed on telescope, Commissioning under way
  - Shared risk science use starting in 2010B ?
- BTFI
  - Delivery anticipated in mid 2010
  - Initially only available to Brazilian users
- SAM
  - Initial tests on telescope in NGS mode during August 09
  - First laser launch mid 2010
  - Shared risk science use 2011A?
- STELES
  - Delivery anticipated in early 2011

- More on instruments in Later talks

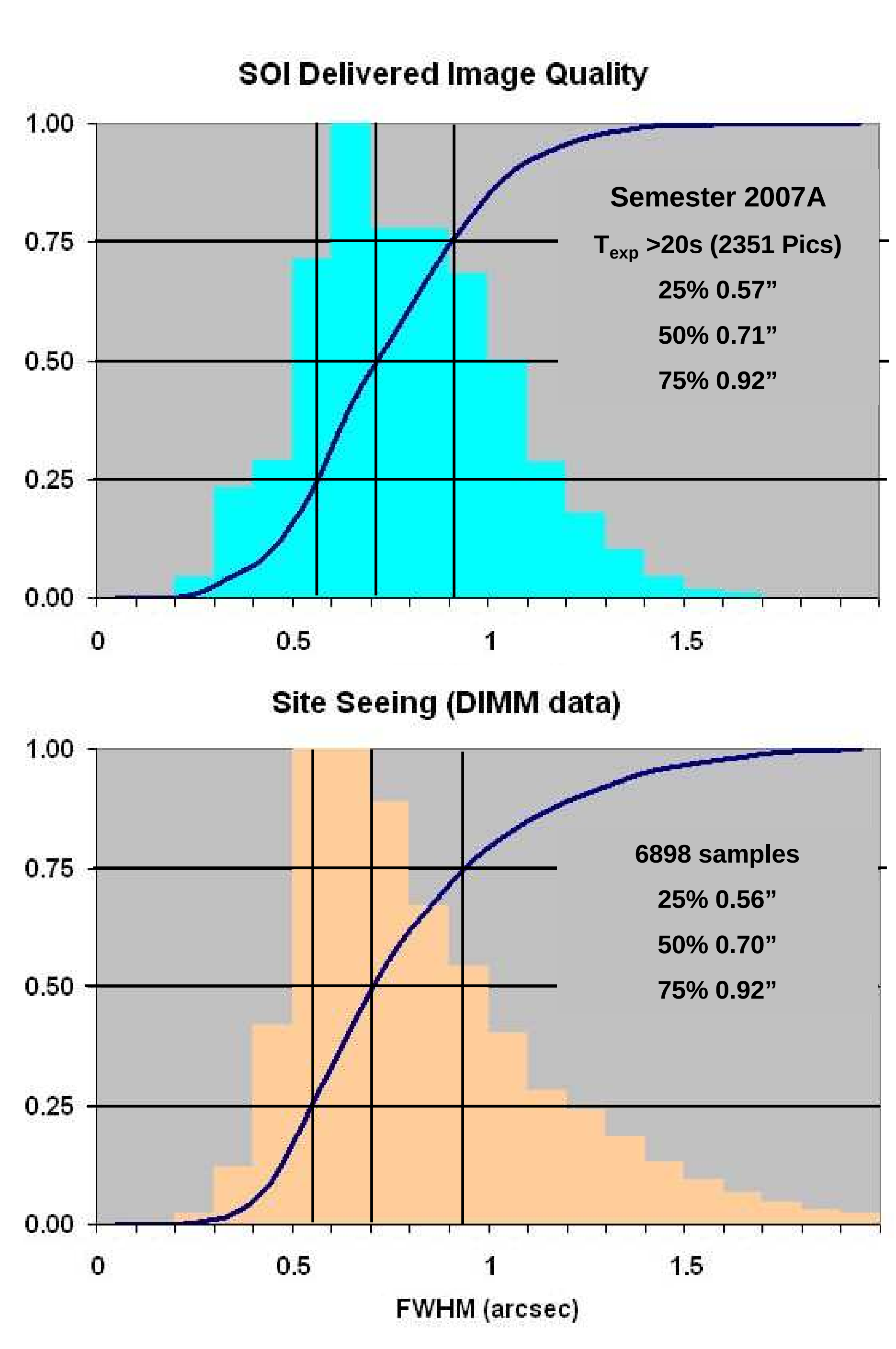
Performance Metrics

- SOAR costs ~US$ 12k/night
- How much Science you get for your buck depends on:
  - Delivered Image Quality
    - Maximizing this is of course what SOAR is all about
  - Telescope Availability
    - Lost time, lost money
    - Whether its because the telescope or its instruments aren't working …
  - Shutter Open Time
    - … or because you are slewing, finding your object, tuning the optics, reading out the detector, or offsetting between dithered exposures
  - Mirror Reflectivity
    - We don't want a 4.1m telescope with the effective collecting area of a 1.5m, especially in the blue
    - Having 3 mirrors (4 for side-ports) is not a great start

  And other things yet to be quantified

- How well are we doing ?
- How can we do better ?

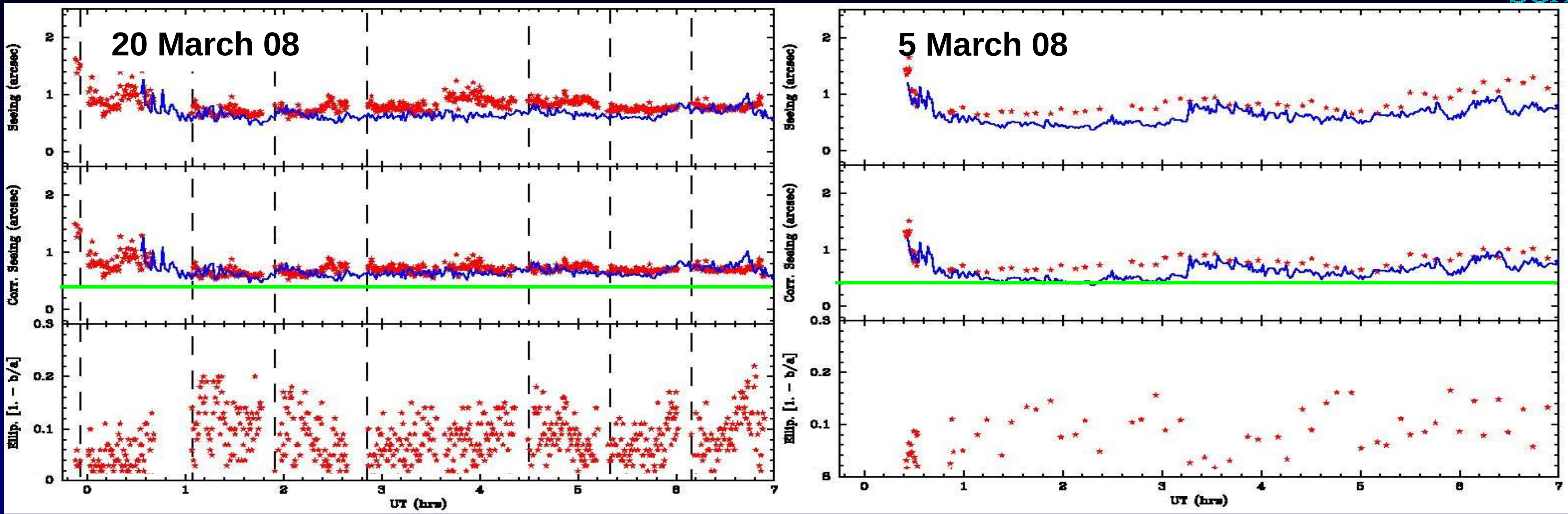
Delivered Image Quality



Since replacing lateral supports

- Regularly achieve FWHM consistent with site seeing
  - But some degradation in the very best seeing
- Best images
  - ~0.4" in V w/ SOI
  - ~0.3" in J w/ Spartan
    - But requires considerable attention to telescope focus
  - ~0.21" in K w/ OSIRIS (under sampled)
- Mirror stays tuned for extended periods when telescope is tracking
  - But keeping things tuned remains a hit on observing efficiency

Delivered Image Quality



- Optics Tuned
  - After ~1st hour (Typically see rapid change @ start of night)
  - Every ~2 hours during night
  - After Large elevation change
- DIQ matches seeing monitor
  - But significant overhead

- Optics only tuned at start of night
- DIQ much worse than DIMM

- It pays to keep the optics well tuned whenever the seeing is good, however, this entails significant overhead

DIQ Issues & Solutions

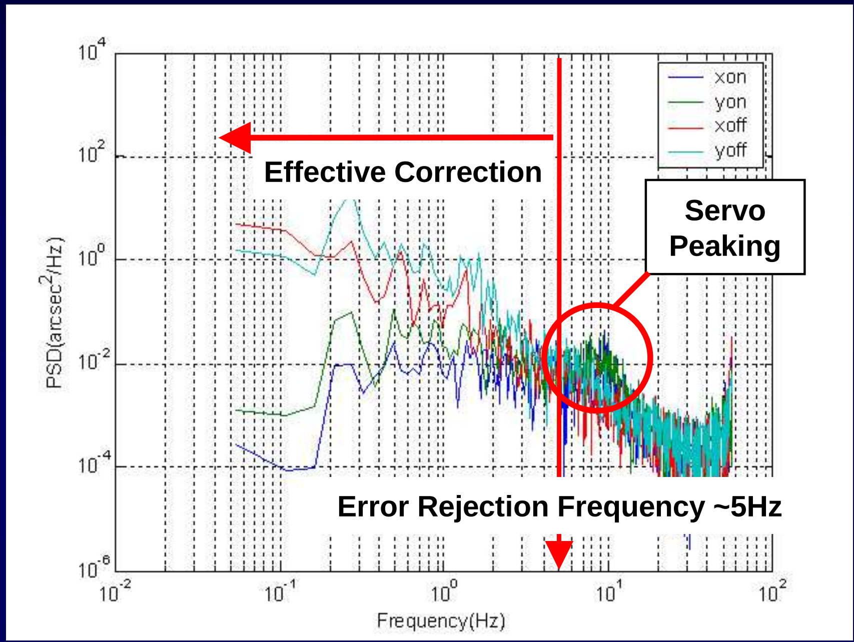
- Residual low order aberrations not handled by open loop control
    - Focus – strong, incompletely modeled temperature dependence
    - Astigmatism – residual astigmatism after large changes in elevation
  - Upgrade guiders to include low-order wave front sensing capability allowing closed loop control

- Poor Tip-Tilt servo Performance
    - Does not fully correct atmospheric tip tilt
    - Does not suppress mount jitter & wind shake
  - Developing new digital servo hardware (next slides)
- Wind Shake
  - Improve Tip-Tilt performance
  - Implement wind screen

- Dome & Mirror seeing
  - Mirror flushing system was included in design, but has never been implemented
  - Understand optimal use of daytime cooling & night time ventilation
  - Eliminate “chimney” effect from staircase and freight elevator

Tip-Tilt Servo – Current performance

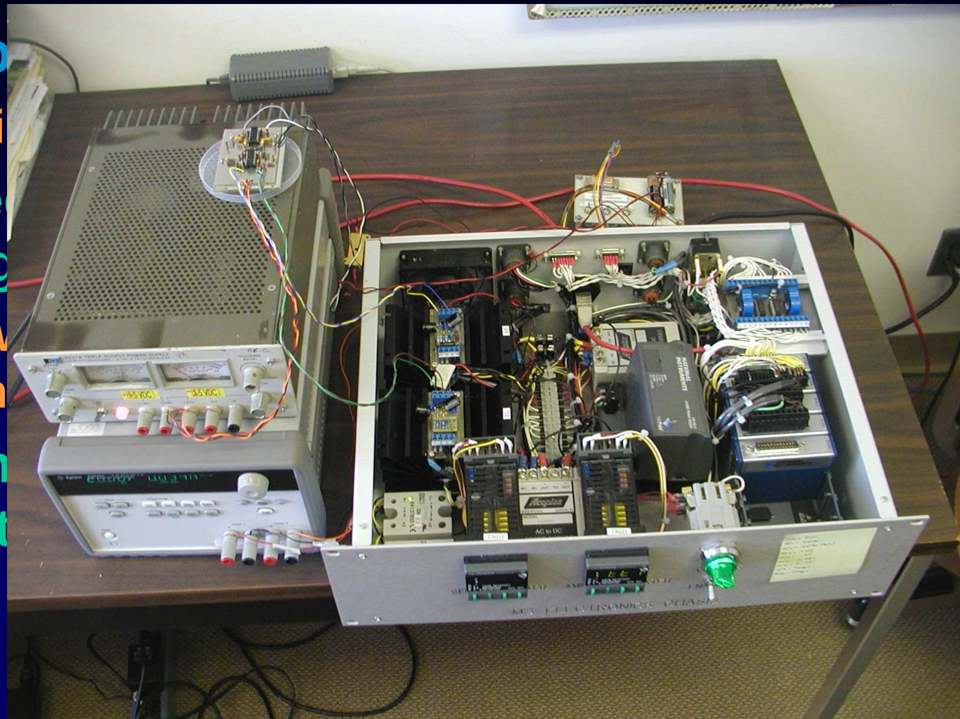
- **Current Best Case Performance**
  - Bright Star (R < 13), Frame rate > 200Hz → Servo limited performance



  - Error Rejection Frequency is only ~5Hz
    - Only get correction for frequencies lower than this
    - Servo peaking actually *amplifies* frequencies just above this
  - Error Rejection at ~1Hz is only ~ 10db
  - Residual jitter σ_{tt} ~ 0.06" RMS (0.14" FWHM) with no wind
    - Significant degradation of DIQ for both SPARTAN & SAM in best seeing

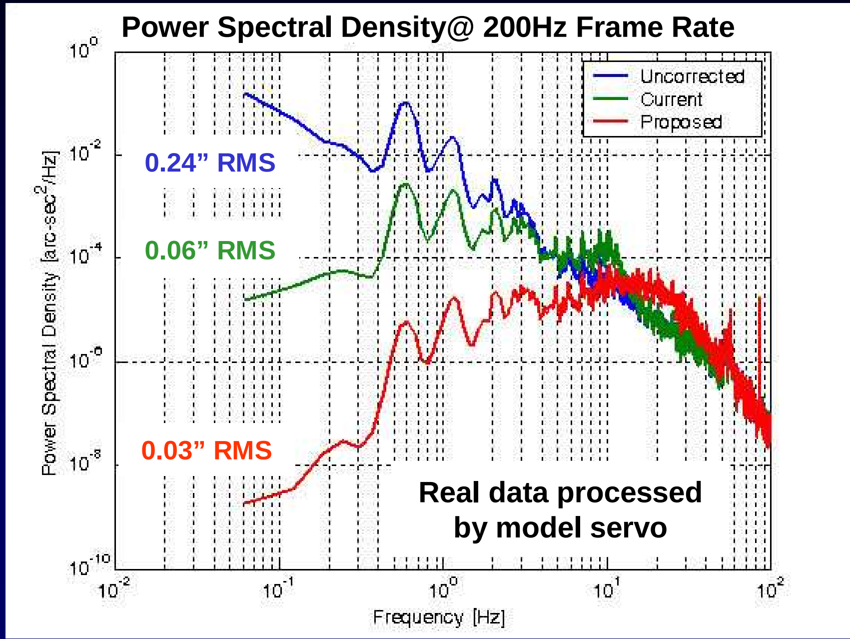
Tip-Tilt Servo – Problem & Solution

- Current Positio rformance
  - Severe axi 0Hz, nonlinear
  - As configure op, the guider signals being
    - This loop v ncies, and measurem l sensor
  - In addition th nics are Inflexible and difficult t

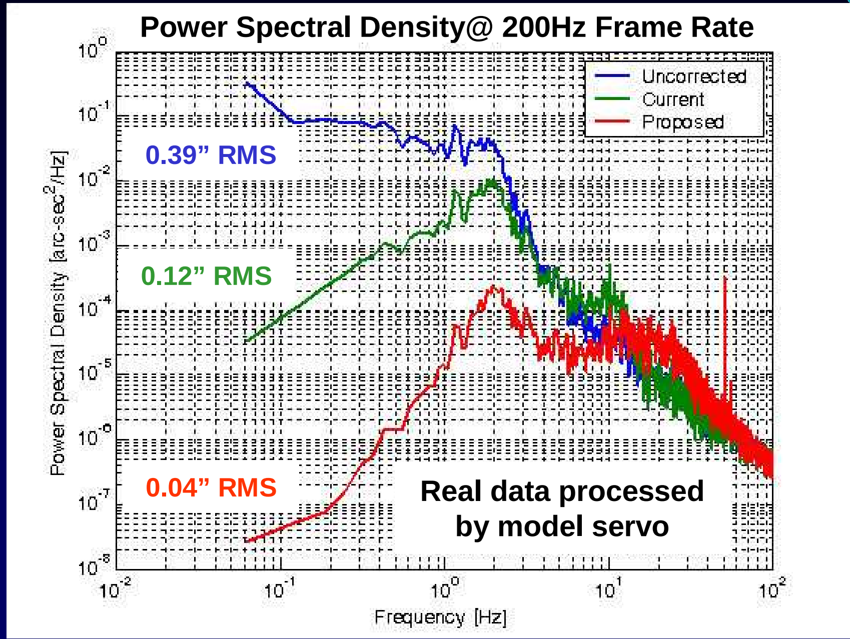


- Old hardware being replaced by a modern digital servo controller
  - Guider signals will be used to drive M3 directly
    - Current position sensors only used to position mirror when not guiding
  - Improved performance with the flexibility of a fully programmable
  - Being developed as a “plug & play” replacement for the existing hardware
  - New hardware is currently under test in the laboratory and should go to the telescope next month

Tip-Tilt Servo – Predicted Performance



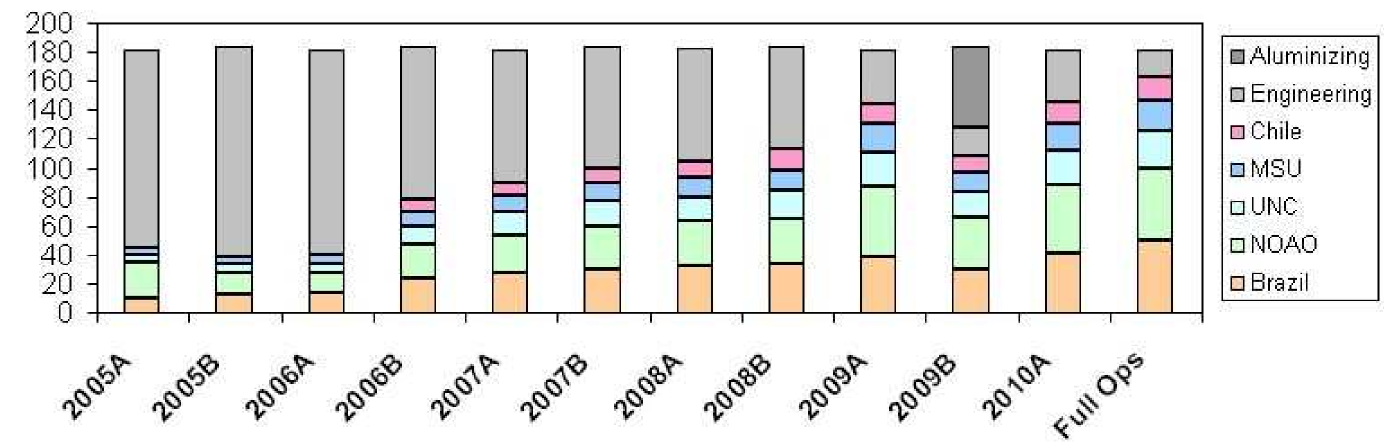
No wind



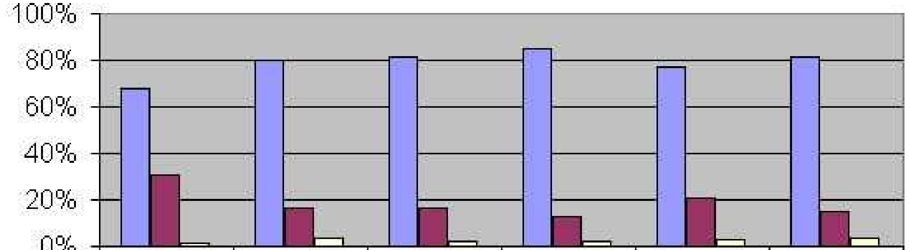
With max operating wind speed

- Given the expected performance @ 200Hz frame rate Tip-Tilt will meet original expectations. This requires an R < 13 guide star.
  - Corrects Atmospheric Tip-Tilt (very little power above 10Hz)
  - Squashes mount periodic error
  - Significantly attenuates wind shake
  - Residual jitter
    - σ_{tt} ~ 0.03” RMS (0.07” FWHM) with no wind
    - σ_{tt} ~ 0.04” RMS (0.09” FWHM) with max operating wind speed

Availability

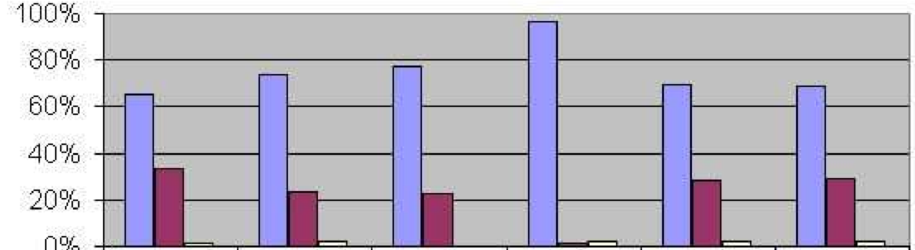


SOAR Availability (All Partners)



	2007A	2007B	2008A	2008B	2009A	2009B
Used Science	68%	80%	82%	85%	77%	81%
Lost Weather	31%	17%	16%	13%	21%	15%
Lost Failure	1%	3%	2%	2%	3%	4%

SOAR Availability ((Brazil)



	2007A	2007B	2008A	2008B	2009A	2009B
Used Science	65%	74%	77%	96%	69%	69%
Lost Weather	33%	24%	23%	2%	28%	29%
Lost Failure	1%	2%	0%	2%	2%	2%

Observing Efficiency

SOAR Observing Efficiency	Science	Readout	Pointing	Acquisition	Other
Total	57%	17%	9%	13%	7%
Average	55%	11%	9%	14%	11%
Average (no time Series)	48%	7%	12%	18%	17%
SOI	69%	3%	9%	11%	8%
SOI (Time Series)	75%	17%	4%	4%	0%
Goodman	29%	19%	14%	24%	14%
Goodman (Time Series)	64%	25%	3%	9%	0%
OSIRIS XD	61%	2%	11%	15%	10%
OSIRIS Hi Res	31%	3%	12%	21%	34%

- Analysis of Brazilian Service Observing logs for 2008B + 2009A
  - Percentage of clear hours on nights scheduled for observing
    - Start of night set up including initial tune of mirror is NOT included
  - Science = shutter open time on science targets, calibrations excluded
  - Readout = readout time and related overheads
  - Pointing = time while moving telescope until guiding
    - Includes slew time, optics settling time, guide star acquisition
  - Acquisition = time from 1st acquisition to 1st science exposure
  - Other = everything else
    - Calibration lamps, dither time in IR
    - Mirror tuning and focusing during observing time
    - Failures (~2% in Brazilian time)

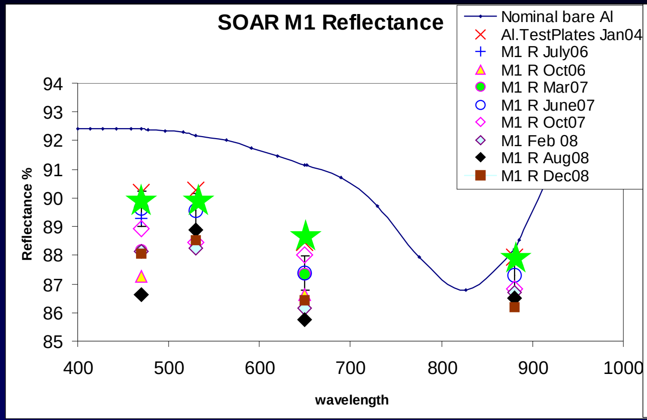
Observing Efficiency

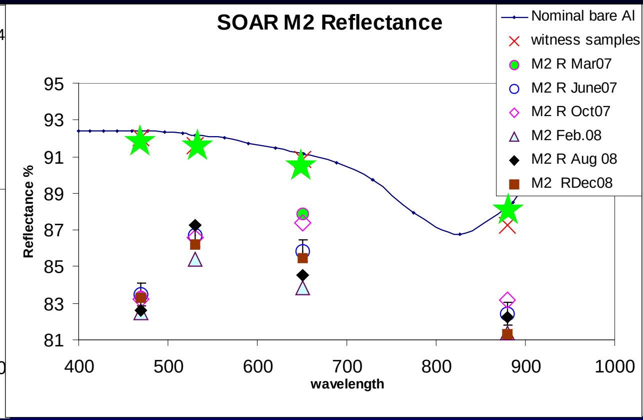
- Where are improvements possible
  - Optics tuning with wave front sensor
    - Procedure is already automatic & fairly streamlined
    - Limit set by
      - exposure time (to average out seeing)
      - Adjustment time of M1 support system
      - Occasional slow convergence when conditions are unstable
    - Best “solution” is to implement wave front sensing with guider
      - Allows tuning without moving from target position
      - Focus adjustment with M2 is rapid & correction of astigmatism with M1 is not too slow
  - Slew to object
    - Telescope is fast, dome is slower but not too bad
    - Adjustment of M1 to new position is glacial
    - Large changes of Elevation must be accomplished in stages for mirror safety
    - No improvement possible → observing programs must be planned with this in mind
  - Guide star acquisition
    - Guide star selection should be done in advance, or worst case during slew
    - Improvements to the guider pointing model would improve efficiency of finding selected star too

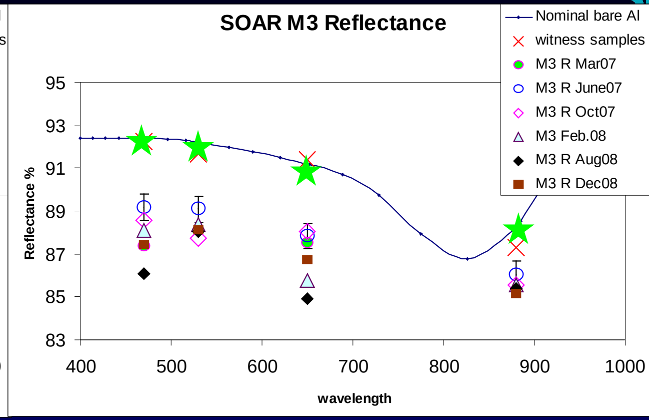
Observing Efficiency

- Where are improvements possible (ctd.)
  - Target acquisition
    - Little overhead for imagers
    - Big overhead for Spectrographs (Goodman & OSIRIS both)
      - Hard to center on narrow slit
      - Slit position is not stable & reproducible
      - Time to switch between acquisition & spectroscopy is long
  - Time to switch between instruments
    - Most of the steps are fast, but they tend to happen in series rather than parallel
      - A general problem
- Instrument Specific Issues
  - Goodman
    - Slow CCD readout
    - Need to take quartz flats during night to correct fringing (slit instability)
    - Some mechanisms (e.g. slit changer) are slow
    - Lacks scripting capabilities to automate common actions
  - OSIRIS
    - Need to take quartz flats during night to correct fringing (slit instability)
    - Some mechanisms are slow
    - Dithering – but that's the IR for you – but could it be faster ?

Mirror Reflectivity



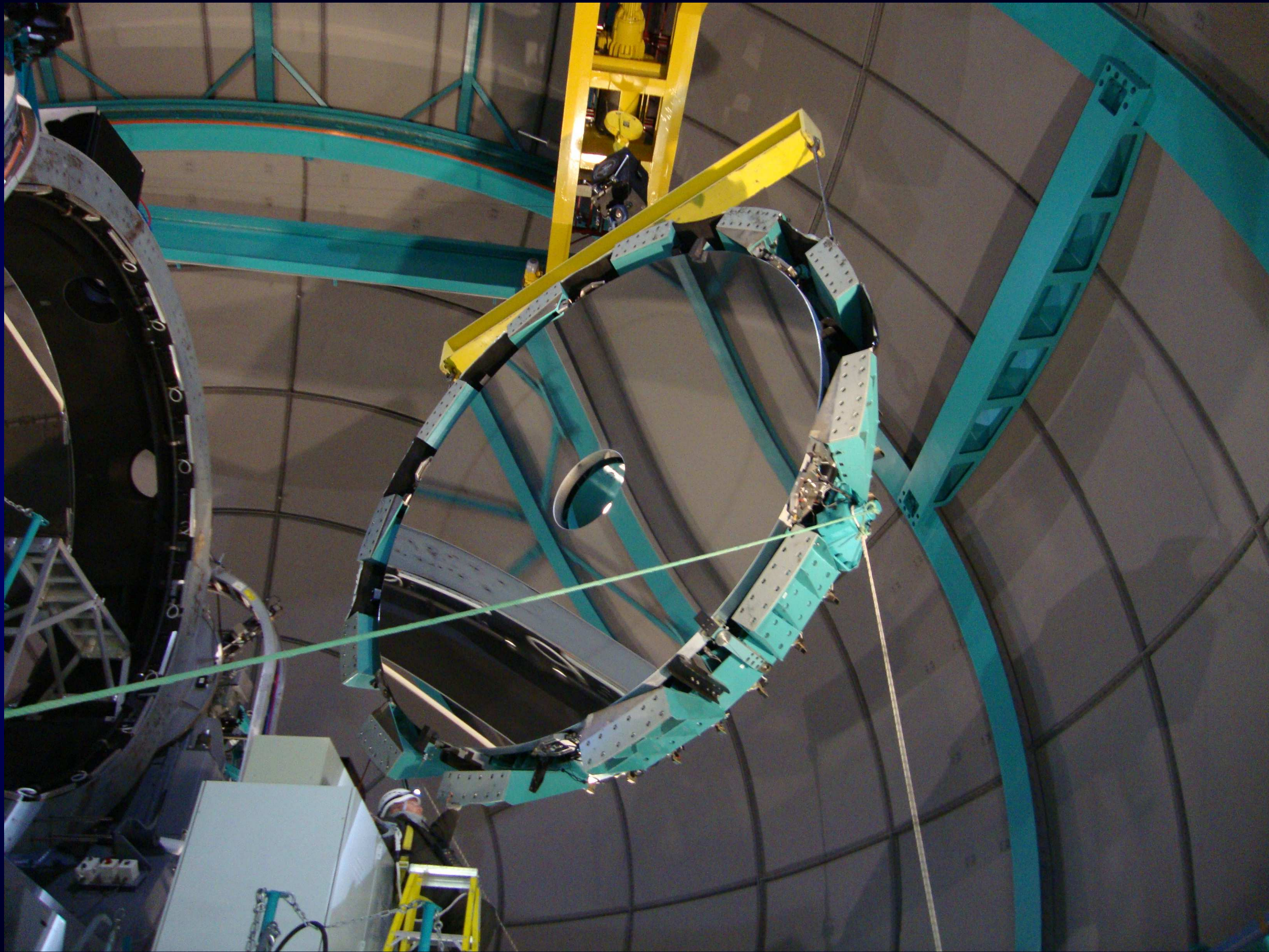




	Before Aluminizing				After Aluminizing			
	470	530	650	880	470	530	650	880
M1	86.5%	86.6%	85.7%	85.9%	89.8%	89.9%	88.5%	88.1%
M2	83.0%	86.0%	86.0%	81.0%	91.6%	91.3%	90.0%	88.4%
M3	86.0%	87.0%	86.0%	85.5%	92.4%	92.3%	91.0%	88.4%
Total	61.7%	64.8%	63.4%	59.5%	76.0%	75.7%	72.5%	68.8%

- All three mirrors were recoated in Nov 2009
  - M1 Al sputtered in the Gemini plant
  - M2 & M3 conventional aluminizing on Tololo
  - Recovered reflectivity and quality of original coatings
- Aluminizing every 4-5 years is probably required
  - It is a big task however

Recoating M1



Recoating M1

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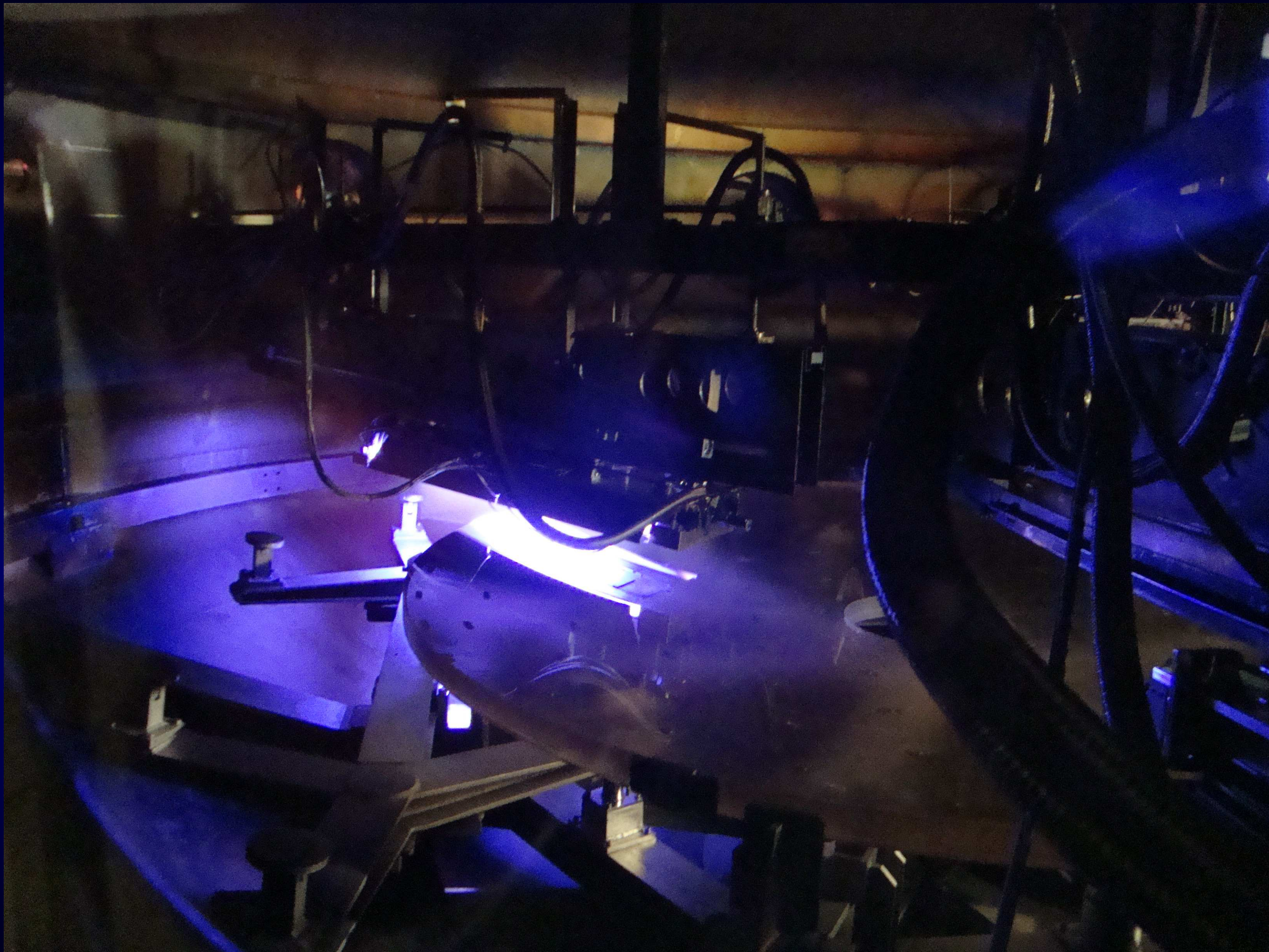

Recoating M1

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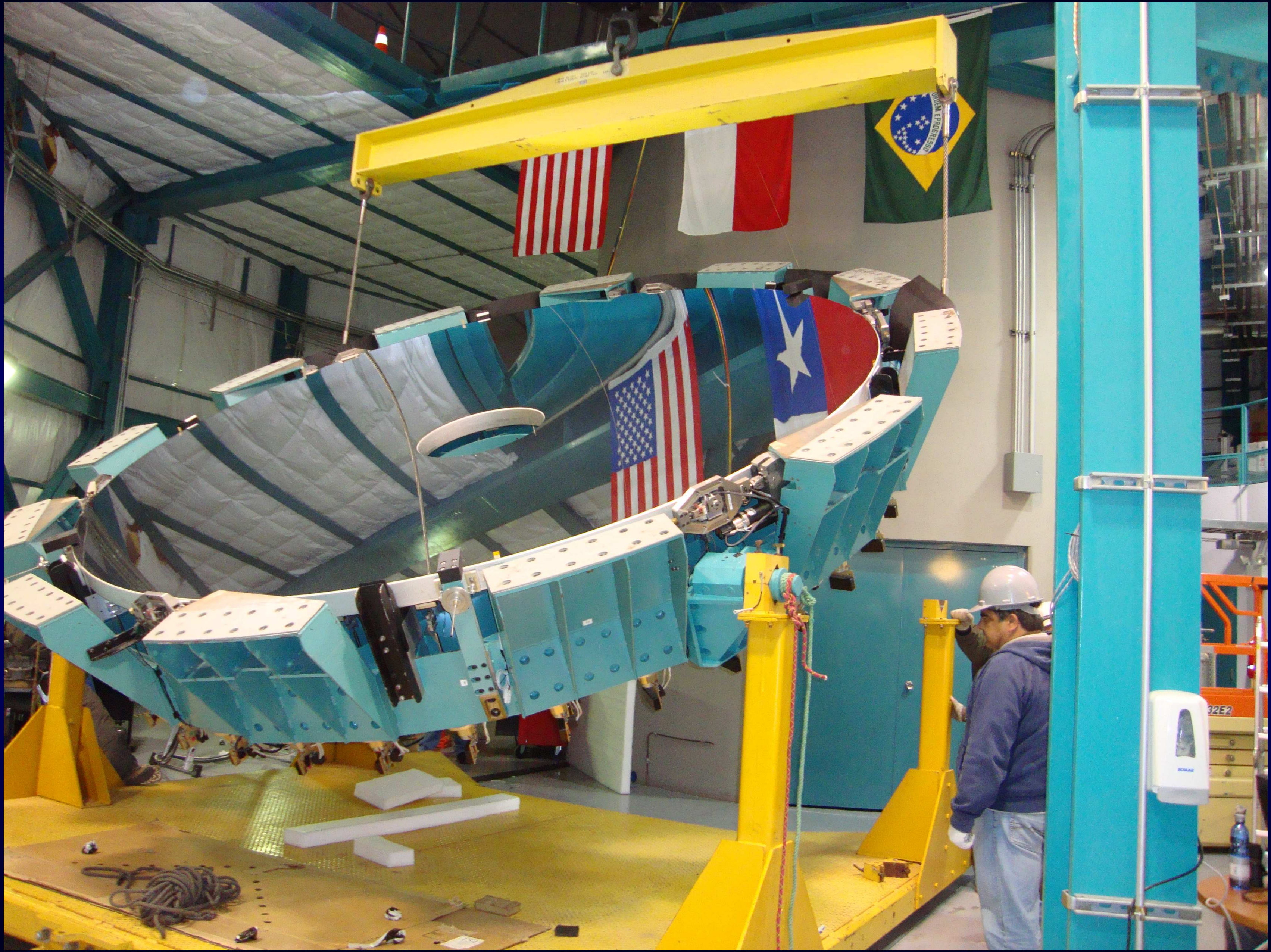
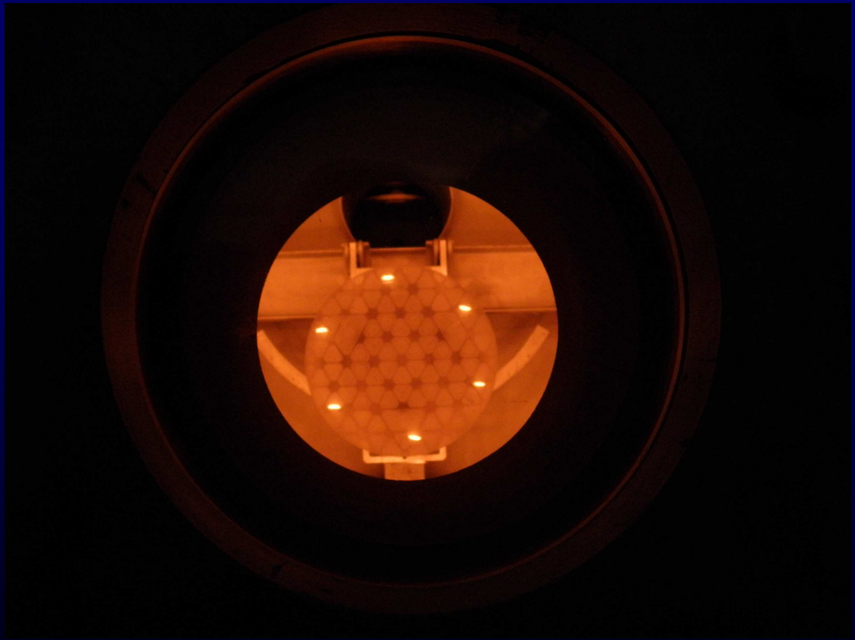
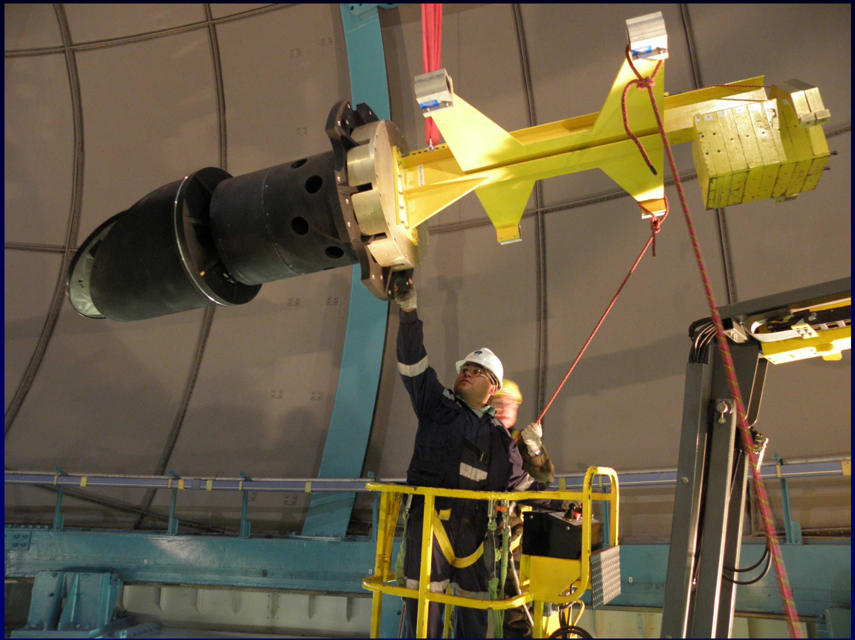
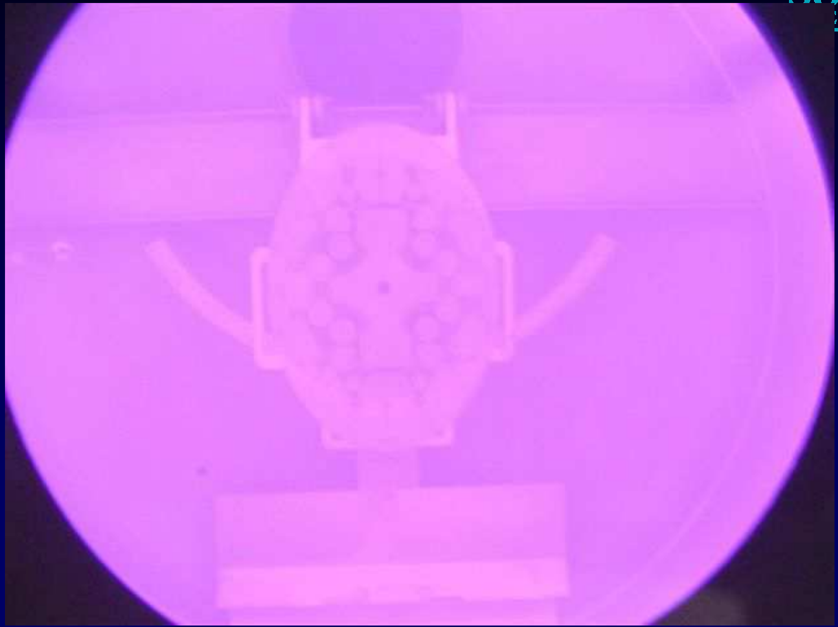


Recoating M2



Recoating M3



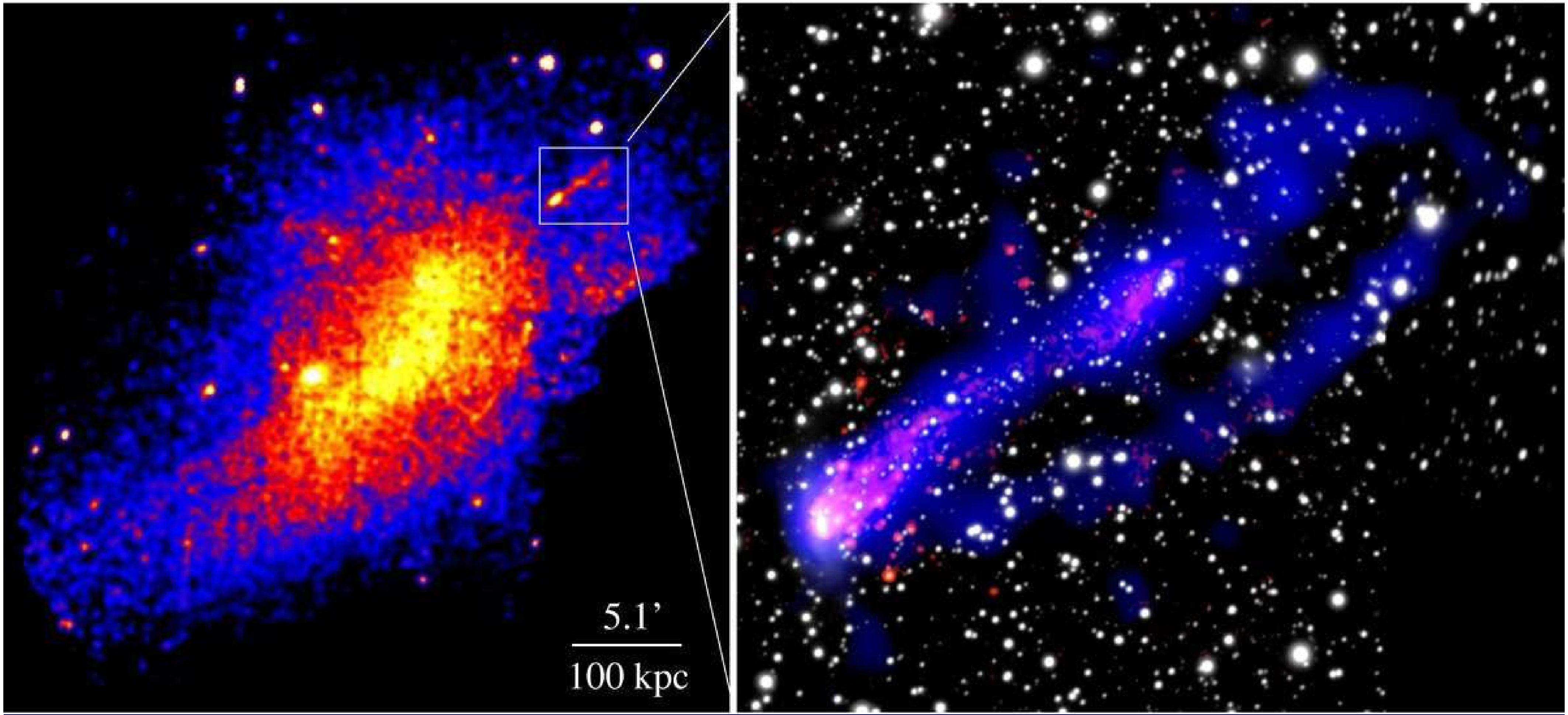


The Aluminizing Team

Science with SOAR

- SOAR data has been used in 40 refereed publications, 5 PhD and 1 MSc theses to date
- Some selected highlights:
  - Haislip et al 2005 Nature – Highest Z GRB known at the time
  - Kepler, Castanhiera, et al 2005 … 2009 (4 papers, thesis) – ZZ Ceti stars
  - Cecil & Rashkeev 2007 (AJ) – High resolution imaging of Mercury
  - Oliviera, Steiner 2007 – CAL 87
  - Beers et al 2007 (AJ) – Metal poor stars in the galactic halo
  - Groh et al 2007 (A&A) – Confirmation of WR candidates in Westerlund 1
  - Donahue et al 2007 (AJ), 2009 (ApJ) , Gimeno et al 2007 (AJ), Santiago et al 2008 (A&A) – studies of galaxy mergers and cooling flows
  - Tokovinin et al (2008 PASP, 2010 AJ) – Speckle observations of binaries
  - Barlow et al 2008 (ApJL) 2009 (AJ) – white dwarf binaries
  - Pellegrini et al 2009 (ApJ, thesis) – detailed study of the Orion bar
  - Hsieh 2009 (AJ) – Main asteroid belt comets

Science with SOAR



Left: XMM-Newton 0.5-2 keV mosaic of A3627 from an 18 ks observation. Right: the composite X-ray (Chandra) / optical (SOAR) image of ESO 137-001's tail. From Sun et al (2010) ApJ 708, 946