Current Instruments and Upgrades

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Facility Instrument Capabilities

The optical workhorse instruments are almost identical for both sites, with a typical science usage of ~900 h per year per instrument.

Each telescope also has a workhorse near-infrared spectrograph with a usage of ~500 h per year each.

Gemini provides spatial resolution of 0.5" optical to 0.35” NIR in all instruments under good natural seeing, 0.08” within a field of 10" by means of ALTAIR and 0.06” within a field of 85" by means of the GeMS MCAO.

The facility instrument suite must enable multi-instrument queue and switching instruments in about two minutes, for efficiency and for strong Target of Opportunity service.

Gemini Facility Instrumentation, 2022B offered modes and 2018-2019 stats.

Instrument	Site	Visible	Infrared	Imager	Long Slit	IFU	MOS	AO Suptd.	Usage (hrs/yr)	FT Prop. % Demand [a]	Proposal % Demand [b]
GMOS-N	N	✓		✓	✓	✓	✓		850	56	48
GMOS-S	S	✓		✓	✓	✓	✓		1006	62	57
GNIRS	N		✓	~	✓	([c])		✓	516	14	16
F-2	S		✓	✓	✓		✓	([d])	476	34	15
GSAOI	S		✓	✓				✓	70	([e])	6
NIFS	N		✓			✓		✓	104	8	9
NIRI	N		✓	✓				✓	105	12	6
GHOST	S	✓				([f])			-	-	-

[a] The fraction of total hrs requested in all FT proposals received for the semester, per telescope. GN FT demand does not sum 100% because of the contributions from `Alopeke and GRACES. GPI FT demand was 4%.

[b] The fraction of total hrs requested in all proposals received for the semester, per telescope. It does not include LLP, DD, and FT programs. Neither site sums to 100% because of the contributions from non-facility instruments: `Alopeke, GRACES, POLISH2, Maroon-X at GN, and Zorro, IGRINS, Phoenix, and GASP at GS. GPI demand was 5%.

[c] GNIRS IFUs commissioning planned for 2022A.

[d] MOS commissioned completed, AO feasibility study planned for 2022A.

[e] GSAOI is not offered for FT proposals.

[f] High resolution fiber spectrograph, commissioning phase planned for 2022A.

Facility Instruments: **GMOS-S/N**

Optical multifunction spectrographs and imagers.

Spectral range of 0.36–1.03 µm (QE>80% within the range 0.45–0.93 µm). Core operating modes:

- 5.5′ square field of view, broad and narrow band imaging, IQ~0.5" under IQ 20%-ile.
- 5.5′ long slits, R ~630–4400 for 0.5" slit (depending on the grating). Max. R ~8800.
- 5.5′ x 5.5′ Multi-Object Spectroscopy.
- 7" x 5" or 3.5" x 5" IFU, fiber fed, 0.2" spaxels.

Has an OIWFS, minimizing flexure between the WFS and the FPU, with small or no vignetting.

A mechanical fault on the GMOS-S OIWFS has recently restricted guiding to the PWFS2: **we are planning a 1-week intervention at the CP lab in September.**

Detectors upgraded twice in the last decade, in 2017 by the current Hamamatsu detectors. **GMOS-S CCD1 has an intermittent CTE issue, currently not present.**

GMOS has 22 filter slots, easy to interchange, and many times has welcomed user designed filters, including an Instrument Upgrade Project (IUP) award. **We are considering a IUP public request for proposals to carry on a small upgrade in 2023 as suggested by the STAC (e.g. the broadband filter system).**

An ongoing upgrade is providing a new low-resolution grating to each GMOS with simultaneous coverage of range 0.4–0.8 µm, aiding programs which usually require a combination of the B600 and R400 gratings to achieve more uniform response in that range.

Facility Instruments: **GNIRS (GN)**

NIR multifunctional spectrograph. Spectral range of 0.8–5.4 μm, variety of resolution modes sampled by four (short/long-blue/red) camera options. Core modes:

- Cross-dispersed spectroscopy within 0.8–2.5 μm, slit lengths of 7" (SC) or 5" (LC). Multi-order sampling and R ~ 1800, 5400, or 18,000 for 2-pixel slit.
- Long Slit spectroscopy in selected portions of the range, slit lengths of 99" (SC) or 45" (LC). R ~ 1200–18000 for 2-pixel slit.
- Imaging in small (~10") fields of view dependent on filter, spatial sampling of 0.15"/pixel (SC) and 0.05"/pixel (LC).

It can be used with the ALTAIR AO system.

Instrument Upgrade Project: **GNIRS IFUs in build phase, commissioning planned for early 2022.**

A repair of the short-red camera is considered for 2023. The mode is unavailable due to a lens crack. Needs a 2 month instrument shutdown.

Instrument/Mode	GMOS-N IFU-R	GMOS-N IFU	NIFS	GNIRS LR-IFU	GNIRS HR-IFU	GPI-2
Spatial sampling (")^2	0.2 × 0.2	0.2 × 0.2	0.103 × 0.043	**0.15 × 0.15**	**0.05 × 0.05**	0.014 × 0.014
Sampled field (")^2	3.5 × 5	5 × 7	3 × 3	**3.2 × 4.8**	**1.25 × 1.8**	2.4 × 2.4
Spaxels	500	1000	2000	**672**	**900**	~37,000
Max. spec. resolution	7100	7100	4500	**7200**	**18000**	80
Spectral range (μm)	0.36 – 1.03	0.36 – 1.03	0.94 – 2.4	**1.0 – 5.4**	**1.0 – 5.4**	0.9 – 2.4

Current and future IFU capabilities that will be available at Gemini North, which will allow to explore some synergies as the ones between the GMOS-N IFU-R and GNIRS LR-IFU modes.

Facility Instruments: **FLAMINGOS-2 (GS)**

F2MOS capability to be offered in 2022.

Imaging capability in the J, H, Kb, Ks, Kr broad bands with a sampling of 0.18"/pixel and an image quality of 0.4" over a field of view of 6.1', for IQ 20%-ile conditions.

4.4′ long-slit mode with average spectral resolution R ~2800 over the single bands J, H and K-long (1.9-2.5 µm) and R ~1000 with simultaneous coverage on the wider spectral ranges YJH and HK.

We are assessing the performance report and preparing what's needed for a first F2MOS call in 2022: A PhaseI Tool release with the mode, instructions and performance information in the public page, and a new Gemini Iraf/Pyraf release with an updated data reduction recipe.

Mask Field of View	6′ x 2′	Targets from F2 pre-image or catalog.
Max. # of 4.5" length slits	72	Nodding along slits (100% on source).
Max. # of 1.8" length slits	153	Offsetting to sky (50% on source).
Spectral coverage	0.97—2.48 µm	YJH, HK, J, H, K-long band modes.
Spectral Resolution	700 / 2000	Single broad / extended band, 0.54" slits.
Spatial image quality	0.4"	H-band, IQ 20%-ile.
Max. # of masks/cycle	9	On-telescope mask exchage in dark time, with 2 nights out the queue.

In early 2020 we initiated a project to complete the last phase of the **multi-object spectroscopy (MOS) mode commissioning, which was completed this year.**

We are considering a 2-weeks shutdown at the end of 2021B for **upgrades: spectroscopic filters raising throughput in 8—12%, improving thermal insulation and utility wheel to include the Y and J-low (1.1 µm) filters.**

Facility Instruments: **NIRI, NIFS & ALTAIR (GN)**

NIRI provides the primary NIR imaging capability at GN in the spectral range 0.9–5 μm, with a maximum field of 120" x 120" at 0.117"/pixel.

- Natural seeing imaging with three camera options: f/32, f/14, and f/6, with FOV of 22" x 22", 51" x 51", and 120"×120".
- The f/32 mode is best suited for longer λ's (2.5–5 μm).
- The f/14 or f/32 camera can be fed by ALTAIR for AO assisted imaging (with or without laser guide star).

Upgrade: The new detector controller work is progressing well. **We hope to connect the new ARC controller to NIRI later this year to compare the performance with the current GNAAC.**

NIFS 3" x 3" integral field spectroscopy covers the range 0.95–2.4 μm with R ~ 5000.

- With ALTAIR achieves spatial resolution of 0.15". Needs a tip/tilt guide star nearer than 25" of the science target, r ≲ 15 mag and r ≲ 18.5 mag for the non-laser and laser ALTAIR modes resp.
- Using natural seeing and the PWFS2, the achieved spatial resolution is 0.4", while the location of the guiding star can be as far as 6.5'.
- Coronographic mode using occulting disks of 0.2" and 0.5", suited to adaptive optics observations and best performing at H and K bands.

There was an issue with the cooling system so **NIFS' return to the telescope is delayed until October.**

ALTAIR is the facility natural/laser guide star AO system of GN. "Transparent" for the science instrument, as it reproduces the telescope focal ratio (f/16), pupil size and pupil position.

GN laser upgraded in 2019 and we have procured new dichroics to improve ALTAIR transmission under 1 μm and over 2.4 μm. **The new dichroics are still in the testing phase.**

Facility Instruments: **GSAOI & GeMS (GS)**

GSAOI is a NIR camera, covering the spectral range 0.9–2.4 μm, and samples a field of 85" x 85" at 0.02"/pixel. It is the primary imaging instrument designed for GeMS.

- 22 filters available, broad and narrow band.
- Hawaii-2RG detector mosaic, one of them has more artifacts than the others, but we have not yet considered a replacement. Changing a detector in the mosaic is a major task.

We are considering to replace the optical window with a spare because the coating has developed small stains: It does not affect the general performance except for a stable small low spatial frequency effect in the overall transmission.

GeMS MCAO provides WF correction over a 85"x85".

- Strehl ratio from 15% to 50% (in the 1-2.5 micron range)
- Needs 3 natural guide stars with r < 18 mag.

A new laser was commissioned in 2018, and the NGS-2 was commissioned in 2019.

A third DM has been procured and had a successful laboratory acceptance in late 2019.

We have started a project to **upgrade the Real Time Computer** in order to have a more stable system.

In 2022 **we plan to perform a Feasibility Study on GeMS +F2 spectroscopy**.

Visiting Instruments

The VI Program offers PIs the opportunity to use their own instruments, with support from Gemini engineering and operations staff.

- With the help of the instrument teams, these instruments can be made available to the larger user community as well.
- In recent years, some of these Visiting Instruments have been much sought after, comprising a significant fraction of Gemini usage at both telescopes.

The VIP currently expands Gemini capabilities to R~88,000 optical and R~45,000 NIR spectroscopy, diffraction limited spatial resolution down to 0.016" by means of speckle imaging, high precision polarimetry and high resolution mid-IR spectroscopy.

Frequent or resident visiting instruments.

Instrument Capability	‘Alopeke & Zorro	Instrument Capability	GRACES (GN)	MAROON-X (GN)	IGRINS (GS)	TEXES (GN)
Bands	u, g, r, i, z, H_α (350–1070 nm)	**Spectral range (μm)**	0.4–1.0	0.5–0.92	1.45–2.45	5–25
FOV (circular)	6.7" or 60"	**Fiber/Slit**	1.2"	0.77"	0.34"x 5"	0.5"x4"
Spatial resolution	0.016" or seeing lim.	**Max. spec. resolution**	60,000	85,000	45,000	80,000
Additional Capability	Dual camera, subarray fast readout	**Additional Capability**	Does not use a port	RV precision ~20 cm/s	Slit viewing camera	8” slit & lower res.

Later today there will be talks by Greg Mace about IGRINS (& IGRINS-2) and Jacob Bean about MAROON-X.
Suresh Sivanandam will give a talk about GIRMOS on Wednesday, a community lead instrument project complementing GNAO.

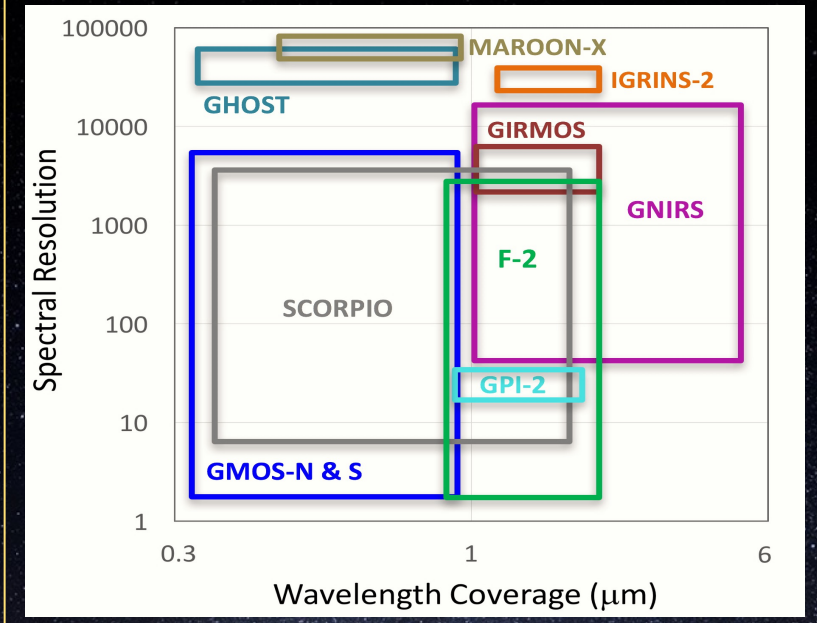
- Later today Quinn Konopacky will talk about the GPI-2 upgrade and tomorrow Alan McConnachie will talk about GHOST and Massimo Robberto about SCORPIO.
- Tomorrow, Scot Kleinman will give a talk about the **future instruments** and Gemini Development activities.
- Gaetano Sivo will bring a news update about **GNAO** on Wednesday, and Paul Hirst will present the **GLAO** Feasibility Study.
- Later today there will be a workshop about the **GMOS and F2 mask making procedures** hosted by Rodrigo Carrasco & Ricardo Salinas.
- Tuesday: I will be available in chat sessions on Tuesday and Thursday, please bring your questions and ideas about instrument upgrades or future instruments.

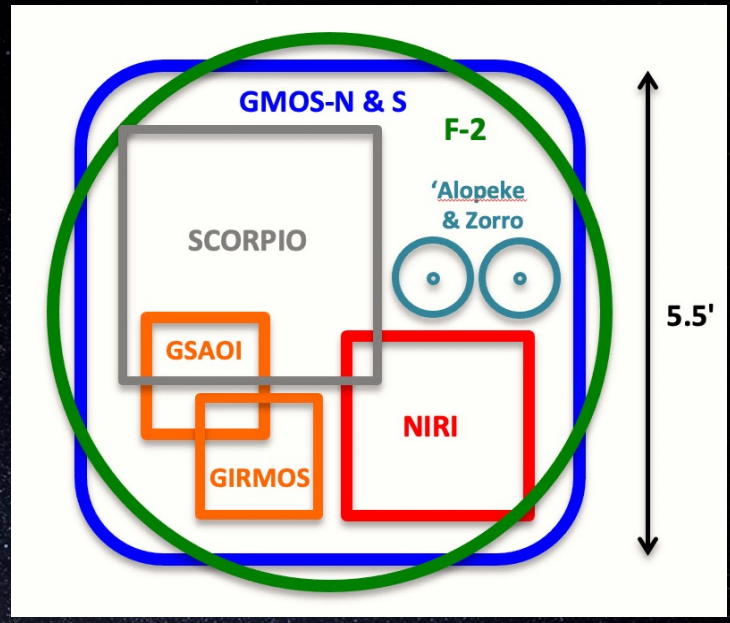
Thank you

Current and Future Capabilities summary

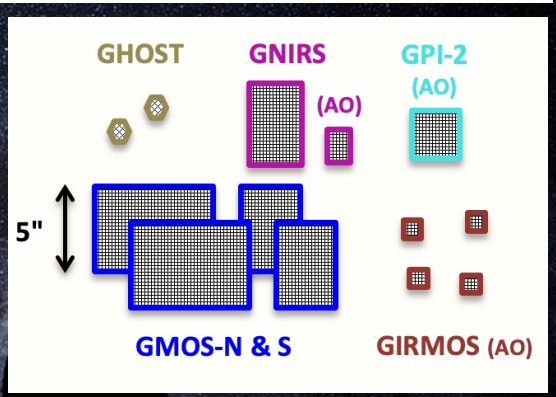
Gemini provides its community with the best possible competitive instrumentation suite within technological, budget and staffing constraints.

- Operates 4 facility instruments plus 1 AO system at each telescope.
- Incorporates a new facility high resolution spectrograph.
- Builds a major workhorse multi-channel instrument for transient source follow up.
- Develops an advanced AO system for GN.
- Runs three major upgrades of workhorse instruments and a long-term program to support use motivated upgrades.
- A rich Visiting Instrument Program also contributes to the diversity of capabilities.





Left: Wavelength coverage and spectral resolution schematic for current and future facility instruments. There is one GMOS per telescope, with multi-object spectroscopy capability. GRACES is a long term visiting high resolution spectrograph and GHOST is the next high resolution facility to operate in GS after 2020. **Top right:** Field of View (FOV) for current and future Gemini imagers. GSAOI 85" field of view is fed by the multi-conjugate AO system GeMS, and GIRMOS ~85" FOV to work with the future GN AO facility. **Right:** FOV for Gemini IFUs, including the community lead GPI-2 (in upgrade phase) and GIRMOS (in design phase).



Appendix 1: Future Instruments

- **GHOST**, a bench high-resolution optical spectrograph that is ready to be commissioned at GS. It will allow dual target observation in a 7' FOV, to fiber-feed a bench spectrograph with spectral resolution up to 70,000. **See Alan McConnachie's talk.**

- **SCORPIO**, a highly versatile instrument capable of performing simultaneous 8-band (g, r, I, z, Y, J, H and Ks) imaging, very-wide band spectroscopy across the optical and near-infrared, and very-high cadence observations down to tens of milliseconds, designed to enable rapid follow-up of Rubin Observatory Legacy Survey of Space and Time (LSST) identified sources at the GS telescope. Currently in the Build Phase, the instrument is expected to arrive at the end of 2023. **See Massimo Roberto's talk.**

- **IGRINS-2** is an exciting R~40,000 HK spectrograph, following up on the success of the popular visiting instrument IGRINS. The instrument is being provided by KASI and will be installed at GN in 2023. **See Greg Mace's talk.**

- Upgraded GPI (**GPI-2**): GPI is an extreme adaptive-optics imaging polarimeter/integral-field spectrometer, which provides diffraction-limited data between 0.9 and 2.4 microns. After completing its base science objectives it is being prepared for shipping to the UND for upgrades and re-commissioning at GN in 2023. **See Quinn Konopacky's talk about GPI-2 and Eric Nielsen's talk on GPI results.**

Gemini is also considering turning some visiting instruments into facility instruments. Two of them are:

- **MAROON-X** is a high-resolution optical spectrograph currently operating at GN, with radial velocity precision better than 1 m/s. **See Jacob Bean's talk.**

- **GIRMOS** is a community-lead project designed with high performance MCAO and the ability to carry out simultaneous high angular resolution, spatially-resolved infrared spectroscopy of four objects within a 2' field of view when used with the future **GN AO system** that Gemini is currently designing. **See Suresh Sivanandam's talk.**

Appendix 2: Obsolescence Program & Major Breakage Mitigation

- The instrument suite at both sites has an average age of 19 years from the me of their delivery. This puts them at almost twice their designed lifetime and given that many took several years to build, many components are approaching 25+ years old. All cryogenically cooled mechanisms are prone to abnormal wear and have a higher tendency to fail due to operation at very low temperatures typically without lubrication.
- Both for the obsolescence and for the Major Breakage mitigation we performed an analysis specially focused limited on items for which we have minimal to no spares. The subsystems covered include:
- Detectors – Optics – Mechanisms - Electronic (Motors and Boards).
- Estimates on the likelihood of subsystem failure are based on prior failure history and best guess assumptions. Estimates of impact are based on assessment by the Instrument scientists on observing capability loss. Likelihood and impact are categorized in a relatively coarse, but indicative, three-level system (1-3, low-high):
- Detailed studies of the various vulnerabilities. The next step will be to determine what mitigations are possible, and cost them in both hardware and FTE terms.