Paranal Instrumentation Programme

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ABSTRACT

The development plan for instrumentation at the Paranal Observatory was outlined at SPIE in 2012. Its overall goal is to keep Paranal at the forefront of ground-based astronomy. In addition to the completion of the current second generation instruments, the installation of the Adaptive Optics Facility and execution of the Very Large Telescope Interferometer mid-term implementation plan, it will allow one new instrument, or instrument upgrade, to be initiated per year. The plan is divided into two phases. Over 2013-2017, instruments are selected and developed with the criteria of filling the VLT capabilities and maintaining the balance between dedicated and general purpose facilities. Beyond 2018, the instruments will be deployed in the era of maturity of the European Extremely Large Telescope (E-ELT). The strategy for the second phase derives from analysis of VLT science in the E-ELT era, to be fully shaped in the coming five years. The Call for ideas for a new instrument for the New Technology Telescope at La Silla, fully funded by the community, has just been issued.

Keywords: IR and optical ground based instrumentation, Paranal Observatory

1. THE PROGRAMME

With the construction of the E-ELT, ESO will offer two main observatories to its community after 2020: Paranal (integrating the VLT and the E-ELT) and the Atacama Large Millimeter/submillimeter Array (ALMA). The fundamental goals for the Paranal instrumentation strategy can be summarised by quoting the strategic goals for ESO formulated by ESO Council in 2004 and 2011:

• *ESO must retain 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.*

When considering the VLT instrumentation projects currently under construction, in 2018 the second generation VLT and VLT interferometer (VLTI) instruments and the Adaptive Optics Facility (AOF) will be complete, and all VLT/I instruments, but five, will either be new or recently upgraded. This complement of instruments will cover most options in imaging (including adaptive optics [AO] and VLTI working at the diffraction limit) and spectroscopy in the 300-24000 nm range (c.f. Figure 1). Four integral field unit (IFU) instruments (two AO-assisted) and at least four multi-object spectrographs will be in operation (none AO-assisted). The Paranal Observatory will provide polarimetry, high contrast imaging and coronography, fast photometry and superb astrometry, and also the finest instruments for precise radial velocity (RV) determination. In order to keep the Paranal Observatory competitive, a continuous initiative regarding new instrumentation development was planned from 2013.

The strategic view, considerations and managing principle of the Paranal Instrumentation programme were presented at the SPIE[1]; we just recall here that the development plan is separated into two phases, with a cross-over in ~2018.

Phase 1 (Projects initiated before 2018/deployed before ~2025): 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 the scientific use and output of Paranal instruments should be optimised. It is important to preserve a balance between specialised instruments and workhorse instruments, with the latter covering a wide range of scientific interests.

Phase 2 (Long-term opportunities in the E-ELT era, after ~2025): 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 per year to a single problem. This approach could open up new perspectives in astronomical research. The last two instruments of the decade (started in 2018/2019), should be fully integrated into this long-term perspective. Their selection will occur after a careful reflection on the scientific use and role of the VLT in the E-ELT era. To this purpose, several scientific conferences will be held in the coming years to direct the choices and finalise the strategy and its implementation.

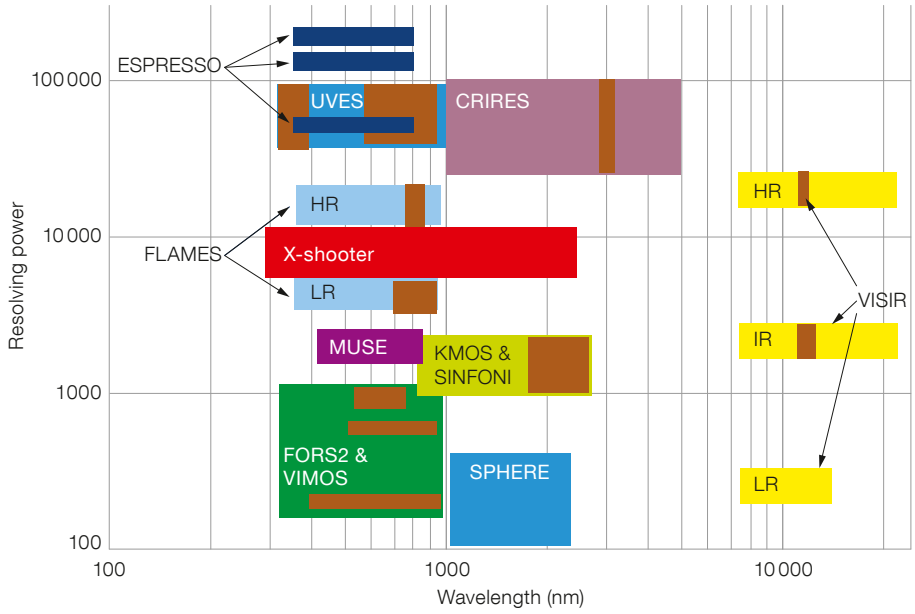

Figure 1:The wavelength-spectral resolving power domain of the VLT instruments

1.1 Role of La Silla

Today the success of 4-metre-class telescopes is often linked to the ability to occupy scientific niches. HARPS at the ESO 3.6-metre telescope is a good example of such a success story. The specific added value of the La Silla 4-metre-class telescopes for ESO can be summarised:

- La Silla continues to be a competitive site providing unique opportunities to its users;
- the ESO community continues to request the ESO 3.6-metre telescope and the NTT at reasonable to high oversubscription rates and both telescopes continue to produce good publication rates
- the ESO 3.6-metre telescope and the NTT are maintained to VLT technical standards and provide excellent image quality and efficiency at negligible technical down time;
- a minority of Member States have access to national 4-metre-class telescopes;
- La Silla provides the opportunity to dedicate a 4-metre class telescope to one, or a few, scientific questions;
- 4-metre-class telescopes with state-of-the-art (workhorse) instrumentation release pressure on the observing time at the VLT (and in the future, possibly for the E-ELT).

Considering that the current NTT instrumentation is reaching the end of its life cycle (EFOSC2 went into operation in 1990, SOFI in 1998), ESO has just launched a call for a new instrument for the NTT to be built in the community. This new instrument could replace either SOFI or EFOSC2 or both, and would 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 NTT operations.

The NTT call was open for both specialised instruments, taking advantage of the large amount of dedicated observing time, as well as state-of-the-art workhorse instruments addressing broad needs of the ESO community. The call for ideas has received an enthusiastic answer from the community, and a total of 19 ideas have been received, which are currently under evaluations. The selected projects will be invited to write a proposal and, after a further selection, a Phase A study will follow.

1.2 New instruments for the VLT

Following a series of Phase A studies and recommendations by the Science Technical Committee, the following new instruments are now in process.

CUBES: In UV spectroscopy from the ground (i.e., 300-380 nm spectral range), a large increase of efficiency with respect to the existing instruments (UVES and X-shooter) is possible. In addition, this spectral range complements that of the E-ELT and JWST. An efficient UV spectrograph can cover a broad science case and could be a world-leading instrument for many years to come. Located at the Cassegrain focus, it could be easily exchanged. The CUBES concept will be developed by a consortium of Brazilian institutes and ESO[2]. The project has passed Phase A review and has been recommended by the STC for the start of the design and construction phase will commence following the ratification of Brazilian accession to ESO. An UV-dedicated conference has been organized.

CRIRES upgrade: CRIRES is equipped with a pre-disperser and currently delivers a fraction of one echelle order per observation. A cross-disperser could increase the simultaneous wavelength range by a large factor. An upgrade that considers the installation of a set of cross-dispersers and new detectors has passed Phase A and is now in the design and construction phase[3]. It will answer a number of scientifically pressing questions, and will in addition satisfy several of the above considerations (such as complementarity with JWST and improvement of efficiency).

MOONS and 4MOST: The proposal to build a new, powerful multi-object spectrograph (MOS) has been strongly endorsed by the ESO community and advocated in several instances by the STC. After a call for ideas, two competitive MOS Phase A studies were awarded: 4MOST[5]and MOONS[6].

MOONS is a near infrared facility (0.8-1.8 μm) which can host up to 1000 fibres at the Nasmyth focus of the VLT. The field of view is about 500 square arcminutes. It can operate either at lower resolution (R~5000) or at higher resolution (R~20 000) in two selected spectral regions.

4MOST is proposed for the 4-metre VISTA telescope, with a field of view of more than 3 square degrees. It will host up to 2400 fibres and will work in the optical (0.3-0.9 μm). Sixteen hundred fibres will feed two lower resolution spectrographs (R~5000), with 800 fibres to two higher resolution spectrographs (R~20000).

These two instruments are largely complementary in almost all aspects: spectral coverage, telescope used, field of view and scientific aims. Given the outstanding science cases presented by the two consortia, the enormous range of applications of large field spectroscopy and the strong push by the community to increase the ESO MOS capabilities, together with the strong complementarity with JWST and E-ELT, both instruments have been recommended for design and construction by STC. The work for MOONS has started, 4MOST will follow.

2. Potential new Instruments 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. This list is not intended to be exhaustive.

Workhorse instrument to complement/support FORS2 and X-shooter: FORS2, X-shooter and ISAAC (and also EFOSC at the NTT) are 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, infrared spectroscopy in the 2.4-5 μm regime will no longer be 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?

New Instrument for the AOF: ESO has proposed a development in two phases: a short term solution, ERIS, that will follow-up NACO and feed SPIFFI, the SINFONI spectrograph; a new, ambitious instrument, still to be decided, to exploit the AOF, in the focus occupied by GRAAL and HAWK-I. A high Strehl *B*- to *R*-band imager would be one attractive possibility. A multi-IFU, AO-assisted, large field spectrograph would also be unique, and its scientific merits should be studied.

In either case, the instrument may require a considerable amount of research and development. The scientific discussion about a new AO-assisted instrument of this type should start soon.

2.1 New VLTI instrument

The VLTI will continue to provide the highest angular resolution, even in the E-ELT era. The rising demand for imaging capability of stellar surfaces, close circumstellar environments and extragalactic sources sets a clear path for the VLTI medium term development plan. PIONIER, GRAVITY, MATISSE and the second generation fringe tracker are and will be the immediate answers to that request. The continuous and successful effort to improve the VLTI's robustness and performance will be essential too.

However, improving the spectral coverage (visible to mid-infrared) and the imaging capability of VLTI should remain a high priority in the years to come. PIONIER already provides this and GRAVITY will provide observing modes close to the most demanded AMBER ones, but with greater sensitivity and much improved Fourier uv plane coverage

While it seems premature to start a new project given the enormous on-going effort to complete and operate GRAVITY and MATISSE, some avenues to be explored for the VLTI in the coming years include:

1) Secure the continuity of PIONIER and offer it to the community
2) Continue to offer a visitor focus at the VLTI
3) Explore the six-telescope imaging capabilities of VLTI with the existing infrastructure.

3. Potential VLT instrument upgrades

Even if most of the VLT/I instruments will be new or recently upgraded, the 15 years of VLT experience demonstrate that there are frequent requests for upgrades (mostly of detectors) and that these have served the community very well. Upgrades under consideration are:

X-shooter: Two proposals to upgrade X-shooter have been submitted and have been evaluated..

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

SPHERE: The deformable mirror is formally below specification, and a replacement could be needed if its performance was to deteriorate.

All major upgrades will be treated as any other project, and compared to running or planned instruments in order to decide priorities. It must be clear that starting one project per year implies that either a new instrument or a major upgrade can be initiated, but not both.

3.1 Infrastructure Upgrades

In order to derive the required performances, several of the instrument will require a substantial upgrade of the present Paranal infrastructure. For this reason, on going projects concerned with infrastructure upgrades for insruments have been inserted in the Paranal instrumentation program, and they are now part of it. The VLTI complex needs a deep change to adapt to MATISSE[11] and GRAVITY[12], but also to reduce the vibration level, to enhance the image quality provided by the AT, and to host a second generation fringe tracker for MATISSE. The VLTI infrastructure work has been structured in 6 main projects: PR1 (ATs maintenance station), PR2(Prima astrometry), PR3 (NAOMI, ATs AO), PR4 (Lab upgrade for MATISSE and GRAVITY), PR5 (Second Generation Fringe tracker), PR6 (Vibration control and system aspects).

The VLT Adaptive Optics Facility (AOF) is also now part of the program. AOF and its progresses are fully described in [13] and in references therein.

4. Roadmap

In the coming years the resources dedicated to Paranal instrumentation progressively will progressively increase, to a new level that can sustain the "one new start per year" plan. Table 1 shows the proposed timetable. Years 2013 and 2014 have been full of activities. Detailed reports from the different projects are given separately in this volume.

Most noticeably, the three major VLT 2nd generation instruments have been successfully accepted in Europe and brought to the telescope. KMOS[6] is offered for several months now; MUSE[7] has completed its second commissioning run, showing all its potential, and SPHERE[8] has recently gone through a successful first commissioning run, which has shown a very good integration in the VLT operations, spectacular core-diffracted images and very good contrast. MUSE will be offered to the community starting on October 2014, while SPHERE will follow six months afterwards.

The VLTI PRIMA astrometric facility was successfully operated[9], but obtained a long term astrometric precision several times worse than the requirements[10]. The status of PRIMA astrometry and its perspectives went through a gate review, which has shown that, while the causes of the under-perfomance are well understood, the implementation of the solutions would be incompatible with the timescale of the scientific goals and with the resources available to the Paranal instrumentation programme, so the recommendation of the ESO executive has been to suspend this experiment and dedicate to the new 2nd generation VLTI instruments: MATISSE[11] and GRAVITY[12] which are advancing towards the Preliminary Acceptance Europe, expected in the coming 18 months.

year	Phase A/ Prel. Study	Design/ Construction	Delivery
11	ERIS MOS		
12	CUBES CRIRES Up.	ERIS	KMOS VIMOS Up.
13		MOONS CRIRES Upgrade	MUSE
14	Letter of Interest NTT	4MOST	SPHERE VISIR Upgrade ~~PRIMA astrometry~~ LFC for HARPS
15	New I (NTT)	CUBES	VLTI PR1 VLTI PR4 GRAVITY
16	New II	New I (NTT)	MATISSE SPIFFI Upgrade ESPRESSO AOF
17	New III	New II	CRIRES Upgrade VLTI PR3 (NAOMI)
18	New IV	New III	CUBES (?)
19	New V	New IV	MOONS ERIS VLTI PR5 (2GFT)?
20	New VI	New V	4MOST New I(NTT)

Figure 2. Development Plan for the Paranal instrumentation Programme. The VLTI infrastructure has been split in PR1 (AT station), NAOMI (AT adaptive optics), PR4 (Infrastructure for GRAVITY and MATISSE), PR5 (Second Generation Fringe Tracker). The dates in last column refer to the end of the works for the infrastructures (VLTI and AOF), and to the time the instruments are brought to the observatory.

A comparison between Figure 2 and a similar one presented two years ago[1], shows that, while we have been able to complete a number of important projects, and to advance substantially in the others, a general delay is present in the programme. In addition to instrumentation, the programme includes large projects aiming at modifying the Observatory infrastructure to host the new instruments (ESPRESSO, GRAVITY, MATISSE) plus the Adaptive Optics facility, and some of these activities have requested more effort than previously planned. This situation, when inserted in a fully

allocated, resource-constrained programme, has generated the need of a hiatus, a sudden interruption of some of the projects, in order to free the resources needed to finish the project in critical phase, or close to completion. This has therefore generated the decision to halt for 6 months (April-October 2014) the ESO work on the CRIRES upgrade and on the ERIS design. Initiatives are taken to managing this overheating situation, without cancelling any of the existing projects.

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