# Gemini-North Adaptive Optics (GNAO): Science overview and status updates

*Gaetano Sivo, Julia Scharwächter, Stephen Goodsell, Jennifer Lotz, GNAO team*

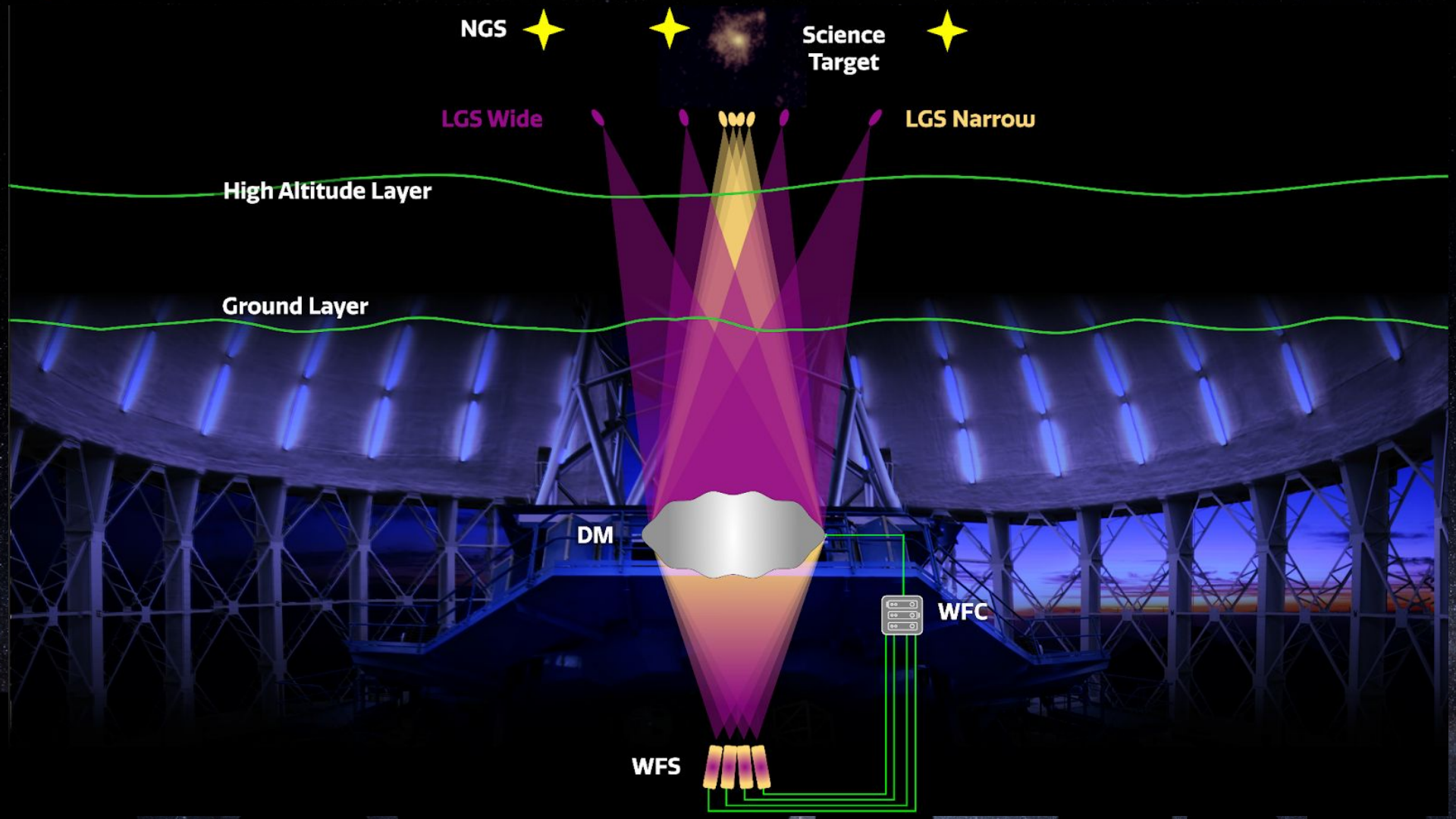
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders
NRC·CNRC
Agencia Nacional de Investigación y Desarrollo
MINISTRY OF SCIENCE, TECHNOLOGY, INNOVATION AND COMMUNICATION
PÁTRIA AMADA BRASIL BRAZILIAN GOVERNMENT
Ministerio de Ciencia, Tecnología e Innovación Argentina
한국천문연구원 Korea Astronomy & Space Science Institute

# GNAO goals

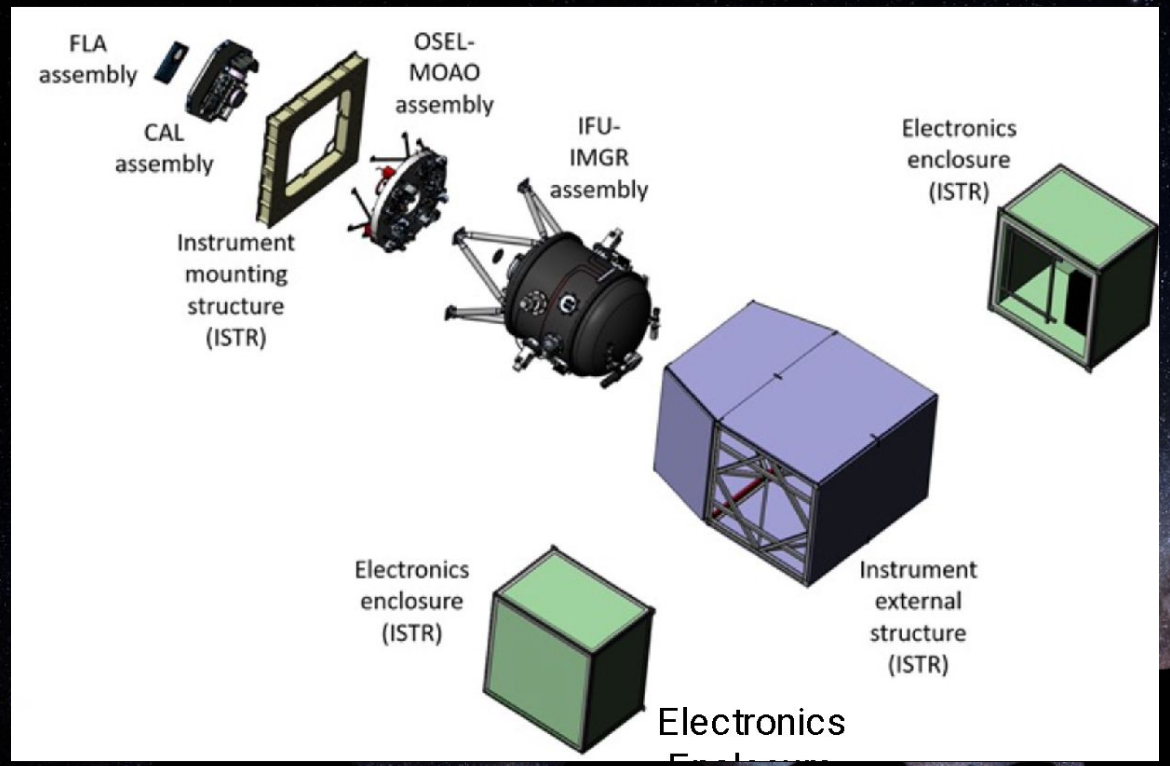
- Revitalize aging AO facility at Gemini-N
- Utilize Maunakea, one of the world's best sites for AO
- Support nightly queue operations for AO
- Support GIRMOS, Canadian-built TMT-pathfinder instrument
- Enable a path for adaptive secondary mirror at Gemini-N
- Build upon the MCAO legacy of GeMS

→ ***Support high-spatial resolution, wide-field NIR AO imaging and spectroscopy for MMA/time-domain astronomy, cosmology, stellar populations, + diverse science cases in era of JWST, Rubin operations***

# GNAO Modes


NGS
Science Target
LGS Wide
LGS Narrow
High Altitude Layer
Ground Layer
DM
WFC
WFS

# Gemini IR Multi-Object Spectrograph




**GIRMOS is an AO-fed multi-object integral field spectrograph and imager**

- Can simultaneously observe 4 objects spectroscopically across Y, J, H, or K-bands yielding up to 10x improvement in survey completion time compared to single-object AO spectrographs
- Has an additional multi-object AO (MOAO) system that can improve performance over the full AO-corrected field
- Has an imager that images the GNAO narrow and wide field, which can also be used in parallel during spectroscopic observations

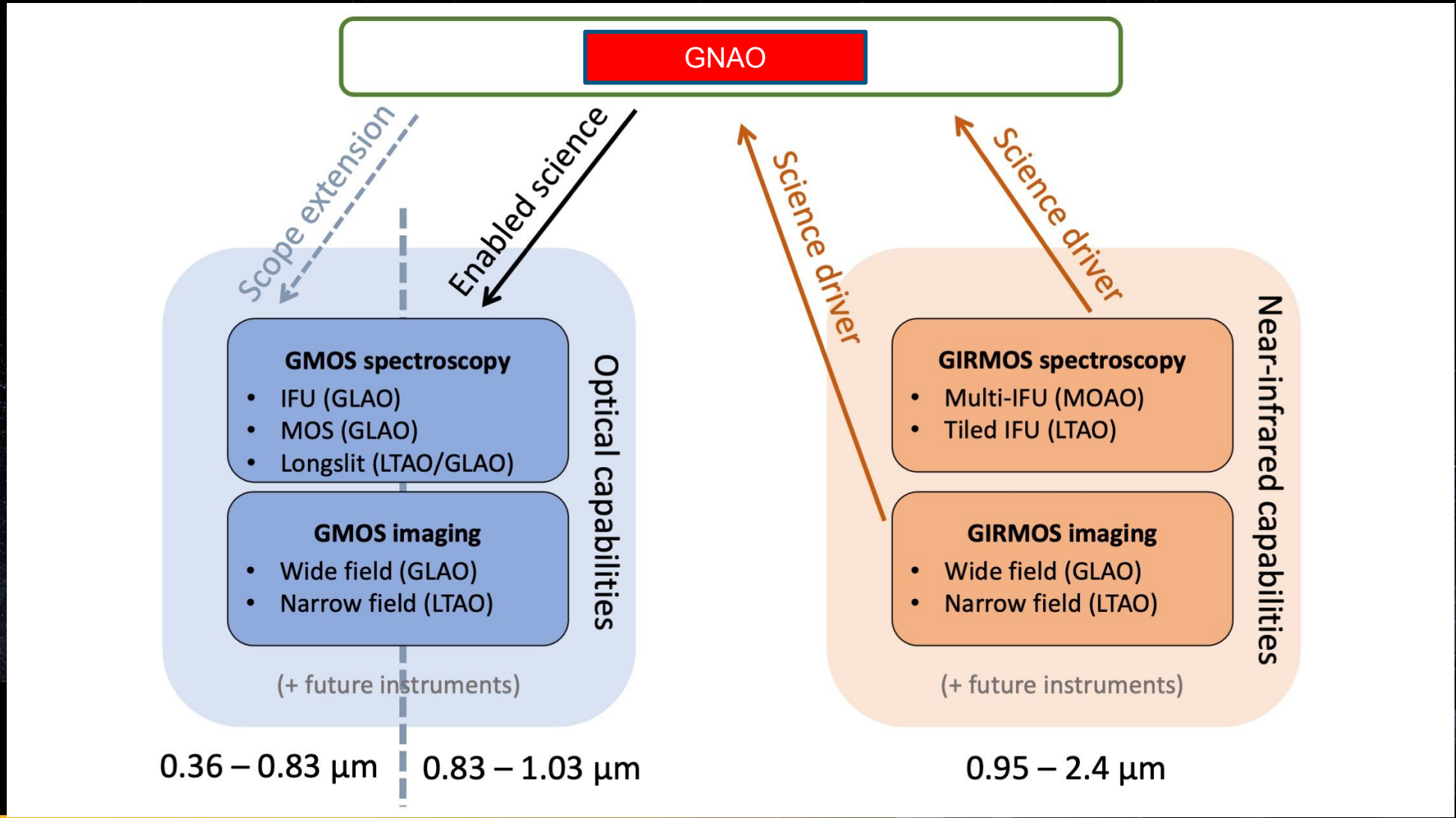
See S. Sivanandam's talk

# GNAO in a nutshell

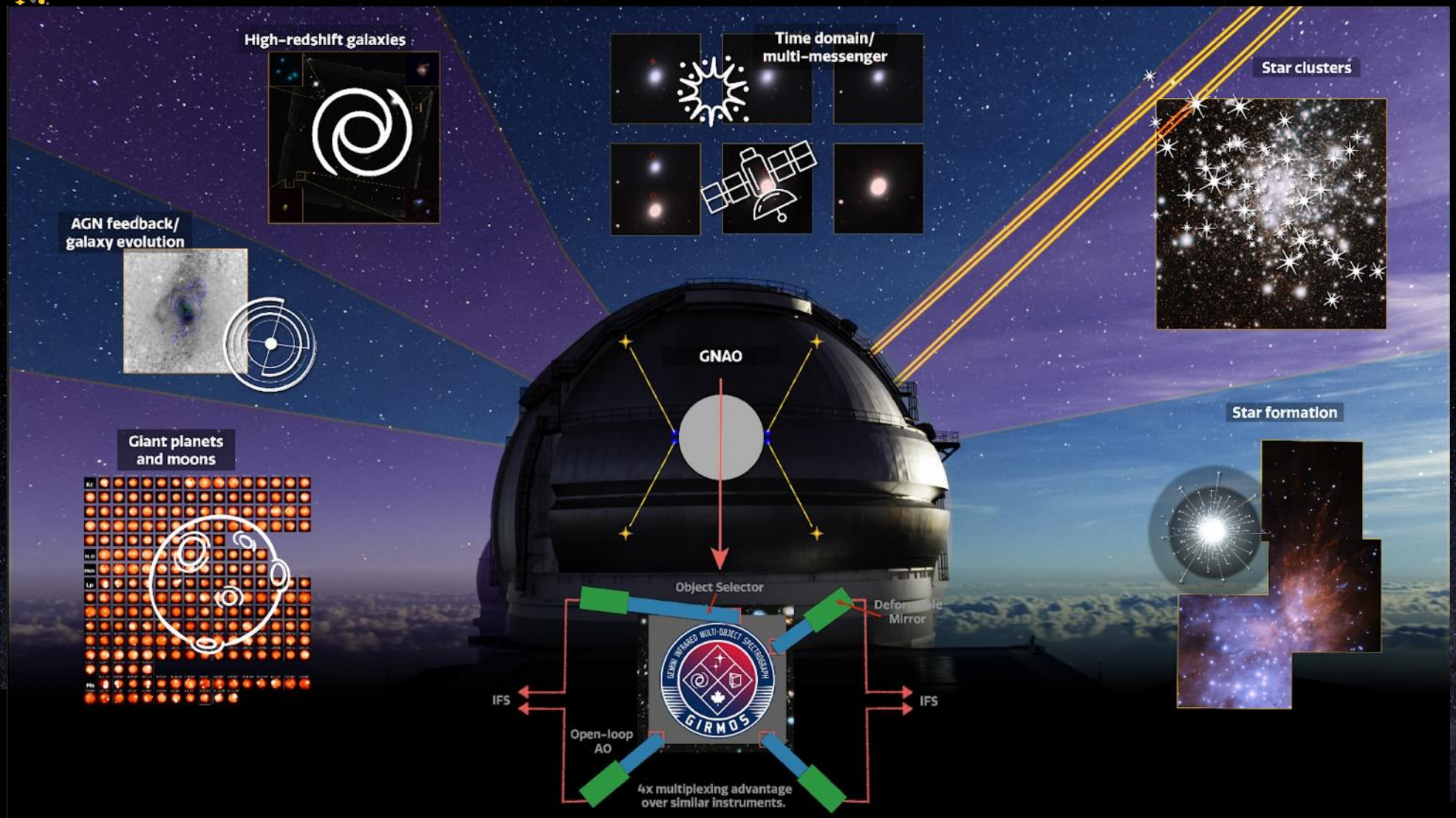
- GLAO-LTAO @ Gemini North
- Designed to feed Imaging and Spectroscopic instrument
  - Visiting/Facility instrument GIRMOS including imager
- Needs to deliver WF correction (GLAO) over 2’ FoV in the NIR
  - GIRMOS IFUs (+MOAO when needed)
  - Imager in large field 85”x85”
- Needs to deliver NF correction (LTAO) in a 20”x20” in the NIR
  - GIRMOS Tiled IFU mode 8”x8”
  - Narrow field imaging 20”x20”
- Keep open future upgrade
  - Components could be used with an ASM for the ~6’ FoV GLAO

See S. Sivanandam’s talk

# GNAO science capabilities



# GNAO Science Cases



# Science cases

**High-resolution facility for multi-messenger events**

- Gamma-ray bursts and gravitational wave events
- Solar system transient events
- Unknown transients in the era of Rubin Observatory's Legacy Survey of Space and Time

# Rapid follow up of multi-messenger events

Famous example GW170817:

- First gravitational wave event with detection of electromagnetic counterpart
- Neutron star merger associated with short GRB and kilonova

GNAO narrow-field mode:

- Study kilonova emission starting from ~15 min after a GRB event


FLAMINGOS-2/Gemini-South imaging of GW170817 (natural seeing)

*Credit: Gemini Observatory/NSF/AURA/Edo Berger (Harvard), Peter Blanchard (Harvard), Ryan Chornock (Ohio University), Leo Singer (NASA), Mansi Kasliwal (Caltech), Ryan Lau (Caltech) and the GROWTH collaboration, Travis Rector (University of Alaska), Jennifer Miller (Gemini Observatory)*

# Science cases

## High-resolution facility for multi-messenger events

- Gamma-ray bursts and gravitational wave events
- Solar system transient events
- Unknown transients in the era of Rubin Observatory's Legacy Survey of Space and Time

## Powerful capabilities for survey science

- Galaxy surveys at intermediate and high redshift
- Globular clusters and intermediate-mass black holes
- Lensed galaxies
- Young star clusters, ultra-compact HII regions
- Galaxy nuclei and supermassive black holes

# Science cases

## High-resolution facility for multi-messenger events

- Gamma-ray bursts and gravitational wave events
- Solar system transient events
- Unknown transients in the era of Rubin Observatory's Legacy Survey of Space and Time

## Powerful capabilities for survey science

- Galaxy surveys at intermediate and high redshift
- Globular clusters and intermediate-mass black holes
- Lensed galaxies
- Young star clusters, ultra-compact HII regions
- Galaxy nuclei and supermassive black holes

## Flexible availability for solar system and multi-epoch studies

- Monitoring giant planet atmospheres, their disks, and satellites
- Multi-epoch studies of protostellar outflows and jets
- Icy small solar system bodies

# Science cases

## High-resolution facility for multi-messenger events

- Gam
  gravit
- Solar
  event
- Unkn
  the e
  Obse
  Surve
  Time

## Powerful capabilities for survey science

The review of the Programs (and Science) White Papers by the U.S. community, along with the RFI 2 documents, led the panel to conclude that the case for continued support of development over the next decade is strong:

1. AO/High-Contrast Imaging are key enabling technologies for high science priorities identified by the Exoplanets, Stars, and Galaxies science frontiers panels;
2. They play an essential role in boosting the scientific return and efficiency of existing facilities (e.g., Gemini, Keck, Magellan, DKIST) with modest-scale investment throughout the 2020s;
3. NSF Mid-scale program opportunities have been identified (e.g., GNAO, GmagAO-X, LIGER) to nurture existing 6–10 m class telescopes.
4. Such investments in AO systems development is a key risk mitigation strategy for ELTs, whose full resolution and sensitivity potential can only be realized with AO, and which is recognized as the most important technical risk for both GMT and TMT.

- Galaxy nuclei and supermassive black holes

## Flexible availability for solar system and studies

nt planet
their disks,

udies of
tflows

system

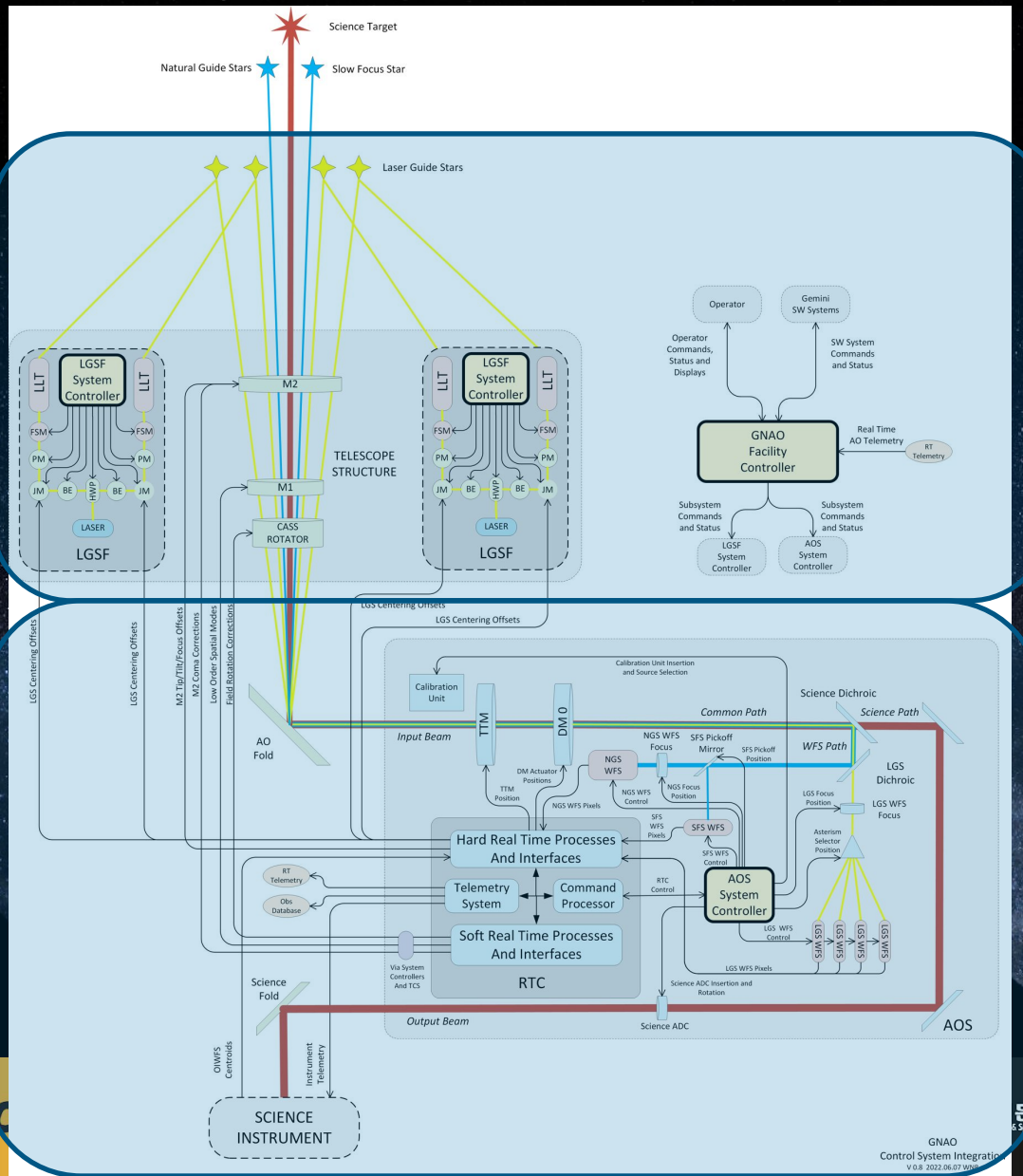
# GNAO Performance Requirements

| Imaging | FoV | *K*-band (2.2μm) Performance | *H*-band (1.65μm) Performance | *J*-band (1.25μm) Performance |
|---|---|---|---|---|
| GNAO WFM (GLAO) 60% sky coverage | 85″ × 85″ | 120 mas FWHM | 150 mas FWHM | 200 mas FWHM |
| GNAO NFM (LTAO) 60% sky coverage | 20″ × 20″ | SR 35% | SR 20% | SR 10% |
| GNAO on-axis (LTAO) 12 mag *R*-band limit | On-axis | SR 60% | SR 45% | SR 25% |
| Detector | HAWAII-4RG 4k × 4k | | | |
| Plate Scale | 0.021″ | | | |
| Wavelength (μm) | 0.83 – 2.4 | | | |

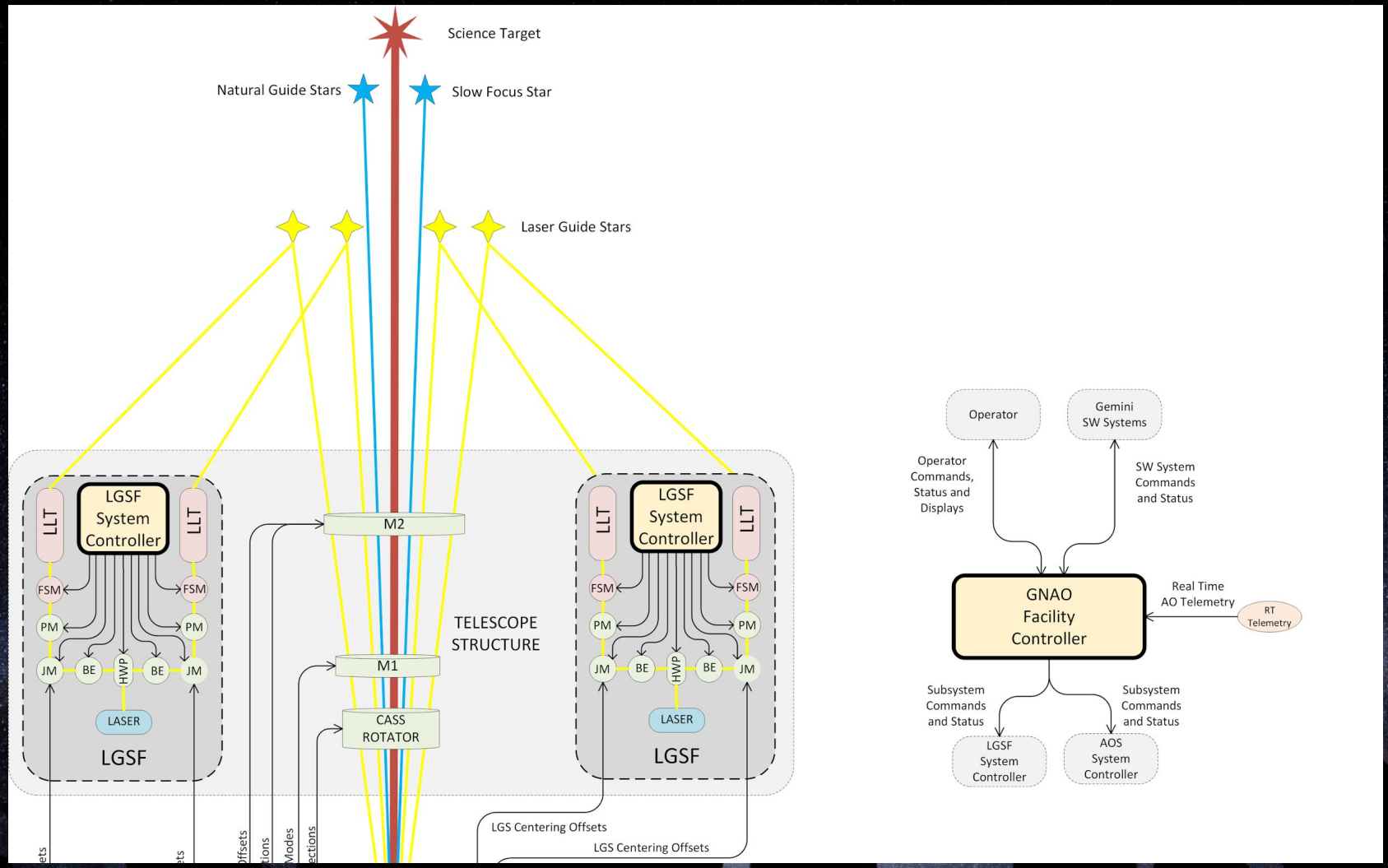
# GNAO Configuration

- GLAO-LTAO @ Gemini North
- Laser constellation created using 2 Topticas each split in 2 feeding their own LLTs
- AO Bench
  - 4 LGS WFS fed by two constellations size possible
    - GLAO constellation for GIRMOS spectroscopy and wide field imaging
    - LTAO constellation for GIRMOS tiled IFU and diffraction limited imaging
  - 1 DM
  - As little but effective optics as possible

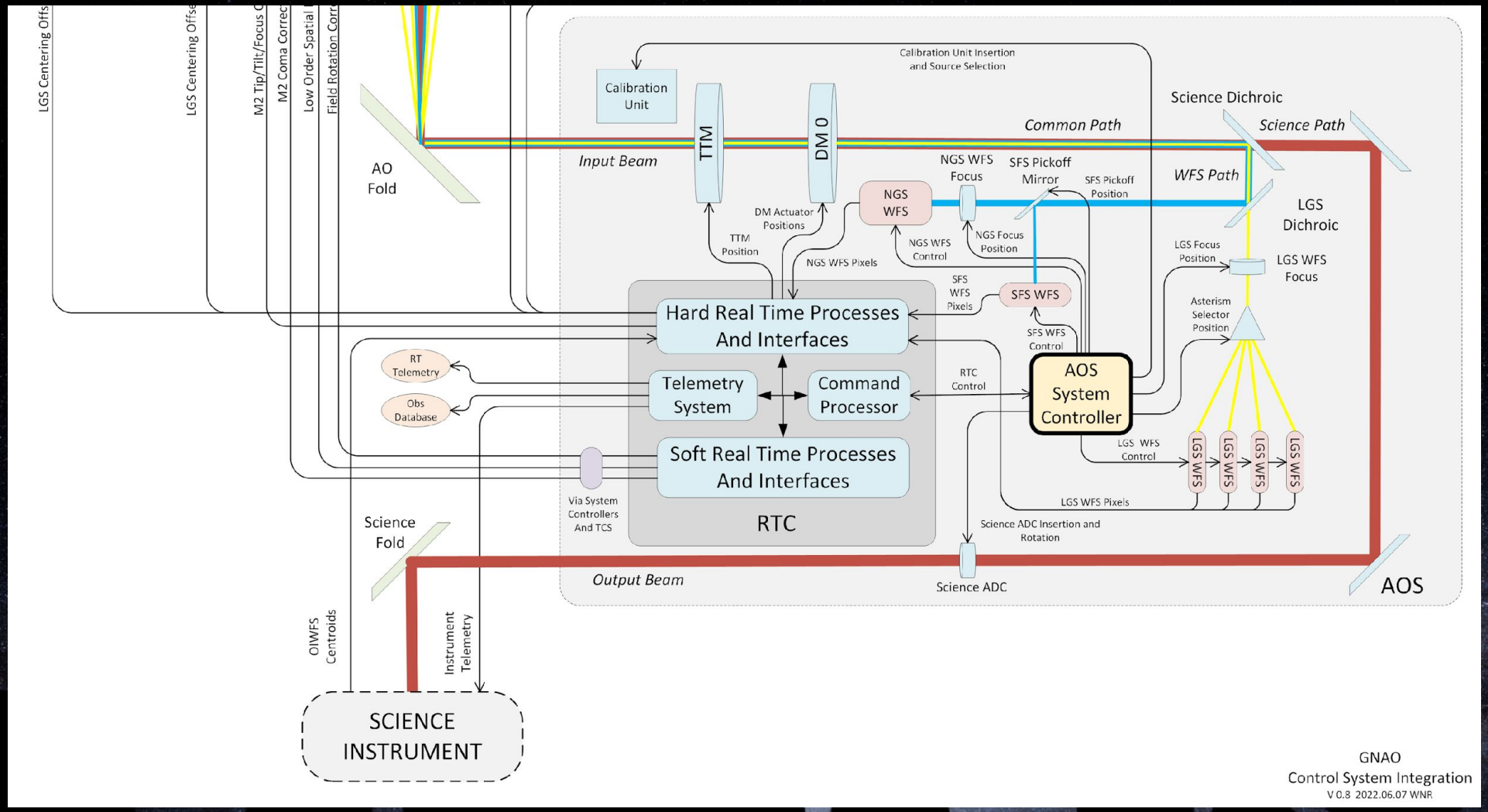
# GNAO Architecture



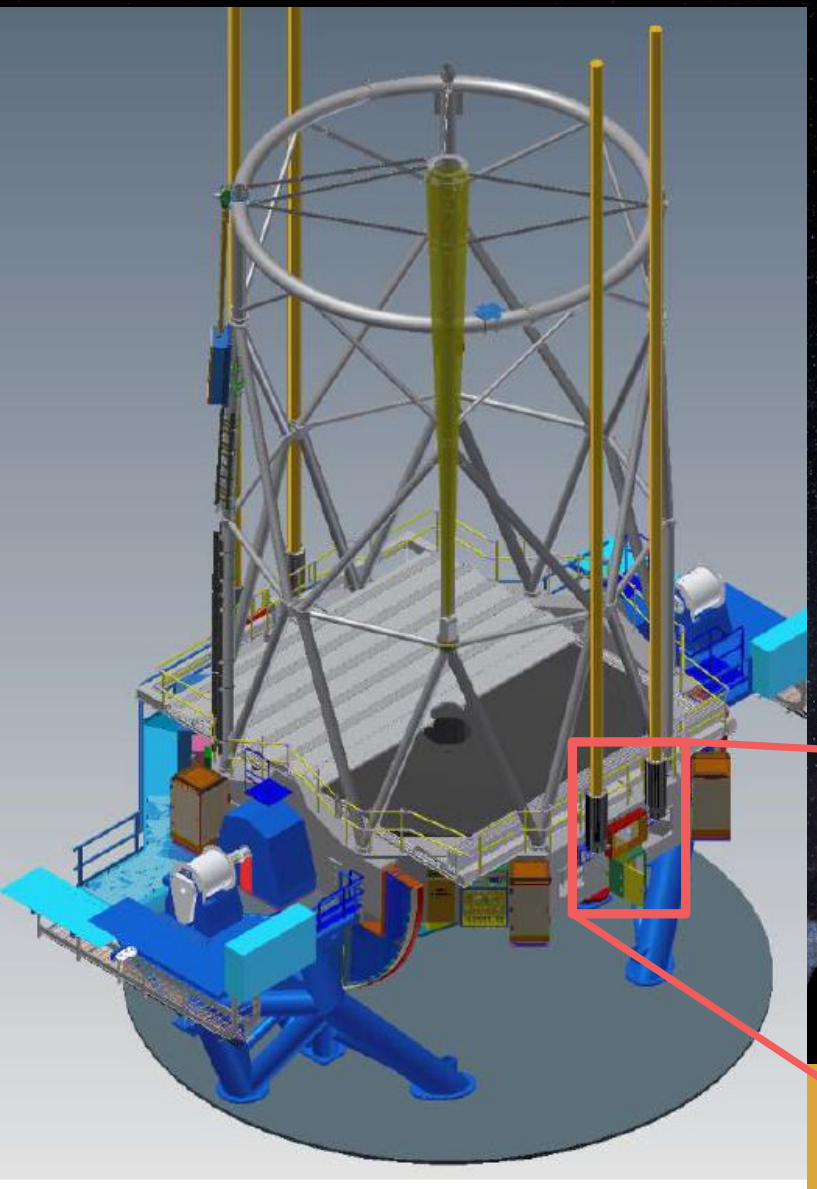
# GNAO Architecture

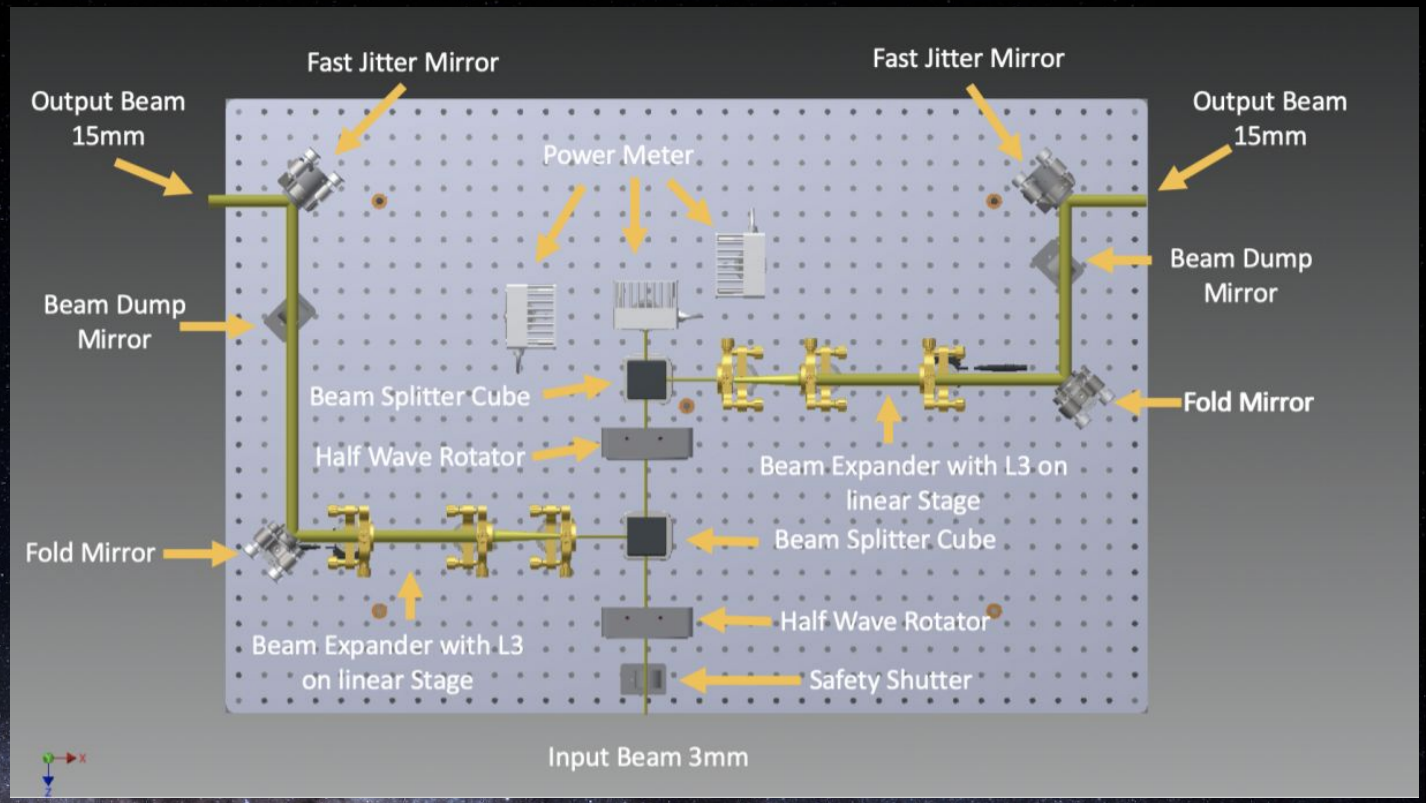


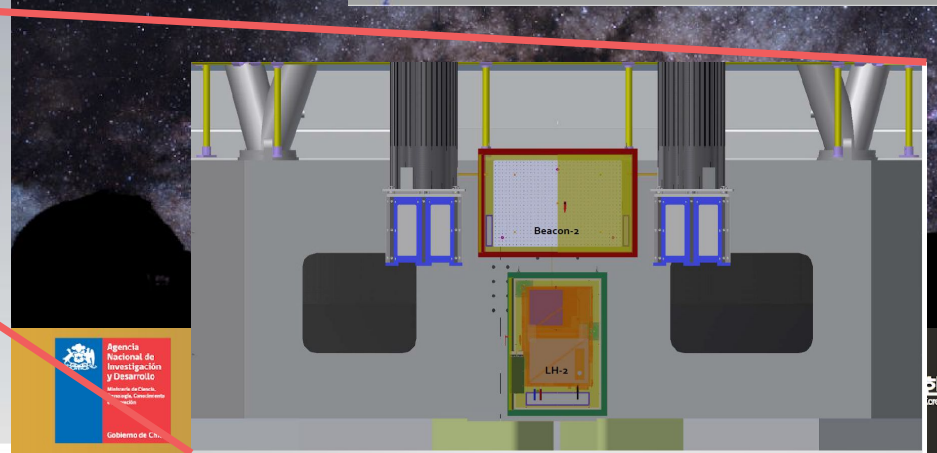
# GNAO Architecture



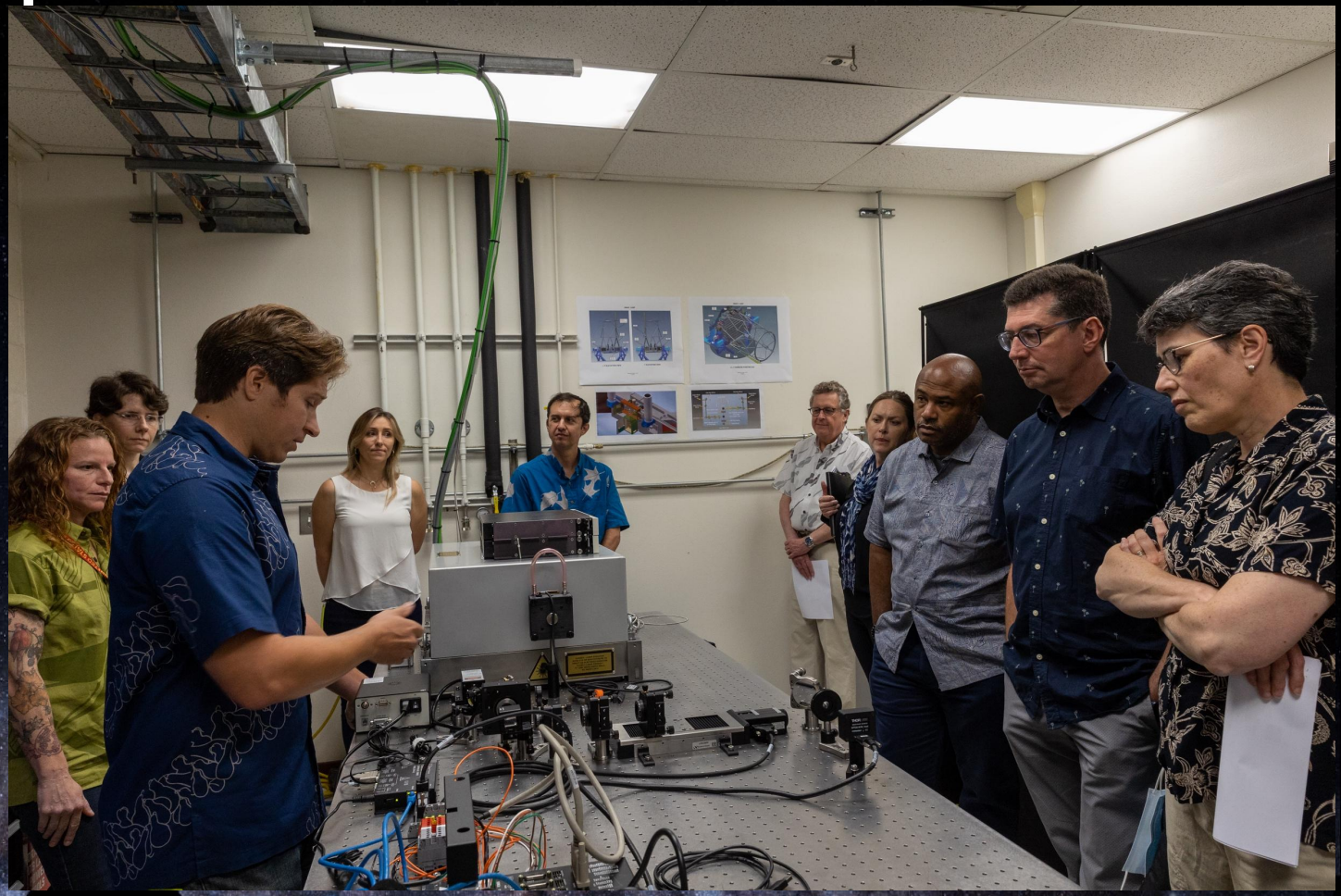
# BEaCoN and LGSF Structure





# LGSF Lab pictures



# LPC installation

On-sky test to measure the deflection of the optical axis of the LPC due to the relative flexure with respect to the optical axis


**LPC first light 07/21/2022**

# Conclusions

- GNAO has made significant progress especially w.r.t. AOB procurement (GNAO's critical path)
- Phase A contracts are being signed
- The other WP (LGSF, SyCo, RTC) advancing as planned
- First hardware being assembled and installed
- Timeline: First light Q2FY28