The Future of Gemini Adaptive Optics

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Head of Telescope / Adaptive Optics Group
The Telescope and Adaptive Optics Group

Who are we?

Luc Boucher - Detector Engineer
Paul Hirst - Scientist
Olivier Lai - AO Scientist
Hana Benhizia - Intern

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
Gemini Telescope and AO Systems

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Facility AO is unusual, we want it to be functional, easy to use and available for every instrument!

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Gemini Telescope and AO Systems

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Do you ever do science without autoguiding?

- Facility AO Systems
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Altair Sky Coverage
95%

LGS and LGS+P1 “super-seeing” mode

Figure 1. The original Altair LGS system sky coverage as a function of galactic latitude using the onboard STRAP NGS WFS (black) and LGS+P1 sky coverage (red). The LGS+P1 mode offers greatly enhanced sky coverage, but as described in the text, reduced image quality. For targets near the galactic plane, the existing system is preferred due to high NGS star availability and increased performance. Near the galactic pole, many more targets are available using the LGS+P1 mode.

We also tested P1 sending the tip/tilt corrections directly to the Altair tip/tilt mirror. However, loop functionality was not stable in this configuration because it was not truly a closed loop feedback system. P1 feeds the Altair tip/tilt mirror, corrections are sent by P1 that are applied to the science beam but are not immediately seen by P1. Repeated tip/tilt corrections applied to the Altair tip/tilt mirror are eventually offloaded to M2, but the bandwidth of this offload was not great enough to create a stable loop system using Altair+P1. Therefore, all P1 tip/tilt corrections are applied directly to M2.

Although the LGS+P1 mode offers nearly all-sky availability, there is significant performance degradation over the original LGS mode using Altair's onboard avalanche photo diode based tip/tilt sensor (STRAP). This is primarily due to the effect of tilt-anisoplanatism, where the tip/tilt produced by the atmosphere isoplanatic patch near the P1 NGS star is different from that of the science target due to the large (5 – 7 arcmin) distance between the science and P1 targets. Although generally the LGS+STRAP will produce better image quality, this is only if a star is available near (25 arcsec) the science target. In the absence of a STRAP star, the LGS+P1 mode is particularly beneficial.
Fraction of Publications with AO

Keck/Gemini AO Publications

- Keck AO Fraction
- Gemini AO Fraction

Years: '00 to '15
Short Term Plans
Completion in 2016

- GeMS
- NGS$^2$
- Astrometric 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.
NGS²
NGS$^2$
NGS$^2$
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?
4.7.4 LMCT decommissioning Options

4.7.4.1 Two laser combination option

The decommission will affect only the laser components inside the LSE. The BTO remains unmodified. Once the LMCT is decommissioned, the SodiumStar laser may be launched directly into the BTO without the combination module.

4.7.4.2 Separated laser option

Depending on the location of the laser head on the BTO, the LMCT decommission will remove the laser component and BTO stages to the SodiumStar laser head location. There is a minimum impact to operations.

4.8 Conclusions

Our preferred option to mount the SodiumStar LH and EC is outside the LSE at the laser output box level. This option is shown in Section 4.7.3. This location allows us an easy and smooth integration of the new system into the BTO and telescope structure. There are no main concerns regarding the EC connection to the telescope or the software implementation.
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
Gemini Telescope and AO Systems

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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, NGS², DM0, A&G, NICI+?
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Legends: 1 = Complete, 2 = Work In Progress, 3 = Not Started
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 Suppression 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.