The Future of Gemini Adaptive Optics

Chad Trujillo
Head of Telescope / Adaptive Optics Group

The Telescope and Adaptive Optics Group

Who are we?

Luc Boucher - Detector Engineer

GN

Paul Hirst - Scientist
Olivier Lai - AO Scientist
Hana Benhizia - Intern

GS

Vincent Garrel - GeMS Instrument Scientist
Markus Hartung - AO Scientist
Tom Hayward - Telescope Scientist
Lucie Leboulleux - Intern
Gaetano Sivo - AO Postdoc

Gemini Telescope and AO Systems

What do we support?
What we do affects all science collected at Gemini!

- General telescope optical performance, alignment, collimation
- Telescope vibration suppression
- Guiding performance with the peripheral guiders
- Interfacing with instrument teams for on-instrument guiding
- Instrument team-driven optical issues

- Facility AO Systems
  - Altair
  - GeMS
- Standalone AO
  - GPI

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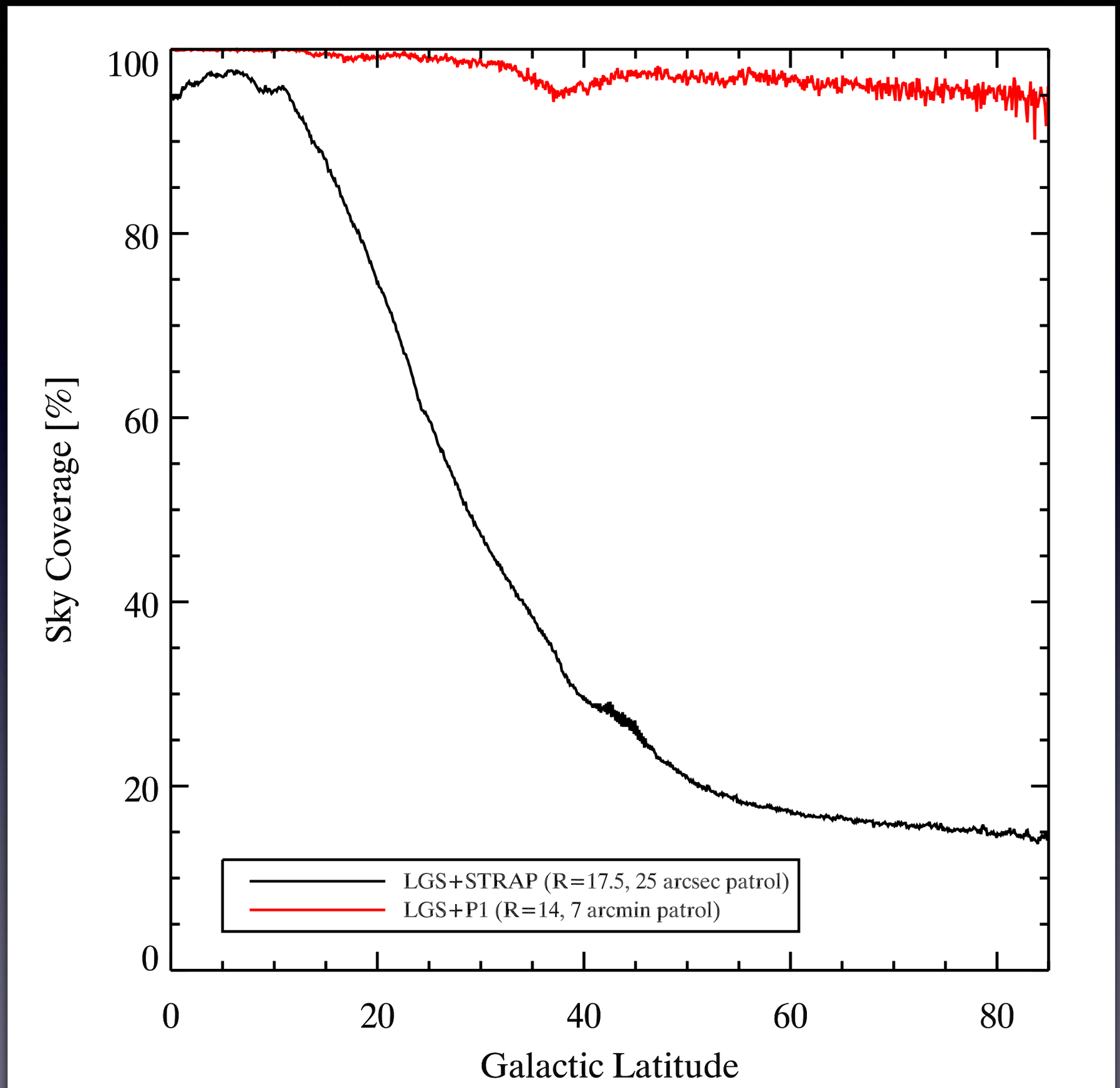
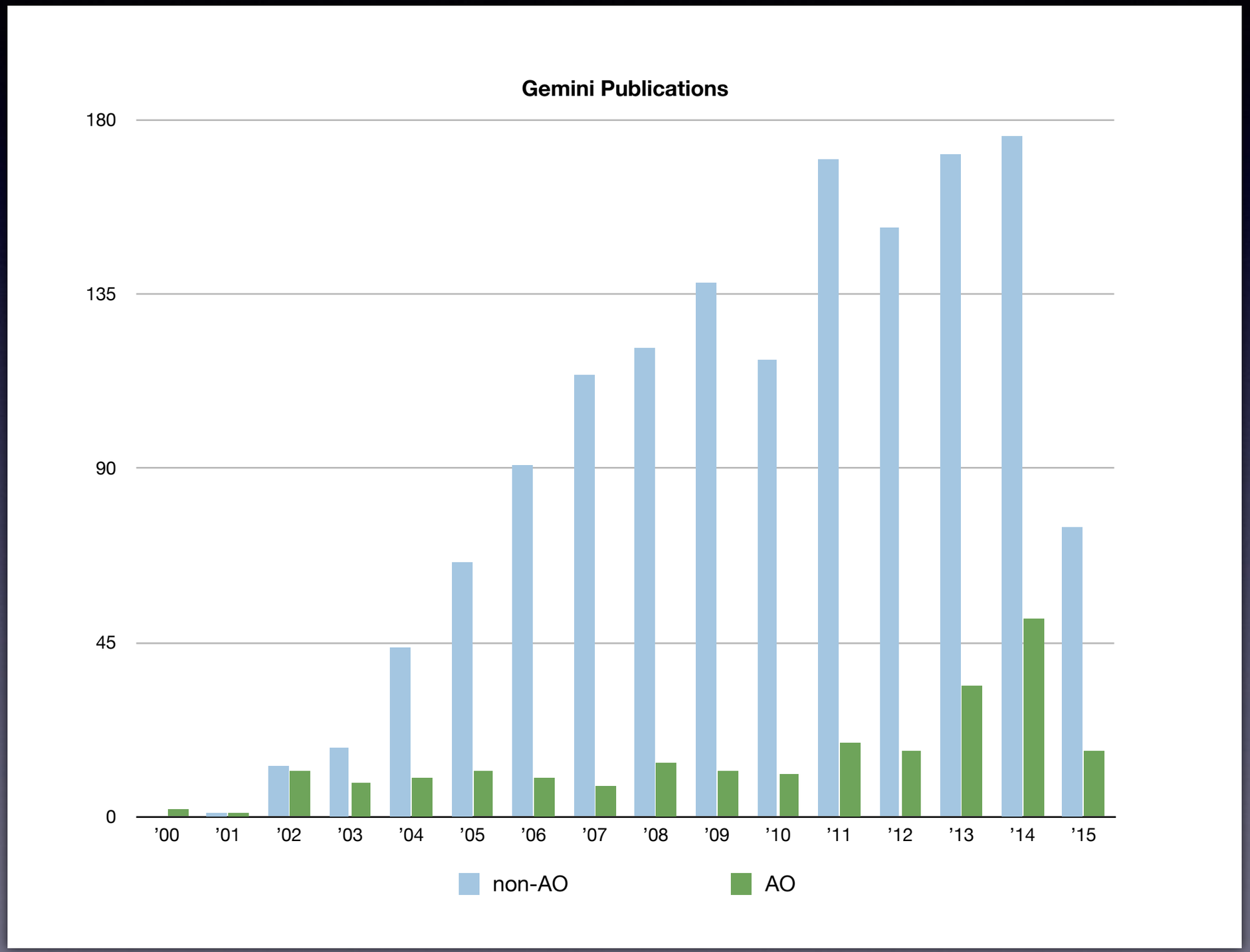
Do you ever do science without autoguiding?

Altair Sky Coverage 95%

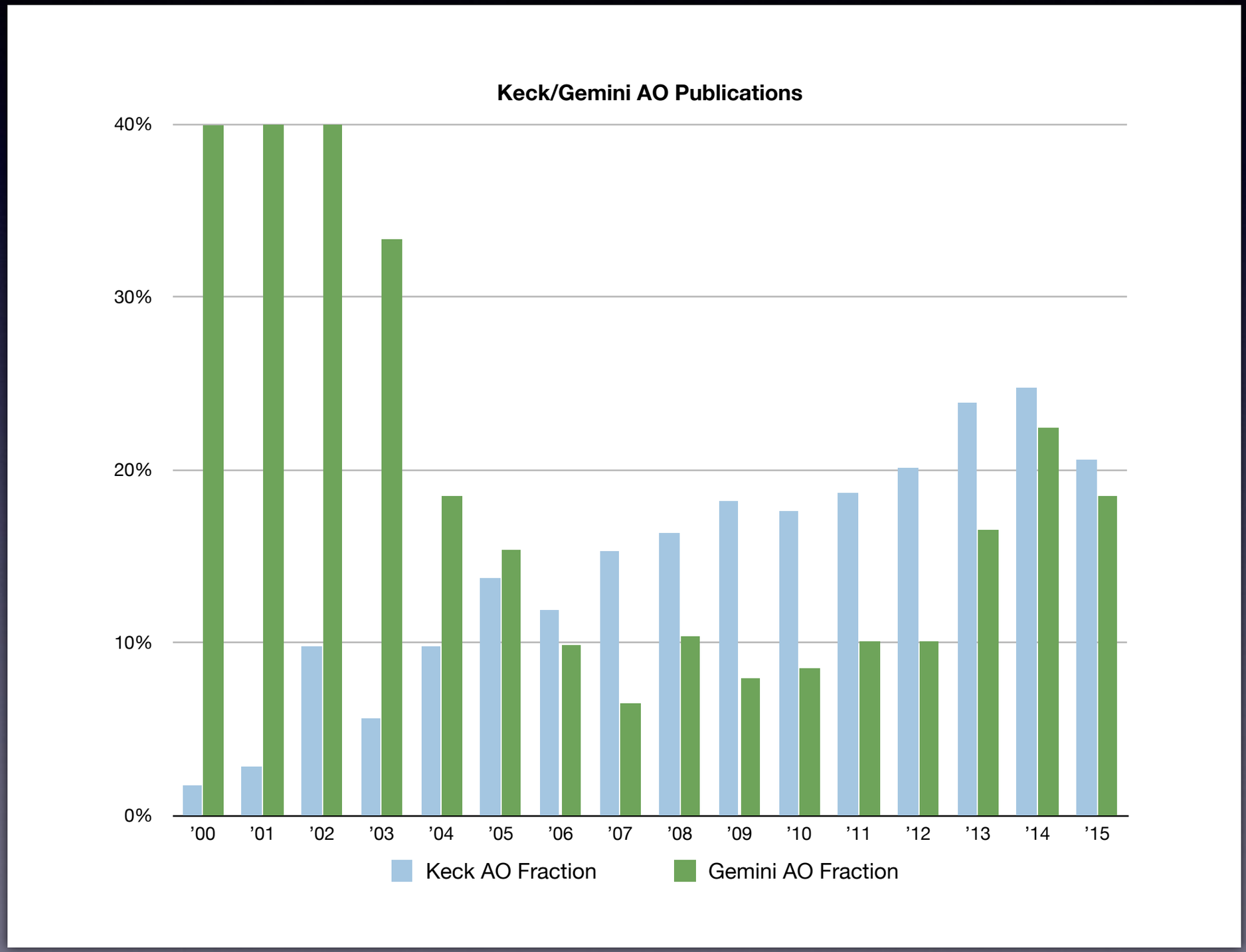
LGS and LGS+P1 "super-seeing" mode



Gemini AO Publications



Fraction of Publications with AO



Short Term Plans
Completion in 2016

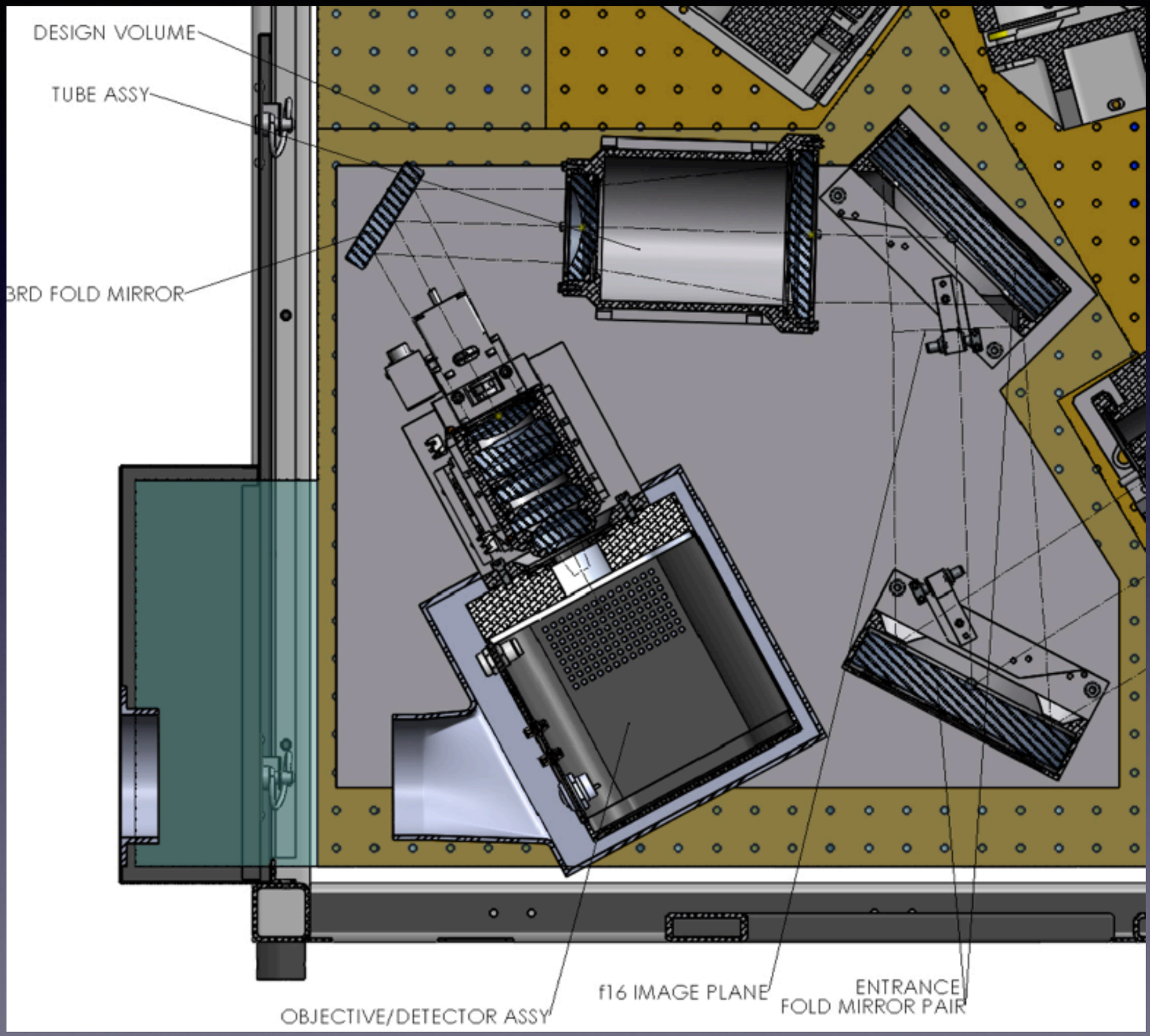
- GeMS
  - NGS^2
  - Astrometic Masks (see Mark Ammons talk)
  - commission GMOS, then F2
- Vibrations
  - GN 12 Hz Vibration correction with M2 with Altair (works with PWFS/GMOS) (see poster by Tom Hayward)
- Telescope Collimation (see poster by Tom Hayward)
- New Data Archive (see poster by Paul Hirst)

NGS^2

- GeMS uses 5 laser guide stars for high-order corrections.
- GeMS uses 1 to 3 natural guide stars for tip/tilt and focus.
- The current NGS subsystem suffers from low throughput despite several attempts to correct it.
- The Australian National University is building an improved NGS subsystem, NGS^2.
- NGS^2 design will have no moving parts (robust), and will improve sensitivity by at least 1.5 magnitudes, a factor 2.5 improvement in sky coverage.
- It should be commissioned in 2016 between GeMS runs with little change to the science user interface.

NGS^2

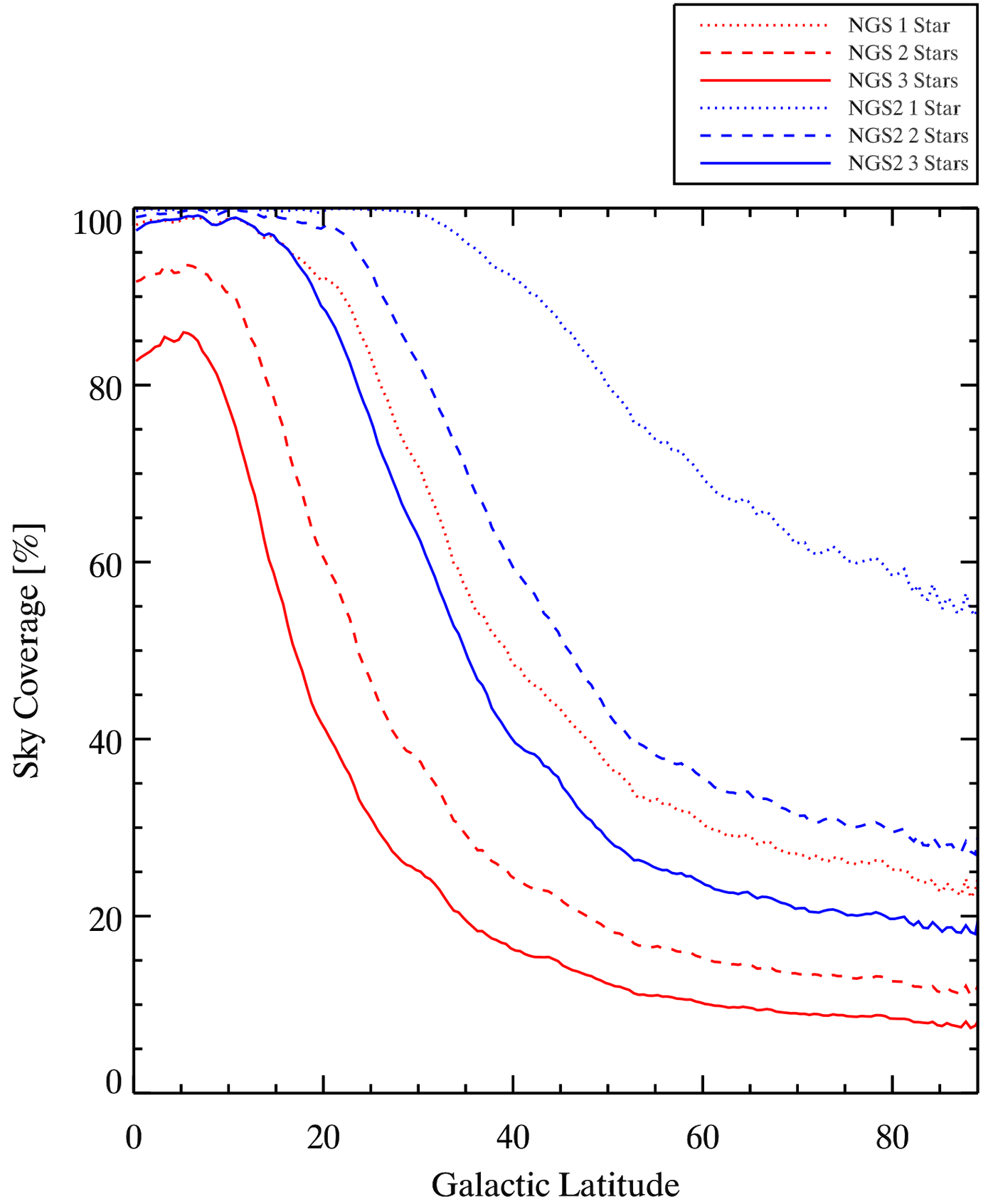
NGS²


DESIGN VOLUME
TUBE ASSY
BRD FOLD MIRROR
OBJECTIVE/DETECTOR ASSY
f16 IMAGE PLANE
ENTRANCE
FOLD MIRROR PAIR

NGS²

GeMS Sky Coverage

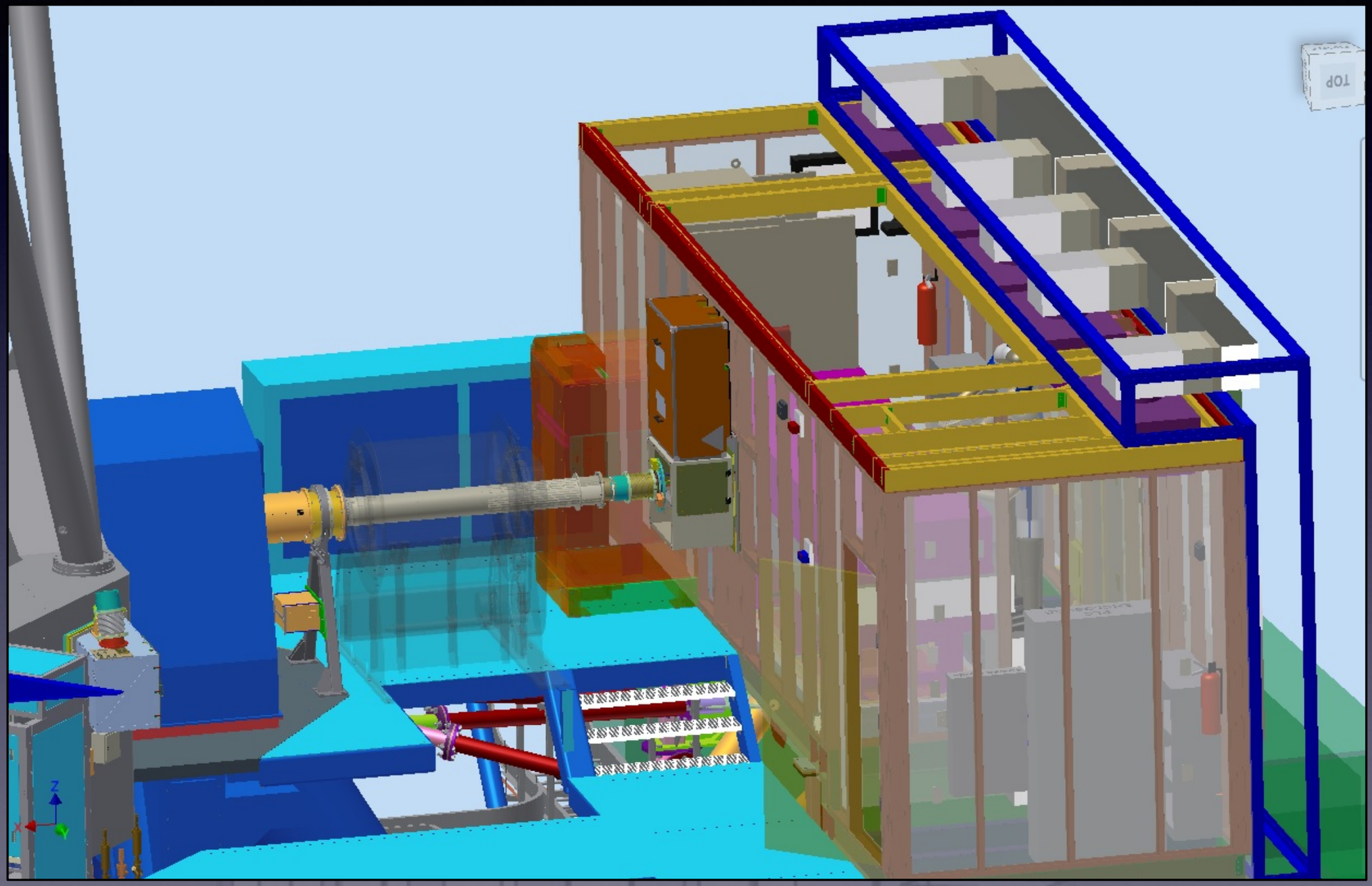
with NGS vs NGS^2



Medium Term Plans
Completion in 2017-18

- LGS Facility for Gemini South
  - Main Goal is to increase robustness and reduce costs
  - ~$1.25 million cash
  - <3 year payback
- Altair RTC (Olivier Lai poster - CHAOPTIX)
  - Current Altair computer is era Y2K
  - Highest risk component to GN AO
  - Will provide CPU for advanced algorithms / calibrations
- A&G II
  - Obsolescence Mitigation
  - Performance Improvement
- GPI
  - Possible upgrades in conjunction with move to GN?

Gemini South LGS



Long Term Plans
Completion in 2018+

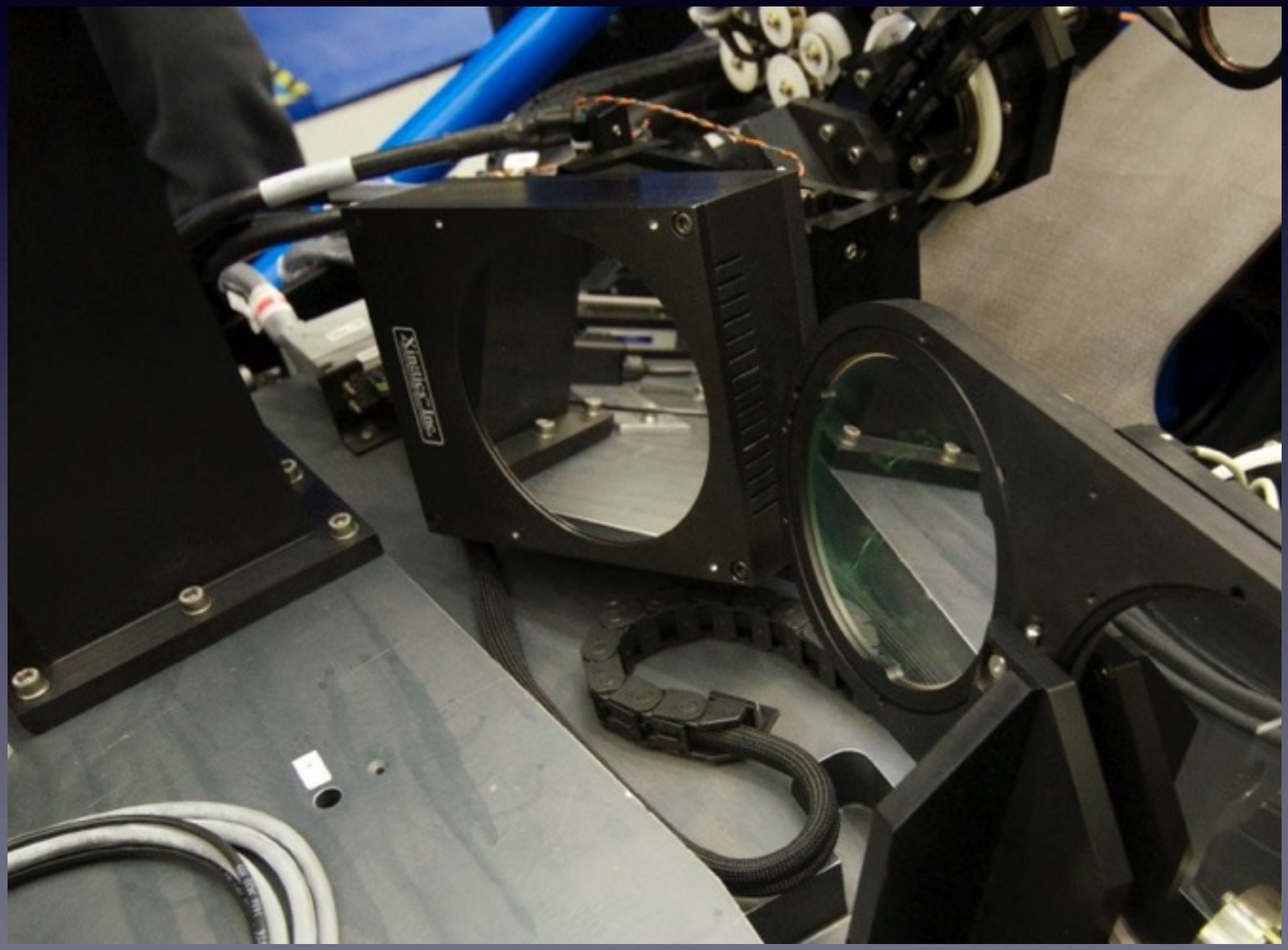
- GeMS DM0
  - Currently GeMS has only 2 DMs out of 3
  - Long procurement time, so will begin now
  - Risk mitigation and performance improvement upon installation
- Rapid ToO with LGS at both sites
  - LSST - Gemini - ELTs
  - Low risk and low cost
- Gen 4#4
  - GN AO next generation system?
  - Laser Tomography AO?
  - Synergy with other Mauna Kea observatories

- We are starting these now

Long Term Plans

Completion in 2018+

DM0



Rapid Target of Opportunity Laser Adaptive Optics

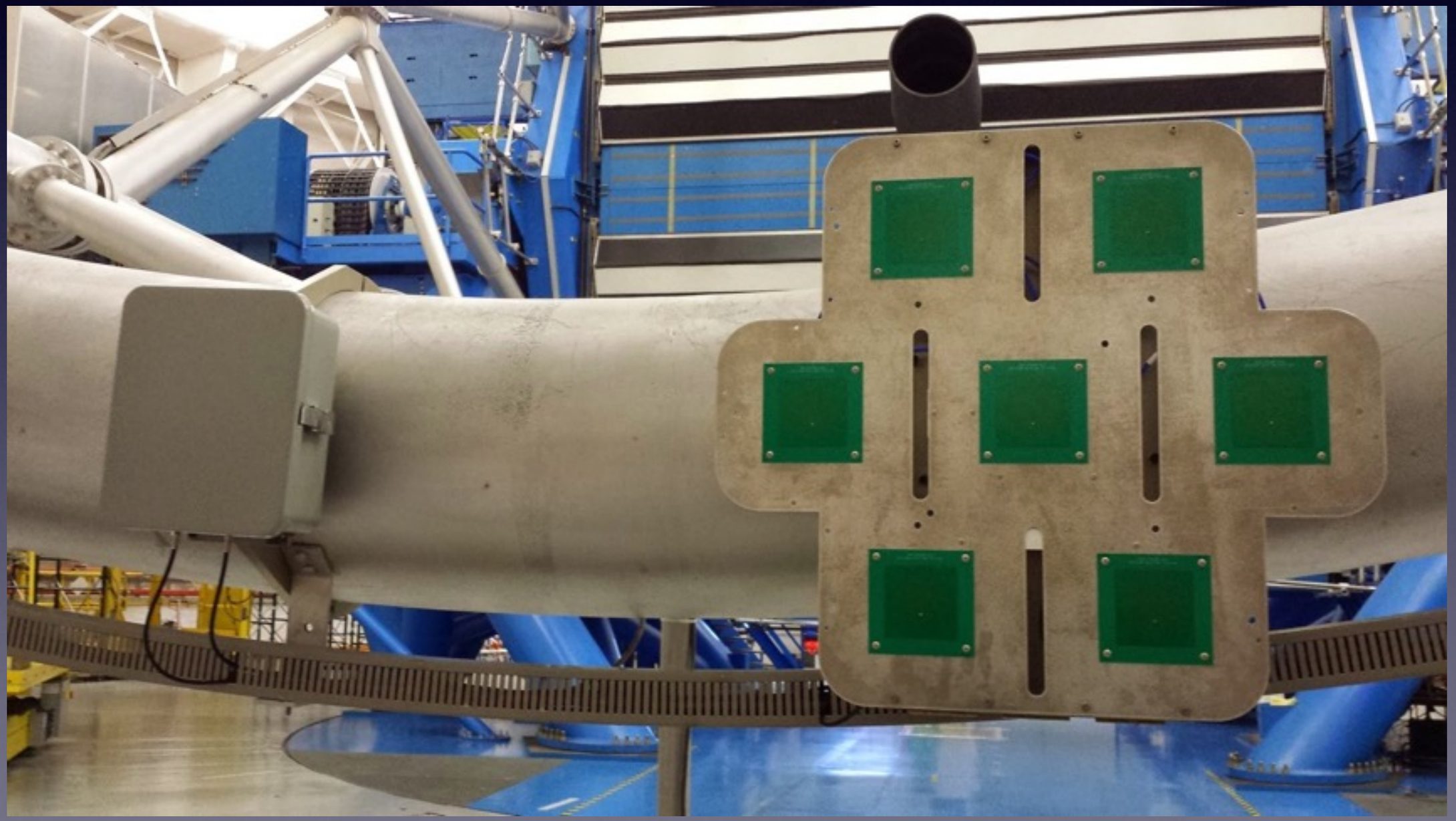
- Improvements Needed
  - Laser Spotters
    - Transponder-Based Aircraft Detection (TBAD)
  - Laser Readiness (next generation lasers)
    - GN laser can be ready in ~1 day and is fairly robust, however a next generation laser might be preferable
    - GS laser (after upgrade) could be available any time
  - Laser Clearing House (full sky request - RoboAO)
    - Request the entire sky in patches prior to ToO trigger.

At GN, this could be done very soon. GS requires new laser.

If RToOs are to become commonplace, we could use an RToO broker system

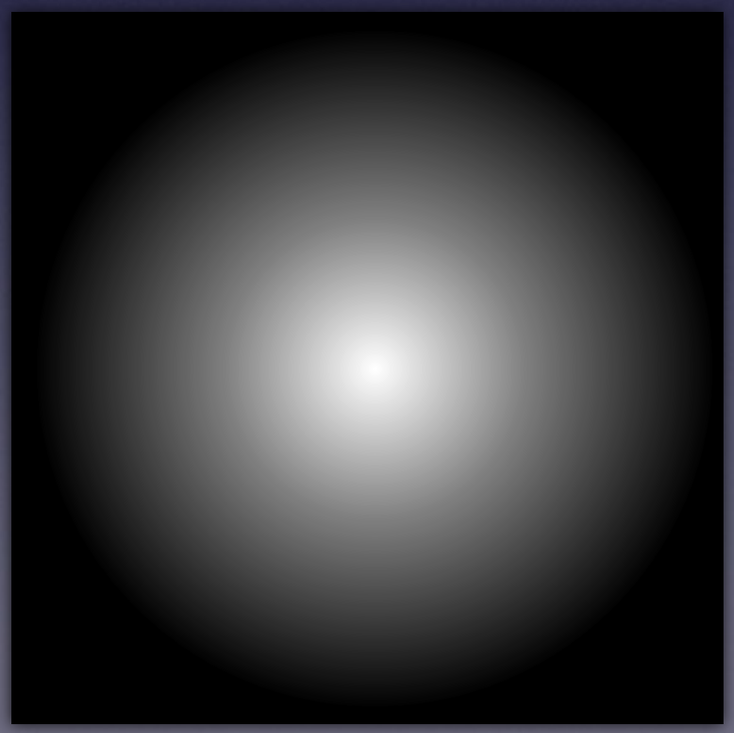
Rapid Target of Opportunity Laser Adaptive Optics

Transponder-Based Aircraft Detection (TBAD)



Rapid Target of Opportunity Laser Adaptive Optics

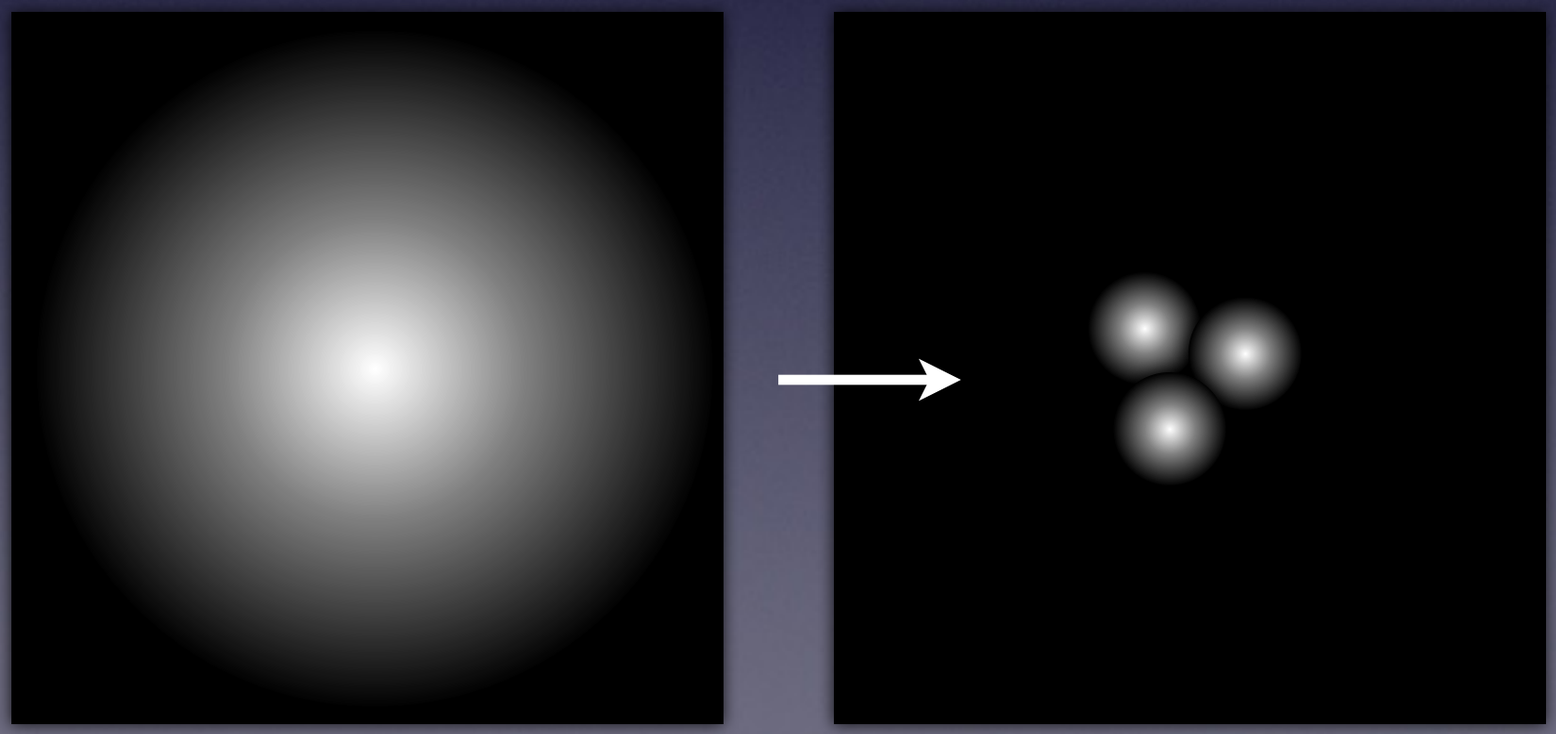
LSST
0.6” Vis



Rapid Target of Opportunity Laser Adaptive Optics

LSST
0.6” Vis

Gemini
0.1” Vis/IR
spectroscopy

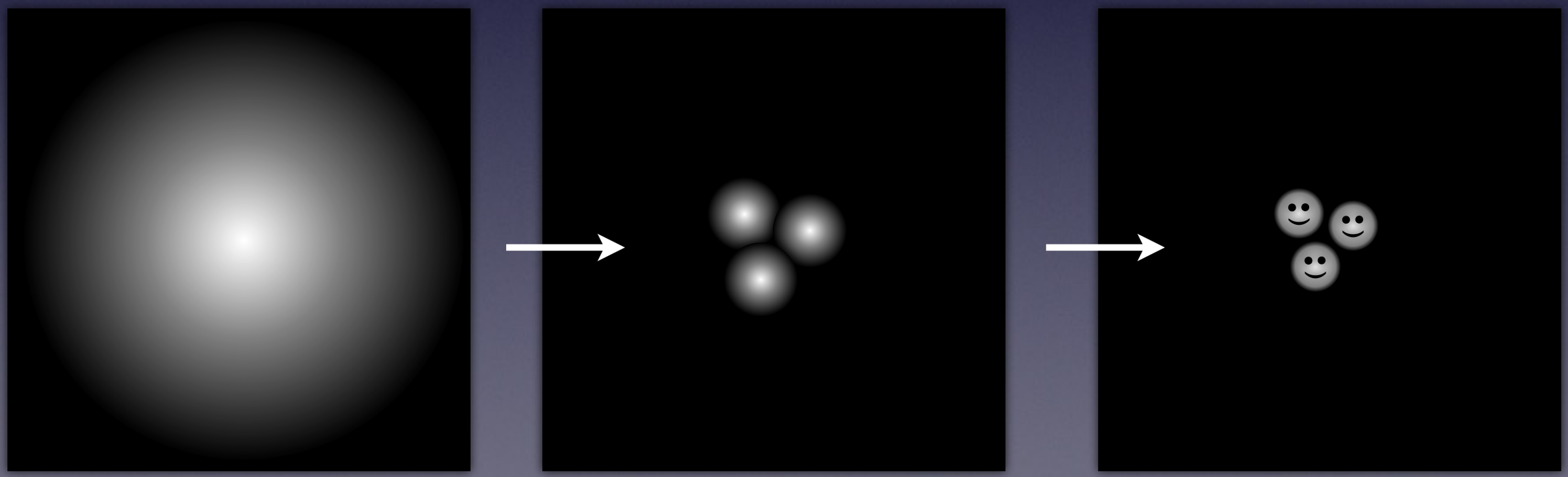


Rapid Target of Opportunity Laser Adaptive Optics

LSST
0.6” Vis

Gemini
0.1” Vis/IR
spectroscopy

TMT/GMT/E-ELT
0.015” IR
spectroscopy



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What do people want?

NGOs:
Better AO
ToOs/Time Domain
Upgrade GN AO system
GeMS + F2
GeMS + GMOS
Heavy oversubscription of GeMS/GSAOI
Altair + GMOS
Gen4#4: LTAO, GLAO, XAO, SCAO

STAC: GMOS CCD, IR Detector Controller, Laser, Altair RTC, NGS^2, DM0, A&G, NICI+?

	'15 Q3	'15 Q4	'16 Q1	'16 Q2	'16 Q3	'16 Q4	'17 Q1	'17 Q2	'17 Q3	'17 Q4	'18 Q1	'18 Q2
GS												
GeMS + GMOS	*1*	*2*	*1*	*1*								
GeMS + F2			*1*	*2*	*1*	*1*						
Vibration Mitigation		*1*	*1*	*1*								
GeMS Astrometric Masks	*1*	*1*	*2*	*1*								
NGS2	*1*	*2*	*3*	*3*	*1*							
GeMS + P1?						*1*	*1*					
Laser Upgrade	*2*	*2*	*2*			*3*	*3*	*1*				
DM0	*1*		*1*	*1*				*1*	*3*	*1*		
GN												
Vibration Mitigation	*1*	*1*										
Altair + GMOS	*1*	*1*	*1*									
IR Detector Controllers			*1*	*2*	*2*	*1*						
Altair Real Time Computer	*1*	*1*			*2*	*1*	*1*	*1*	*1*	*3*	*1*	
A&G II	*1*	*1*	*1*	*3*	*3*	*3*	*2*	*2*	*2*	*3*	*1*	
Gen 4#4							*1*	*1*	*1*	*1*	*3*	*3*

GeMS Astrometric Masks

- A common request among GeMS users is better astrometric calibration.
  - Static distortions are relatively well characterized (~100 mas).
  - Dynamic distortions can change from night to night (~10 mas).
    - Unless you have rich fields, the dynamic distortions are difficult to characterize.
- Considering the installation of 2 deployable astrometric masks.

GeMS Astrometric Masks

- The first is a pinhole mask upgrade to the artificial calibration sources.
  - there is a deployable constellation of ~10 sources
    - too few for robust astrometric solutions
    - they can move slightly due to gravity/temperature
  - we will upgrade this to a stable pinhole mask of ~100 sources (similar mask material to GMOS slit masks)
- Will allow astrometric calibration before/after science

GeMS Astrometric Masks

- The second is a diffractive mask for simultaneous use during science in isolated fields.
  - Can be deployed when needed
  - Creates pseudo-images of the science target
  - These can be used to improve astrometry of the science target
- (See talk by Mark Ammons)

What are our goals?

We provide robust, low-maintenance services that perform well, services whose functionality is understood in detail and documented, and services that are easily accessible and available to those that use them.

- We are in the development group, so we are interested in improving things
- Telescope image quality should be optimal
- We want AO to be widely accessible to everyone: competitive performance, easy to use, high sky coverage, many instrument modes

Gemini South LGS

- The current laser guide star facility for Gemini South / GeMS is extremely difficult to maintain.
- It only reached peak (specified) power of 50 Watts shortly after delivery several years ago.
- It costs a large amount of money in subcontracts to Lockheed Martin / Coherent Technologies each year ($250k in 2014, for example)
- It takes a dedicated team of in-house laser specialists as well (2 FTEs).
- Even with these expenditures, there is a large amount of risk each run that power will be maintained.
- Current generation lasers offer much better robustness.

Gemini South LGS

- The Toptica SodiumStar laser is a solution that could meet our needs.
  - Robustness
    - ~30 min warmup
    - all night at full power
    - low maintenance requirements
  - Possible resource sharing (parts, service contract) with other observatories
    - Keck, VLTs, Gemini
  - 22 W Toptica is equivalent to our current LMCT laser operating at 35 W.

- Other vendors may be able to provide higher power at a similar price, but robustness needs to be demonstrated.

Telescope Collimation, Vibration Supression and Data Archive

- Recent improvements to the telescope collimation, which was responsible for inducing astigmatism and focus errors especially when guiding with the peripheral wavefront sensors. (See poster by Tom Hayward).
- Recently implemented 12 Hz vibration supression at Gemini North using Peripheral Guiders and GMOS OIWFS. Plan for implementation with Altair (Tom Hayward poster)
- As a cost-saving transition plan measure, Gemini is moving the data archive in-house (See poster by Paul Hirst).

GeMS + GMOS/F2

- We are currently working on commissioning GeMS with GMOS and then F2.
  - This requires updating the measurement method for estimating instrument-specific aberrations (non-common path aberrations, NCPA). (Telescope/AO Group effort)
  - It also requires small software changes to many parts of the operational software system (PIT, OT, ODB, seqexec, and TCC). (Operational Software Effort)
- Why now?
  - GeMS+GMOS best with CCDs optimized for the red.
  - GeMS+F2 best with MOS mode.