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EUROPEAN ORGANISATION FOR ASTRONOMICAL RESEARCH IN THE SOUTHERN HEMISPHERE

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Paranal Instrumentation Programme Plan
and 6 Monthly Report, March 2023

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CHANGE RECORD

Version	*Date*	*Paragraph*	*Changes made*
Cou-2047	03.04.2023		Cou-number on pages 47 to 50
Cou-2047 rev.	26.04.2023	Cou number in header of pages 47 to 50	Wrong Cou-number (Cou-2016) was replaced by right one Cou-2047

1. Executive Summary

The Paranal Instrumentation Programme (PIP) provides new instrumentation and infrastructures, or upgrades to the existing ones, to fulfil the mandate: "*The VLT ... to stay at the forefront of image quality through novel adaptive optics concepts – and efficient new instrumentation in order to maintain its world-leading position*" (ESO Long Term Perspectives document (ESO Long Term Perspectives document [ESO/Cou-1689 rev, 2016]).

This plan (and report) is updated biannually. The programme includes (in *italics* the projects already in operation or integration/commissioning at Paranal):

- *the VLT/I second generation instruments (GRAVITY, ESPRESSO and MATISSE), the upgraded CRIRES+, the upgrade of the VLTI infrastructure to accommodate the second generation VLTI instruments, the upgrade of the GALACSI Infrared Sensor (IRLOS), the imager and spectrometer ERIS – all offered for observations to the community*
- two multi-object spectrographs (MOONS for VLT and 4MOST for VISTA)
- two new instruments (*NIRPS* and SOXS) for La Silla, fully funded by the community, NIRPS starting operation
- development of an upgrade and replacement plan for the VLT workhorse instruments
- a visible MCAO instrument for UT4/AOF (MAVIS)
- the upgrade of FORS
- CUBES, a new, efficient UV spectrograph
- the enhanced GRAVITY+ system at VLTI

Initiating approximately one new instrument and one instrument upgrade every two years, the programme planned to reach a quasi-steady state in ~2021, with eight to nine projects running at any time. The COVID-19 pandemic has delayed the completion of several on-going projects, so the number of projects presently running is higher than foreseen, but this quasi-steady state will be reached in 2023. In principle, increase in scope, delay, or overspend is accommodated within the total resources available by either rephasing or de-scoping the existing projects, or by shifting the start of new ones. Recent delays and the restrictions adopted as a result of the higher-than-estimated inflation rate have forced the start of BlueMUSE Phase A study to the beginning of 2024. Based on the very successful MUSE, the project is considered a low technological risk. It will be initially followed up by a reduced team (project manager, scientist, and engineer) with very limited ESO deliverables, the same follow-up scheme used for CUBES.

ERIS commissioning continued; it was offered in all modes except the high contrast mode. The problems related to the pupil wheel are now understood and the AO limiting magnitudes greatly improved. The instrument has been made fit for the start of regular operations. NIRPS, the near IR planet hunter, had the main echelle replaced by the final, high performance one, and commissioning is now finished. MOONS, 4MOST and SoXS, in integration in Europe, advanced towards PAE. CUBES passed PDR.

A risk policy for the programme is active. The long-term spending power of the PIP budget is protected by indexing for inflation the non-contracted funds. In a similar way, human resources are allocated as FTEs/Year at a flat rate. A new lessons learned exercise has been organised by the Director of Programmes for March 2023 and will include in-house and consortium-led projects. A new section to the plan has been added to this issue, to cover minor projects.

2. Introduction

The fundamental goals for the Paranal Instrumentation Programme are summarised in several strategic ESO documents (Cou-994, 2004; Cou-1689 rev., 2016), and were confirmed in the recent article dedicated to the decadal ESO strategy (The Messenger 183, p.3, 2021): "*Ensure that the current facilities remain at the forefront of astronomical investigations, by e.g. Ensuring, in partnership with the community, that VLT, VLTI, ALMA (with ESO's partners), including their instrumentation, continue to be state-of-the-art*".

As far as the VLT/I instruments are concerned, this strategy is implemented following the guidelines discussed in the "Science Prioritisation Report" document (STC-551, 2015) and the guidelines for decommissioning the VLT instruments and upgrades (STC-569 and STC-570, 2016, STC-587, 2017). A roadmap for the VLT/I has been presented to STC (STC-658, 2020) that includes the outcome of the VLT2030 process (STC-646, 2020).

The instrumentation development plan provides a framework for the implementation of new instrumentation and upgrades and proposes an implementation that allows a renewal of the Paranal instrumentation consistent with the available resources, while maintaining the commitments taken for the running of VLT and VLTI projects. The plan does not include obsolescence management or maintenance of ageing instruments; these are the responsibility of the Paranal Observatory, although they are implemented within the PIP projects in the event of instrument upgrades.

The complement of VLT/I instruments in operations or approved (see figures 1 & 2 and the tables in Appendix A) cover most options in imaging (including Adaptive Optics (AO) and VLTI diffraction limit) and spectroscopy in the 300-24000 nm range.

The wavelength/resolution coverage is not the only relevant parameter space; the Paranal instrumentation set includes five Integral Field Unit instruments (three AO-assisted) and at least four multi-object spectrographs. The Paranal Observatory provides polarimetry, high contrast imaging and coronography, fast photometry, and superb astrometry as well as the finest instruments for precise Doppler shifts determination.

The strategy for the VLT in the era of full ELT operations has been developed through discussions with the community at large and a dedicated workshop, which took place in June 2019. The workshop is summarised in STC-639 (2019), STC-646 (2020), and a Messenger article (Messenger Vol. 177, p. 51, 2019). The STC, in its 95th meeting, recommended starting the Phase A study of GRAVITY+ immediately, and BlueMUSE not later than 2022. An additional call that will include a high-resolution MOS is planned to follow in 2024.

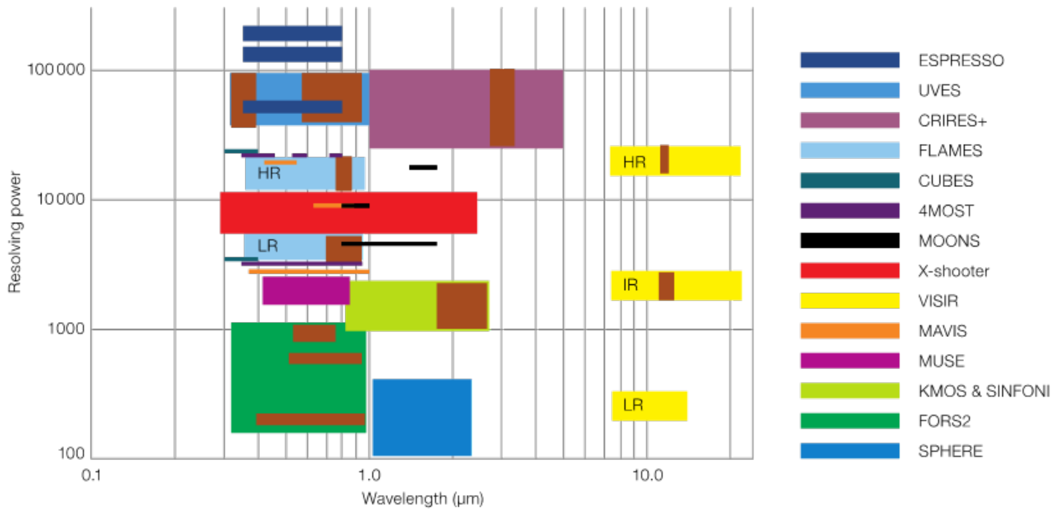


Figure 1: Wavelength - Resolving Power diagram for the VLT instruments, including those under design and construction.

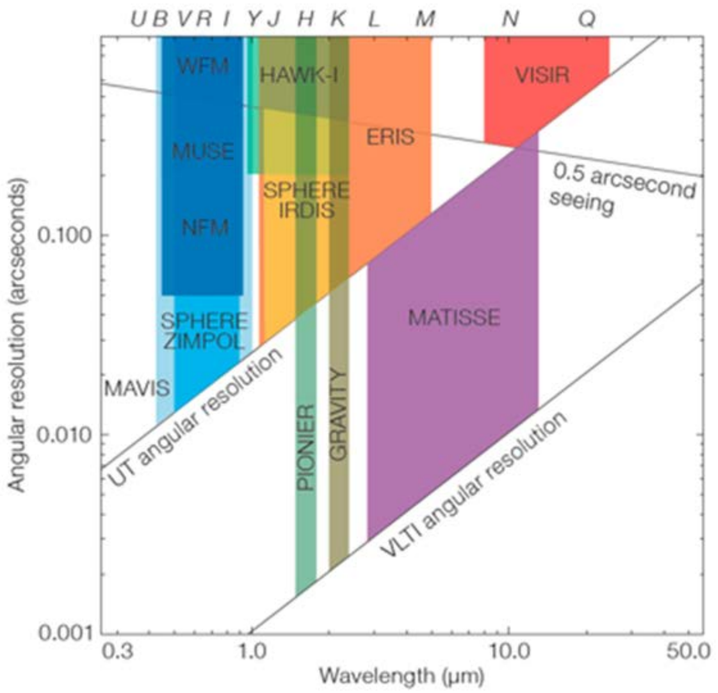


Figure 2: Wavelength - Angular Resolution diagram for the VLT and VLTI instruments, including those under design and construction. MAVIS will replace HAWK-I at UT4.

3. Current Programme

Table 1 summarises the status of the projects under PIP governance. It contains projects in all phases, from design to commissioning. MAVIS started the design phase in early 2021, followed by CUBES and GRAVITY+ in early 2022. After the outburst of the COVID-19 pandemic, the situation is now normalised for all projects, though delays in the delivery of specific components might still be considerable.

Project Name	Description	Status
1. ERIS	AOF Imager and Spectrograph	Commissioning/Operations
2. MOONS	IR Multi-Object Spectrograph for VLT	Integration Europe
3. 4MOST	Optical Multi-Object Spectrograph for VISTA	Integration Europe
4. FORS Upgrade	New Detector, ELT electronics & SW	Design & Construction
5. MAVIS	Visible MCAO for UT4	Preliminary Design
6. GRAVITY+	Upgrade of infrastructures for VLTI	Design & Implementation
7. CUBES	UV Spectrograph	Final Design
LA SILLA		
8. SOXS @ NTT	X-Shooter – for NTT	Integration Europe
9. NIRPS @ 3.6m	IR Planet RV and atmospheres	Operations
PHASE A Studies		

Table 1: List and summary description of running Paranal Instrumentation projects. Delivery dates are given in table 2. Phase A studies are not approved projects.

3.1 Recent Instruments at Paranal

Several instruments and projects have been offered for observing incrementally, for several years. CRIRES+, ESPRESSO, MATISSE have reached Provisional Acceptance Chile (PAC). For IRLOS and VLTI facility (GRA4MAT) all steps for PAC have been completed, only minor actions may be left, so we no longer report on these projects, as part of the programme.

At the end of ERIS commissioning, the pupil wheel of NIX failed, but after the analysis and adaptation of the control parameters is now working. The AO limiting magnitudes are now also close to expectation (the simulations were too optimistic). The long-awaited new echelle for NIRPS was delivered and mounted in the instrument, enhancing greatly its performance. The GRAVITY+ intervention planned on UT2 was postponed because it must happen at the same time as the M1 recoating, which has been postponed to 2023.

3.1.1 ERIS

Principle Investigator	R. Davies, MPE
Consortium Institutes	MPE Garching (lead) INAF/Arcetri Astrophysical Observatory, Firenze UK ATC, Edinburgh ETH Zürich NOVA Leiden ESO (associated)
ESO Project Team	A. Glindemann (PM), H. Kuntschner (PS), A. Cortés (PE)
Installation Location/Date	Cassegrain UT4/2021
Status	Commissioning Phase
Guaranteed Nights	210

3.1.1.1 *Overview/Description*

ERIS is a new instrument for the Cassegrain focus of UT4, comprising:

- A new diffraction limited IR imaging camera (“NIX”)
- A modified version of SPIFFI to adapt it to the new AO module (“ERIS-SPIFFI”)
- An AO WFS module (visible NGS, LGS), which will use any one of the four AOF lasers (one at a time).

ERIS with its IR imaging camera replaces the functionality of the most important NACO modes in imaging (1-5 µm) with enhanced AO performance, using the AOF’s deformable secondary mirror for AO correction. These improvements are also transferred to SPIFFI, resulting in better AO performance compared to SINFONI, including increased sky coverage.

3.1.1.2 *Highlights of period*

The last commissioning run took place in early November 2022 as planned, and the science verification in December 2022. Six half nights for Paranalisation followed at the end of January 2023.

ERIS Science Verification was conducted from 2 to 6 December 2022. Most of the planned SV observing programme could be accomplished. There were 87 submitted proposals. 23 observing programmes were scheduled for a total of 40 hours of observations. Five of the seven top-ranked proposals could be fully completed, the other two were partially completed. In total, eleven programmes could be completed, seven received partial data and three programmes could not be started.

Several technical problems surfaced during these runs but most of them have been resolved in the meantime, some of them during a dedicated intervention in December 2022:

Intermittent problems with the AO acquisition camera led to replacing the camera with its spare and it was sent back to Europe for further analysis. Once repaired it will be sent back to Paranal as a spare.

A problem with the pupil alignment could be traced back to the mounting of the adapter/rotator on the flange of the Cassegrain focus. This was fixed during the December 2022 intervention. However, the final confirmation that this problem can be closed is pending.

At the same time the pupil wheel of the NIX camera failed in November 2022 but worked again during the intervention in December 2022 after NIX had been warmed up. After some further problems when it was cooled down again some improper parameter settings of the motor controller were identified as the root of the problem in January 2023. Now the pupil wheel is operational again. However, this was too late for performing the pending final tests on the remaining high-contrast imaging mode reported in the last period so that they cannot be offered for Period 112 starting in October 2023.

The ERIS AO team had already commissioned the capability to use any of 2 lasers (#2 or #4) from UT4 and, during two nights of Technical Time in January, provided support to the task of commissioning the capability to use the 2 other (#1 and #3). The crucial activities were completed (pointing model of the lasers, Control Matrices generation) but some other ones could not be completed due to bad weather and telescope closure (e.g., run Science OBs with any of the 4 lasers, characterise performance, map of the leakage of laser light in the NGS WFS channel). This will be done by the Paranal team during twilight in March 2023.

During the Operational Readiness Review (ORR) two red flag issues were identified: the first one concerned the problems with the pupil wheel, which are now resolved, and the second one concerned the documentation of the emergency procedures. The latter has been closed and the documentation upgraded accordingly.

In the next period, the pending tests for the high-contrast imaging mode will take place and science operations will start.

3.1.1.3 *Technical activities*

Milestone schedule			
Major Milestones	Planned date at kick-off/Stated in agreement	Actual date, or current best estimate	Slip (months)
ERIS PDR	Q1 2016	Q1 2016	0
ERIS FDR	Q1 2017	May 2017	2
ERIS PAE	Q4 2019	Q3 2021	20
ERIS PAC	Q4 2021	Q4 2023	24

Current main risks	
Risks	Planned action
Pupil misalignment affecting high contrast imaging	Further analysis and realignment

Brief bullet summary of upcoming activities for next period
• Pending tests for high-contrast imaging modes

Brief bullet summary of upcoming activities for next period
• Science operations

3.2 Projects Currently Under Development

A few projects are being developed in collaboration with consortia in ESO Member States. MOONS and 4MOST are in the AIT Phase, CUBES passed its preliminary design review in November 2022, while MAVIS will go through PDR at the end of March 2023. GRAVITY+ has a non-standard development, with reviews and implementations interleaved. The third review milestone has been moved because of a clash with the MAVIS PDR and with other GRAVITY+ activities in Paranal. The intervention on UT1 has in fact been moved to 2023 because the telescope was not available. MOONS and 4MOST are converging towards PAE despite a couple of months delay with respect to the previous biannual report. Most of the HW has been delivered to the lead institutes. MOONS has performed the first cooldown with both spectrographs, and 75% of the fibres have been mounted. The corrector has been commissioned at Paranal. For 4MOST, the corrector is at AIP, the loop with the metrology cameras has been closed together. One of the two low resolution spectrographs has been delivered while the high resolution is going through local acceptance at the partner premises. The Paranal Instrumentation Programme is also responsible for the development of the infrastructure upgrades, enabling the instruments to deliver their best performance, and 4MOST is of this nature.

3.2.1 MOONS

Principle Investigator	M. Cirasuolo, O Gonzales, UK ATC (Astronomy Technology Centre)
Consortium Institutes	CAAUL, GEPI, INAF, AIUC, ETH, ESO, University of Cambridge, University of Geneva
ESO Project Team	P. Hammersley (PM), A Manescau (PE), A Bayo (IS)
Installation Location/Date	Nasmyth platform of UT1, Q2 2024
Status	Integration Phase
Guaranteed Nights	298

3.2.1.1 *Overview/Description*

MOONS is a 0.8 to 1.8 microns multi-object spectrometer for the Nasmyth focus of the VLT. The instrument is fibre fed, has a multiplex of 1000, and covers a total field of 25 arc minutes in diameter. There are two spectral resolving powers, ~4000 spanning the full wavelength range and a higher resolution mode which gives ~9000 in the I window and ~20,000 in a region in H windows. The instrument itself has two main parts:

- The rotating front-end, which is at the focal plane and houses the fibre positioners, acquisition system, metrology system for the fibres, etc.
- The cryogenic spectrograph, which houses the spectrograph optics, VPH gratings and detectors.

3.2.1.2 *Highlights of period*

All the components except the last science detectors have been delivered. The Integration Readiness Meeting was successfully held in July 2020 and both the spectrometer and front end are currently being integrated.

The first cold test with five cameras (side one, which is complete and side two, which has two of the three cameras), was made in February 2023. The problems found in the earlier cool down were resolved and the detector adjustment modules now work reliably. The image quality on all detectors is as expected. There are still three science detectors to be delivered to the consortium, which should be completed by May 2023. The delay was in part caused by having to return two Hawaii 4 RG detectors for repair. However, this delay has led to the expected PAE being pushed back until November 2023. Thus, the instrument is now expected to arrive on Paranal in Q1/2024.

Installation of the positioners on the plate is continuing. When tests were made moving all the positioners through difficult trajectories some initial issues with the cables were found. This affected about 25 of the positioners but was successfully resolved. It did, however, lead to a delay in the installation of the positioners. The mechanics for the rotating front end (RFE) completed in Portugal has been shipped to the UK-ATC. There was a successful mission to the UK-ATC in January 2023 to mount the RFE on its support and check the calibration screen. The positioner plate will be installed into the RFE in May 2023.

The field corrector was successfully mounted and tested on UT1 in October/ November 2022. The performance of the corrector was as expected, and half arc second images were obtained.

The OPS software, particularly the one for source selection optimisation and trajectory, has functioning prototypes and work in improving its performance is progressing. The pipeline is also progressing with many of the recipes being operational.

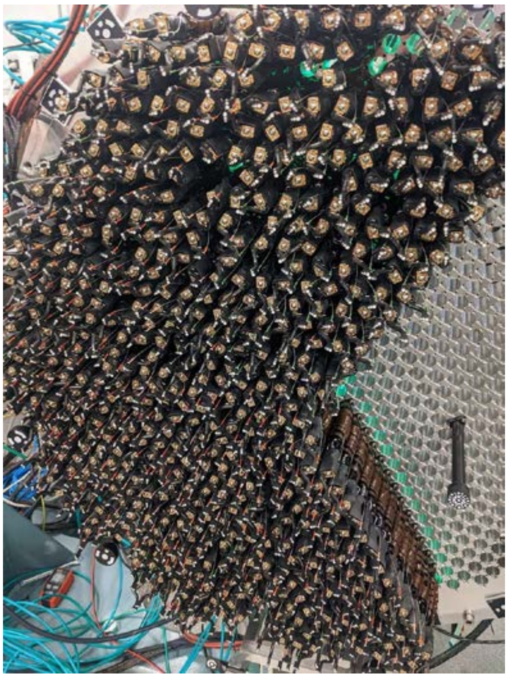


Figure a) 66% of the positioners have been mounted and the first test moving all the positioners have been made.

Figure b) The rotating front end mounted on the support mount.

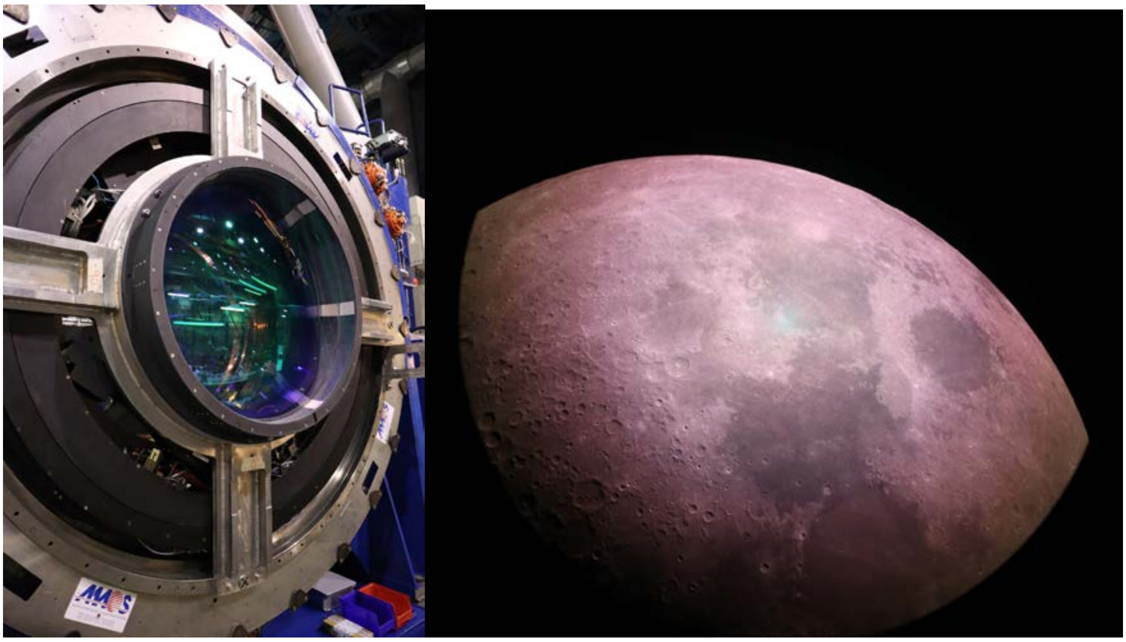


Figure c) the corrector mounted on UT1 and the first light image, projecting onto a screen. The Moon appears red because the anti-reflection coating is optimised for the red and IR, not the blue.

3.2.1.3 *Technical activities*

Milestone schedule			
Major Milestones	Planned date at kick-off/Stated in agreement	Actual date, or current best estimate	Slip (months)
Kick-off meeting	October 2014		
PDR	September 2015	22 October 2015	1
FDR	Q4 2016	Q1 2017	3
PAE	Q3 2019	Q4 2023	51
PAC	Q2 2020	Q2 2024	51

Current main risks	
Risks	Planned action
Delays during AIV.	
Shipping costs.	

Brief bullet summary of upcoming activities for next period
• Run cold tests with the full instrument. • Completion of the Rotating front end • Prepare for PAE and hold the TRR

3.2.2 4MOST

Principle Investigator	Roelof de Jong, AIP
Consortium Institutes	Leibniz Institut für Astrophysik Potsdam (AIP) Australian Astronomical Observatory (AAO) Centre de Recherche Astrophysique de Lyon (CRAL) Zentrum für Astronomie der Universität Heidelberg (ZAH) Institute of Astronomy, Cambridge (IoA) Max-Planck-Institut für extraterrestrische Physik (MPE) Max-Planck-Institut für Astronomie (MPIA) Nederlandse Onderzoekschool Voor Astronomie (NOVA)
ESO Project Team	J.-F. Pirard (PM), J Amiaux (PE), V. Mainieri (PS)
Installation Location/Date	VISTA Telescope 2023/2024
Status	AIT Phase
Guaranteed Nights	70% for five years' operation (more than 2200 multiplex); options up to 10 to 15 years' operation, with respectively 20% and 15% fibres hours.

3.2.2.1 *Overview/Description*

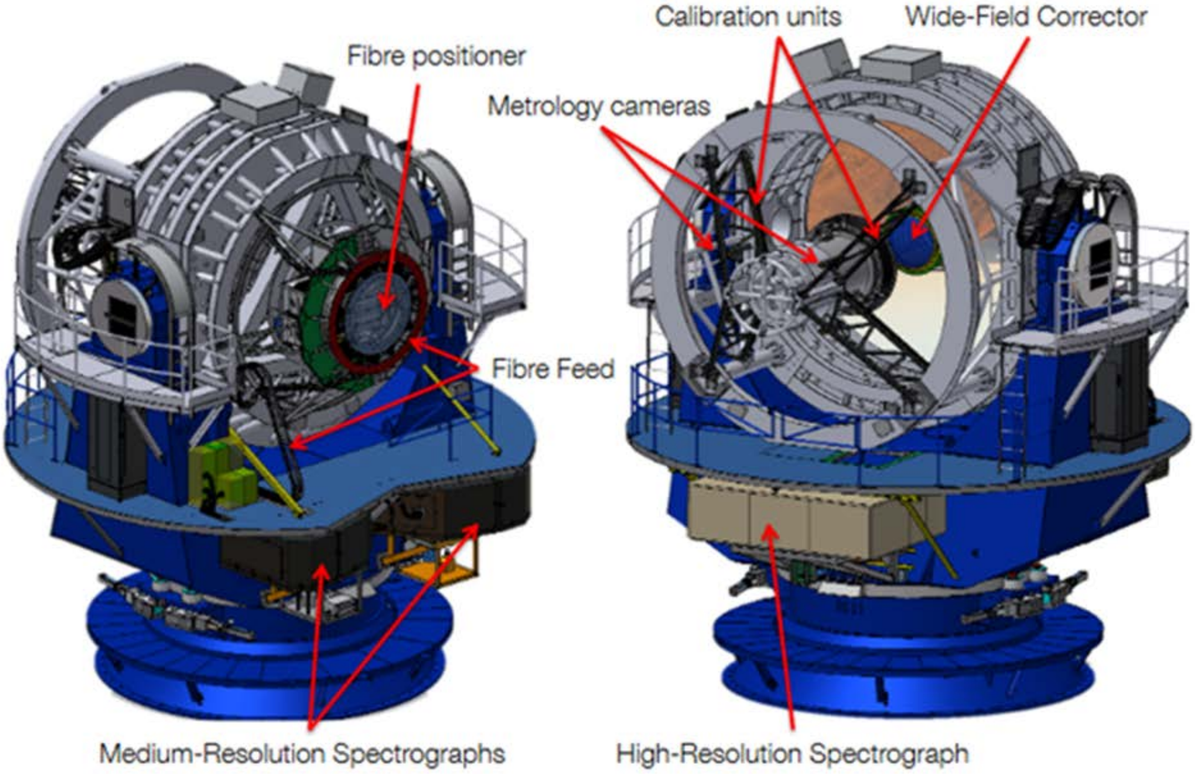
4MOST will provide the ESO community with a world-class optical spectroscopic survey facility that will make major contributions to many of the science areas: From the Extreme Universe (Dark Energy & Dark Matter, Black Holes), to Galaxy Formation & Evolution, to the Origin of Stars and Planets. The unique capabilities of the 4MOST facility are enabled by its large field-of-view, high multiplex, its broad optical spectral wavelength coverage, and a dedicated telescope at a first-class astronomical site: VISTA at Paranal.

As a spectroscopic survey facility, operations of 4MOST will be different from normal operations. To efficiently fill all fibres and to make low target density surveys possible, all 4MOST surveys will be merged into one survey and observed simultaneously.

4MOST's unique capabilities result from:

- Large field of view (>4 deg2)
- Spectral resolutions (LRM: R>5,000, HRM: R>18,000) for both galactic and extragalactic applications
- High multiplex (>1400 in LRM, >700 in HRM)

- Minimum broad wavelength coverage in LRM (400-885 nm)
- Minimum broad wavelength coverage in HRM (393-435, 516-573, 610-679 nm)
- Implementation at the Cassegrain focus of the VISTA telescope (Paranal).



Overview of 4MOST Facility Design.

3.2.2.2 *Highlights of period*

- Delivery of the LRS2 & HRS spectrographs to Potsdam
- Delivery of the calibration system to Potsdam
- Local Acceptance Review of the Wide Field Corrector
- Preparation of TRR Activities
- End of VIRCAM Operation before M1 recoating

3.2.2.3 *Technical activities*

The 4MOST facility project is progressively finalising the MAIT phase. Several subsystems and test set-ups are being delivered and tested at Potsdam. The system integration is progressing with the first delivered subsystems:

- The WFC System local acceptance Review took place last February.
- The LRS-B has been reintegrated at Potsdam and some retrofitting has been performed on the LRS-A and Detector Systems to solve some non-compliance and/or to implement some improvements.
- The HRS has been reintegrated at Potsdam. The green channel camera sent back to New Zealand for recoating has now been repaired and will be shipped back soon.

- The CaCW reliability is still under testing. An NCR has been escalated to ESO to reduce de-rotation range and is being evaluated.
- Several activities took place in the integration hall: retrofitting of AESOP hexapod, Focal Surface Test Tool (FSTT) integrating and testing, first integration of focal plane subsystems on the Cassegrain Test Stand (CTS).
- Camera physical CCD to Datum measurements has been completed for 6 A&G/WFS allocated cameras.
- The Secondary Guiding camera has been installed for integration testing and could successfully produce images.
- The control software development is in progress with the move to VLT Software 2022, the development and testing of the Secondary Guiding software, the coding of templates, the validation of TCS interface.
- The control electronics is fully delivered. The team is supporting the different system activities.

3.2.2.4 *Scientific/Operations activities*

In terms of science & operations, the highlights are the following:

- OpR 3 has started. OpSys and FROG are working on creating the raw dataset equivalent to 2 weeks of observations. The feedback loop from DMS to OpSys will also be developed during the running of this slow rehearsal. There has been excellent interaction with ESO on many of the interfaces for the designated visitor mode. These interfaces are partially even ahead of schedule.
- The Catalogue Readiness Review planned for March 2028 has focused efforts on defining and providing all catalogues required for 4MOST. The Survey catalogues are almost all now based on real targets instead of mock targets, making realistic simulation possible taking shared targets between surveys into account.
- All fifteen selected Community Programmes have submitted articles that will be published in the next ESO Messenger thereby assuring that the goals and strategy of all approved 4MOST programmes are available to the entire astronomical community.
- Most Surveys have completed advanced versions of their Survey Management Plans that form the input to the overall 4MOST Survey Management Plan to be submitted to ESO.
- A Data Release Plan (DRP) was formulated to provide schedule and content of the 4MOST data releases in the first 5 years of its operation. Initial discussion with ESO on the DRP have taken place with agreement reached on many points.
- The preparations for the next Science Team Meeting (STM2023) have started. STM2023 will take place in Bristol, UK at the University of Sussex, on 8-12 May 2023.

3.2.2.5 *Vista Modification*

The preparation of the VISTA Telescope modification is progressing:

- The mechanical parts for the VISTA modification are in manufacturing at the Paranal workshop.
- The parts necessary for the cooling, the electrical and the network modification have been shipped to Paranal.

- During the last months several technical runs on the VISTA Telescope in the VIRCAM configuration have taken place to validate as much as possible the new TCS software in terms of new interface, wavefront sensor, upgrade to new VLT software before the change to the 4MOST configuration.
- The recoating of the VISTA Telescope is taking place in March 2023. In April 2023, some final characterisation of the telescope will be recorded before the final decommissioning of VIRCAM, a first set of modification will take place between May and June 2023.

3.2.2.6 *4MOST Project*

At project level, the following activities are taking place:

- The 4MOST Project at ESO is preparing all the activities for the 4MOST acceptance. The PAE Plan shall be issued soon. It is foreseen to split TRR and PAE in sub-milestones to allow the shipment and the implementation of the telescope sub-system in advance of the rest of the facility.
- A PAC Plan is also under preparation.

Milestone schedule			
Major Milestones	Planned date at kick-off/Stated in agreement	Actual date, or current best estimate	Slip (months)
Kick-Off	August 2016	June 2016 (Letter of Intent)	-3
PDR	June 2016	June 2016	0
FDR1	February 2018	May 2018	3
FDR2	February 2018	March 2019	13
TRR1	June 2021	May 2023	22
TRR2		September 2023	26
PAE1	December 2021	September 2023	22
PAE2		October 2023	23
PAC	September 2022	September 2024	24

Current main risks	
Risks	Planned action
Delays of sub-system delivery and system AIT	Rescheduling of project. TRR-PAE schedule updated
Technical Problem with the CaCw and LLF	Management of identified problems taking place. Brainstorming session being organized with expert.
Lack of Manpower in particular for Operation System (profile: experienced software engineer)	Action taken by management

Brief bullet summary of upcoming activities for next period
• Local Acceptance Reviews (LAR) of several subsystems: AG&WFS, FSTT, LFF • TRR and PAE • Review of the Survey Management Plan

3.2.3 MAVIS

Principle Investigator	François Rigaut
Consortium institutes	Australian Astronomical Observatory, ANU & Macquarrie, INAF (Arcetri, Padua, Milano, Capodimonte) Laboratoire d'Astrophysique de Marseille
ESO Project Team	P-Y Madec (PM), H. Kuntschner (PS), U. Seemann (PE)
Installation Location/Date	UT4 Nasmyth A, ~2030
Status	Preliminary Design
Guaranteed Nights	150 + 50 (additional funds provided by MAVIS)

3.2.3.1 *Overview/Description*

MAVIS is the Multi-Conjugate Adaptive Optics system in the visible for the VLT. This system will replace GRAAL/Hawk-I on UT4 towards 2030. The target specifications require a Strehl ratio larger than 10% at 500 nm in a 30" field of view. Science cases have been developed around such a concept and showed that an Integral Field Unit would benefit many of these (~50% or more). Thus, a spectroscopic mode is being developed as well; the IFU would have a 3.6x2.5" with wavelength coverage of 370-950 nm for a resolution >5,000 (possibly >10,000; 25mas or 50mas sampling respectively).

3.2.3.2 *Highlights of period*

- The MAVIS Consortium actively prepared the documentation for the PDR review; the documentation was delivered at the beginning of February 2023 as planned, and the PDR process is now on-going. It covers the complete MAVIS instrument and encompasses 70 documents. The review is planned for 30 March 2023.
- The MAVIS schedule has been updated with the delivery of the PDR documents. The FDR is now scheduled for December 2024; the PAE is planned in May 2029; the installation on the telescope should happen in February 2030, and the PAC in August 2030. This represents a bit more than 2.5 years delay due to a re-assessment of the duration of the different phases of the project based on the actual preliminary design and a better understanding of the work to be done during the MAIT and commissioning periods. As compared to the initial schedule, the PDR is delayed by 7 months. The duration of the Final Design phase has increased by 8 months (total duration 15 months), the MAIT phase will last 10 more months (total duration 4 years and 5 months), and the time needed to reach the PAC is now 15 months instead of 8 months. When compared to the development time of other Paranal Instrumentation projects, this new schedule seems realistic.
- The MAVIS consortium approved the CRE submitted by ESO concerning many updated Applicable Documents. The preliminary design of MAVIS will be evaluated against the previous version of the applicable documents. The reviewers are asked to spot inconsistencies (if any) with the new versions, to be fixed by the consortium during the final design phase. After the PDR, the Technical Requirement Specifications will be updated to include the new version of the applicable document.

3.2.3.3 *Technical activities*

Milestone schedule			
Major Milestones	Planned date at kick-off/ Stated in agreement	Actual date, or current best estimate	Slip (months)
KO Design and construction	June 2021	June 2021	0
PDR	August 2022	March 2023	7
Long Lead Item	February 2023	September 2023	7
FDR	September 2023	December 2024	15
Assembly Read. Rev.	May 2025	July 2028	38
Test Read. Rev.	January 2027	January 2029	24
PAA/E	April 2027	May 2029	25
PAC	December 2027	August 2030	32

Current main risks	
Risks	Planned action
Funding envelope is not sufficient for the cost of hardware, and could be impacted by inflation, currency exchange, supply chain constraints and the value of materials throughout the project. The additional funding secured by the consortium leaves a shortfall of about 500 k€.	▪ Descope and postpone descoped option(s) to later phase ▪ Identify better cost to performance options for the high cost of components. ▪ Procure critical components as early as possible (detectors, slicers)
Delays in procurement of parts/material due to tension on the supply chain worldwide (Russia-Ukraine war).	▪ Procure critical components as early as possible (detectors, slicers)
Project understaffing, due to an increased number of projects led by Astralis and due to the additional 2.5 years delay to completion.	▪ Inform the MAVIS Executive Board and Steering Committees about the additional delays and seek for longer support as well as a high level of priority amongst the Astralis led projects.

Brief bullet summary of upcoming activities for next period
• Follow-up the PDR critical actions (if any) to allow starting as soon as possible the final design phase • Finalise and release the new version of the Technical Requirement Specifications • Start preparing the Long Lead Item review, to allow an early procurement of the critical components (see the project risks) • Follow-up closely the MAVIS DM Tech. Dev. Contract: Test Review to be successfully passed (June 2023) and start of the manufacturing of the scale one prototype of the MAVIS DM • Follow-up on ALICE and NGCII procurement milestones

3.2.4 CUBES

Principle Investigator	Stefano Covino
Consortium institutes	INAF - Istituto Nazionale di Astrofisica, Italy, (consortium leader) STFC-UKATC - UK Astronomy Technology Centre, UK Durham University Centre for Advanced Instrumentation, UK LSW-Landessternwarte, Heidelberg, Germany NCAC- Nicolaus Copernicus Astronomical Centre, Poland IAGUSP Instituto de Astronomia, Geofísica e Ciências Atmosféricas and LNA Laboratório Nacional de Astrofísica, Brazil
ESO Project Team	O. Sqalli (PM), M. Schöller (PS), P. Bristow (SE)
Installation Location/Date	UT1-2-3 in 2027
Status	Phase B: Preliminary Design Review
Guaranteed Nights	90

3.2.4.1 *Overview/Description*

The interaction with the consortium is so far quite easy and smooth. The data package for the PDR review (Preliminary Design Review) was submitted on 17 October 2022. Reviewers acknowledge the considerable effort and work performed by the consortium. The details provided as well as the models show that the design and analysis made are quite advanced, some at FDR level already. Nevertheless, some critical actions were identified. Indeed, the position and the performance of the atmospheric dispersion compensator (ADC) needs to be carefully analysed on the one hand, and, on the other hand, the mechanical model needs to be updated in order to reflect the integration and alignment steps of the alignment plan and to be at PDR level.

A fibre link is being studied for simultaneous observations with CUBES and UVES. Technically, the option is feasible, and the implementation is possible. The PDR data package demonstrates this. The decision as to whether ESO would like to implement this option, needs to be made as soon as possibe to avoid unecessary work at the consortium level.

The action items reulting from the PDR review will be closed in Q1/2023. The aim is to have the long lead item review in July 2023 to allow the consortium to purchase the optical elements and the detector.

The CUBES facebook page was also created: (https://www.facebook.com/CUBES-105746434528638 by the Consortium.

3.2.4.2 *Highlights of period*

The Consortium has also started to work on the ESO ICS SW standard documentation (ELT) to get acquainted with this new environment.

Many meetings with the consortium took place to clarify the interfaces with the UVES link, the interfaces with the Test Stand and the liftig tools in Paranal, all the tests needed for the PAC and PAE, the logistics aspects including the transport containers showing that INAF is ramping up the activities not only to fulfill the PDR milestone but also to prepare the FDR.

The Progress Report # 2 took place on 20 September 2022: all open questions regarding the PDR preparation were clarified. This includes, the mechanical models, the optical models, the detector trade-off, the cryostat trade-off, the required analysis, and the list of documents to be sent. A single, full-scope PDR was decided.

The INAF Consortium actively prepared and consolidated the documentation for the PDR review

The PDR data package was sent on 17 October 2022. The PDR review meeting took place on 30 November and on 1 December 2022. The PDR review board report was issued and forwarded to INAF at the end of December 2022. There are 98 RIXs closed with actions.

3.2.4.3 *Technical activities*

Milestone Schedule			
Major Milestones	Consortium Project Plan	Actual best estimate	Slip (months)
Start of Phase B	T0	T0: 15 February 2022	0
KM1 Kick-off Meeting (KoM	T0 + 1 month Kick-off: 24 March 2022	T0 = 1 month Kick-off: 24 March 2022	0
KM2 Delivery of Prototype (grating)	T0+9 months	T0 + 9 months	0
KM3 Preliminary Design Review (PDR)	T0 + 9 months	T0 + 9 months	0
KM4 Long Lead Items Review	T0 + 17 months	T0 + 17 months	
KM5 Final Design Review (FDR)	T0 + 24 months	T0 + 24 months	
KM6 Intermediate Milestone: Assembly Readiness Review	T0 + 45 Months	T0 + 45 Months	
KM7 Test Readiness Review (TRR)	T0 + 45 Months	T0 + 45 Months	
KM8 Provisional Acceptance (Europe) (PAE)	T0 + 57 Months	T0 + 57 Months	
KM9 Intend to Accept and PTO of the Instrument	T0 + 63 Months	T0 + 63 Months	
KM10 Provisional Acceptance (Chile) (PAC)	T0 + 65 Months	T0 + 65 Months	
KM11 Final Acceptance (Chile) (FAC)	T0 + 77 Months	T0 + 77 Months	

End of Agreement (EOA)	T0 + 101 Months	T0 + 101 Months	

Current main risks	
Risks	Planned action
ADC position	The dispersion in the UV is high. Therefore, for the guiding star, either a narrow band filter is needed or an ADC in a different position. An action was defined during the PDR review for clarification
Fiber link implementation	The design is made to implement the fiber link, but the project is waiting for the green light from ESO. In case it is refused, this would represent a considerable work performed by INAF for no added value.
Costs increase an inflation	The major risks identified are the detectors: an alternative to the E2V detectors exists and is 123k€ cheaper but associated with Risks. Savings were made by adapting the CUBES design to the ERIS carriage (250 k€) and by using the ESO test stand (50 k€).

Brief bullet summary of upcoming activities for next period

- Third Progress report in March 2023
- follow up of the actions to be closed for the PDR. The critical items are:
  - confirmation of the position of the ADC (atmospheric dispersion compensator)
  - consolidation of the mechanical models and interfaces
- Long lead items review: Optical elements (slicer, grating, lenses) and detector
  - Data pack in June 2023
  - Review meeting in July 2023

3.2.5 GRAVITY+ Project

Principle Investigator	F. Eisenhauer (MPE)
Consortium Institutes	Germany: MPE, MPIA, U. of Cologne, France: IPAG, LESIA, OCA, CRAL Portugal: CENTRA UK: U. of Southampton Belgium: Katholieke Universiteit Leuven
ESO Project Team	F. Gonté (PM), S. Oberti (PE), J. Woillez (PS)
Installation Location/Date	VLTI, over period Q2 2022 to Q4 2025
Status	Design and Implementation
Guaranteed Nights	277 single UT nights (divided by 4 for use of 4 UT VLTI)

3.2.5.1 *Overview/Description*

GRAVITY+ aims at upgrading several key capabilities of the VLT interferometer. They will improve the performance of the GRAVITY instrument on the UTs, and also serve other current and future VLTI instruments. A smaller subset also benefits observations with the ATs. GRAVITY+ subsystems can be developed largely independently from each other and will bring performance improvement in an incremental manner, as they are deployed. Key upgrades are:

- GPAO: New state-of-the-art higher order adaptive optics systems at the Coudé foci of the four UTs, replacing the MACAOs, upgrading the CIAOs, delivering increased coherent fluxes on bright objects such as e.g., exoplanet host stars.
- GRAVITY wide: External fringe tracking at wide separations using differential delay lines and star separators, significantly increasing the sky coverage of the interferometer for e.g., extra-galactic and microlensing science.
- LGS: New laser guide stars for UT1-3 to be used together with the UT4 4LGSF to further increase sky coverage for VLT interferometric observations, delivering increased coherent fluxes on faint objects such as e.g., extra-galactic active nuclei.
- Additional infrastructure performance improvements by reduced telescope vibrations, improved fringe tracking, background reduction in GRAVITY, and (already implemented in anticipation of GRAVITY+) higher throughput GRAVITY grisms.

3.2.5.2 *Highlights of period*

The Delta FDR for the BC-DDL was held in December 2022. Several critical actions have been defined to allow a good MAIT phase and well prepare the PAE process.
The loop has been closed on the AO test bench in Nice with the first WFS version and the first Corrective Optics version.

The Upgrade of the UT2 centrepiece has been postponed from November 2022 to April 2023 due to an issue with the handling tool of the M1 cell in the Main Mirror Building on Paranal.
The MANHATTAN system has been fully upgraded and is now in a period of tuning. Large level of vibrations has been detected on the M4 of the UTs and are being investigated, hoping for a direct mitigation.

The sub-Nasmyth platform for the UTs have been produced in Europe and are being transported by boat to Chile. The procurement for the upgrade of the cable wrap has been made and delivery should be made soon.

Milestone schedule			
Major Milestones	Planned date at kick-off/ Stated in agreement	Actual date, or current best estimate	Slip (months)
Phase A			
Phase A Kick Off			0
Phase A review			0
Agreement Signed	2021-12	2022-01-11	1
Phase B-E			
Kick off	2021-01-11	2022-01-11	0
Milestone 1: System PDR,	2022-02	2022-02-17	0
Milestone 1: GPAO PDR	2022-02	2022-02-17	0
Milestone 1: GRAVITY Wide Operation	2022-02	2022-09	7
Milestone 2: GPAO FDR	2022-07	2022-07	0

Milestone schedule			
Major Milestones	Planned date at kick-off/ Stated in agreement	Actual date, or current best estimate	Slip (months)
Milestone 2: BC DDL FDR	2022-07	2022-12	5
Milestone 3: System FDR	2023-03	2023-09	6(+6)
Milestone 3: LGS FDR	2023-03	2023-03	6(+6)
Milestone 3: BC DDL PAE	2023-03	2023-11	8(+2)
Milestone 4: GPAO PAE	2023-09	2024-04	7(+1)
Milestone 5: Operation GPAO NGS	2024-04	2024-10	6
Milestone 6: System PAE	2024-09	2024-12	3
Milestone 6: LGS PAE	2024-09	2024-12	3
Milestone 7: GPAO LGS operation	2025-04	2025-10	6
Complete System PAC	2025-10	2026-03	6

Completed Milestones – Pending Milestones – (+XX) slip variance since last STC

3.2.5.3 *Technical activities*

The following Technical Time Requests on Paranal have been completed:

- TTR-110.0013 (October 2022): major upgrade of the GRAVITY fringe tracker.
- TTR-110.0014 (December 2022): further improvement to GRAVITY fringe tracker, deployment of GRAVITY faint (reduced metrology contamination to spectrometer), and improvement to GRAVITY wide.

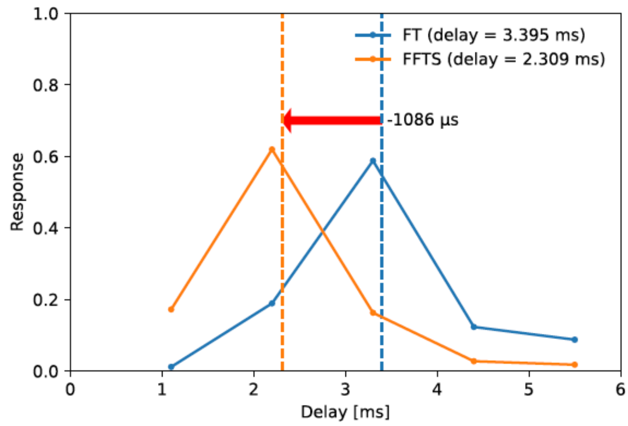


Figure 3: Piezo response before (blue) and after (orange) the fringe tracker upgrade, measured at the standard 909 Hz operating frequency. The latency gain (red arrow) is slightly larger than 1 ms

- TTR-110.0015 (January 2023): GRAVITY faint, and Manhattan upgrade.
- TTR-110.0016 (February 2023): GRAVITY faint completion, GRAVITY fringe tracker Kalman upgrade.

The following TTRs are on-going:

- IRIS upgrade is complete at the hardware level and should be finalised during the next period for the software part.
- VLTI/UT accelerometer extension; All telescopes have been upgraded with new accelerometers on the Coudé train (2 accelerators are still faulty and the update of the control software to reject the vibration is ongoing. The transfer function of the delay lines has been measured and shows a delay of 2.2 to 2.6 ms. Narrow band filter is being tested to reject specific vibration pick).

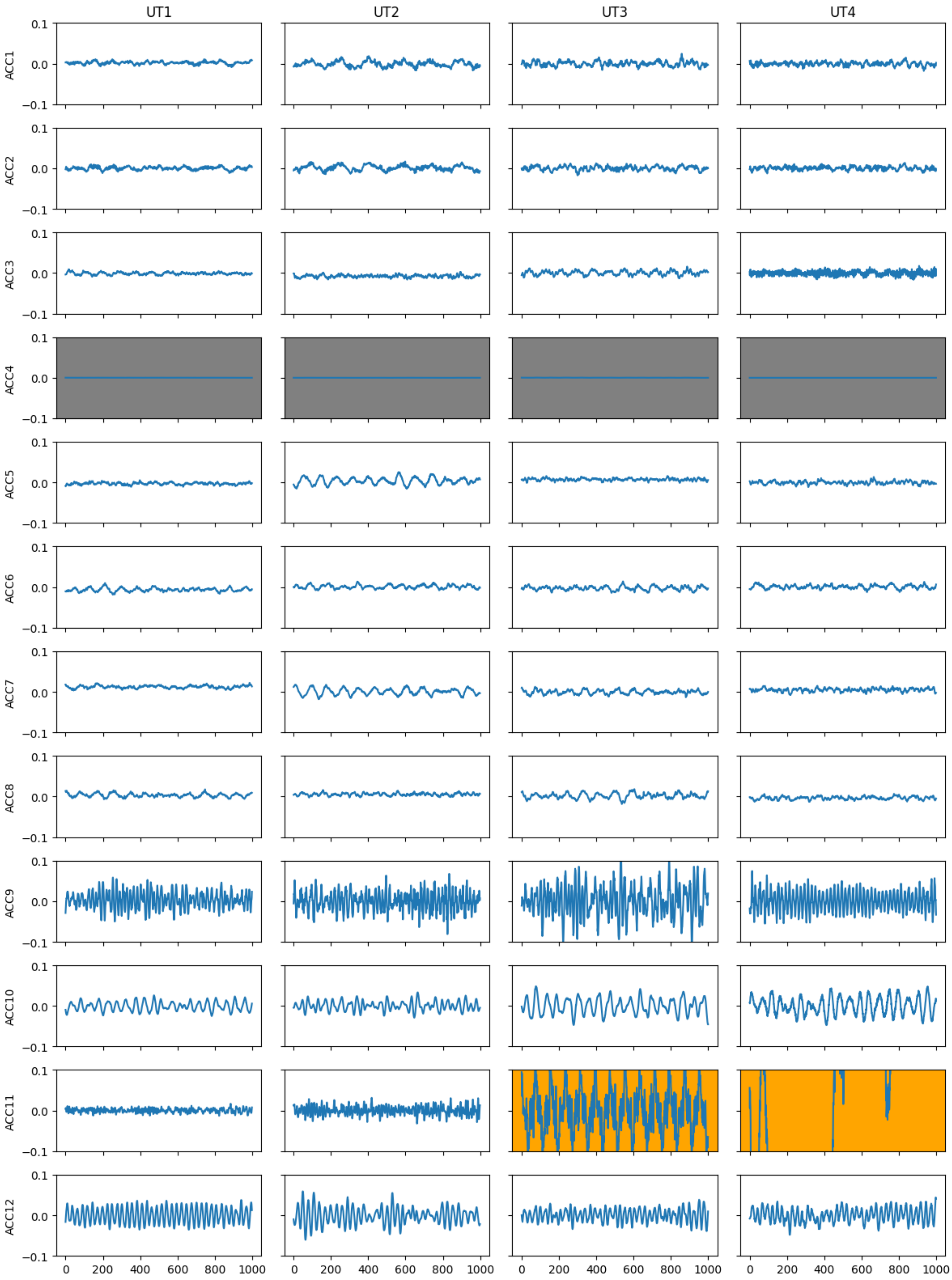


Figure 4: Waveform snapshots from the 12 accelerometer channels across the 4 UTs. Faulty channels are highlighted in orange. Channels corresponding to the not-yet-installed M8 accelerometers are greyed out (It will be implemented with GPAO). Note that UT4/M4 has a different gain than the other to avoid saturation (pick of vibration at 200 Hz).

- Dark hole testing in order to reduce star flux at short separation for exoplanet high contrast observation is progressing and will continue its development in the next periods

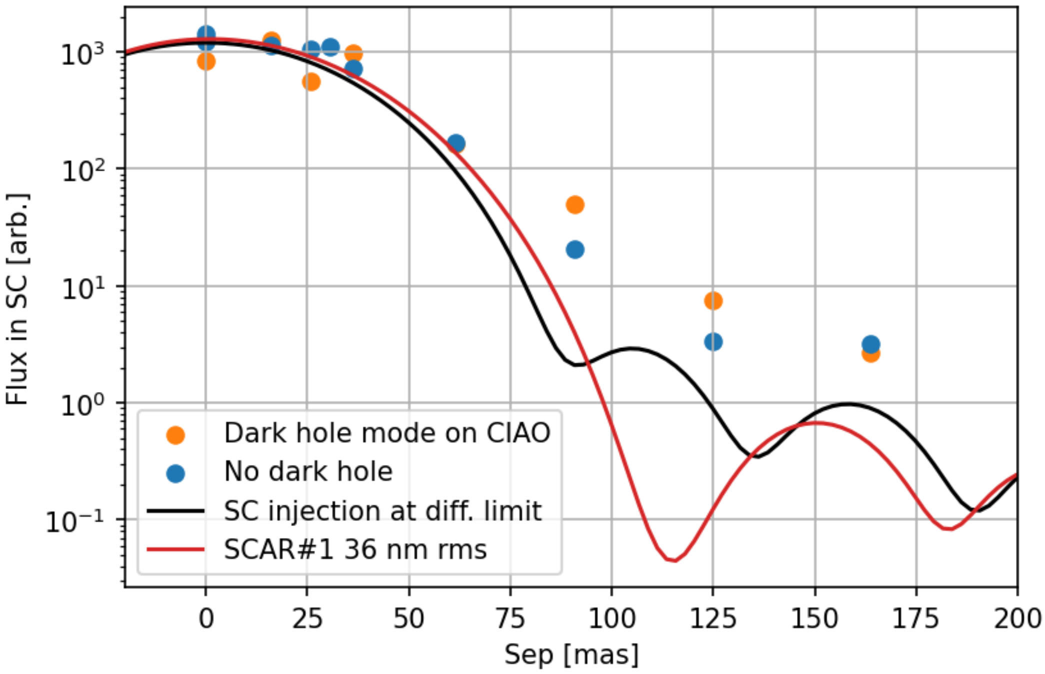


Figure 5: Flux injected in SC for different separations, with and without dark hole. The solid lines correspond to fibre injection simulations and the points correspond to the measurements on GRAVITY.

In Europe, several integration activities are on-going:

- The Nice AO test bench has now a full AO LGS with loop closed.

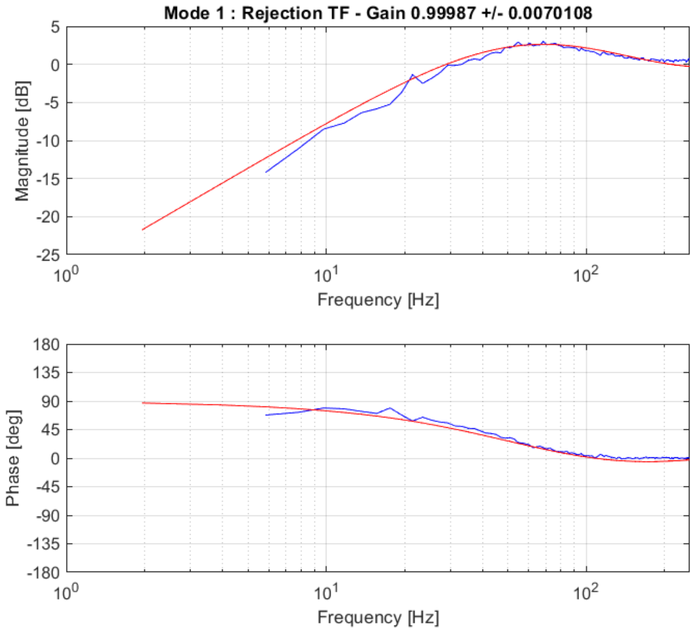


Figure 6: Transfer function on 1 mode of the AO system on the test bench

- MPE is developing the NGS WFS and has procured a second version of the DM to ALPAO with a 43*43 actuator baseline, first DMv2 should be delivered in September 2023
- The Sub-Nasmyth platform have been produced

Figure 7: Sub-Nasmyth platform in production in Germany before shipment to Chile

- The BC-DDL prototyping is progressing in parallel to the procurement of major components

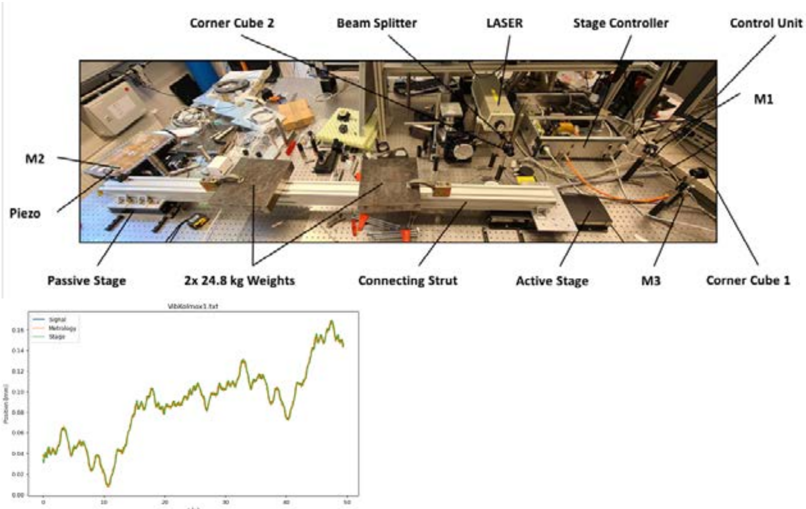


Figure 8: Left: BC-DDL Test bench and right perturbation rejection result

3.2.5.4 *Scientific activities*

The following commissioning on Paranal have been completed:

- GRAVITY Faint Commissioning
- First extra-galactic breakthrough science with GRAVITY wide is on its way.
- First galactic microlensing breakthrough science with GRAVITY wide has been challenging.

Current main risks	
Risks	Planned action
Paranal manpower requested for UT Upgrade not available due to operation.	We have communicated to the Paranal management that the request was made for key activity and removing the staff would endanger the schedule of the mission and the delivery of the UT for operation.
DM performance not achieved yet on the prototype	A new version is being developed by ALPAO and should correct the lack of performance.
Delay from TNO to deliver the LPS.	The full impact is not known yet, but it will be at the end up to a year of delay. Re-scheduling will be necessary and securing the FTE due this shift will be needed.

Brief bullet summary of upcoming activities for next period

GPAO Integration and test
- Integration of the NGS and of the corrective optics on the Test bench in Nice
- Follow up of the contract with ALPAO
- Further development of the RTC and testing in Nice

BC-DDL
- Procurement, integration, and testing of the BC-DDL

Paranal technical activities
- UT1 and UT2 centrepiece upgrade
- Sub-Nasmyth and cable wrap upgrade for UT1,2,3
- Finishing the IRIS upgrade for VLTI Dual Feed
- 2 runs on UTs and ATs MN2, Fringe Tracker and Gravity faint validation

3.3 Upgrades and Refurbishments

The programme is involved in upgrade and refurbishment projects, which are led by ESO. They include major obsolescence avoidance for which support from the Directorate of Operations is asked for. In collaboration with the STC, the VLT/I programme scientists have developed a strategic view that identifies the 'workhorse' instruments for the VLT, i.e., instruments that will have a substantially longer lifetime and will stay many more years at the telescope (STC-570 and STC-587). These are the instruments subject to upgrade and refurbishment. Mere obsolescence fight is not part of the PIP programme. At present the FORS upgrade is running and will make the renewed FORS the first ELT-compliant instrument, also providing a new detector and three new grisms. FORS Upgrade has suffered some delays (beyond COVID-19) because of over-commitment of the ESO staff to other high priority projects and because the main deliverable, the new detector, suffers from considerable delays by the manufacturer.

3.3.1 FORS upgrade

Principle Investigator	ESO
Consortium institutes	INAF Obs. of Trieste, P. Di Marcantonio (PM), M. Nonino (PS)

ESO Project Team	F. Derie (PM), A. Manescau (PE), R. Siebenmorgen (PS)
Installation Location/Date	End 2025
Status	Final Design (phase C)
Guaranteed Nights	None

3.3.1.1 *Overview/Description*

FORS2 is a highly demanded workhorse that shall remain operative at VLT for the next 15 years (STC-588). FORS control electronics and software as well as whole operations and data flow software shall be upgraded with the latest standards. The full ELT Framework and standards will be deployed on FORS-Up for test and validation of the ELT ICS on a real and representative instrument. For years, the Instrument Operation Team has been requesting the upgrade of FORS2 with a 4K x 4K broadband detector to improve the operations of the instrument, eliminating the need for exchange of the RED or BLUE detector systems, with direct impact on instrument maintainability and reduction of risk. An additional requirement is to minimise the absence of FORS2 from operations. The project plans to upgrade first FORS1 in Garching, to be on the VLT for 2025 with a beta version of ELT Framework, ELT-VLT gateway and NGCII.

According to the ELT Framework development plan and the availability of the Templates in ELT format, FORS-Up expected planning is five years from authorisation to proceed till PAC of FORS1+MOS-MXU on UT1. There will be no downtime of FORS2 operation until the commissioning of FORS1 with MOS in P115 and with all modes including MXU in P116. At that time, the ELT Framework shall be advanced enough for its deployment on FORS1 on UT1. Therefore, it is expected that FORS will be back in full operation for P117 with full ELT standards.

3.3.1.2 *Highlights of period*

Phase C started on 1 September 2020 with a clear technical baseline definition and the required resources.

The COVID-19 lockdown and late delivery of FORS-1 from La Silla impacted the project both in Europe and in Chile. The actual delay in the design activities is about two years on PAE. The FDR was held in October 2021. Main board recommendations are to better analyse the risk of planning due to NGC-II development, to consolidate the commissioning and calibration plans with Paranal and to further detail the calibration unit. Other sub-systems, the control electronics, and software passed the milestone with minor actions. The performance and design of the three new grisms are confirmed on prototypes made by INAF Brera. The project is now concentrating on the refurbishment of the drives and electronics of FORS1 at INAF Trieste. The project has also made significant progress with FIMS. The new CDD is ready, but delivery acceptance is pending the last measurements of QE at 350 nm. The CDD cryostat is refurbished and is currently under cry-vacuum test (see picture). Refurbishment of FORS Cassegrain lifting and handling carriage is done according to the last Safety regulation (CE marking). Its delivery is expected in about one month. The coding of the ICS software according to ELT standards is progressing very well. Many functions are already demonstrated by tests at INAF.

3.3.1.3 *Technical activities*

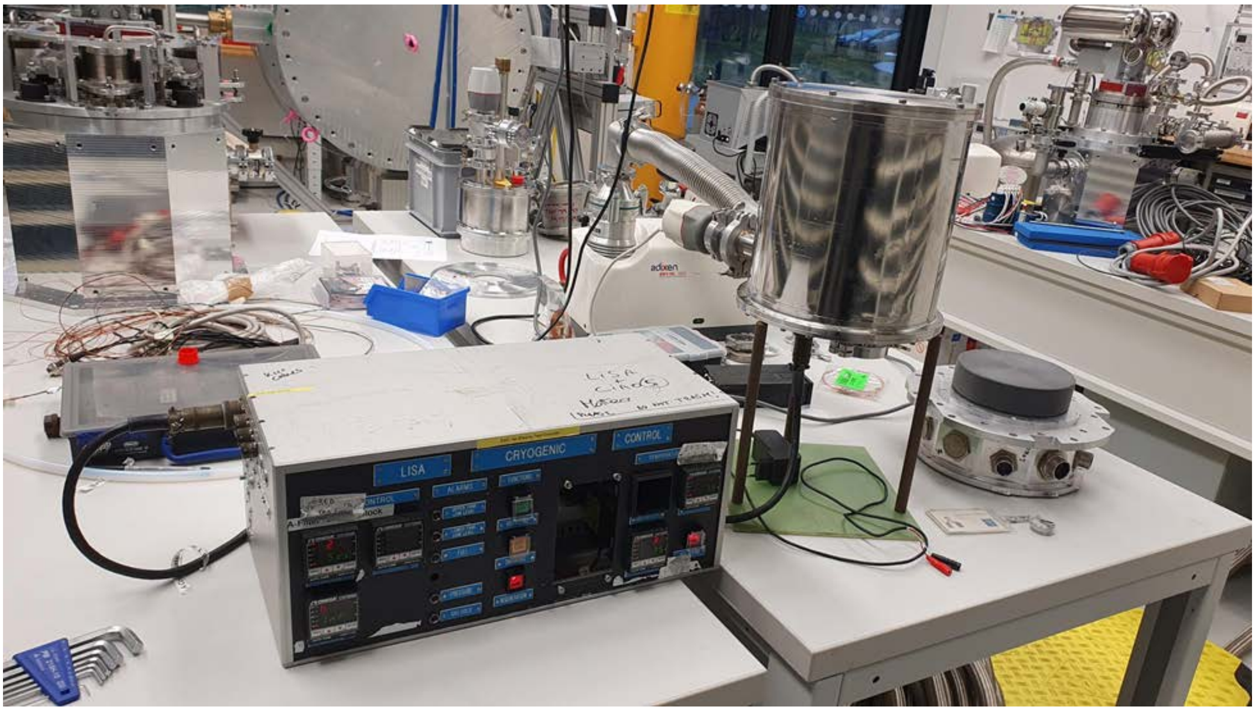
- Update of the Schedule and budgets required due to different delays.
- The final design of the New Calibration Unit (ESO internal FDR).
- Delivery acceptance of the broadband CCD231-84 procurement with E2V.
- Delivery acceptance of Cassegrain carriage with MBE1.
- Follow-up of INAF-OATs Trieste technical and scientific collaboration.
- On-going Pipeline and QC upgrade for the new broadband CCD.
- Coordination follow-up with all software teams in charge of ELT-VLT Gateway, OLAS and ELT NGC-II Detector.

Milestone schedule			
Major Milestones	Planned date at kick-off	Actual date, or current best estimate	Slip (months)
Phase C (Kick Off)	01 September 2020	01 September.2020	0
Phase C (FDR)	23 December 2020	25 November 2021	11
Phase D (TRR)	01 July 2022	01 July 2024	24
Phase D (PAE)	03 January 2023	01 January2025	24
Phase E (PAC)	01 April 2024	01 April 2026	24

Current main risks	
Risks	Planned action
Design of Calibration Unit on critical path	New sub-system FDR.
NGC-II development on critical path	Close collaboration with detector group.
Delivery of new CCD by E2V	Additional measurements at 350 nm and performance simulation

Brief bullet summary of upcoming activities for next period

- Acceptance of new CCD when QE clarified.
- Order for three Phase Holographic GRISM (600B, Na and K line) with INAF Brera.
- Functional test of FORS1 mechanisms at INAF.
- Functional test of ICS and PLC S/W.
- Functional test of new control electronics.
- Preparation of the test facility and Cassegrain simulator for FORS-Up test in Europe in 2024.
- Development of Operation and Maintenance S/W.



Picture: Broadband CCD bath cryostat under test at ESO.© ESO

3.4 La Silla Instrumentation

The Paranal Instrumentation Programme also covers projects for La Silla. These projects are only contemplated because they are at a minimal cost to ESO. Following the STC recommendations, ESO launched a Call for Ideas for scientific projects at the NTT for a new instrument to be provided by the community. SOXS (Son Of X-Shooter) for the NTT and NIRPS for the 3.6m telescope were selected.

The strategic view is to dedicate the NTT for the follow-up of transient events, and the 3.6m telescope for exo-planet studies to support future exo-planet space missions. The timeline of the two projects extends the La Silla lifetime well beyond 2025. As for the other projects, in the past two years, both NIRPS and SOXS have reported no negligible delays but now NIRPS has been offered to the community after commissioning, while SOXS is completing its integration in Europe and is expected to start the PAE process in the coming six months.

3.4.1 SOXS for NTT

Principle Investigator	S. Campana
Consortium Institutes	INAF-Brera, Italy INAF-OACN, Capodimonte INAF-OAPD, Padua INAF-OACT, Catania INAF-TNG, Trieste INAF-OAR, Roma INAF-OATO, Torino Universidad Andrés Bello, Chile Finnish Centre for Astronomy with ESO (FINCA) Weizmann Institute, Israel

ESO Project Team	L. Pasquini (PM/PE), M. Schöller (PS)
Installation Location/Date	3.5m NTT, 2023
Status	MAIT
Guaranteed Nights	900.

3.4.1.1 *Overview/Description*

SOXS is a new state-of-the-art instrument for the NTT on La Silla. SOXS will be a high-efficiency spectrograph with a Resolution-Slit product of 4,500” over the entire band capable of simultaneously observing the complete spectral range 350–2000 nm. SOXS will have a 12” slit and will be specifically suited for rapid response observations of transient objects. The Consortium will also contribute to the operation of the telescope.

3.4.1.2 *Highlights of Period*

SOXS is developed by 12 institutes, and each sub-system goes through a local readiness review before it is shipped to the AIT hall, in Padova, Italy.

All sub-systems but the NIR spectrograph (which is in integration at INAF-Merate) have been delivered to Padova and are mounted on the SoXS main structure at the NTT simulator.

The NIR spectrograph is on the critical path, and the aim is now to close PAE before September 2023.

3.4.1.3 *Technical activities*

- **Instrument flange:** The instrument flange is finished and installed on the NTT simulator, supporting all the SOXS sub-systems.
- **Co-rotator System: Co-rotator:** It has been installed and tested in real conditions, driving the two cable-chains.
- **Calibration Unit:** The Calibration Unit has been improved in many aspects related to maintenance and handling. The mechanics has been modified to allow for a better handling and accessibility for replacement of the lamps. The new system has been manufactured and integrated, the internal re-cabling has been completed. The improved system has been installed and tested and works satisfactorily. The repeatability of the mechanical installation has been verified.
- **Common Path:** The Common Path is aligned and fully working. Some straylight affecting the acquisition and guiding camera was discovered. As the camera will also be an imaging scientific channel this must be avoided, and the issue is currently being worked on.
- **Acquisition and Guiding Camera:** The Acquisition and Guiding Camera has been aligned and is installed on the flange. The repeatability of the mechanical installation has been verified. Minor improvements are pending in the cabling and in the characterisation of the system.
- **UV-VIS Spectrograph:** The internal alignment of the spectrograph has been verified, as well as the repeatability of the mechanical installation, which, after several cycles of mounting/dismounting, is repeatable within 50 microns, consistent with the expectations.

The final alignment is on-going using the light sources from the Calibration Unit. Minor activities are on-going in parallel on the NGC system (one board will be replaced).

- **NIR Spectrograph:** The NIR spectrograph is under installation and test at INAF – Merate. The MUX and then the science grade IR array were installed into the vacuum vessel and tested. The NGC had a faulty channel, but this issue was solved with a replacement board from ESO. The cryo-vacuum control system, both electronics and software, was greatly improved and is continuously under test. The team is progressively getting more knowledge of the system behaviour and confidence. Finally, after having solved many issues, the first images of the spectrograph with the SG array in cold conditions were obtained in February 2023 and are being analysed to remove straylight and ghosts. The goal is to conclude this phase in Merate in April 2023, but the precise schedule is still uncertain because of the unknown number of the cooldowns needed to complete the work.
- **Instrument Control System:** Software and electronics are going in parallel to all the other activities. No concerns.
- **Operations Software:** The development of the main software tools planned for the operation phase (pipeline, scheduler, QC web page, ETC) is proceeding in parallel to the physical realisation of the instrument.
- **Instrument Platform**: The platform has been produced and will soon be painted and ready. The plan is to instal it in early autumn 2023 on La Silla, before making the instrument available for all the other activities, pending a detailed agreement with the La Silla observatory.

The NIR spectrograph is on the critical path. The consortium aims at starting the PAE process in July 2023, after three months of system testing in Padova with the full instrument.

Milestone schedule			
Major Milestones	Planned date at kick-off/Stated in agreement	Actual date, or current best estimate	Slip (months)
Official kick-off/MoU for Phase A	n/a	3 March 2017	n/a
PDR	n/a	20 - 21 July 2017	n/a
FDR	n/a	19 - 20 July 2018	n/a
MoU for construction	n/a	10 October 2018	n/a
PAE	July 2020	July 2023	36
PAC	March 2021	March 2024	36

Current main risks	
Risks	Planned action
SOXS may exceed the weight limit of the NTT building crane.	The real weights are traced, and the risk should not be present (NIR spectrograph pending).

Brief bullet summary of upcoming activities for next period
• Internal Delivery of NIR spectrograph • Full integration and system tests.

3.4.2 NIRPS for the 3.6m

Principle Investigator	R. Doyon; University of Montreal F. Bouchy, Observatoire de Genève
Consortium Institutes	*PI Institutes:* Université de Montréal (“UdeM”) Université de Genève (“UniGe”), Observatoire Astronomique *Other participating institutes:* Instituto de Astrofísica e Ciências do Espaço (“IA-P”), Porto Instituto de Astrofísica de Canarias (“IAC”), La Laguna, Tenerife Université de Grenoble – Alpes (“UGA”), Saint-Martin-d'Hères, France Universidade Federal do Rio Grande do Norte (“UFRN”), Natal, Brazil NRC Herzberg Astronomy
ESO Project Team	N. Hubin (PM/PE), C. Péroux (PS), G. Lo Curto (LPO scientist))
Installation Location/Date	First light of NIRPS Front-End Q4 2019 First light of NIRPS Back-End Q2 2022
Status	Integration Phase
Guaranteed Nights	725 nights

3.4.2.1 *Overview/Description*

NIRPS is a fibre-fed high spectral stability and high-resolution spectrograph for the 3.6m telescope to be operated in tandem with HARPS. NIRPS covers the 973-1800 nm spectral range. The NIRPS RV precision (after calibration and data reduction) must be better than 1 m/s over short- and long-time scales (years), to execute coherent and long-lasting programmes. None of the HARPS modes, polarimetry included, shall be compromised. NIRPS has a high efficiency mode with R = 80,000 and a high precision mode with R = 100,000.

To allow the parallel operation of NIRPS and HARPS, a new fibre adaptor has been built. This also encompasses, beyond a tip-tilt stage, a low order adaptive optics system for the IR. This fibre adaptor allows to mount piggy-back a separate K-band spectrograph.

To be competitive with various other activities in the field of extrasolar planets, NIRPS must be executed on the fastest feasible timescale.

3.4.2.2 *Highlights of period*

- NIRPS with new IOF grating commissioning activities completed.
- A merged ESPRESSO-HARPS-NIRPS pipeline was released mid-February 2023 for the first time (2 Python modules, advanced telluric correction, and RV, will be added to the pipeline package in the next release of the pipeline).

- NIRPS operation documents delivered and being released to support the start of operation on 1 April 2023.
- NIR LFC manufacturing on-going at CSEM with acceptance planned in April 2023 and installation in Q2/2023.

3.4.2.3 *Technical Activities*

The NIRPS spectrograph AIV was completed, and 1st light achieved mid-June 2022.

- New IOF grating with improved performance replaced the existing grating in July/August 2022 and commissioning in December 2022 and in January 2023 took place. The stretcher was also modified to reduce modal noise. The performance of NIRPS was improved and modal noise reduced to an acceptable level (NIRPS performance is essentially in Specs right now). Variation of resolution for the different orders was observed but no explanations found so far. The next commissioning focused on end-to-end operation is on-going at the time of writing. An interface meeting was organised with CSEM for the upcoming delivery of the NIR Laser Frequency Comb to La Silla expected in Q2/2023.
- A merged ESPRESSO-HARPS-NIRPS pipeline was released mid-February 2023 for the first time (2 Python modules, advanced telluric correction, and RV, will be added to the pipeline package due to the unavailability of one Consortium key person for the integration into the pipeline).
- NIRPS was included in the Call for Proposal for period 111 and will start operation on 1 April 2023 without NIR LFC, which will be offered in period 113 despite its completion during Period 111.

Milestone schedule			
Major Milestones	Planned date at kick-off/Stated in agreement	Actual date, or current best estimate	Slip[1] (months)
Official kick-off	n/a	January 2016	n/a
PDR	n/a	October 2016	n/a
FDR	n/a	May 2017	n/a
Front-End PAE	November 2018	September 2019	10
Front-End Comm	March 2019	Started December 2019 September 2021	24
Back-End PAE	March 2019	November 2021	32
Back-End Comm	September 2019	June and September 2022	33
PAC	December 2019	Q2 2023	40

Current main risks	
Risks	Planned action
NIRPS-BE stability non-compliance.	end-to-end stability test done after reintegration at La Silla and before commissioning and are good.

1 The value for "slip" is a bit arbitrary, as the MoU states the dates for milestones in months after kick-off, while the fact sheet uses the dates planned at FDR. The FDR happened to coincide with the final signature of the MoU.

Brief bullet summary of upcoming activities for next period
• NIRPS start of operation in April 2023 • Prepare acceptance of the NIR LFC at CSEM before shipping and installation at La Silla Q2 2023 • Close remaining actions for PAC

3.5 Minor activities

The programme includes a few small projects or activities that are briefly reported in this section.

3.5.1 CRIRES+ absorption cell pipeline

Following the STC recommendation, ESO has launched with the CRIRES+ PI (A. Hatzes, Tautenburg) a small project aiming at producing a Python pipeline for the absorption cell data of CRIRES+, to obtain precise (~3 ms^{-1}) radial velocities. The project is expected to be completed in Q1/2024. The first VIPER SW (Pre-)Release, together with the current version of the Manual and Test report was received on 24 February 2023. End of January 2023 a live demonstration was given at ESO by the lead developer.

3.5.2 MATISSE adaptation to GRA4MAT and to GRAVITY+

The installation of GRAVITY as fringe tracker for MATISSE has implied a substantial modification of the MATISSE operation SW and pipeline, which was not planned in the instrument development. Similarly, when GRAVITY+ will be installed, ESO will need to modify MATISSE and re-commission it. ESO is in contact with the PI of the MATISSE Consortium, B. Lopez (Nice), to sign an agreement that covers these new activities.

4. The Future

The recent VLT/I instruments will start operations after the first light of the ELT. The VLT in the era of mature ELT operations has been studied with the ESO community and a strategic view has been developed using dedicated workshops and user surveys, in consultation with the STC and in harmony with the Strategy Working Group (SWG) and ESO's science prioritisation working group. The VLT and VLTI scientists have prepared, in collaboration with community representatives, a roadmap document for the VLT/I (STC-658, dated 07.10.2020), the main strategic points of which are analysed in the next sections (see also The Messenger 177, 67, and STC-639, 2019).

4.1 Strategic View

The VLT/I will continue to serve a large community and provide unique data in the JWST and ELT era. It is recognised that the Paranal Observatory and the ESO community have some clear strengths, the most notable being:

- Flexibility of operations, small/large programmes, reactivity, monitoring
- Diversity and quality of instruments; unique workhorses such as X-Shooter and MUSE

- Uniqueness and world leadership in some areas:
  - High resolution spectroscopy
  - Integral field spectroscopy
  - High contrast imaging with AO
  - Interferometry
  - Access to blue in the era of JWST and ELTs.

The main strategic choices are to:

1. **Focus on unique VLT/I strengths and exploit the uniqueness of the VLT/I**
2. The VLT/I shall continue to host a mix of workhorse and dedicated instruments
3. PIP should commit no more than 50% of all the available resources until 2030 in these first projects, leaving margin for future ideas and proposals.

As to the potential new projects presented at the VLT in 2030 workshop, STC recommended to immediately start with the Phase A study of GRAVITY+, followed, not later than 2022, by the Phase A of BlueMUSE.

BlueMUSE is a seeing-limited, blue-optimised, medium spectral resolution, panoramic integral field spectrograph. It has a similar architecture and many systems, which resemble the very successful MUSE instrument but with a new and distinct science case enabled by its main characteristics: (1) a wavelength coverage 350 – 580 nm; (2) an average spectral resolution R=4000; (3) up to 2 $arcmin^2$ field-of-view. Among the science goals, it will survey large samples of massive stars in our galaxy and the Local Group, study ionized nebulae, starburst, and low surface-brightness galaxies. At high redshift, it would allow for the first time to detect the intergalactic medium unambiguously in emission as well as to study the evolution of the circum-galactic medium properties near the peak of the Cosmic Star formation history. While ESO has completed the Phase A study of GRAVITY+ as quickly as possible, the impossibility to close many pending projects and interventions and the recent restrictions impose a patient approach. Plans are discussed in more details in section 4.6 and the following pages.

As part of the VLT2030 process, ESO plans to have a second round for VLT/I instruments. The call should not be issued before the start of the new projects. It will potentially include an HR-MOS for which a strong science case was presented at the VLT2030 workshop.

4.2 VLTI

With the completion of NAOMI and GRA4MAT (STC-658), which is based on the current VLTI Roadmap (STC-599, The Messenger 171,14,2018), the VLTI entered Epoch 2. The VLTI roadmap foresees:

Epoch 2: 2020-2025

- <u>Fully exploit the existing infrastructure by upgrading the existing instrumentation</u>. GRAVITY+ represents a major upgrade of the VLT/I infrastructure.

- Increase the sky coverage and angular resolution capability by doubling the delay line optical path. This was studied and is under implementation since 2020 under Paranal governance.
- Host visiting instruments pushing the technique in new directions. Several projects for the VLTI in the community have been funded and are under development.

Epoch 3: beyond 2025

- VLTI imaging capability might be expanded by adding more telescopes and building a 6-to-8T beam combiner. There are some projects in the community to fibre-link VLTI telescopes, at the exploratory level.
- VLTI might be used as a development platform for a next generation optical interferometer**.** GRAVITY+ is a step into that direction by pushing AO+LGS on 8-m class interferometers.

4.3 Visitor Focus

Visitor instruments are usually designed for a specific science case and do not have the reach of a facility instrument. They have a minimal interface with the telescope, and ESO has no specific requirements about HW and SW standards other than safety and that visitor instruments are operated by the Consortium. The data products of visitor instruments do not necessarily have to be compliant with the ESO archive.

The availability of a free focal station to host visitor instruments has been advocated in several instances and at the VLT2030 workshop, several potential visitor instruments were presented for VLT and VLTI: ASGARD for VLTI: FT + J-band spectro + L-band nuller; RISTRETTO: AO+spectro for spectrum of one planet; HIRiSE: link between SPHERE and CRIRES+; PIU: polarimetric bonnette for UVES.

Since the Workshop, additional projects have contacted ESO with an interest to be considered as visitor instruments: MADAM: fringe tracker+JHK spectrograph, and MEDRES, an infrared IFU for SPHERE (a spin of the SHERE+ proposal of 2019). Both projects have contacted ESO in 2023 and are under review.

Instruments at Cassegrain focus are, in general, easier to remove and a pragmatic approach is to provide regular access to a Cassegrain focus shared with an instrument built explicitly to be easily removed, such as CUBES. As for Nasmyth instruments, they cannot be exchanged, and it does not seem appropriate to leave one focus permanently unused at present. The time between the decommissioning of one instrument and the installation of a new one could be used for hosting visitor instruments. Since October 2019, the Nasmyth focus on UT1 occupied by NACO has been free, waiting for the arrival of MOONS. According to STC-569, FLAMES should be decommissioned in the long term and its focus could be made free until a new instrument is built. The VLTI Visitor focus is officially open as of P104, and two instruments can be accommodated, one on the AMBER table and one on the FINITO table.

4.4 Instrument decommissioning

ISAAC was decommissioned to make way for SPHERE, and MIDI was decommissioned to be replaced by GRAVITY. AMBER was decommissioned after P101 and VIMOS after P100. The decommissioning of VLT/I instruments follows a discussion with the STC (see STC-569). CRIRES+ has replaced VIMOS, NACO was decommissioned in October 2019 (to be replaced by MOONS), possibly followed by FLAMES. HAWK-I will be decommissioned and replaced by MAVIS (~2026). VIRCAM will be decommissioned in 2023. The potential decommissioning of VISIR is discussed in a separate STC document.

Each time a new instrument is accepted, the instrument to be decommissioned is identified (at the time of the new project Final Design Review at the latest), based on a grid of criteria that includes scientific potential, complementary with new instruments (and therefore coverage of the parameter space), instrument status, and future perspectives, as explained in STC-569.

4.5 Upgrades

The documents STC-587 and the roadmap VLT/I instrumentation STC-656 identify which instruments will be operated in the long term and will therefore require an upgrade or a refurbishment to maintain them at the forefront for the next ~15 years. In addition to the on-going GRAVITY+ and FORS upgrades, two additional potential upgrades have been discussed:

- **UVES:** The case for keeping UVES has been emphasised in STC-570 and STC-587. In the long term, a general refurbishment of this instrument is necessary to guarantee its life and to improve its efficiency. The complementarity with the UV spectrograph shall be considered, as well as the scientific overlap with ESPRESSO. The number of observing proposals for UVES remains constantly high, the operations of the instrument do not pose urgent challenges. The roadmap document confirms that UVES should be kept in the long term. A UVES-20-year workshop took place in October 2020, showing a wide interest for this instrument, and indicating some priorities for a potential upgrade. A summary paper of the UVES workshop was published (Messenger 183, p. 37, 2021). It is TBD whether the upgrade should be mainly limited to obsolescence or whether it should include a much wider intervention.

- **SPHERE:** The possibility of enhancing the XAO capabilities of SPHERE by coupling high contrast imaging and high-resolution spectroscopy has been advocated and a link from SPHERE to CRIRES+ (HIRISE) and a SPHERE upgrade were proposed at the VLT in 2030 workshop (SPHERE+). HIRISE has been proposed as a visitor instrument. While the SPHERE+ case was not considered compelling by STC, the technology development programme at ESO is collaborating with the project, now known as SAXO+, as pathfinder for the ELT PCS. The SPHERE HODM has several faulty actuators. Even if no further losses occurred in the last years of operations on Paranal, this status is risky in the long term and any SPHERE upgrade shall evaluate the procurement of a new HODM. Other projects connected to SPHERE are being elaborated in the community.

All instruments foreseen to be operated in the long term are either new or have recently been upgraded. FLAMES, HAWK-I and VISIR are in a ‘maintenance only’ status. This means that no upgrade is foreseen, no obsolescence fight planned and if a major failure occurs, it will not be repaired. No urgency for other upgrades has been identified at present.

All major upgrades are treated as new projects and compared to running or planned instruments to decide on priorities.

4.6 Development Plan

The development plan laid out in Table 2 and Table 3 shows the projects under construction and the ones planned. It is based on the present planning and on the ESO resource allocations for the running projects. For future projects, projections are made using typical effort figures expended on previous VLT instruments. So far, the FTE requests for the PIP programme exceeded what had been established in the ESO Long Range Plan for the years 2015 – 2026. The reasons are delays in major projects and an underestimation of the effort needed. The ESO staff effort should have reached a steady state of 26 FTEs/year after 2020 but is instead showing a smooth decline, partially caused by the delays induced by COVID-19. Starting in 2017, staff effort contingency has been included at programme level to cover potential delays in the projects and unforeseen extra scope. To cover the need of expertise in some areas, hiring temporary support or agreements with institutes are needed, which need to use ~0.3 MEUR/year of the capital investments budget to pay for the additional staff effort.

GRAVITY+ is a very ambitious project, which requires a considerable fraction of the PIP overall resources. ESO tried to accommodate it into the programme, with a rather fast schedule (the project is planned to finish in 2026). This caused the stretching of the PIP resources beyond the planned BFL amount in 2022 and 2023 and had an impact on the development of those projects (FORS Upgrade, CUBES, BlueMUSE) recently started or which are about to start.
Table **2** shows the development timetable. It includes the start of the BlueMUSE Phase A study in early 2024.

Year	**Phase A**	**Design & Construction**	**Delivered (PAE)**
2013		CRIRES+ MOONS	MUSE
2014	NTT Call for Ideas	4MOST	SPHERE PRIMA Astrometry (discontinued)
2015		NIRPS NACO Survival	LFC for HARPS VLTI PR1 GRAVITY BCI
2016		SOXS X-Shooter ADC	GRAVITY CIAO VISIR Upgrade VLTI PR4 NACO Survival

Year	Phase A	Design & Construction	Delivered (PAE)
2017	MCAO for UT4 (Pre-Phase A)		ESPRESSO X-Shooter ADC MATISSE
2018	FORS Upgrade		AOF VLTI PR3 (NAOMI)
2019	MAVIS	IRLOS Upgrade	CRIRES+ NIRPS FE
2020	CUBES	FORS Upgrade	
2021	GRAVITY+	MAVIS	ERIS IRLOS Upgrade
2022		CUBES GRAVITY+	NIRPS BE VLTI PR5 (GRA4MA)
2023			SOXS MOONS 4MOST
2024	BlueMUSE		
2025	New/Upgrade	BlueMUSE	FORS Upgrade
2026		New/Upgrade	GRAVITY+
2027			CUBES
2029			MAVIS

Table 2: Development plan for the Paranal Instrumentation Programme. Column "Delivered" refers to shipping to Paranal for instruments and to the end of the integration for infrastructure projects (AOF, VLTI).

Effort has been allocated for 2023 and beyond to the new initiatives. In the event of conflicts of critical expertise, projects close to completion usually have the highest priority.

ESO goals for 2022 included PAC for MATISSE, and to complete the commissioning of GRA4MAT and of ERIS. They have been fulfilled although a short commissioning run of ERIS is left for the full characterisation of the high contrast modes.

Based on previous experience, the 26 FTEs allocated to PIP can support up to eight projects in a semi steady state. The open projects are now 9 (see
Table 1) and the programme must focus on finishing the pending ones, especially the two large facilities, MOONS and 4MOST. It is, however, expected that ERIS and NIRPS will be completed in 2023. The programme is extremely careful in embarking on new projects, and this is done only after a detailed scrutiny of the allocated resources is completedFigure 9: Paranal Instrumentation configuration in 2024, according to the present plan. MOONS and 4MOST are expected to pass PAE in 2023, FORS upgrade in 2025.
Figure 9 shows the status of the Paranal instrumentation in 2024, according to the present programme plan.

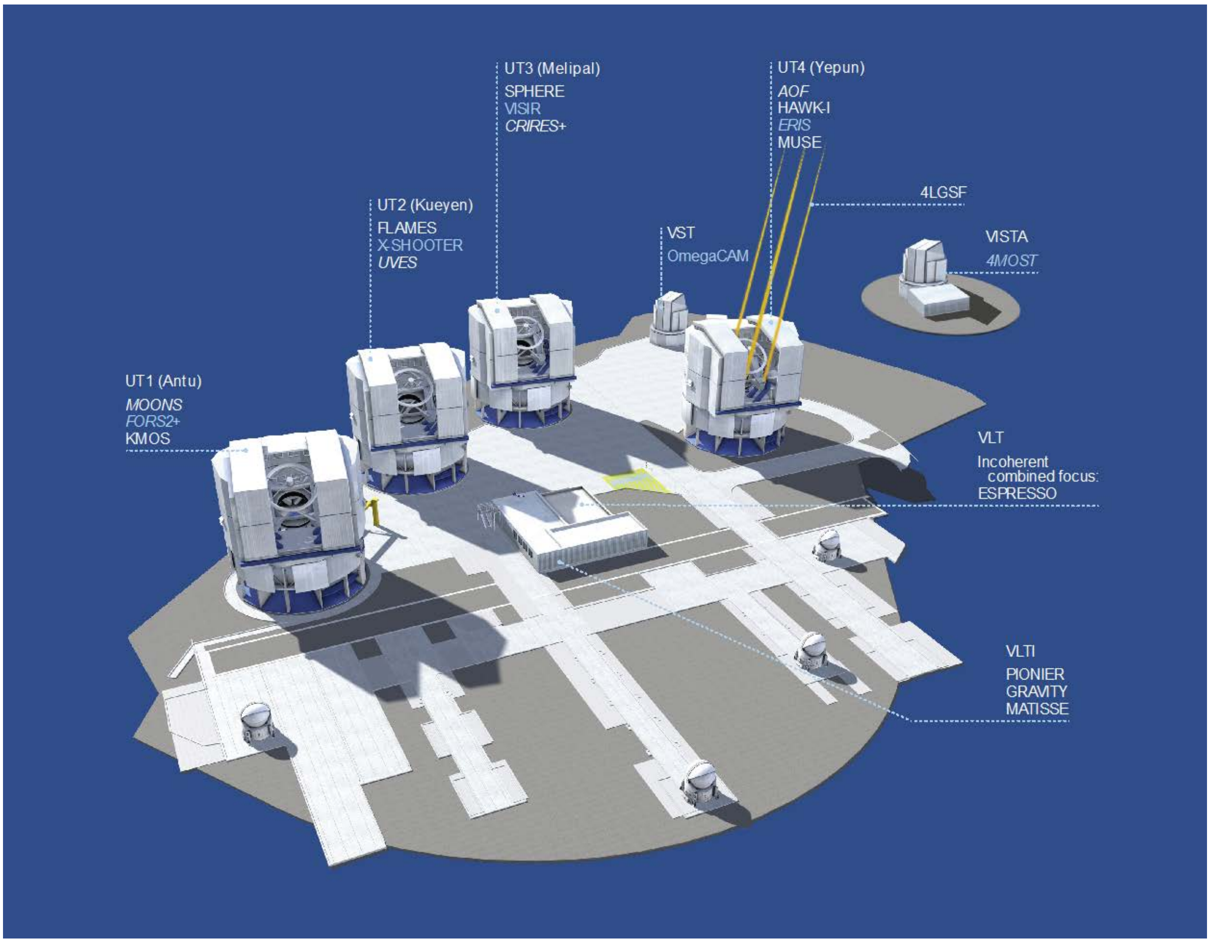


Figure 9: Paranal Instrumentation configuration in 2024, according to the present plan. MOONS and 4MOST are expected to pass PAE in 2023, FORS upgrade in 2025.

4.7 Milestones for the coming projects

The following table summarises the approval and definition milestones for the next periods. Because of the recent restrictions, BlueMUSE will start phase A only in 2024, after that a new TBD project could be started.

Date	BlueMUSE	New / upgrade
Q1 2024	Phase A KO	
Q3 2024 (TBC)		CFI /workshop
Q1 2025	Phase A Review	
Q2 2025		Selection
Q4 2025 (TBC)	Design & Construction	Phase A KO

Table 3: Upcoming milestones for new projects. They have been shifted by 1 year with respect to previous plan, as a consequence of the organization restrictions put in place as answer to the high inflation.

The table below shows in more detail the upcoming milestones for the major projects:

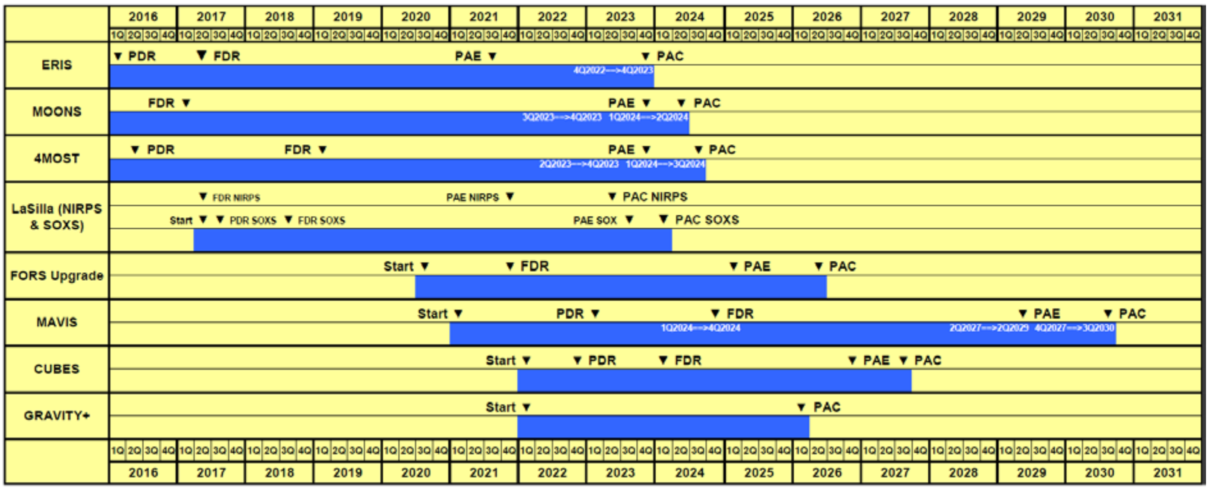


Table 4: Main milestones for the running (approved) projects. GRAVITY+ has many mixed milestones, which cannot be usefully represented in this scheme.

5. <u>Managing the Programme</u>

The Paranal Instrumentation Programme is managed according to the approved ESO internal project management procedures. One programme manager and one programme engineer run the programme, guided by two programme scientists, one dedicated to the VLT, Survey Telescopes and La Silla, and one to the VLTI, and a programme controller. Programme control has recently been included into the new Programme Planning and Control Office of the Directorate of Programmes.

5.1 Procurement Procedure

Input for the selection of new instruments is provided via normal routes such as the STC and its subcommittees, scientific conferences, or directly from the community.

The procedure leading to instrument construction follows the normal VLT model: Top-Level Requirements are prepared and issued with a Call for Proposals. One or more Phase A studies can be funded to develop concepts, draft technical specifications, Cost-to-Completion (CtC) and schedule. Following the Phase A reviews, a decision is made on construction of the instrument. All steps are done in consultation with the STC. If the procurement model is an ESO-led consortium, a competitive process is normally used to select external institutes as partners. For upgrades or smaller projects (or in the event of urgency), this competitive process may be waived.

When possible, R&D or prototyping is carried out and funded within the instrument projects themselves. Areas of general development, which are essential for instrumentation and cannot be allocated to a single instrument or have development times that go beyond the construction period of one instrument, are carried out by the Technology Development Programme.

The programme must retain flexibility to react to the evolving scientific and technological landscape and to re-assign priorities. New proposals are evaluated in collaboration with the STC against the existing plan. Acceptance of a new project may result either in cancelling/de-scoping or re-phasing planned projects. A similar evaluation is made if one of the running projects requests a substantial increase in the allocated resources. In planning resources for new projects (which have not yet been fully defined), figures derived from experience are used. The governing bodies are fully kept informed of the evolution of the planning as well as of the status of the approved programme by means of this document and presentations to the STC and its La Silla - Paranal subpanel.

5.2 Resources

Resources (cash and effort) are allocated to the programme according to the Budget and Forward Look document. Each project has an allocated budget and cash expenditure profile and a CtC, which includes cash and staff effort. Project managers request resources from the ESO matrix through the standard ESO process.

A summary of the CtC of all PIP projects is given in

Instrument	Budget at Completion (k€)	Invoiced (k€)	ESO Initially Planned FTEs	Cost of ESO Initially Planned FTEs (k€)	ESO Used FTEs	Cost of ESO Used FTEs (k€)	ESO Planned FTEs to Complete	Guaranteed Time Observing (Observing Nights) UT / VISA / 4m / 3.6 & NTT	Consortium Furnished Equipment (k€)
ERIS	3,341	4,588	26	3,447	40	5,280	1	210/0/0/0	2,700
MOONS	6,912	7,729	9	1,269	26	3,594	7	298/0/0/0	3,700
4MOST	5,200	3,452	23	3,248	39	5,207	12	0/0/1278/0	14,766
LaSilla (NIRPS & SOXS)	100	114	6	771	7	1,741	2	0/0/0/1625	5,895
FORS Upgrade	1,350	343	16	2,281	4	1,044	6	n/a	n/a
MAVIS	8,400	366	24	3,526	3	714	17	194/0/0/0	4,000
CUBES	2,800	102	8	1,118	1	180	14	90/0/0/0	1,800

GRAVITY+	6,300	743	34	5,116	9	1,274	33	277/0/0/0	11,800
GRAND TOTAL	**34,403**	**17,437**	**145**	**20,776**	**129**	**19,033**	**90**	**1069/0/1278/1625**	**44,661**

Table 5. This is updated in each issue of this document.

A limited contingency is included but not assigned to each project and held by the programme manager who must contain all costs within the approved value of the total programme. Unexpected costs beyond this, due to technical problems, delays, or enlarged scope need to be paid from the future programme resources, requiring delays or cancellation of future instruments. Similarly, major requests for staff effort in areas of high priority will cause delay in other running projects or a strategic change in their organisation, for instance by increased outsourcing to institute partners. The risk of delays to one project impacting other projects is mitigated by allocating staff effort contingency beyond the currently planned completion dates of each major project.

The plan is based on the planning for BFL 2022. The overall effort and expenditure profile is shown in Figure 10 and Figure 11. Overall funding has reached an average value of approximately 3.8 (2018) MEUR/year cash (plus carry-over) and in the long term will level at 26 FTEs/year of staff effort. The programme aims to reach a quasi-steady state of around eight approved projects running at any time. So far, the Programme has required more staff effort than planned, and some capital is being used to hire temporary effort to finish the running projects.
The staff effort for future projects is requested by the programme, and kept in one job, until, after a successful Phase A review and acceptance of the project proposal, the project is approved. At this point, a separate job is created, and the project becomes autonomous.

The evolution of the allocated staff effort with time for the whole Paranal Instrumentation Programme is shown in Figure 10. Different projects are indicated with different colours, and the green wedge on top shows the FTEs available for the future projects and contingency.

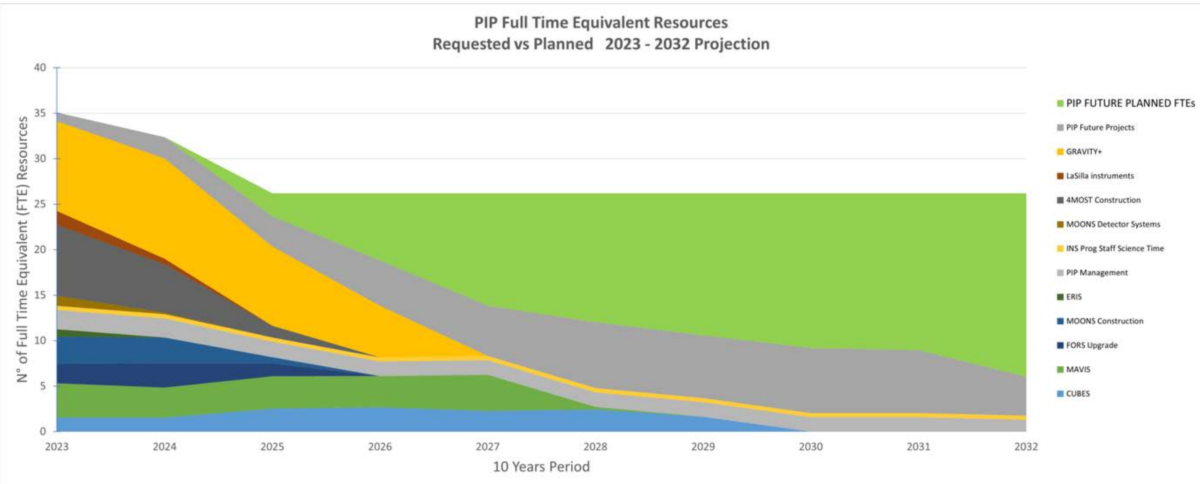


Figure 10: Distribution of the ESO allocated human resources to the programme for the different projects (March 2023). The green slice on top (JOB408) is available for new projects and contingency. The dark grey slice (PIP future projects) includes provisions for BlueMUSE.

5.3 source indexation

Since 2019, the Paranal Instrumentation Programme benefits from indexation, adjusting the resources to the official ESO inflation index, as for the rest of the ESO budget. The indexation is implemented in two ways: as far as staff effort is concerned, this is kept at a constant level after 2024, irrespective of the increase in staff cost. Thus, it is allocated in FTEs and not in Euros. As far as capital is concerned, the non-committed capital is indexed, and the cash evolution is shown in Figure 11, in which the committed and uncommitted expenditures are separately given. The reason for indexing the uncommitted fraction only is due to the fact that PIP agreements, MoU and contracts are all fixed price values, not indexed, and they will continue to be.

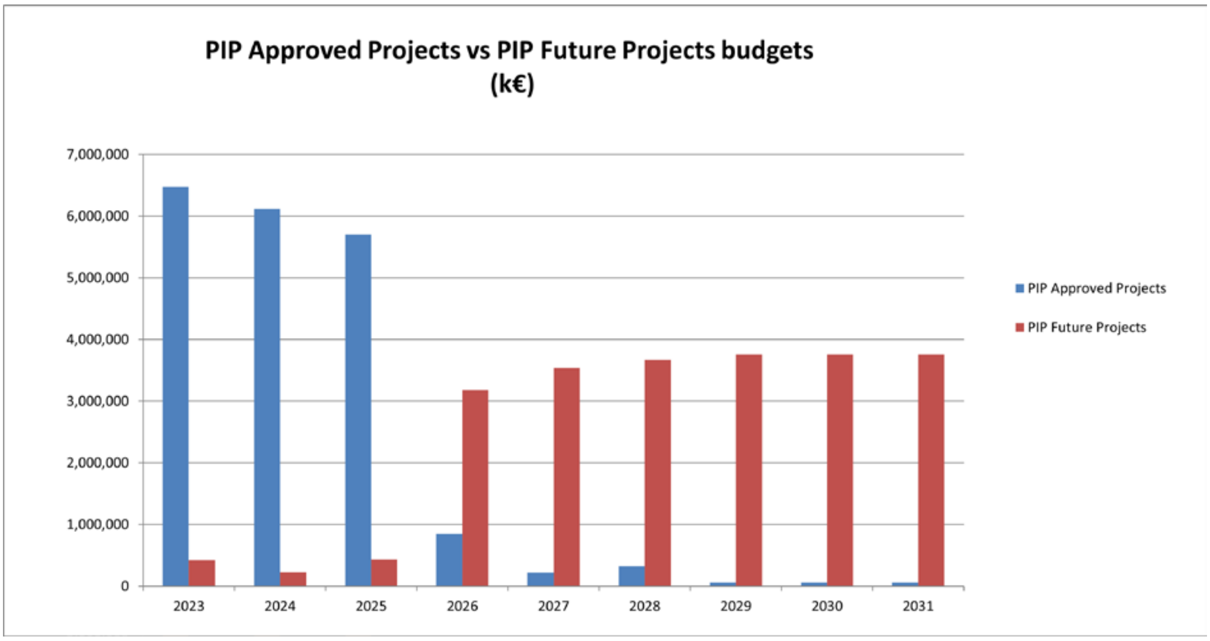


Figure 11: Paranal Instrumentation Programme capital expenditure profile (staff effort not included). In red the funds not yet committed to approved projects (it includes BlueMUSE and contingency), to which indexation is applied.

5.3.1 Planning

The La Silla - Paranal observatory offers 19 foci and 21 instruments (14 foci and 16 instruments for the VLT/I only). With one new project (instrument or upgrade) starting every year, the average life of an instrument in operations will, in the steady state, be some 16 years. By interspersing the programme with upgrades, the instrument suite can be maintained and will remain world leading.

The table below summarises CtC for running PIP projects. It also provides figures for GTO nights and consortia furnished equipment. The material costs in the first column indicate costs to ESO. The invoiced amounts refer to March 2023. ESO FTE (planned) refer to what had been foreseen for each project at the approval of the project. When comparing the numbers with the FTE (cost-to-completion) needed to complete the project, it is evident that most projects have substantially underestimated the need of ESO effort in the past, as well as the total time, by a factor ~1.5.

Instrument	Budget at Completion (k€)	Invoiced (k€)	ESO Initially Planned FTEs	Cost of ESO Initially Planned FTEs (k€)	ESO Used FTEs	Cost of ESO Used FTEs (k€)	ESO Planned FTEs to Complete	Guaranteed Time Observing (Observing Nights) UT / VISA / 4m / 3.6 & NTT	Consortium Furnished Equipment (k€)
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GRAND TOTAL	**34,403**	**17,437**	**145**	**20,776**	**129**	**19,033**	**90**	**1069/0/1278/1625**	**44,661**

Table 5: Paranal Instrumentation Programme - Financial Table.

5.4 Risk Register

A document describing the risk policy for the whole programme, which is applicable to all projects has been released. It is in line with the one adopted ESO–wide and resembles the one for the ELT. The programme risk register is regularly being reviewed and updated. It contains six active risks at present. A description of the top programme active risks is given below.

Risk	Description	Impact	Mitigation
Early Projects - High Increase in components costs	Price increase may hit those projects that are in their initial phase and have not ordered HW.	Descoping, deliver less than expected, non-implementation or delay of new projects.	- Use project(s) specific contingencies (Hardware) - Optimise project(s) spending profiles. The budget for the highest risk project: MAVIS, has been indexed,
Over costs	Some projects close to end incur over-spending and ask ESO for extra funds	For the cost-cap programme, the impact is that less funds will be available for new projects.	A limited contingency is kept at programme level. Optimize payment profile.
GRAVITY+ needs more resources than foreseen	GRAVITY+ uses about 1/3 of all PIP resources. A large under-request (typical of most projects) cannot be absorbed by the programme without endangering all other projects.	Impact on all running and new projects	Several steps: borrow from future by reducing number of FTEs; use cash from programme to pay for ‘extra effort’; accept PIP overspend at organizational level (as in 2022). Spread G+ over more years.
Delay in ESO deliverables to PIP projects	All new projects (e.g., FORS+, MAVIS, CUBES, G+) depend on ESO deliverables Due to projects complexity and interdependencies, ESO furnished items could be delayed.	The achievement of programme/projects time objectives could be jeopardised. Negative impact on ESO Reputation	Identify projects interdependencies, collect “needs dates” and clarify time constraints. Monitor projects evolutions and report. Foster inter-projects coordination and exchange of information.

Table 6: Main active programme risks.

5.5 Schedule and Coordination

A higher level of schedule coordination for the Programme is needed, especially to better manage the many interventions at Paranal and the use of common resources and facilities (telescope, integration hall, etc.). A link to each schedule is available through the PIP project summary in the PIP intranet and a programme-wide planning is maintained and updated.

In addition to the main milestones, it is essential to prepare and follow-up the schedule of the activities on Paranal. This includes not only the telescopes and instruments but also the use of the integration facilities and other resources. The coordination of these activities is one of the main tasks of the programme engineer. A schematic example of the coming activities on Paranal and La Silla is provided in the table below for Q2/2023 and Q3/2023.

	UT1	UT2	UT3	UT4	VLTI-AT	NIH	CCL/La Silla VISTA
April		G+ Center piece upgrade					VISTA upgrade
May	G+ platform and cable wrap				G+ Comm		VISTA upgrade NIRPS-LFC AIV
June		G+ platform and cable wrap					
July			G+ platform and cable wrap		G+ Comm		
August	G+ Center piece upgrade						
Sept.							

Table 7: Planned Paranal and La Silla activities for the semester April - September 2022

6. APPENDIX A: Characteristics tables of Paranal instruments in operation and in construction

VST + ΩCAM	(0.3-1 µm 1x1 Degree)
VISTA	(0.8-2.5 µm eq. 46x46 arcmin)
FORS2	(0.3-1 µm, 6.8x6.8 arcmin)
AO assisted	
HAWK-I + AOF (GLAO)	(0.8-2.4 µm 7x7 arcmin)
Diffraction limit (1 UT)	
VISIR	(0.8-24 µm 32x32 arcsec)
ERIS	(1-5 µm 2x2 arcmin)
SPHERE	(0.6-2.3 µm 11x11 arcsec)
MAVIS	(0.4-1 µm 30x30 arcsec)
Diffraction limit (VLTI)	
MATISSE	(3.5-12 µm, ~1 arcsec)
GRAVITY	(2-2.4 µm, 2 arcsec)
PIONIER	(1.5-2.4 µm)

Table 8: Imagers

IFUs	
MUSE	(1x1 arcmin) (7.5x7.5 arcsec **AO assisted**)
FLAMES	(7x7 arcsec, 15*2.4x3 arcsec)
ERIS (SPIFFI)	(0.8x0.8, 3.3x3.3 arcsec) **AO assisted**
KMOS	(24* 2.8x2.8 arcsec on 7 arcmin Ø field)
X-Shooter	(1.8x4 arcsec)
SPHERE	(1.73x1.73 R=50)
MAVIS	(2.5x3.7 arcsec R=~5900 or 11-14000) **AO Assisted**
MOS	
FORS2	19
KMOS	24 mini-ifus
FLAMES	< 130 or 15 mini-ifus + 7 to UVES-RED
MOONS	1000
4MOST (VISTA)	2400
No MOS AO assisted	

Table 9: IFUs and MOS

GRAVITY	2-2.4 µm R=22 & 500 & 4,000
VISIR	8-13 µm R~500
FORS2	0.3-1 µm R=300-3,000
MUSE	0.46-0.93 µm R~3,000
ERIS	1.1-2.45 µm R=2-4,000
KMOS	0.8-2.5 µm R~3,600
SPHERE	1-2.3 µm R-100-700
4MOST/MOONS	0.4-0.92/0.8-1.6 µm R~6,000 and ~20,000 (both)
X-Shooter	0.3-2.4 µm R=6-10,000
FLAMES	0.37-0.9 µm R=6-20,000
VISIR	10 µm R=3,200 & 25,000
CRIRES+	0.95-5 µm R=40-100,000
UVES	0.3-1 µm R=40-120,000
ESPRESSO	0.38-0.8 µm R=130-210,000 *4UT R=70,000
CUBES	0.3-0.4 µm R=7000- 22000
HARPS (3.6m La Silla)	0.38-0.68 µm R=115,000
NIRPS (3.6m La Silla)	0.98-1.4 µm R=100,000
SOXS (NTT La Silla)	0.35-1.8 µm R=4-5000

Table 10: Spectrographs

Polarimetry: FORS2 (Circ.and Lin.), HARPS, SPHERE, CRIRES+
High Contrast/Coronography: SPHERE, VISIR
RV Precision: ESPRESSO (<0.1 m/s), HARPS (<0.3 m/s), CRIRES+ (<3 m/s), NIRPS
FAST Photometry: VISIR (5ms), HAWK-I Burst mode (2ms), FORS2 (2ms)
Astrometry: Gravity (30 µarcsec, goal 10), ERIS (300 µarcsec)
Polarimetry: FORS2 (Circ.and Lin.), HARPS, SPHERE, CRIRES+

Table 11: Summary of some of the special modes

7. Appendix B : Configuration of Paranal in 2024

In the following table the instrument configuration at Paranal in year 2024 is reported, as given in Figure 9.

UT1	UT2	UT3	UT4	VLTI	COMBINED	VISTA
MOONS FORS2 KMOS	FLAMES X-Shooter UVES	SPHERE VISIR CRIRES	HAWK-I ERIS MUSE	GRAVITY MATISSE Pionier	ESPRESSO	4MOST