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COUNCIL

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Paranal Instrumentation Programme 2015-2020

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1 Executive Summary

Following the ESO Council's 2004 resolution (ESO/Cou-991 rev.) and the ESO strategic view as articulated in the ESO Long Term Perspectives (LTP, ESO/Cou-1377, 2011), an instrumentation programme for Paranal is presented for the period 2015-2020 with the aim of keeping Paranal at the forefront of ground based astronomy. It includes:

- The completion of the current VLT/I 2nd generation instruments
- The installation of the Adaptive Optics Facility (AOF) with the imager and spectrometer ERIS
- The upgrade of the VLTI infrastructure to accommodate the 2nd generation VLTI instruments
- Two multi object spectrographs (MOONS for VLT and 4MOST for VISTA)
- The upgrade of CRIRES
- A new UV spectrograph (CUBES) in collaboration with Brazilian institutes, and
- One or more instrument for the NTT, fully funded by the community.

The plan is divided into two phases:

- Until 2018, instruments are selected and developed with the criteria of fully exploiting the VLT capabilities and maintaining the balance between dedicated and general purpose facilities.
- Beyond 2018, the instruments will be deployed in the era of full E-ELT operations. The strategy for the second phase will be fully shaped in the coming years.

Approximately one new instrument, or instrument upgrade, can be initiated per year. However, since the programme uses all the available resources, any increase of scope, delay or overspend must be accommodated within the total resources available by either re-phasing or de-scoping the existing projects, or by shifting the start of new ones. The start of new projects will be possible only if current projects are completed, and no major emergencies arise.

A roadmap for the 2015-2018 period is presented.

2 Introduction

With the construction of the E-ELT, ESO will offer two main observatories to its community after 2024: Paranal/Armazones (integrating the VLT and E-ELT) and ALMA.

The fundamental goals for the Paranal instrumentation strategy can be summarized by quoting the strategic goals for ESO, formulated by Council in 2004 (ESO/Cou-994), and reported in the most recent ESO Long Term Perspectives document (ESO/Cou-1377, 2011):

- *ESO must retain European leadership in astronomical research in the era of Extremely Large Telescopes (ELTs) by carefully balancing its investment in its most important programmes.*

- *The VLT must continue to receive effective operational support, regular upgrades – especially 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 for at least another decade; the unique capabilities of the VLTI must be exploited.*

The overall Paranal mid-term and long-term scientific strategy will be fully developed in the “ESO in the 2020’s” report prepared by the panel reviewing ESO’s current and future scientific programme, lead by the Director for Science, R. Ivison. The instrumentation development plan does not define the long term strategy for the Paranal observatory, but rather provides a framework within which to implement new instrumentation in the years 2015-2020, bearing in mind that, for the next 10 years, the Paranal Observatory will be the main source of ground-based optical and IR data for the ESO community. The plan proposes an implementation that will allow a continuous renewal of the Paranal instrumentation, consistent with the available resources, and maintaining the commitments taken for the running VLT and VLTI projects, provided there are no major delays to instruments under construction or increase of scope to the programme. In particular the overall funding scheme must make sure that the resources are available within ESO to solve obsolescence problems and to maintain aging instruments, though these are beyond the scope of this plan and are covered in the LTP.

When considering the VLT instrumentation projects currently under construction, in 2018 the 2nd Generation VLT and VLTI instruments will be complete, and all VLT/I instruments but five will be either new or have been recently upgraded. X-Shooter and CRIRES will be less than 10 years old. FORS2 and UVES have been upgraded in the past.

This complement of instruments (see Figures 1,2 and the Tables in the appendix), will cover most options in imaging (including Adaptive Opics (AO) and VLTI diffraction limit) and spectroscopy in the 300-24,000 nm range. After the decommissioning of ISAAC, no low-resolution spectroscopy capability in the 2.4-5 micron range is available (ERIS does not provide spectroscopy beyond K band). Should the need for low-resolution spectroscopy in the 3-5 µm regime be identified as mandatory for the VLT, this capability could be inserted in the specifications of one of the new instruments to be built.

The wavelength/resolution plane is not the only relevant parameter space; four Integral Field Unit instruments (two AO-assisted) and at least four multi object spectrographs will be in operation. No deployable multi-object AO assisted spectrograph will be present. The Paranal observatory will provide polarimetry, high contrast imaging and coronography, fast photometry and superb astrometry, not to forget the finest instruments for precise radial velocity determination. In order to keep the Paranal observatory competitive however, a continuous initiative regarding new instrumentation development is planned. The flow should be continuous because a peaked effort, similar to the one needed for the 2nd Generation instruments, is not affordable when simultaneously implementing the E-ELT programme.

Considering an overall instrument development time of ~7 years, the plan is separated in two phases, with a transition in ~2018.

The first phase is devoted to providing the VLT with instrumentation that maintains a balance between general purpose and dedicated instruments. The second phase is dictated by the strategy of how the VLT will be used in the E-ELT era. This strategy will be fully developed in the coming years and its development will profit from a thorough discussion with the community at large.

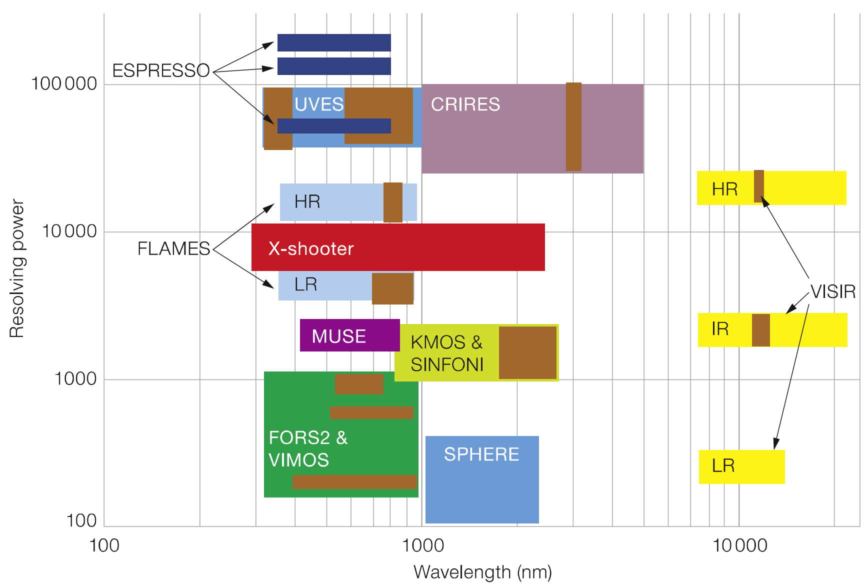

Figure 1: Wavelength-Spectral Resolving power diagram for the VLT instruments of first and second generation.

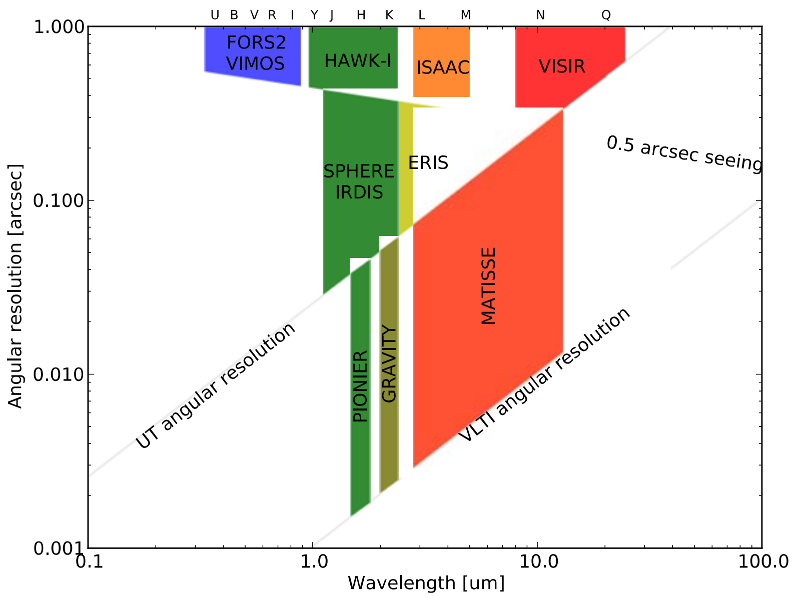

Figure 2: Wavelength-angular resolution diagram for the VLT/I instruments of first and second generation.

3 Current Programme

3.1 Recent Instruments

The last 18 months witnessed the smooth and successful installation and commissioning of three major VLT instruments, with the consequent occupancy of all VLT Nasmyth foci and the decommissioning of ISAAC. All of them are, or will be soon, offered to the users. On VLTI, the process that started with the analysis of the performances of the PRIMA astrometry facility and continued with the PRIMA gate review, ended with the hard decision of ceasing the effort on this project (although most of the hardware developed for it will still be used).

3.1.1 KMOS

KMOS is an infrared 0.8-2.5 μm spectrograph providing a resolving power 3000 and offering multi-object capability using 24 Integral Field Units (IFUs) with pixels of 0.2" and field of view (FOV) of 2.8 x 2.8", deployable over a 7.2 arcminute diameter field of view.

KMOS has been in operation since October 2013 in spite of a delay in granting Provisional Acceptance Chile (PAC). The non compliant items were 1) the induced vibrations generated by the Closed Cycle Cooler (solved), 2) an improvement of the vacuum tightness of the instrument, and 3) some problems with the reliability of a few arms. The reliability problem has been studied and understood and a solution found. The first set of 4 arms have now been modified, and the rest will be modified in an intervention planned in February 2015. Several components of the cryostat have been changed or modified to improve the vacuum tightness. Meanwhile, the PAC data package has been fully accepted and the complete instrument design has been archived in the ESO Product Data Management (PDM) system.

3.1.2 MUSE

MUSE (Multi Unit Spectrograph Explorer) is an Integral Field facility for the VLT. With a FOV of 1x1 arcmin, fine sampling, intermediate spectral resolution and large spectral coverage in the visible, it uses an advanced image slicer, twenty-four parallel spectrographs and a large detector area. In addition, MUSE will work assisted by the AOF, which will further enhance its performance.

The commissioning of the instrument has been completed. The instrument has excellent performance: (throughput, peaking above 35% end-to-end, high image quality). The instrument is offered for Observing Period 94 (October 2014). The PAC scheme needs to be worked out to include the commissioning with AOF and the Narrow Field Mode. The main outstanding problem is the stability of the detector readout electronics for 5 of the 24 cameras, for which the Read Out Noise varies in time between ~2 and ~4.5 e^-/pixel. A plan with a series of interventions aimed at tracking down the problem and curing it has been prepared and agreed and will be implemented with immediate effect.

3.1.3 SPHERE

SPHERE (Spectro-Polarimetric High-contrast Exoplanet Research) will detect faint objects very close to a bright star, ideally reaching giant planets. In addition to high Strehl ratio, the SPHERE AO system is designed to attenuate the light of the central bright star and subtract the residual speckle halo. SPHERE incorporates three science instruments that efficiently reduce speckle noise and cover the visible and Near Infrared (NIR) spectral range: a dual imaging camera (IRDIS), the NIR integral field spectrograph (IFS) and the visible polarization instrument (ZIMPOL).

The instrument is approaching the end of the commissioning phase and is offered for Observing Period 95 (April 2015), after Science Verification (SV) in December 2014. The commissioning runs have been very successful and smooth for such a complex instrument, excellent contrast (10^{-6}) is reached in good conditions. The main concern is the lifetime and performance of the High Order Deformable Mirror (HODM) which currently has 17 (out of 1377) dead actuators. In spite of mitigation measures to reduce risks (constant flushing of the HODM with Nitrogen to keep a low humidity level) one new dead actuator appeared after the third commissioning period, and the electrical properties of several actuators show signs of deterioration. A plan for the development of a new HODM has been prepared and reviewed, but not implemented yet. The development will require two years for procurement and about 1.6 MEUR cost. A decision on the procurement is expected in 2015 once the necessity for such a replacement is firmly established. If the replacement is approved, financial support from the consortium will be explored.

3.1.4 PRIMA Astrometry

PRIMA was a VLTI infrastructure enhancement project driven by different science cases. Among these science cases, PRIMA-Astrometry aimed to turn VLTI into an instrument capable of detecting the astrometric wobble induced by exoplanets at the 10 mas level on their host stars. This was a considerable challenge, since it pushed the interferometer to new limits. This science case was put forward by the ESPRI consortium, which was heavily involved in the project, providing significant parts of the infrastructure. After several years of integration, PRIMA was brought to a fully operational level. Only the final astrometric performance did not match the level requested by the science case. A red-flag report was issued at the end of 2011 describing the limitations of the systems. The STC and Council were kept appraised of the situation at every meeting since the red-flag report was issued.

Following the red flag, the PRIMA team developed a deep understanding of the issues facing PRIMA-Astrometry, discovering and resolving numerous unexpected problems, and developed a detailed recovery plan with estimates of the time and resources needed to bring PRIMA to full operation. A stage-gate review was held at the end of January 2014, which examined both the plan to completion and the science case in light of the successful launch of ESA's satellite GAIA. Following the review and input from the ESO Visiting Committee, the ESO Executive presented its findings to the STC, together with a proposal to cease activities on PRIMA and concentrate future efforts on ensuring the success of the second generation VLTI instrumentation. In addition, the Executive proposed to start good faith negotiations with the consortium over GTO compensation.

As reported at the June Council, the STC recommended the discontinuation of the PRIMA project at their 82nd meeting (ESO/STC-532). Following input from the Council, the formal negotiations over the GTO have now started. Much of the PRIMA hardware is a permanent part of the VLTI infrastructure and will continue to be used. The key staff have been re-deployed and are working to bring the VLTI infrastructure up to a point where it will be able to support the second generation VLTI instrumentation.

PRIMA has been a long and difficult project and it is crucial to learn lessons for the future. A formal PRIMA Lessons learned review is now also in process[1]. The purpose of the review is to investigate the reasons that led the project to fail to achieve its objectives within the planned time and cost envelope. Specifically it will identify possible systematic flaws, at all levels, which could affect other, present or future projects, undertaken by the Organization so that proper corrective measures can be put in place avoiding similar occurrences.

The review itself comprises of a review of the existing documentation, confidential written input from team members past and present including the consortium and based on a questionnaire, together with a series of face to face interviews with the key staff. An update on the activities of the panel and any emerging conclusions will be given to Council at the December 2014 meeting.

3.2 Projects Currently Under Development

A number of projects are being developed in ESO Member States. GRAVITY and MATISSE are well advanced in the integration phase and ESPRESSO has started procurement and integration after Final Design Review (FDR). MOONS is now in the design phase. The Paranal Instrumentation Programme is also responsible for the development of the infrastructure upgrades, enabling the instruments to exploit their best performance, and three of the main projects of the programme, the Adaptive Optics Facility (AOF), ESPRESSO and VLTI Facility are of this nature.

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[1] The review panel comprises:

Chairman	Ian Robson	Ex STFC Director of Technology
Secretary	Fabio Biancat Marchet	ESO Project Management Department Head
Member	John Monnier	University of Michigan, Member of ESO STC
Member	Marco de Vos	Astron, Member of ESO STC
Member	Gero Rupprecht	ESO Directorate of Programmes, QA/PA

3.2.1 VISIR Upgrade

The VISIR upgrade aims to optimize the performance of VISIR to enhance its scientific output. The approved project plan combines hardware upgrades and improved software support as well as enhancements of the science operations of VISIR, including the procurement and installation of a Water Vapour Monitor.

All of the upgrade steps (conducted in 2012) have been fully successful but the replacement of the detectors by larger 1k x 1k Si:As Aquarius arrays (a development at Raytheon funded by ESO) has not resulted in the expected improvement of performance. Excess low frequency noise (ELFN) has been identified as the root cause of the lack of sensitivity. Since this effect is inherent to the detector design it cannot be remedied by modifying detector parameters. The best mitigation strategy is faster chopping with the VLT's secondary mirror (M2). After successful testing commissioning of faster M2 chopping is planned in November 2014 immediately followed by a first re-commissioning run of VISIR. The instrument is offered for Observing Period 95 (April 2015) in service mode and with a sub-set of modes.

3.2.2 GRAVITY

GRAVITY is a four beam combination second generation instrument for the VLTI. Its main operation mode makes use of all four 8m Unit Telescopes to measure astrometric distances between objects located within the 2" field-of-view of the VLTI. With the sensitivity of the UTs and 10μas astrometric precision, it will allow to measure orbital motions near the Galactic Centre with unprecedented precision. Other modes of the instrument include imaging and the use of the 1.8m Auxiliary Telescopes. GRAVITY requires a number of modifications to the Paranal infrastructure to be hosted in the VLTI lab together with MATISSE and to obtain its best performance.

GRAVITY is in its assembly phase. After the first fringes were obtained, integration is progressing with the beam combiner instrument at MPE in Garching and with the AO system at MPIA in Heidelberg.

The project is experiencing some challenges especially in the areas of metrology; the AO modules team was reinforced and the present (ambitious) schedule foresees Preliminary Acceptance Europe (PAE) in the second half of 2015.

3.2.3 MATISSE

MATISSE (Multi-Aperture mid-Infrared SpectroScopic Experiment) is a four beam-combiner 2nd Generation instrument for the ESO VLTI, designed to be sensitive from the L to the N band. MATISSE's multi-way combination will provide a capability to create simple images at interferometric resolution of a wide range of targets.

The instrument is well advanced in the integration and test phase, with the N-band cryostat and cold optics delivered from MPIA and successfully tested. The L-M band cryostat is planned to follow soon (November 2014). The integration of warm optics, electronics and software is progressing well.

The present schedule foresees PAE at the end of 2015, however the need to re-manufacture some warm optics components may introduce delay.

3.2.4 ESPRESSO

The Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations (ESPRESSO) is a super-stable Optical High Resolution Spectrograph for the Combined Coudé focus of the VLT. It can be operated by either one of the UT or collecting the light from the 4 UTs simultaneously.

The procurement of some parts, such as the vacuum vessel and the thermal enclosure is being completed. Other parts are being procured or are in different stages of integration (echelle gratings, optical bench, mirror blanks for the spectrograph collimator, cameras).

The preparation of the combined coudé laboratory is progressing well and the thermal enclosure is expected to reach Paranal in November 2014.

The ESPRESSO schedule foresees, after the thermal enclosure, a Delta-FDR at the end of the year. The installation of the coude' interfaces and optomechanics are planned to be completed in March 2016, at the time of the spectrograph PAE.

ESPRESSO is changing significantly some of the Paranal infrastructure and one challenge has been the correct management of the change requests needed to advance the project. This has taken more time and effort than initially estimated and has created some friction with the consortium. Following the positive experience with AOF, one mitigation step has been to dedicate one person (the project manager G. Lo Curto) to this task and to transfer him temporarily to Paranal. This strategy has proven successful and it is intended to use it for every project that needs significant infrastructure changes. On the technical side, one potential risk is the possible delay in the delivery of the Laser Frequency Comb unit (the one for HARPS has not yet been delivered), mitigation for this has been studied and alternative solutions are possible (Fabry-Pérot etalon).

3.2.5 AOF

The VLT Adaptive Optics Facility (AOF) consists of six main subsystems: the M2-Unit hosting the Deformable Secondary Mirror (DSM), the Four sodium Laser Guide Star Facility (4LGSF), GALACSI the AO module for MUSE, GRAAL the AO module for HAWK-I and ASSIST a test bench for qualification in Europe. Several modifications have been implemented on UT4 in order to accommodate all these systems. The AOF will upgrade the UT4 with a new M2-Unit hosting an Adaptive Secondary mirror (1170 actuators), Four Laser Guide Stars (4x 22W Sodium beacons) launched from the telescope centrepiece and AO modules to provide user optimized adaptive correction modes.

AOF has completed the system test for the GRAAL natural guide star adaptive optics mode. This validated the complete chain of AOF systems: the ASSIST test bench and turbulence simulator, the DSM, the GRAAL modules with WFS cameras and real-time computer SPARTA. The project will continue with the GRAAL Ground Layer mode tests. An implementation readiness review was held in April 2014 and validated the project's commissioning strategy in Paranal. All lasers for the 4LGSF have been delivered to Garching and two of them have been integrated with the launch telescopes and successfully tested. Flexure tests have been carried out on GALACSI and the results show a sound mechanical structure. The UT4 Upgrade is complete and a final acceptance report has been produced. The Astronomical Site Monitoring upgrade is also progressing well.

In this time of sequential tests the major challenge is to hold the project schedule. For instance, a failure of the electrical contacts of the DSM has recently introduced a slip of 2 months to the overall schedule. The plan of the AOF has a sequence of milestones and foresees: PAE GRAAL in first quarter 2015; PAE 4LGSF and GALACSI in fourth quarter 2015; DSM Installation in third quarter 2016; PAC of AOF in second quarter 2017.

3.2.6 VLTI Infrastructure

The mid-term VLTI implementation plan foresaw the construction and operations of a number of facilities aimed at enabling PRIMA and optimizing the performances of the 2nd generation instruments GRAVITY and MATISSE, including adaptive optics for the Auxiliary Telescopes (NAOMI) and a second generation fringe tracker. The plan was implemented through 6 separate projects created in 2012 (VLTI PR1-PR6). It has been recognized, however, that given the strong interconnections between the many VLTI components, a higher level of system view, planning and coordination was needed. So a "VLTI Facility project" has been defined, following the AOF scheme and encompassing the old projects as work packages. The project is led by a full time Project Manager (F. Gonté), Project Scientist and Project Engineer. The PM, who will start formally on 1st January 2015, will also oversee the implementation on site. The project management plan is presently under review and will go into force in early 2015. While GRAVITY and MATISSE will remain separate projects, they will report to the VLTI facility as far as interfaces, intervention on the infrastructure (including schedule) are concerned.

3.2.6.1 AT Maintenance Station (PR1)

This work package includes mainly the development of a new maintenance station for the Auxiliary Telescopes (AT). The current maintenance station has very limited access, which makes the integration and alignment of the Star Separator and NAOMI very difficult, and it necessitates the risky transport of the ATs down to the integration hall. The new maintenance station is built on the VLT platform and connected to the AT rail system making its access as easy as any other station.

The contract for the excavation was placed in July 2014 and has been completed. The civil construction work is now underway and will be completed by April 2015.

3.2.6.2 PRIMA Astrometry (PR2)

The project is discontinued. (Section 3.1.4 above)

3.2.6.3 Adaptive Optics System for the Auxiliary Telescopes (PR3 = NAOMI)

The New Adaptive Optics Module for Interferometry (NAOMI) will be developed for and installed at the 1.8-metre Auxiliary Telescopes (ATs). The goal of the work package is to equip all four ATs with a low-order Shack-Hartmann adaptive optics system operating in the visible in order to overcome the limitations of the current system.

To help the overall ESO effort situation, the corrective optics for NAOMI will be built under contract by the Institut de Planetologie et d'Astrophysique de Grenoble.

The current timeline foresees Preliminary Design Review (PDR) in the first quarter 2015, FDR in the fourth quarter 2015 and shipment of the first system to Paranal in the third quarter 2017. The installation of the remaining three systems is planned by the end of 2017.

3.2.6.4 Infrastructure for VLTI Second-Generation Instruments (PR4)

This work package covers the infrastructure to be implemented for the 2nd generation of VLTI instruments. It includes the upgrade of the VLTI laboratory in preparation for the arrival of the GRAVITY and MATISSE instruments, the installation of star separators in the UT Coudé rooms and in the ATs.

The VLTI will be closed to operations for six months starting in April 2015 to allow major modifications to the laboratory and to the ATs to host the new instruments.

3.2.6.5 Second Generation Fringe Tracker (PR5)

The work package main goals include the delivery of the differential delay lines (DDL) #3 and #4, currently being manufactured, and of the 2nd generation fringe tracker (2GFT).

In collaboration with the MATISSE consortium, a Phase A study started in Q2 2014 investigating the possibility to use of GRAVITY as a fringe tracker. The report is due in Q1 2015.

In parallel there is a pre-study by the MATISSE consortium on a shorter timescale with the aim of studying which key science objectives of MATISSE can be achieved at which performance levels of a fringe tracker. The result of this pre-study will be used together with the Phase A study to decide on the strategy for the 2GFT.

In case of a positive outcome of the Phase A study, the project will make GRAVITY the Fringe Tracker of MATISSE, but only after the commissioning of both instruments. The decision a stand-alone 2nd Generation Fringe Tracker is linked to the successful implementation of GRAVITY as a fringe tracker.

3.2.6.6 VLTI 2nd generation performance (PR6)

The objective of this work package is to proactively improve the performance of the VLTI infrastructure and reach a level compatible with the challenging science cases of the future instruments, GRAVITY and MATISSE. This performance work package works in parallel with the functionality-oriented VLTI 2nd Generation Infrastructure work package (PR4).

A performance roadmap for the VLTI infrastructure was delivered in May 2014. This roadmap identifies a list of key performance aspects that should be investigated in preparation for the commissioning of GRAVITY.

The first objective is the readiness of the infrastructure towards robust fringe tracking, that relies on two pillars: 1) the instantaneous Strehl delivered by the telescopes and 2) the level of differential piston on the various telescope baselines. Translated into VLTI current and upcoming sub-systems, the roadmap suggested: a) the continuation of the AT/NAOMI adaptive optics with a higher level of priority, b) the investigation of UT/MACAO performance and c) the development of a vibration metrology on the UTs.

The second objective of the roadmap is to investigate the astrometric baseline stability on the UTs, ahead of the arrival of GRAVITY at Paranal.

The roadmap is being consolidated based on the first results that are emerging; most notably, the test on UT/MACAO has confirmed that the field stabilization noise seen by SPHERE is also present at the VLTI, and that eliminating this contribution would bring immediately a large improvement in Strehl ratio.

3.2.7 MOONS

MOONS is a 0.8 to 1.8 micron multi-object spectrometer for the Nasmyth focus of the VLT. The instrument will be fibre fed, and have at least 800 (goal 1000) fibres over a total field 25 arc minutes in diameter. There will be two spectral resolutions; ~4000 spanning the full wavelength range and ~20000 in two regions in the J and H windows.

MOONS has completed all of the necessary documentation and the Agreement has been signed with the Consortium. The Kick off Meeting was held in October 2014. The development plan foresees PAE at the end of 2019 and PAC in 2020.

3.3 Projects paused in the hiatus

In the FTE planning exercise carried out in September 2013, (using the new tools developed for the matrix), it was not possible to fully satisfy the staffing requests for 2015 and beyond. This was exacerbated in the following months by the need to put additional effort into the infrastructure changes needed for GRAVITY, MATISSE and ESPRESSO, plus a six-month slip on AOF and further detector problems on VISIR. In April 2014 three actions were taken:

1. A scientific prioritisation of the entire ESO programme was initiated under the leadership of the new Director for Science. This involves members of the STC, UC and VC and will report to STC in April 2015 and to Council in June 2015.
2. CRIRES+, ERIS and the planning for the NACO refurbishment were put on hold (in terms of ESO effort) for six months to allow the effort to be re-deployed.
3. The FTE planning exercise was brought forward and included long range planning on a six year baseline to fully explore the effort requirements over the coming years.

The FTE planning is now substantially complete and it is clear that ESO does not have sufficient effort to continue to lead the ERIS project. It is also clear that some targeted training and hiring will be needed to ensure the full skill set is in place for the E-ELT. This is included in the 2015 BFL document.

3.3.1 CRIRES+

The CRIRES Upgrade project (CRIRES+) will transform CRIRES into a cross-dispersed spectrograph. By using 6 gratings as cross-dispersing elements, it will be possible to cover the whole 1-5 µm wavelength range and increase the simultaneous wavelength coverage by a factor of at least 10 relative to the present configuration. New gas cells will be used to calibrate the instrument over the whole spectral range and obtain precise (a few ms^{-1}) radial velocities. A polarimetric unit will be added.

The Consortium partners were keen to continue their work during the hiatus and a critical minimum support by ESO was provided during this period.

The collaboration agreement has been updated and signed by ESO and the consortium in June. Although the hiatus presented a major challenge, the project mitigated it by re-arranging activities and redistributing work to the ESO partners. The three science HAWAII2RG detectors were delivered to ESO in May. In July and August, acceptance testing has been performed.

Starting in July, CRIRES, including the MACAO fore optics module, was removed from the Nasmyth platform of UT1 for NACO to be reinstalled in lieu of CRIRES. On 23 July 2014, the MACAO-CRIRES warm bench suffered severe damage in an accident during its transport from UT1 to the storage area.

The CRIRES cold part has been shipped to Garching and is now being re-installed in the new technical building at ESO. The warm part will be shipped to Garching in October 2014 in order to analyse the damage and to work on a recovery plan for this part of the instrument. The repair of the MACAO will be added to the scope of the CRIRES+ upgrade. A refurbishment of the MACAO was already included. No major impact in the CRIRES+ schedule is expected, but must be confirmed after the damage analysis. It will clearly impact the Programme contingency and the allocated effort.

3.3.2 ERIS

ERIS is a new instrument for the Cassegrain focus of UT4, consisting of a diffraction limited infrared (IR) imager which will replace a set of the most important NACO capabilities, an AO Wavefront sensor (WFS) module which will use the AOF deformable secondary mirror and any one of the 4 AOF lasers (one at a time - SCAO), and an upgraded version of SPIFFI to adapt it to the new AO module.

During the six months hiatus the detailed effort planning for all ESO projects was completed, which led to the clear conclusion that ESO cannot continue to lead ERIS. At the same time the Science Prioritisation exercise led by the Director for Science confirmed that ERIS is needed and should be delivered as soon as possible. Therefore ESO has asked the ERIS Consortium partners to take the leadership of the instrument together with several of the ESO work packages, leaving at ESO only some subsystems (detectors and wave front sensors).

In order to maintain a schedule in the 2019 timeframe, however, it was also clear that a simplification of the technical concept is necessary. Such a concept is under discussion with the consortium and includes:

- Replacing the Pyramid WFS by a copy of the GALACSI/GRAAL WFS – avoiding testing and a new development
- SPIFFI and the IR imager are not inside the ERIS structure but are interchangeable – which substantially simplifies the optomechanical design , and
- Eliminating the IR tip-tilt sensor.

The discussion with the Consortium partners is on-going, aiming at reaching rapid agreement and final contract signature. The STC will be kept up to date with the developments.

3.3.3 NACO Refurbishment

NACO was originally supposed to be decommissioned after its removal from UT4, but the importance of keeping an AO imager at the VLT before the arrival of ERIS, in particular to continue the monitoring of the Galactic Centre and support observing the peri-event in 2017/18 has been recognized. A special STC meeting was held in December 2013 to evaluate different solutions; the recommended one was to reinstall NACO at the focus of CRIRES on UT1 which would be vacated for the CRIRES upgrade. The re-installation of NACO carried some risks, because of the critical state of three major components: the detector, the field selector and the real time computer. One of these risks materialized and the detector is no longer working properly. The failure is currently under investigation and the baseline is to repair it.

A preliminary refurbishment plan has been developed, which shows that the full intervention would require a rather major upgrade, with the cost of 1 MEUR, the need for 10 FTEs over a total duration of three years, including a substantial downtime from the telescope. Further work on this plan was stopped in the 6 months hiatus. The resources needed for this refurbishment are considerable and they partially overlap with the needs for ERIS in the detector and AO areas. It is questionable if the investment is appropriate, given its duration and the fact that NACO will be decommissioned after ERIS is in operation.

As far as the long-term survival for the observations of the Galactic Centre, the NACO refurbishment will be further studied, but also alternative backup solutions (such as using MAD, already recommended by STC, ESO/STC-497) will be considered, as mitigation of the risk of a major failure of one of the critical components.

3.4 Recommended Instruments pending contract agreement

3.4.1 CUBES

In UV spectroscopy from the ground (300-380 nm spectral range), a large increase of efficiency with respect to existing instruments (UVES and X-Shooter) is possible. In addition, this spectral range is complementary to the E-ELT and JWST. An efficient UV spectrograph can cover a broad science case and will be a world-leading instrument for many years to come. Located at the Cassegrain focus, it will be built to be easily exchangeable. The CUBES concept was developed by a consortium of Brazilian institutes and ESO. It is an instrument of intermediate size and cost, largely funded by the external partners, and is very well suited for a Brazilian partnership. The project has passed Phase-A review and has been recommended by the STC. The detailed design and construction will commence following the ratification of Brazilian accession to ESO. The development plan foresees a duration of only three years from Kick Off (KO) meeting to PAE.

3.4.2 4MOST

4MOST will be located on the 4-metre VISTA telescope, with a field of view of more than three square degrees. It will host up to 2400 fibres and will work in the optical (0.3-0.9 μm). The goal is to have three spectrographs: with sixteen hundred fibres that feed two lower resolution spectrographs (R~5000), and 800 fibres to one higher resolution spectrograph (R~20000). Currently the consortium has secured funding for two of the three spectrographs. It has been proposed to work in survey mode for a minimum of five years.

After a Call for Ideas in 2010 and competitive Phase A studies, 4MOST was recommended for design and construction by STC (ESO/STC-522).

ESO/STC-522 recommended to ESO:

- to find a mechanism to involve the community in the definition of the survey to guarantee the proper return to the community
- to address the resources needed to operate 4MOST in public survey mode
- that the requirement of be dismountable should be maintained
- that the management of Consortium should be strengthened

Following the STC recommendation, further work has been carried out to address open items from the Phase A review and the STC recommendations. Signature of the 4MOST agreement is currently foreseen for 2015.

4MOST is a major project and will impact significantly the existing VISTA infrastructure. It will therefore be treated as an “infrastructure project” (see section 3.2 above) from the outset.

3.5 La Silla Instrumentation

The Paranal Instrumentation Programme also covers any projects for La Silla. These projects by design are only contemplated if they are at a minimal cost to ESO.

3.5.1 Laser Frequency Comb (LFC) for HARPS

The project aims at developing and procuring a novel calibration unit for HARPS at the 3.6m telescope based on the Nobel Prize-winning technology of Laser Frequency Combs. This new calibration system shall ensure, among others, a long-term precision of ~30 cms^{-1} with HARPS, and it is the technology adopted as the baseline for the ESPRESSO calibration.

The project is suffering substantial delay because of technological issues in the durability of the photonic crystal fibre used for the last stage of spectral broadening. The LFC is required to be a turn-key system with minimal maintenance requirements and the current durability of the fibre is not compatible with this requirement. However, progress has been made; the physics is understood and the present plan foresees the PAE and commissioning of the LFC in spring 2015.

3.5.2 New Instrument for NTT

Following the STC recommendations, ESO launched a Call for Ideas for scientific projects at the NTT that includes a new instrument to be provided by the community. This new instrument can replace either SOFI (in operation since 1998) or EFOSC2 (in use since 1990) or both and will be available to the ESO community for 50% of the time until 2021. Additional observing time with the new instrument will be available for interested groups through the co-funding of the NTT operations.

The NTT Call for Ideas was open for specialized instruments taking advantage of large amount of dedicated observing time, as well as for state-of-the-art workhorse instruments addressing broad needs of the ESO community. Such an instrument is required to be at negligible cost to ESO. After selection, seven groups have been invited to answer to a Call for Proposal.

4 The Future Programme

4.1 Programmatic drivers

This instrumentation development plan follows from consideration of a number of basic drivers. These are discussed below to give a flavour of the factors what will be taken into account when selecting new projects and upgrades.

4.1.1 Phase 1

In the next decade the VLT will remain the leading ground-based telescope until the start of operations of the ELTs. There is no indication that the size of the Paranal user community will decrease. On the contrary, new member states may join ESO, increasing the pressure on the Paranal facilities. Consequently in Phase One, the scientific use and output of Paranal instruments should be optimized, not only maximizing their throughput, but also their operational efficiency. It is important to balance as much as possible the pressure between the different telescopes and to preserve a balance between specialized and workhorse instruments, with the latter covering a wide range of scientific interests.

4.1.2 Phase 2 – Paranal & E-ELT

From 2019 onwards, new instruments and upgrades will be considered part of Phase 2. This phase is still relatively open and different scenarios can be envisaged. The E-ELT will be fully operational and astronomical research with 8-metre class telescopes may evolve towards a model where a large fraction of the time is devoted to dedicated experiments and large collaborative projects. In this context the four VLT Unit Telescopes together could provide a unique opportunity to dedicate up to ~1200 nights/year to a single problem. This approach could open up new opportunities in astronomical research. ESPRESSO and VLTI are already able to exploit the 4UTs simultaneously but new options are possible, such as equipping the 4UTs with 4 clones of the same instrument, to perform really vast, dedicated surveys.

The last two instruments of the decade (starting phase A in 2019/2020) will likely start operations after the first generation E-ELT instruments. Their selection will occur after a careful reflection on the scientific use and role of the VLT in the E-ELT era.

The E-ELT will be an additional telescope in the Paranal observatory, and the strengths of each unit in the entire system should be maximised. Synergy and the ability to complement E-ELT capabilities are therefore important criteria for the VLT. Several aspects are unique to the VLT with respect to the E-ELT: the larger FOV, the VLTI angular resolution, and the access to the UV domain. The E-ELT will be one telescope, while the VLT includes 4 UTs. More observing time will be available at the VLT for a single programme or user. Some E-ELT instrumentation capabilities should be duplicated at the VLT, to ensure that the E-ELT is used only when its special characteristics are really needed.

4.1.3 Paranal, HST & JWST

By 2018 the HST will most likely no longer be in operation, and JWST will be about to enter operations. HST capabilities that will be unavailable include UV spectroscopy and high-resolution imaging in the B- to R- bands. The former is impossible from the ground beyond the atmospheric limit. An instrument able to provide diffraction-limited observations in the B- to R- bands over a sufficiently large field could recover an important part of the missing parameter space.

Complementarity with JWST includes:

- High resolution spectroscopy
- Observations of Bright sources
- Diffraction limited observations at short wavelengths
- Flexible operations
- Wide wavelength coverage, and
- Wide field.

It might also be advantageous to provide some overlapping capabilities with JWST. The difference in performance for multi object low resolution spectroscopy in a small FOV is too great in favour of JWST to justify a duplication from the ground, but wide field, multi-IFU diffraction limited spectroscopy merits study.

4.1.4 Paranal & Ground Based Observatories

The relationship of Paranal with other ground-based observatories (including ALMA) has still to be discussed in depth. In general, the Paranal choices will be driven by the scientific requests of the ESO community rather than by the developments of its competitors.

4.1.5 Visitor Focus

The availability of a free focal station to host visitor instruments was advocated in the past. However, with all foci occupied, a focus becomes a valuable resource. It does not seem worthwhile to leave a focus permanently unused. Should a compelling case be presented for a future visitor instrument, a facility instrument may be temporarily removed.

4.1.6 Maximize Efficiency/ Optimize use of observing time

The fact that the pressure is particularly high on some instruments must be considered: to provide maximum scientific return implies also to maintain a similar pressure on all telescopes. This is a priority.

4.1.6.1 Improve efficiency

The possibility of greatly improving efficiency (throughput) and operational efficiency (duty cycle) of the instruments is generally limited. Detectors are close to optimal performance in most cases. Improvements in throughput or operations may bring small gains. Some exceptions, such as VIMOS and VISIR, were identified in the past and lead to important upgrade projects. The VIMOS upgrade is completed, while the VISIR one is close to completion. Further exceptions are high resolution IR and UV spectroscopy, where a gain of factor of up to 5 can be obtained, and they are addressed by the CRIRES+ and CUBES projects.

4.1.6.2 Enlarge spectral coverage

Enlarging the wavelength range which is simultaneously covered saves telescope time when multi-wavelength observations are needed. Considering the success of X-Shooter, this path is surely interesting. However, it should be noted that enlarging spectral range and maximizing efficiency may be conflicting requirements.

4.1.6.3 Share Foci

Optimizing operations and answering the requests of the observers in a flexible way is also an aspect of improving efficiency. The capability of sharing a focus among different instruments is an optimization. There are several flavours of sharing that can be considered:

Simultaneous observations – Observe objects in the same VLT field simultaneously with different instruments. This would bring an immediate gain in efficiency. In practice, this attractive scheme is complex to implement and has been used only in FLAMES, where GIRAFFE and UVES can observe simultaneously within the same field (and within the same scientific project).

Exchange instruments – Adding the requirement to design instruments for easy removal and storage would add flexibility and may help to optimize the use of the telescope. The idea is to allow one exchange every few months. Such a requirement has been built into the CUBES specification and will also provide the possibility to easily free a focus for visiting instruments.

Multi-port adaptor – Another interesting approach would be to build adaptors that serve more (smaller) instruments at the same focus.

4.1.7 Instrument development duration

The typical development time for 2nd generation VLT instruments has been almost 10 years from the time of conception, and 6-7 years after the start of the design phase. On the other hand, a long lead time should not be assumed to be inevitable and the programme can develop simpler instruments on shorter construction times if this becomes an agreed goal.

One interesting opportunity is to expand the current procurement scheme and create a new class of visitor instruments, with a broader interest to the community; operated by the constructing team, but also executing proposals from the community at large (in the manner of the VLTI instrument PIONIER).

4.2 Instrument Definition and Procurement Procedure

Input for the selection of new instruments will be provided via normal routes such as the STC and its sub-committees, scientific conferences, or directly from the community. In the case of conferences, the emphasis will be on 8-metre telescope science, rather than technological concepts. The first workshop in this series, “ESO in the 2020s”, will take place in January 2015. The conference will help conclude a report scheduled to be presented to STC and Council in 2015.

A key aspect of future instrument planning will be an attempt to develop and coordinate longer-term strategy more effectively. To help in this, a small working group will be set up with representation from ESO, STC and the broader community to advise the ESO Executive on the selection and deployment of instruments. Since all foci are currently filled, the working group will also need to identify the instrument that will be decommissioned to free a focus.

The procedure leading to instrument construction will follow the normal VLT model. Top-Level Requirements will be prepared and issued with a Call for Proposals. One or more Phase A studies will be funded to develop concepts, draft technical specifications, cost to completion and schedule. Following Phase A reviews, a decision will be made on construction of the instrument. All steps are done in consultation with the STC.

In situations where the procurement model is an ESO-led consortium, a competitive process will normally be used to select external institutes as partners. For upgrades or smaller projects (or in case of urgency), this competitive process may be waived.

When possible, R&D or prototyping will be 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 is not static, and must retain flexibility to react to the evolving scientific and technological landscape and to re-assign priorities. New proposals will be evaluated in collaboration with 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 will be 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 based on past experience are used. The governing bodies are kept fully appraised of the evolution of the planning as well as the status of the approved programme though the biannual reports and presentations to the STC and its Paranal subpanel.

4.3 Instrument decommissioning

With the arrival of ESPRESSO in 2016, all VLT/I foci will be used, including the incoherent combined focus. ISAAC has been decommissioned to make way for SPHERE, and MIDI will be decommissioned at the beginning of 2015 to be replaced by GRAVITY. AMBER will remain in operations until GRAVITY is offered for science at which point it will also be decommissioned.

MUSE has taken the focus of NACO, which has replaced CRIRES during the upgrade. When CRIRES+ returns, one of the first generation instruments will have to be dismounted.

In the future, each time a new instrument is accepted, the instrument to be de-commissioned will be identified (at the latest at the time of the new project Final Design Review), on the basis of a grid of criteria that includes scientific potential, complementary with new instruments (and therefore coverage of the parameter space), instrument status and future perspectives.

The instruments in the current programme that will be delivered before 2020 and for which a focus will need to be identified are CRIRES+, ERIS, MOONS (all of which need a Nasmyth focus) and CUBES (which needs to share a Cassegrain focus).

Among the candidates for decommissioning before 2020 on the UTs are FLAMES, VIMOS, NACO and UVES, all of which would free up Nasmyth foci.

- FLAMES and VIMOS are both already more than 10 years old, GIRAFFE will hardly be competitive beyond 2017 and VIMOS can only work with limited configurations. They could be de-commissioned after the spectroscopic surveys have been completed.
- After the S2 event in 2018 and with the advent of ERIS, NACO can be decommissioned.
- With the installation of ESPRESSO and CUBES, most UVES capabilities will be offered (and improved). It might be conceived therefore that, at this point, UVES could be de-commissioned after some 20 years. The UVES slit mode remains however unique.

The important point is that there are sufficient decommissioning options to accommodate the new instruments.

Looking further forward, HAWK-I is the natural candidate to free a focus for a new instrument to fully exploit the AOF (see section 4.4.2 below). HAWK-I is not currently heavily in demand, but it is expected to have a second life with the Ground Layer AO correction offered by the AOF. Nevertheless, it could be de-commissioned after a several years of operation with AOF.

4.4 Potential new instruments and upgrades for the VLT/I

After examining the current complement of Paranal instruments at the telescope or in construction, a number of potential developments can be identified which are listed below. The list is not intended to be exhaustive.

4.4.1 Workhorse instrument to complement/support FORS2 and X-Shooter

FORS2, X-shooter, and ISAAC (and also EFOSC at NTT) have been among the most popular and productive ESO instruments. They are typical workhorses and the user pressure on them is very high. It is important that ESO preserves this class of instrument. With the decommissioning of ISAAC, IR spectroscopy in the 2.4-5 μm range is no longer available. Should the new workhorse be a multi-function multi-wavelength instrument? Or a copy (perhaps slightly modified) of one of the existing, most requested instruments? Such questions will be debated by the ESO/STC/ Community working group mentioned in Section 4.2.

4.4.2 New Instrument for AOF

In answer to the STC request for a plan for AO instruments at the VLT, ESO has proposed a development in two phases: first ERIS, that will follow-up NACO; then a new ambitious instrument, which is still to be specified fully, and would exploit the full potential of the AOF in the focus occupied by HAWK-I (Adaptive Optics Planning ESO/STC-493 (2011), ESO/STC-482). For this instrument it is critical to evaluate its complementarity and competitiveness with JWST. Considering that high resolution imaging in the B- to R- bands with HST will most likely no longer be available, a high-Strehl B- to -R band imager would be an attractive possibility.

4.4.3 Potential VLT instrument Upgrades

Even if most of the VLT/I instruments will be new or recently upgraded, the 16 years of VLT experience demonstrate that there are frequent requests for upgrades (mostly detectors) and that these have served the community very well. Upgrades are especially needed for workhorse instruments, whose lifetime often significantly exceeds the 10 years nominal time of VLT instruments.

Upgrades under considerations are:

X-Shooter: Two proposals to upgrade X-Shooter[2] have been submitted to the Programme Manager. They are presently on hold, because the first priority will be given to solving the poor behaviour of the ADCs. This repair will be considered after the VISIR upgrade has been completed.

FORS2: A proposal to upgrade the FORS2 detector is being prepared by the instrument operations team. The use of a 4kx4k pixel CCD detector would bring substantial operational benefits.

SPHERE: A replacement deformable mirror is discussed in section 3.1.3.

All major upgrades are treated as new projects, and compared to running or planned instruments in order to decide priorities. Starting one project implies that either a new instrument or a major upgrade can be initiated, but not both.

4.5 Roadmap

The roadmap laid out in Tables 1 to 3 below shows the current projects under construction and the planned future projects. It is based on the present planning and on the ESO resource allocations for the running projects. For future projects, the projections have been made using typical effort figures expended on previous VLT instruments. The available resources can support starting one project per year on average, but no new projects will be started for the VLT before 2017 to be able to carry out and complete all the pending upgrades/refurbishments.

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[2] One from the Netherlands and one from Denmark.

The table below summarizes all the projects currently running under the Paranal programme, providing a short description of their purposes.

Project Name	Description	Status
1. KMOS	IR Multi deployable IFUs	Operations, PAC pending
2. VISIR Upgrade	Upgrade detector, disperser, water vapour monitor	Test & Commissioning
3. SPHERE	Extreme AO Planet finder	Commissioning, SV
4. MUSE	Giant Optical IFU	Operations, PAC pending
5. GRAVITY	VLTI Astrometry	Integration Europe
6. MATISSE	VLTI mid IR imager	Integration Europe
7. ESPRESSO	High Resolution 1UT & 4UT	Integration Europe
8. ERIS	AOF Imager and Spectrograph	Design
9. LFC for HARPS	Laser Frequency Comb for HARPS	Integration Europe
10. CUBES	UV Spectrograph	Awaiting Brazilian ratification
11. CRIRES Upgrade	Upgrade, X-disperser, new detectors	Design
12. MOONS	IR Multi-Object Spectrograph for VLT	Design
13. 4MOST	Optical Multi-Object Spectrograph for VISTA	Design, Contract agreement pending
VLTI Infrastructure		
14. PR1	AT Service Station and Alignment	Construction
15. PR2 – PRIMA 2T	PRIMA Astrometry	Discontinued
16. PR3	NAOMI (AO for ATs)	Design
17. PR4	Infrastructure for MATISSE & GRAVITY	Design & Construction
18. PR5	2nd Generation Fringe Tracker	Phase A
19. PR6	Coordination, System, Vibrations control	Conceptual Design
AOF	AO Secondary for UT4 plus its moduli, consists of 5 main subsystems:	Part Integration & test in Europe, part installed
20. 4Lasers	AOF Lasers & Launch telescope	Acceptance Europe
21. DSM	Deformable Secondary Mirror	System Tests
22. GALACSI	AO module for MUSE	Integration Europe
23. GRAAL	AO module for HAWK-I	Integration Europe
24. UT4 Upgrade	UT4 Preparation & modification	Complete

Table 1: List and summary description of running Paranal Instrumentation projects. VLTI infrastructure and AOF facilities have been split into their main projects and subsystems. Delivery dates are given in Table 2.

Table 2 shows the planned development timetable. For the new projects, one year of Phase A is foreseen for all instruments plus a development time of 5 years. This duration is on the short side when compared to 2nd generation instruments such as MUSE, KMOS, SPHERE, but not unrealistic. When considering the process that takes place before Phase A is started, this implies that the selection of the next instruments' capabilities should be made rather soon.

Yr	Phase A	Design & Constr.	Delivered
2012	CUBES CRIRES+ MOS	ERIS	VIMOS Upgrade KMOS
2013		CRIRES+ MOONS	MUSE
2014	NTT Call for Ideas	4MOST	SPHERE PRIMA Astrometry (discontinued)
2015	NTT (New I)	CUBES NTT (New I)	VISIR Upgrade LFC for HARPS VLTI PR1 GRAVITY
2016			MATISSE CRIRES+ ESPRESSO AOF
2017	New II		VLTI PR4 VLTI PR3 (NAOMI)
2018	New III	New II	CUBES NTT(NEW I)(?)
2019	New IV	New III	ERIS VLTI PR5 (?)
2020	New V	New IV	MOONS 4MOST (?)

Table 2 Development plan for the Paranal instrumentation Programme. One year of Phase A is expected to be carried out for new instruments, and the overall duration is typically estimated in 6/7 years. According to the proposed scheme, New I-III are concerned by the first phase. Column "Delivery" refers to shipping to Paranal for instruments and to the end of the integration for infrastructure projects (AOF, VLTI). Dates with question marks are current estimates, to be confirmed.

The roadmap assumes that the projects currently close to completion do not suffer substantial delays with respect to the present schedule. The most critical ones are VLTI infrastructure and AOF, which absorb a considerable fraction of the ESO staff effort. Figure 3 shows the status of the Paranal instrumentation in year 2020, according to the present programme plan. In 2020, all but four instruments will be either new or recently upgraded, and in addition four new projects (three for VLT) will be in design or construction to keep the programme active and alive.

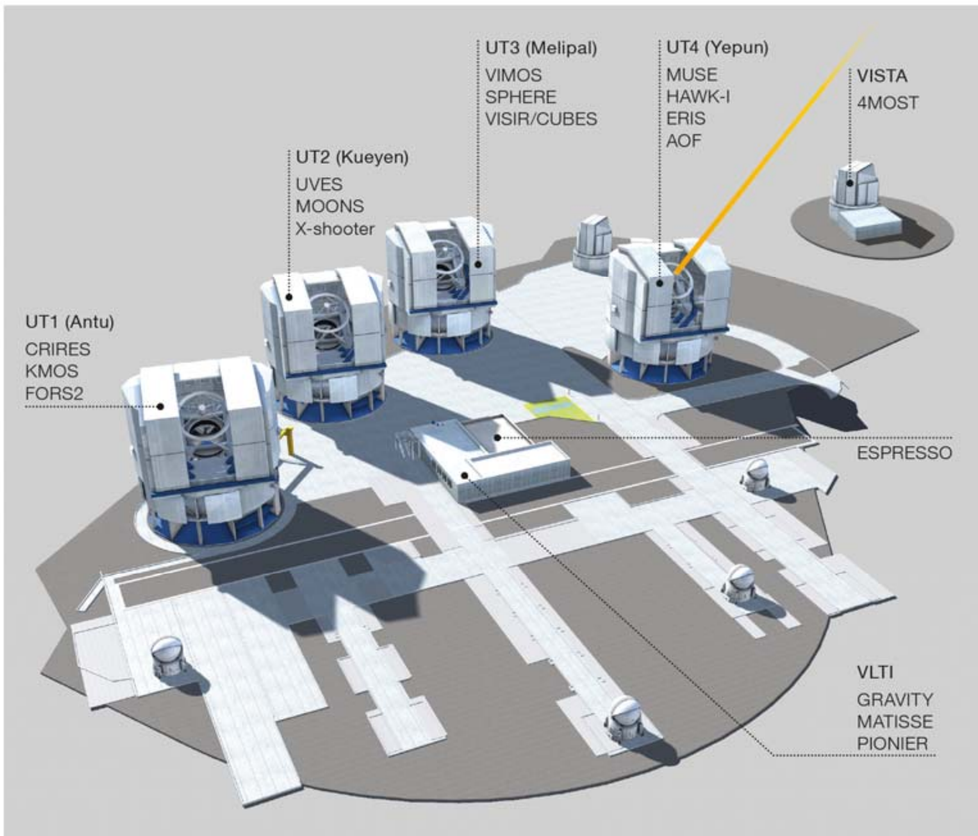

Figure 3: Paranal Instrumentation configuration in 2020, according to the present plan. All but four instruments are new or recently upgraded, 5 new instruments (NEW II-VI in table 2) will be in different phases of completion.

4.6 Milestones for the coming projects

The plan described in this section was first introduced in Oct 2011 to the Paranal sub-committee and in April 2012 to STC. The first version of this document was presented at the STC in April 2013 (ESO/STC-514) and it was presented to the wider community in the December 2013 ESO Messenger. The following table summarizes the approval and definition milestones for the next period. As seen from the table below, assuming a positive answer to the NTT call for proposals (and therefore that NEW I will be an instrument for the NTT), the sequence of instruments and TLRs for the first new VLT project (NEW II) should be ready in ~mid 2016 to allow the Call for Tenders.

Date	**4MOST**	**NEW I (NTT)**	**CUBES**	**NEW II**	**NEW III**
Q2 14		Proposals			
Q1 15		CfP deadline			
Q2 15	Council GTO approval	Council GTO Approval			
Q4 15	Contract agreement	Contract Agreement	Council GTO approval		
Q1 16			Contract Agreement		
Q1 17				Phase A	
Q2 17					CFT
Q1 18				Approval	Selection & Phase A

Table 3: The table summarizes the expected milestones for the coming projects. It assumes that New I will be an instrument for the NTT.

5 Managing the Programme

The Paranal instrumentation programme is managed according to the approved ESO internal project management procedures. One programme manager and one programme engineer run the Paranal Instrumentation programme, guided by two programme scientists, one dedicated to the VLT, Survey Telescopes and La Silla, and one to VLTI.

5.1 Resources

Resources (cash and effort) are allocated to the programme according to the Budget Forward Look. Each project has an allocated budget and cash expenditure profile, and accepted deviations must be balanced within the programme. Project managers request resources from the ESO matrix through the standard ESO process.

Contingency is included, but is not assigned to each project, rather it is held by the programme manager who has to contain all costs within the approved value of the total programme. Unexpected costs beyond this due to technical problems, delays, or enlarged scope, will 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 organization, 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 2015 BFL. The overall resources and expenditure profile is shown in Figures 4 and 5. After the completion of VLTI and AOF, overall funding (including staff effort) decreases to reach a roughly constant value of approximately 4MEUR/yr cash plus 24.5 FTEs/yr of staff effort. This is less than half of the presently used resources and reflects the transition from the 2nd Generation of multiple projects in parallel to the new programme. After the completion of MOONS and 4MOST, the programme should reach a steady state of ~8 projects running at any time.

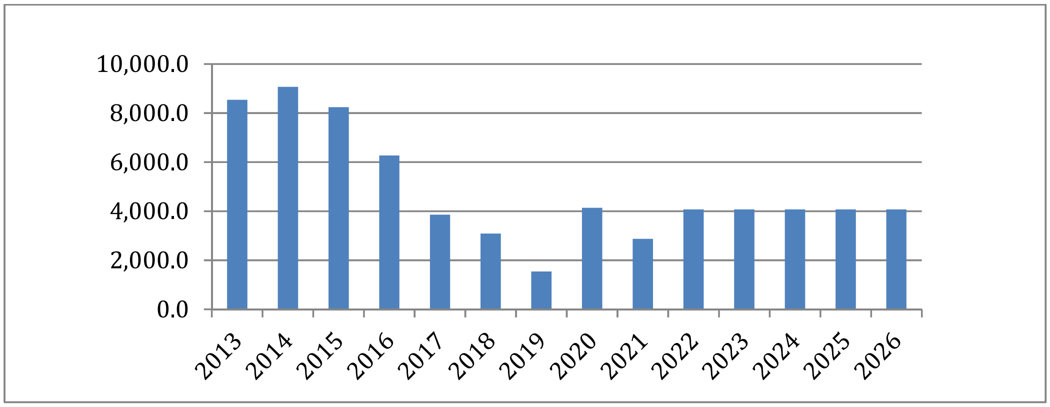

Figure 4: Paranal instrumentation programme capital expenditure profile (staff effort not included, according to the actual projections. The 2014 peak is largely due to carry-over from previous years).

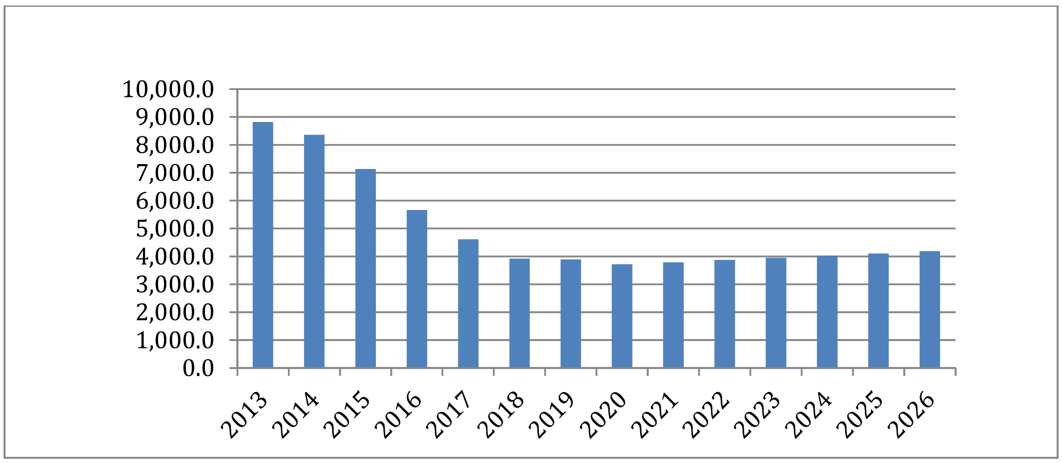

Figure 5: Paranal instrumentation programme staff effort costs (ESO staff effort only).

The Paranal Instrumentation programme covers 19 Foci and 21 instruments (14 foci and 16 instruments for the VLT/I only). With one new instrument or upgrade starting every year, it is clear that the average life of an instrument in Operations on VLT 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. However the overall resource situation (both cash and staff effort) is now at a level where further reductions will have a damaging impact. For example, absorbing the full costs for the SPHERE HODM and the NACO refurbishment is feasible as a one off measure, but repeating this would be dangerous. It should be noted that the new instrument for the NTT (NEW I) and CUBES are possible because both instruments are planned at a very low cost to ESO.

APPENDIX A: Characteristics tables of Paranal instruments in 2018

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)
VIMOS	(0.35-1 µm, 4x7x8 arcmin)
WIFI, GROND, SOFI, EFOSC(?)	
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)
Diffraction limit (VLTI)	
MATISSE	(3.5-12 µm, ~1 arcsec)
GRAVITY	(2-2.4 µm, 2 arcsec)

Table 4 Imagers at Paranal in 2018.

IFUs	
MUSE	(1x1 arcmin) (7.5x7.5 arcsec **AO assisted**)
VIMOS(?)	(1x1 arcmin) IFU discontinued after MUSE?
FLAMES(?)	(7x7 arcsec, 15*2.4x3 arcsec) out if MOONS selected?
ERIS (SPIFFI)	(0.8x0.8, 3.3x3.3 arcsec) **AO assisted**
KMOS	(24* 2.8x2.8 arcsec on 7 arcmin Ø field)
XShooter	(1.8x4 arcsec)
SPHERE	(1.73x1.73 R=50)
MOS	
FORS2	19
KMOS	24 mini-ifus
FLAMES(?)	< 130 or 15 mini-ifus + 7 to UVES-RED
VIMOS	< 500
4MOST/MOONS	>1500/>250
No MOS AO assisted	

Table 5 IFUs and MOS at Paranal in 2018.

AMBER	1.46-2.5 µm R=35-12000
GRAVITY	2-2.4 µm R=22,500,4000
VISIR	8-13 µm R~500
FORS2	0.3-1 µm R=300-3000
MUSE	0.46-0.93 µm R~3000
SINFONI	1.1-2.45 µm R=2-4000
VIMOS	0.36-0.9 µm R=200-2500
KMOS	0.8-2.5 µm R~3600
SPHERE	1-2.3 µm R-100,-700
4MOST/MOONS	0.4-0.92/0.8-1.6 µm R~6000 and ~20000 (both)
X-Shooter	0.3-2.4 µm R=6-10000
FLAMES(?)	0.37-0.9 µm R=6-20000
VISIR	10 µm R=3200, 25000
No low or Int-R spectroscopy in 2-4 µm	
CRIRES	0.95-5 µm R=40-100000
UVES	0.3-1 µm R=40-120000
ESPRESSO	0.38-0.8 µm R=120-220000 ***4UT R=60000**
FEROS(?), HARPS	0.37-0.93 µm R=48000 038-0.68 µm R=115000

Table 6 spectrographs at Paranal in 2018.

Polarimetry: FORS2 (Circ.and Lin.), HARPS, SPHERE, CRIRES? VISIR?
High Contrast/Coronography: SPHERE, VISIR?
RV Precision: ESPRESSO (<0.1 m/s), HARPS (<0.3 m/s), CRIRES (<3 m/s), FEROS? (<25 m/s)
FAST Photometry: VISIR (5ms?), HAWK-I Bust mode (2ms), FORS2 (2ms)
Astrometry: Gravity (30 µarcsec, goal 10), PRIMA (10 µarcsec, goal), ERIS(300 µarcsec)

Table 7 Summary of some of the special modes present in the Paranal instruments in 2018.