Connecting ELT to the current VLT operations scheme: how the Telescope and Instrument Operators, as well as other groups at Paranal Observatory, are preparing the staff for the ELT era

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ABSTRACT

Several challenges will have to be faced by the staff at Paranal Observatory in order to be well prepared for a seamless integration of the ELT in the current VLT operations scheme. The Telescopes and Instruments Operator group (TIO) is already undergoing changes connected with some of the identified technological and operational needs for the ELT. This paper will have detailed information about the current training needs, group structural changes, the current activities using the adopted engineering-TIO [2] (eTIO) scheme and the staffing plan that will have to be applied in order to keep the centralized support of the biggest world infrastructure in astronomy at the time of the ELT, to handle daily science operations for seven different telescopes, the VLT interferometer and twenty-one scientific instruments in parallel.

Keywords: Observatories, Training, Operations, Science Operations, Telescopes Operators, ELT, European Southern Observatory

1. INTRODUCTION

The ELT is a new telescope to be installed at ESO Paranal Facility. From its conception, the ELT will be added to the current VLT infrastructure of operations, in order to be a new telescope in the pool of existing systems. This also implies that the actual facility needs to be maintained, updated and enhanced in order to work in parallel with the ELT during its lifetime.

The ELT is not just bigger that the current Unit Telescopes existing at ESO VLT. This new telescope will demand new skills and background in order to understand the systems behavior (hardware and software) and the meteorological constraints that will drive the selection of the instruments and the observational modes.

The science cases being currently explored for the ELT require a versatile facility with a broad range of instruments and modes able to serve the needs of a community with very diverse scientific interests. The way of operating the ELT will respond to these needs in a manner that optimizes the scientific output of the facility and the usage of the observing time at the telescope.

The operational constraints for the ELT facility are based on the high-level requirement of a strong integration in the general scheme of operations of ESO facilities. The operations policies, tools, and units in charge of operating the ELT will be the same as those in charge of operating other ESO facilities, to the largest possible extent that preserves the full scientific capabilities of the ELT and its instrumentation, and within the practical limits set by the location of the telescope.

Most of the large number of new devices in order to make the best use of the telescope and provide the proper troubleshooting maximizing the telescope availability, will be handled by the training program during the AIV stage of the project. The ELT engineers will generate a training plan for the different systems and subsystems of the facility directed to engineers and operations.

This document will mostly describe the additional training requirements from ELT compared with the current operation modes and the existing VLT observational techniques and meteorological constraints mainly directed to Science Operations Department and the most remarkable changes that operation scheme and staff will experience in preparation of the installation of this new facility.

2. PARANAL SCIENCE OPERATIONS DEPARTMENT

2.1 ESO La Silla Paranal Observatory

The Paranal Science Operation Department (PSO) is part of the ESO's La Silla Paranal Observatory Division (LPO). The other Departments based in Paranal are MSE (Maintenance, Support and Engineering Group) in charge of different technical support areas of the Observatory (System Engineering, Instrumentation, Software, Optics, Mechanics and Quality Assurance) and Paranal Logistics (in charge of coordinating all logistical aspects of Paranal Observatory).

The other LPO departments outside Paranal are: La Silla site and APEX, each with a site manager, in charge of all operational aspects of their particular Observatories.

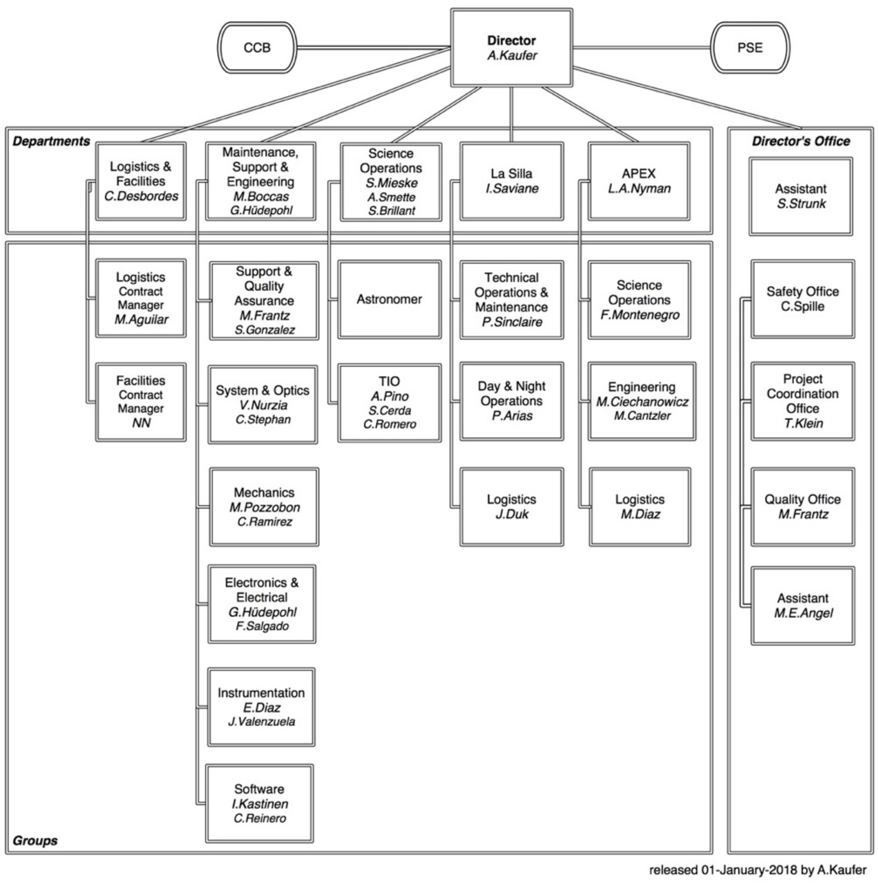

Figure 1. ESO La Silla Paranal Organigram Chart.

2.2 Role and core activities of PSO

Paranal Science Operations Department (PSO) is in charge of producing astronomical data of the highest quality, and maintaining (and whenever possible improving), the scientific and operational performances of the instruments. On a daily basis, PSO works in close collaboration with Paranal MSE department to deliver all instruments and telescopes to nighttime operations. It also validates the set of science and calibration data in terms of quality and completeness. PSO also supports the commissioning of new instruments, or their upgrades, as well as their integration into the operations of Paranal Observatory.

External stakeholders in partnership with PSO are located in Garching (Germany). Those are mainly the Instrumentation Division and the Departments from the Data Management and Operations Office (DMO), in particular its Departments of User Support (USD) and Data Product (DPD), the latter holding two key groups working closely with Science Operations: The Data Processing/Quality Control and Science Data Product group (SDP) groups.

2.3 PSO Staffing

Currently Paranal Science Operations includes 25 Staff Astronomers, 15 Fellow (Postdoc) Astronomers (twelve of them based in Chile, sharing 50% of their duties with Chile Science Office and others three in Garching with 25% of their time assigned to PSO), 24 Telescopes and Instruments Operators (TIOs) and one Senior Executive Assistant.

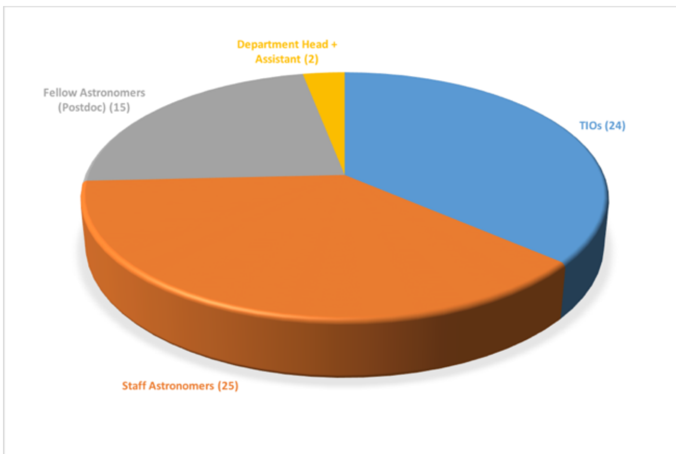

Figure 2. Paranal Science Operations Staffing

2.4 Operations Scheme

In the current operations scheme (SciOps 2.0), day and night activities are shared between Astronomers and TIOs.

During daytime, the Shift Coordinator (SC) which is a senior staff astronomer, is in charge of the coordination matters of the observatory activities in close collaboration with the Chief of Engineering (COE) appointed by MSE Department. The core activities of the Department are performed by either two (2) Astronomers (DA) and Operations Specialist (OS). Throughout the year, the rate of coverage of these activities is 20/80 between astronomers and OS.

For nighttime services, three out of four of the nighttime UT support astronomers have their duty starting-time moved earlier into the afternoon (instead of sunset) and the fourth support astronomer remaining in the “old scheme” (sunset to sunrise) becoming nighttime shift-coordinator for the last few hours of the night. As a result of this scheme, the operations during the first part of the night are shared between Astronomers and TIOs, while during the last part of the night they are supported by the TIO on-duty at the telescope, with the help of the nighttime shift-coordinator whenever is necessary. The VLTI (interferometric facility) support astronomer has not yet moved to the new operations mode, due to the higher complexity of the VLTI operations. Activities are developed during this year in order to enable SciOps 2.0 at the VLTI.

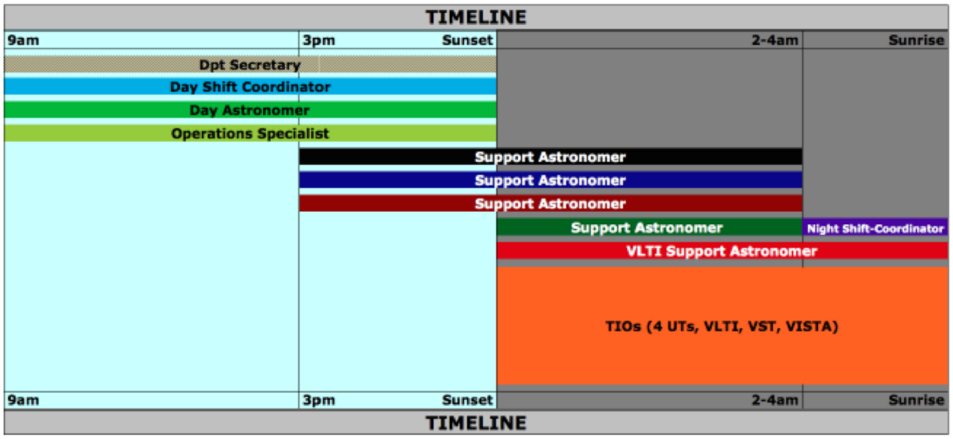

Figure 3. SciOps 2.0 Operations Model and staff distribution [1].

3. TELESCOPES AND INSTRUMENT OPERATORS GROUP (TIO)

3.1 TIO Group Staffing

The Paranal Telescopes and Instruments Operators Group (TIOs) are formed by 24 inter-disciplinary professionals. Their expertise varies from engineering and technical areas (physics, electronics, electric, automation and computing science) to other more exotic such as professional Aircraft Pilots, Air-Traffic Controller and Chilean Navy Officer. In some of the cases they have master's degrees not only in their own fields, but also in astronomy.

A TIO is assigned to work in a 7x7 shift during nighttime. Along with the implementation of the SciOps2.0 Operational mode, a new category of duties was conceived for 50% nighttime and 50% daytime support. For these duties, 9 of the existing TIOs were selected to this new position called Operations Specialist (OS).

3.2 Basics about training program for TIOs

The process of training for the new operators starts with the operation of the Telescope or the Facility. For Unit Telescopes (UT) operations, the training is similar, but for the telescopes VISTA, VST and the VLTi (VLT interferometer) the training is specific for each unit. Senior TIOs are in charge of different training modules (weekly modules). The training and certification for one UT takes around three–four months, for VISTA/VST around two months and for VLTI about six months. This process is driven by the TIO Training Coordinator, who sets the standard and is following-up the process of trainer assignments and trainee needs. During the last years, the process has been optimized by sharing the actual status of the training with a pool of selected people (coordinators and supervisors) in order to monitor the training program and implement adjustments if some deviation arose. The trainee also is giving feedback through the process, which allows to implement changes during the process.

The instruments training starts just after the certification on Telescope Operations. The training can be done by an Astronomer on duty or a senior certified TIO, but the certification is given by an Astronomer (ideally the Instrument Scientist (IS) or an astronomer with a similar level of experience). The certification for one instrument could be obtained after two - three shifts of interaction with the instrument, while for the whole unit (UT + 3 Instruments + first level of Quality Control – QC0) in general it takes three months. Usually after this first period, A TIO can obtain the 'driving" level, while the "fully certified" level can be accomplished after a more extended time operating the instruments and its subsystems. When a TIO is fully certified in all instruments of a single unit (telescope), then SciOps2.0 can be enforced.

Given the seniority and the operational needs, a TIO can be reassigned to a different system. In those cases, especially in case of UT4, the more complex telescope, a senior TIO is in charge of the training and certification process for the telescope, deformable secondary mirror and lasers system.

3.3 Expertise Distribution

In order to explain how the staffing plan covers the current infrastructure at Paranal Observatory, it is necessary to specify the process of assignments. Our Observatory has six telescopes and one interferometer array that need to be operated during the night. Four of these Telescopes (8.2m UTs) hold three instruments on the different foci, while two others are for Survey studies (VISTA, VST), with a single instrument each. The interferometer currently holds three instruments and has four 1.8m Auxiliary Telescopes (ATs).

Today Paranal has a total of 18 different instruments and this is the starting point for the analysis of staffing and expertise. As per the SciOps 2.0 definition, the TIO performs the full operations of the whole UT system (Telescopes, Instruments, QCO assessment) during the night. This requirement implies various steps to be fulfilled. As previously mentioned, additionally VST, VISTA and VLTI systems require a different area of expertise from the UTs.

The expertise is spread among the different systems of the Observatory between the operators group (TIOs and OSs) using the following scheme:

	Operations Assignments								Subsystems			Instruments Certifications			
	Telescopes				Surveys		Intf	Units Total	Macao	LGSF	VLTI	Sc 2.0 (12)	Surveys (2)	VLTI (2)	Total
	UT1	UT2	UT3	UT4	VSA	VST	VLTI								
TIO1	1	1		1			1	4	1		1	6		0	6
TIO2			1	1	1	1	1	5	1	1	1	6	2	2	10
TIO3	1	1		1	1	1		5	1			6	2		8
TIO4			1	1	1	1		4	1	1		6	2		8
TIO5		1	1		1	1		4	1			6	2		8
TIO6			1	1	1	1		4	1	1		6	2		8
TIO7	1	1			1	1		4	1			6	2		8
TIO8 (new)	1	1						2				3			3
TIO9	1	1		1			1	4	1	1	1	9		3	12
TIO10	1		1	1	1			4	1	1		9	1		10
TIO11		1	1		1	1		4	1			6	2		8
TIO12	1		1	1	1		1	5	1		1	6	1	0	7
TIO13	1		1	1				3	1	1		9			9
TIO14		1	1		1	1		4	1			6	2		8
TIO15 (new)	1	1						2				0			0
OS1		1				1	1	3	1		1	3	1	2	6
OS2				1	1	1	1	4	1	1	1	3	2	2	7
OS3	1		1			1		3	1			6	1		7
OS4 (new)	1	1						2				0			0
OS5	1	1			1		1	4	1		1	6	1	2	9
OS6	1	1					1	3	1		1	5		2	7
OS7	1	1			1		1	4	1		1	6	1	2	9
OS8			1	1	1	1		4	1	1		6	2		8
OS9				1	1	1	1	4	1	1	1	3	2	0	5
	14	14	11	12	15	13	10	3.7	21	9	10	5.3	1.6	1.5	7.1
	UT1	UT2	UT3	UT4	VSA	VST	VLTI	Units Average	Macao	LGSF	VLTI	Sc 2.0 Av	Surveys Av	VLTI	Total Av

Certified
In training

Figure 4. TIO Group assignments and expertise distribution

3.4 Certifications

The current workforce gives us full coverage for the existing facilities and gives us up to 136 nights available for contingencies or special activities including training, commissioning, projects, etc. (5.6 nights per staff).

The situation of nighttime operation certifications for the TIO Group permit us to cope with the current operational requirements by having an average operational availability of 3.7 units per staff (either UTs, Surveys or VLTI Facility). In terms of certifications during the last observational period (October 2017 to March 2018) the TIOs provides effectively almost 90% of SciOps 2.0 time for the whole period, including instruments with lower availability and stability for proper training and two training process for new staff.

On average, every TIO is already certified for five instruments (including newer ones) for running SciOps2.0 observations at UTs, while including the operations for the Survey Telescopes and the VLTI, we have a general average of 7.1 Instruments per staff. At the end of the current year we expect that all training processes will be finished, providing an average of 8.2 Instruments per staff with special focus on UT4 operations, because of the new AOF system, and the VLTI for providing additional services for the implementation of SciOps 2.0 at the interferometer later this year.

3.5 TIO Nighttime Support

For any given night, each TIO is assigned a given telescope. The TIO operates that telescope and its instrumentation, in order to maximize their efficiency, while maintaining the safety of people and equipment. The nighttime TIO schedule goes from sunset to the complete shutdown of the telescope at the end of the observations, which must happen no later than 20min before the official time of sunrise.

The certification level determines the telescopes and instruments that a TIO can operate. After the Night Support Astronomer leaves the control room, between 2-4 am, the TIOs continue executing Service Mode (SM) Observing Block (following the Observatory's priorities) relying on observations prepared by with the UT Support Astronomer following different scenarios, with the freedom to adjust to the evolution of the atmospheric conditions. The TIO then have the full responsibility to provide a grade to the executed OBs based on a zero-order quality assessment (image quality and/or rough estimation of SNR with regard to goals set by the PI and ambient conditions). The TIO applies the calibration plan for the corresponding instrument and mode.

In Visitor Mode (VM), the TIO executes the OBs selected by the Visiting Astronomer (VA). In case of any doubts regarding acquisition, target identification, OB execution priority or data quality, the TIO can then request the advice/support from the nighttime shift coordinator. In case of persisting doubts with regard to an OB grading, the relevant information should be included into a PSO ticket, so the daytime team can finalize the grading.

At the end of the night, the TIOs are responsible to put the instrument in calibration mode, execute the telescope and dome closing procedures, launch the calibration sequence for the instruments and send the night-report.

3.6 Daytime Support - Operations Specialist (OS)

The Operations Specialist shares his/her time (according to shifts) between the functions of TIOs (see above) and that of daytime operations support. The ratio of both duties (day-night) should be balanced (50% each) for a given period of time (usually three-four months). Their day shift working schedule goes from 09:00 until handover to the nighttime operations team.

The daytime tasks are the same as those of the Daytime Astronomer, exception made of all activities requiring a unique astrophysics expertise (such as support of VAs in preparing the observing strategy for their program). The OS is responsible for the completeness and quality certification of the data acquired during the previous night. This includes also the calibration frames acquired in the morning. The OS also validates the content of the night report and can request or implement corrections as necessary.

OS is also responsible for delivering the system to the night astronomers at the beginning of the night. This includes making sure the required instrument set-up has been performed (mask manufacturing and insertion, special filters installed, etc.) and verified; making sure the observation queues have been updated, the special observations (e.g. ToOs) are ready. As the OSs are also certified for night operations, they use their knowledge of the night procedures to make sure everything is ready.

Another significant responsibility of the OS is to monitor the instruments through the various QC systems and investigate possible deviations. The OS is at the front-line in case of instrument problems: they use their knowledge, the knowledge database (problem tickets, documentation, etc.) and that of their colleagues to diagnose most issues arising with the instruments. The rest of the time can be used on activities such as contributions to IOT and/or Operations group projects.

3.7 e-TIO activities

The e-TIO is a model that will be fully implemented at the ELT, that takes advantage of the engineering capabilities of the operators in benefit of the observatory. The e-TIO shares duties between operations and more technical developments or tasks related with their area of expertise.

Primary activities under these concepts, are developments for science Operations (Dynamit, quality-zero assessment routines, projects, operational improvements, etc.) and the group of operators certified for the maintenance and design of operation control panels (OPMT). On these cases the certification is given by MSE Software group in order to keep and follow ESO standards when developing or modifying operational panels or for new developments. During the next years, closer connection with other areas (instrumentation, electronics) is expected for these activities.

4. THE ELT REQUIREMENTS

4.1 The dome and main structure overview

The ELT will be a 39m segmented optical Telescope to be built on top of Cerro Armazones in Northern Chile, at a distance of approximately 20km from the existing ESO Observatory at Cerro Paranal. The Telescope will be operated from Cerro Paranal as part of the existing La Silla Paranal Observatory. The final elevation of the plateau will be slightly in excess of 3000m above sea level.

The Telescope will be protected by a rotating enclosure or Dome, which will be used to protect the Telescope from the environment. The Dome will be used during the day to thermally condition the Telescope and the optics to the expected temperature during night, and to limit the wind effect on the Telescope, still providing sufficient ventilation during the night time observation. A specific device, the “windscreen” will be dedicated to this function inside the Telescope Dome.

The optical design of the Telescope is based on a three mirror Telescope where two folding flat mirrors are used to extract the optical beam to a Nasmyth focus. The concave primary mirror (M1) has a diameter of approximately 39m. The 4.1m secondary mirror (M2) is convex and returns the beam, through a hole in the quaternary flat mirror (M4), to the 3.7m concave tertiary mirror (M3) located around the vertex of the primary. The beam is then reflected to the 2.4m quaternary flat adaptive mirror that is inclined at 7.7deg to the beam direction. The fifth mirror (M5) in the train is flat, elliptical in contour and located at the altitude axis of the Telescope. By changing the position of M5 the beam is steered toward the desired Nasmyth focus. From there it is also possible to redirect the beam to a Coudé focus located at ground level.

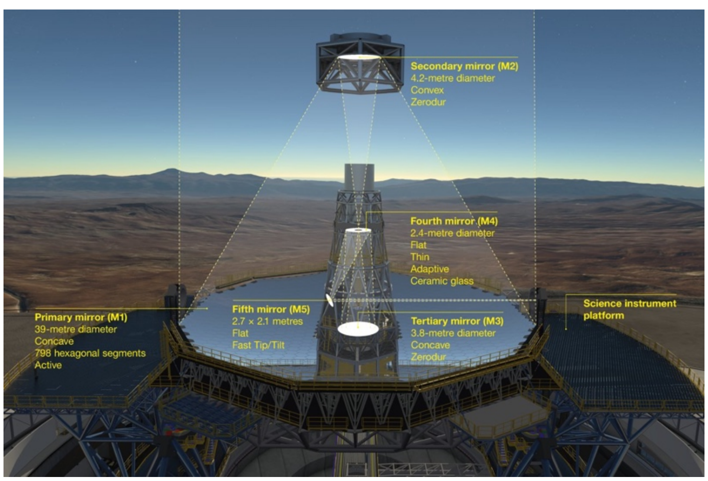

Figure 5. ELT Optical Layout

The optics are mounted on an altitude–azimuth Telescope Main Structure based on the rocking-chair concept for the elevation motions and a yoke structure rotating on tracks for the azimuth motion. The M4 and M5 mirrors are located in a tower extending from the primary mirror support and positioned in the central obscuration of the Telescope.

The instruments will be located on the two Nasmyth platforms, part of the Main Structure. The instruments will be based on adaptive optics and will make use of artificial guide stars produced by up to eight lasers mounted at four specific locations on the Telescope structure,

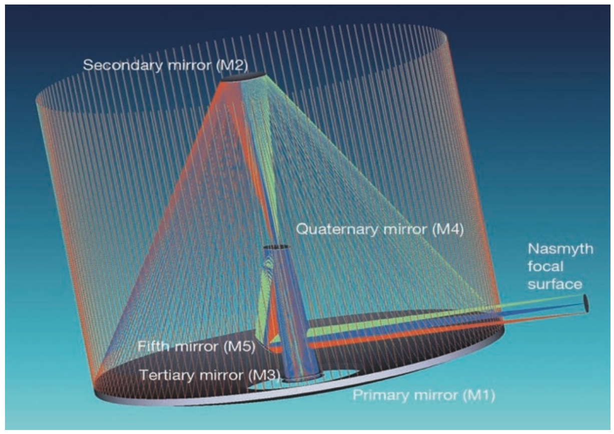

Figure 6. ELT Optical Layout for the Nasmyth configuration

The Figure 8 illustrates a schematic layout of the entire ELT facility. In this design the Dome consists of a hemispherical, steel framed Dome, with a viewing slit that is covered by two sliding doors. The mobile part of the Dome is supported by a series of wheeled motorized bogies, so that it can rotate around the vertical axis.

Both the Telescope and the Dome are mounted on concrete foundations, which are physically separated in order to avoid the transmission of any vibration to the Telescope caused by the Dome.

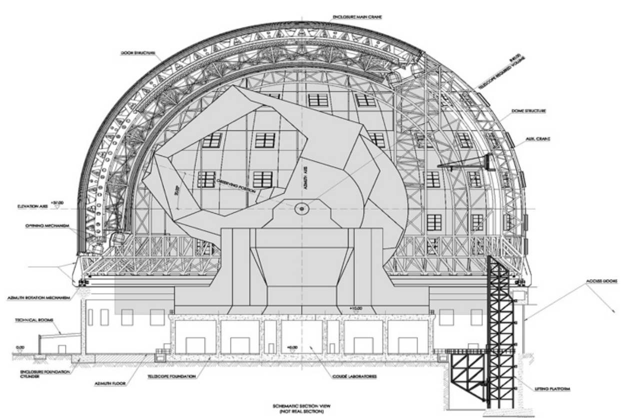

Figure 7. ELT Dome schematic view

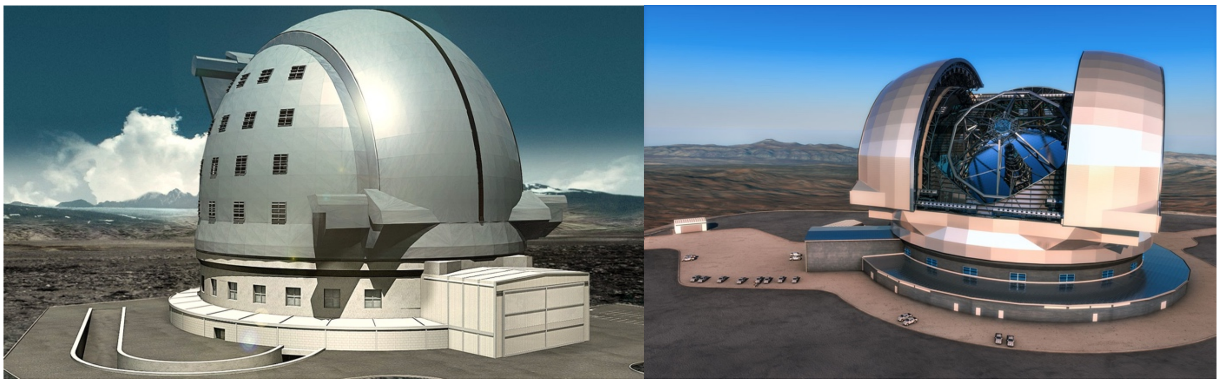

Figure 8. ELT Dome artistic views

4.2 The ELT particularities

Most of the experience in operations and maintenance of the VLT telescopes comes from the VLT facility itself or La Silla observatory. The ELT implies several new systems and subsystem not existing currently in our facilities and demands a series of necessary steps in order to internalize them and have a proper understanding and training in order to keep them running as expected.

The novel optical design of the ELT allows to send the light to the instruments maximizing the Fov but also compensating for mirror deformations and atmosphere perturbations. The giant 39-meters primary mirror (M1) is a concave aspheric array of 798 segments controlled for shape control (active optics) and phasing. The 4-meters M2 unit, is a passive convex aspheric mirror with positioning control. The 4-meter M3 unit is a concave aspheric mirror with active and positioning control. The 2.4-meters M4 mirror, is a flat segmented (6 petals) array with adaptive and positioning control. The flat 2.7x2.1-meters M5 mirror provides fast tip-tilt corrections. This is also a newer array of telescopes optics worldwide.

The optics are mounted on an altitude azimuth telescope main structure that uses the rocking-chair concept with two massive cradles for the elevation motions and two major azimuth tracks. The structure weighs approximately 3000 tonnes. In the central obstruction of the primary a 10-metre-tall tower sup- ports the quaternary and M5 mirrors.

5. THE SCIENCE OPERATIONS PLAN FOR THE ELT

The operations plan for the ELT observatory has been revised to take into account the new telescope baseline and aims at maximising the synergies between Paranal and Armazones, which will be operated as a single integrated observatory. The operations plan describes the operational concepts and plans needed to achieve the ELT top-level requirements, and covers aspects related to the observatory management, the science, technical, maintenance and logistic operations, the off-site development and support, the upgrade paths, the staffing requirements and the operations budget.

5.1 The ELT Instrumentation programme

The development of the ELT science case was accompanied from the beginning by an evolving instrument suite selected to achieve the scientific goals of the project.

The instrumentation plan for the ELT follows on from the 11 design studies developed during the period 2007–2010. The design studies provided an excellent pool of instruments that addressed the broad spectrum of capabilities necessary to attack the ELT science goals. The instrumentation plan is motivated and bound by a wish to deploy cutting-edge instrumentation on the telescope as early as possible without blocking early scientific access to the telescope by excessive commissioning and debugging.

Two instrument concepts have been selected for the first light complement of the telescope: a high spatial resolution multi-conjugate adaptive-optics-assisted camera/spectrograph and an adaptive-optics- assisted integral field spectrograph. These instruments will be mounted on the Nasmyth foci of the telescope. An instrumentation roadmap has been produced that identifies instruments three through five plus the pivotal planetary camera/spectrograph and identifies the key decision points in their construction. The instruments to be mounted on the telescope after first light will start their design and prototyping activities during the period of construction.

First-light instruments were evaluated for their immediate scientific impact, their complementarity with existing high-impact facilities, their scientific flexibility, their secure scientific return and against their coverage of the expected atmospheric conditions. The first-light pair of a diffraction-limited, near infrared camera (MICADO) and a wideband, integral-field spectrograph (HARMONI) will be the starting point for scientific observations. This powerful combination of an imager and spectrograph are able to cover approximately 75% of the science outlined in the most important science cases, as well as offering a solid potential for new discoveries. ELT-IFU and ELT-CAM are both versatile workhorse instruments with the goal of achieving high sensitivity and high spatial resolution at the diffraction limit of the largest planned optical–infrared ground-based telescope.

5.2 First Generation Instruments

A suite of different instruments has been considered to be developed for the first generation of scientific instruments for the ELT. Two of them are expected for first light activities with a third one is being prepared for its first stage.

5.2.1 Harmoni

HARMONI, or the High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph, is one of the first-light instruments installed on the Extremely Large Telescope (ELT) and will function as the telescope's workhorse instrument for spectroscopy in the wavelength range 0.47–2.45 µm. This versatile instrument will offer a set of spatial scales to optimise observations for a wide range of science programmes and observing conditions. In particular, HARMONI will be optimised to exploit the best image quality delivered from a post-focal laser tomographic adaptive optics module.

HARMONI is an integral field spectrograph, which can operate in a number of different ways. The design of the instrument is such that it will be easy to calibrate and operate, providing the ELT with a "point-and-shoot" spectroscopic instrument.

Thanks to the enormous 39-metre main mirror of the ELT, HARMONI will be used to explore galaxies in the early Universe, study the constituents of the local Universe and characterize exoplanets in great detail. In many ways, it will be complementary to ALMA and the James Webb Space Telescope. HARMONI follows in the footsteps of the innovative second-generation VLT instruments.

5.2.2 Maory and Micado

MICADO, or the Multi-Adaptive Optics Imaging Camera for Deep Observations, is one of the first-light instruments for the Extremely Large Telescope (ELT) instrument and takes the Adaptive Optics technique to the next level. It will be the first dedicated imaging camera for the ELT and works with the multi-conjugate adaptive optics module, MAORY.

MICADO will equip the ELT with a first light capability for diffraction limited imaging at near-infrared wavelengths. The design of MICADO (Multi-AO Imaging Camera for Deep Observations) was driven by a desire for high sensitivity and resolution, astrometric accuracy, and wide wavelength coverage spectroscopy.

The sensitivity of the MICADO camera will be comparable to the James Webb Space Telescope, but with six times the resolution.

MICADO will allow the full resolution potential of the giant telescope to be brought to bear on many current areas of research. These include imaging the detailed structure of galaxies at high redshift, the study of individual stars in nearby galaxies, and, using its coronagraphic mode, the discovery and characterisation of exoplanets. MICADO will also be a uniquely powerful tool for exploring environments where gravitational forces are extremely strong, such as close to the supermassive black hole at the centre of our galaxy, the Milky Way.

In addition to its primary imaging role, MICADO also includes a single-slit spectrograph ideal for obtaining spectra of compact objects. It will also be a powerful tool in many areas of astronomy, such as measuring the masses of the central black holes of nearby galaxies from the velocities of their stars and observing high-redshift galaxies to calculate their ages, chemical makeup and histories. The instrument will also obtain spectra of supernovae produced by the first generation of massive stars in the Universe.

Micado provides several observational modes: From Imaging mode in wavelength of 0.8-2.4µm proving more than 30 different filters and its array of 3x3 detectors with 4096x4096 pixels each and a pixel scale of 4mas (FoV ~53”) and 1.5mas (FoV ~20”) allowing astrometry imaging to 50µarsec precision across the whole image, to spectroscopy for single compact objects, using two different settings of 0.8-1.4µm and 1.5-2.4µm at spectral resolving power of ~8000 while also coronagraph plus single conjugated adaptive optics, and finally Time resolve astronomy up to 4mas.

Micado and its multi-conjugate adaptive optics module Maory, provides multi-conjugated adaptive optics system using 6 laser guide stars and 3 natural guide stars. It also compensates high order aberrations to compensate atmospheric turbulence in addition to the ELT M4 deformable mirror. Single conjugated adaptive optics is also available between Micado and Maory.

The performance goal is 60% of strehl at 2.2µm with excellent uniformity over 2arcmin in good conditions.

5.2.3 Metis

The Mid-infrared ELT Imager and Spectrograph (METIS), will be the third instrument on the Extremely Large Telescope (ELT). It will make full use of the giant, 39-metre main mirror of the telescope and focus on five scientific goals: exoplanets, proto-planetary disks, Solar System bodies, active galactic nuclei, and high-redshift infrared galaxies.

METIS’s powerful spectrograph will allow astronomers to investigate the basic physical and chemical properties of exoplanets, like their orbital parameters and structures, temperature, composition of their atmospheres, weather, seasons, etc. Only the innovation of the astronomers at the instrument’s helm place limits on its use.

In addition, METIS will contribute to numerous other areas, including the study of the Martian atmosphere, properties of low-mass brown dwarfs, the centre of the Milky Way, the environment of evolved stars, and gamma-ray bursts as cosmological probes. METIS will also have wide applications working at longer wavelengths and many ways of collaborating with other facilities, such as the future James Webb Space Telescope.

5.3 Operating the ELT at Paranal

A number of principles inherited from the experience of operating the Paranal Observatory is at the core of the operations concept. The top-level goal is to maximize the scientific productivity of the ELT. This is achieved by ensuring an optimal performance level of telescope and instrumentation by extensive use of metrology, as well as of preventive and predictive maintenance, where the most challenging goal will be to perform, within the available day-time hours, all the required maintenance and corrective tasks necessary to have an available telescope at sunset.

There will be procedures designed to provide a safe, efficient and cost-effective operation of the facility to deliver scientific data of high and consistent quality together with all ancillary data needed for their calibration and provide opportunities for technical upgrades and development of new instruments and Adaptive Optics (AO) systems over the lifetime of the facility.

The science operations are based on the VLT paradigm and will be fully integrated, both on-site and off- site, between the VLT and the ELT. Extensions taking advantage of technological developments (e.g., high bandwidth) will be implemented for the integrated observatory. The observatory will provide modalities of use of the facility adequate to the scientific goals of each project, and for the most part observations will be flexibly scheduled to make the best use of available atmospheric conditions. A calibration plan will be executed by the observatory to guarantee that scientific data can be calibrated up to a well-specified level of accuracy. The calibration plan will be the basis for monitoring the system performance by continuously monitoring selected parameters. All the science data obtained, and their related calibrations will be stored in the ESO Science Archive, to ensure the long-term preservation and accessibility of the data to the entire scientific community through appropriate interfaces.

The operations plan identifies all the activities, both short-term (e.g., daily exchange of two newly coated M1 segments) and long-term (e.g., commissioning of new instruments), needed to carry out the above goals. Work plans have been defined for the technical operations, the inspections, the preventive, predictive and corrective maintenance of all subsystems of the observatory. The tracking of problems with the associated generation of work orders will be managed through appropriate software tools (an evolution of the current problem-reporting system and computerized maintenance management system in use at Paranal today).

5.4 Remote operations

The ELT will be the first ESO Telescope to be remotely operated from Paranal control building. This implies many technical challenges and operational definitions as well.

The suit of technology, communications, control and meteorological systems of the ELT, should provide at least the same safety standards than for the VLT. One of the main concerns is to detect when there is risk for the installations because of weather conditions, when to activate closing protocols and how this can be done without becoming more conservative when applying these decisions.

Adding additional facilities to existing Paranal operations scheme, requires that some of the existing roles should be revised, but in general terms our operations scheme should be modified by having a central control center for all sites, which primarily implies the technical implementations and redundancies to ensure the safety and availability of the different sites. On the same side, the current weather officer task should be modified for a centralized and focused monitoring of the different sites. Given the complexity and the quantity of data to be evaluated in parallel for all the sites, we believe is worth thinking in a full-time task for weather monitoring at night and also rely on the data from the field instrumentation to take decisions about closing for dangerous conditions.

According to the preliminary operations plan, it is possible that the ELT is operated during nighttime by two instead of a single operator and one (or two) astronomers. Daytime duties, is expected to be performed by one operations specialist or day astronomer.

5.5 Remote observing mode

The execution of programmes in Remote Mode will allow a user at any location with sufficient connectivity bandwidth to submit updated OBs to the facility immediately before its execution and receive the resulting pipeline-processed data within one minute (TBC) of the completion of each template. Other than the access to sufficient connectivity and suitable hardware (see below) no other requirements will be placed on the location of the user. In particular, no dedicated remote control centre will be maintained by ESO to host users during the execution of their observations.

Remote mode is expected to be the main mode of interaction with the ELT for the execution of ToO observations, for the observation of transient phenomena with non-predictable behaviour, and in general for the execution of any programmes requiring real-time interaction.

Three modalities of Remote Mode observations are envisioned:

1. Unpredictable time-critical observations, in which the activation of a trigger implies the ability of the user to carry out the observations in Remote Mode shortly afterwards.
2. Predictable time-critical observations, in which the Remote Mode observing slot is allocated long in advance.
3. Non time-critical observations, in which the user is contacted at short notice (less than 12 hours; TBC) when the observatory foresees that it is likely that the programme will be executed in the forthcoming night. The user will be expected to be available for the start of the observations once the conditions are suitable for the programme execution. The observations will be rescheduled for a later date if the expected conditions finally did not take place on that night.

The observatory will decide on contacting Remote Mode users of non-time-critical programmes on the basis of the forecast of the conditions on the following night and on the competition for the foreseen conditions by other programmes scheduled in Service Mode.

With the exception of predictable time-critical observations, Remote Mode observing will also be flexibly scheduled.
Given the additional requirements set by Remote Mode on data volume, transfer speed, and pipeline performance, only some instrument and modes may be offered in Remote Mode. Additional remote tools can be also offered in order to improve the user experience.

6. TRAINING PLAN FOR THE ELT

6.1 Training needs for telescope operations

At the level of telescopes operators, the training plan should cover all aspect of this new telescope. The architecture of the ELT is completely new, and most of the systems have been designed especially for this application.

Given the complexity of the systems and the operational modes proposed, we are performing an earlier assessment about the specific needs of training in order to use this background to streamline an informed decision-making process in term of enabling operational modes and specific science cases. Many of these needs are connected with the optics of the telescope and the operations modes using lasers, in specific multi-conjugated adaptive optics and laser tomography.

Acquiring a very good know how on these topics will ensure a better development of the SciOps tasks during the first operational phase of the scientific observations with the ELT.

In general, the ELT will demand various and unique areas of expertise. Being an internal adaptive-optics telescope requires different awareness, new skill sets and technical background while the additional astroclimate parameters and decisions will drive the process of prioritization of the observations and operation modes.

The combination of this adaptive-optics facility, including deformable mirrors and laser systems, and the new generation of scientific instruments will require more, and different monitoring strategies were the staff should incorporate these new techniques and parameters in a common and standard language.

In term of training for understanding, handling, operating and troubleshooting of the control system these are the main topics to include:

- Telescope basics: Optics, devices, main devices and interaction with the operator.
- Telescope Control System: Panels of the telescopes, systems and subsystems, ASM.

- Systems to control: M1 array, m2, m3, m4, m5, altitude axis, azimuth axis, enclosure, hydraulic system, Lasers, CCDs
- Basic Control of the telescope: Moving the telescope, pointing, tracking, acquisition, Active Optics corrections, Adaptive Optics corrections, guiding, Thermal control and others.
- Operating the telescope: Guiding control (FS, AG, RG, PG), chopping, nodding, focusing, optics aberrations, laser system.

In most of these topics, at least in the conceptual and practical part, the operators have experience because they are part of the current operations of the VLT, with exception of the different mirrors controls what will be completely new. This will help in speeding up the training process.

The final scope of these activities will be decided by the ELT AIV team, where the proper training and documentation has to be provided. As expected, the optimization in the operation of the ELT will be very time consuming and would take most of the first year of operations.

6.2 Training needs for adaptive optics systems

After more than 15 years of experience using adaptive-optics with lasers at UT4 telescope, staff has a good knowledge of current techniques and awareness about the meteorological constraints for operations. Most of its background in born by the operations itself however the specificities are so broad that dedicated training has to be widely provided.

The astronomers and operators that drive the UT4 telescope already have experience with the adaptive-optics facility. On the same side, 8 out of 18 existing instruments use adaptive-optics methods in operations. Unfortunately, only the 50% of the operators are in contact with these particular systems, so the plan is to define a process in order to have a balance in the know-how of the group on these techniques in order to provide their services in all the units.

During 2017, the secondary deformable mirror and the suit of 4-laser at UT4 telescope was installed. We are collecting experience from this first operational phase and we understand this will help the staff in learning and internalizing the concepts in order to maximize the efficiency of the corrections and the interaction with the 4-laser guide star facility (4LGSF) for the operational modes for the instruments.

As usual when a new system is installed, the people in charge of the installation and start-up of them, are in charge of preparing internal training to all involved staff. Additionally, the SciOps people selected for working during commissioning and acceptance activities, are in charge of preparing a dedicated training focusing in operational and troubleshooting aspects of the system. Depending on the complexity and needs, this training is focused in some members of the department or is prepared for all.

Looking at the different modes of operations foreseen for the ELT first instruments generation, the staff has no experience in multi-conjugated adaptive optics and very few of laser tomography. The most used modes are single-conjugated and ground-layer adaptive optics. Inserting these new techniques requires a dedicated set of skills and focused training.

Several actions have been taken in order to promote a wider use of these techniques along the operators group. This is why we are performing some changes in the operational model of the observatory (See Merging operations on the surveys telescopes at ESO Paranal Observatory, Paper 10704-71), allowing new operators to be in touch, learn and experience the operation with the UT4 AO Facility. This will also help in enable SciOps 2.0 on this system sooner. These new activities will allow that all current staff of operators will be certified in UT4-AO system by 2022.

In addition to this activity, currently all operators have to learn and operate the different AO conditioning systems for the VLTI (MACAO and CIAO) which help in a first interaction with the AO technique and the operational constraints.

6.2.1 AO Team

After identifying the importance of these areas, the SciOps department has created a position of an AO Specialist, which is an astronomer who is also recruiting different astronomers and engineers with similar interest and needs. The aim of this group is to lead all activities related with the different systems that uses and need from AO techniques and the training program as well.

After collecting information on different institutions, an agreement with Universidad Catolica de Chile allows to generate a training program with laboratories, for astronomers and engineers. This activity is still ongoing and according to the feedback of the attendants it will be decided if more people will attend new sessions, or an internal training program will be created for the different groups according to the particular needs.

6.3 Astro-meteorological training needs for the ELT

The VLT meteorological data is currently monitored by different systems, collecting and displaying the current and historical data, and providing this information to be injected in the scientific images taken. The observations at the VLT are mainly enabled by most known weather constraints as seeing, sky transparency, PWV, coherence time, humidity and wind speed. By definition, the ELT is an AO Telescope, and given to this declaration, additional astroclimate parameters and decisions will drive the process of prioritization of the observations.

The Mass-DIMM and the meteorological tower were installed after the VLT first light, and other additional systems have been tested and certified for operations. During these years, several campaigns have been performed in order to keep characterizing and improving the currently data at the observatory.

Additional instrumentation systems are already in place not only for the use with the UT4-AO facility but also for other purposes like more accurate transparency definitions and looking forward to implementing them at the ELT.

- DIMM
    - The acronym DIMM lasts for Differential Image Motion Monitor. It measures wavefront slope differences over two small pupils some distance apart, caused by the atmospheric turbulence. This measurement of distortion is then converted into an estimate of the image size (seeing FWHM) it would correspond to on a large telescope, using the Kolmogorov-Fried model.
    - The DIMM channel of the MASS-DIMM instrument is imaging a single star through two sub-apertures on a CCD. The MASS-DIMM instrument is attached to an 11″Celestron telescope on an ASTELCO NTM500 direct drive mount. It operates in robotic mode on top of a 7m high tower located 100m to the North of UT4. The seeing is defined as the Full Width at Half Maximum (FWHM) of a stellar image at the focus of a telescope observing at 500nm wavelength and at zenith, limited by an atmospheric turbulence with infinite outer scale. The finite nature of the outer scale of the atmospheric turbulence results in an image quality of large telescope actually better than the seeing due to the reduction of the share of atmospheric image motion in the final image size.
    - In summary, measures Seeing, coherence time, isoplanatic angle, relative flux variation.
- MASS
    - The Multi-Aperture Scintillation Sensor (MASS) consists of an off-axis reflecting telescope and a detector unit which measures the scintillations of single stars in four concentric zones of the telescope pupil using photo-multipliers. A statistical analysis of these signals yields information of the vertical profile of the turbulence Cn2(h). It gives the Cn2(h) for 6 layers placed at 0.5, 1, 2, 4, 8 and 16 km above the telescope pupil. The combination of a DIMM and a MASS gives the possibility to measure both seeing and low-resolution turbulence profiles
- METEO Tower
    - Ambient and dew temperatures, relative humidity, atmospheric pressure, wind speed and direction, rain/precipitation and dust particle sensors for small (0.5 µm) and large size (5 µm) at 10m and 30m.
    - The meteorological stations compute and store average, root mean square and extrema of each parameter during a preset averaging period (20 minutes). The sampling intervals are 2 seconds for digital sensors (wind speed and direction) and one minute for analog sensors (Temperature, Humidity).
- SLODAR

  - The SLOpe Detection And Ranging instrument is optimised to measure the vertical profile of the turbulence in the first 500m above the site. The data is relevant to modelling and understanding the imaging performance of the VLT, both with and without adaptive optical correction.
  - SLODAR is an optical crossed-beams method for turbulence ranging, based on the Shack-Hartmann wavefront sensor observing double stars. The optical turbulence profile (OTP) is recovered from the cross-correlation of the wavefront slope measurements for the two stars.
  - The instrument, has been operating in robotic mode at Paranal since March 2011. The instrument is optimized to measure the vertical profile of the surface layer of turbulence, in the first 100m above the site. The data is relevant to modelling and understanding the imaging performance of the VLT, both with and without adaptive optical correction. It is especially relevant for the application of ground-layer and multi-conjugate adaptive optics systems.
- LATHROP
  - The Low Humidity And Temperature PROfiling microwave radiometer provides Precipitable Water Vapor measurements. The instrument consists of a humidity profiler (183-191 GHz), a temperature profiler (51-58 GHz), and an infrared camera (~10 micrometers) for cloud detection. The radiometer, manufactured by Radiometer Physics GmbH (RPG), is used to monitor sky conditions over ESO's Paranal observatory in support of VLT science operations. The unit measures several channels across the strong water vapour emission line at 183 GHz, necessary for resolving the low levels of precipitable water vapour (PWV) that are prevalent on Paranal (median ~2.4 mm).
- STEREO-SCIDAR
  - SCIDAR (SCIntillation Detection And Ranging) uses triangulation techniques in which the atmospheric turbulence profile above an observatory is recovered from the correlation of scintillation intensity patterns for two target stars with a known angular separation
  - High resolution turbulence profiler (300 layers up to 32km)
  - This instrument is only used when a telescope (AT3) is available, especially when the interferometer is using the UTs.

The information obtained from this suite of instrumentation will help to characterize the actual conditions of the observatory allowing real-time decision assessment for the different observations modes required by the new instruments. The most complex constraints expected, are the conditions to enable more sophisticated modes like MCAO (multi-conjugated adaptive optics) and laser tomography, which requires precise and different information from the actual status of the different atmosphere layers and environmental conditions. The operations with the UT4-AO facility are also helping in the path to characterize our site but also for training our staff given these new variables.

6.3.1 Astrometeorology Team

A joint force between different specialist existing at Paranal Observatory have been gathered in the Astrometeorology Team. Astronomers, operators and Engineers with different and complementary background in different related areas as meteorology, site characterization, atmospheric studies, weather officer, adaptive optics, turbulence studies and astronomical observation and science are part of this joint effort. This group is conceived for studying the link between the meteorology and the astronomy related to the meteorological phenomena that impacts the astronomical observations or operations while Identifying, discussing and defining projects related to the atmosphere (turbulence, PWV, meteorology) and critical for the operations.

Basic mandate of the group is to share and spread knowledge and tools to carry out these projects as efficiently as possible and avoid duplication, coordinate the work on these projects and share the progress and results within the team and Paranal/Sciops/ESO and beyond through appropriate channels (documentation, mails, talks, etc). Furthermore, in a more specific task, study of the impact and correction of the atmospheric components leading to telluric lines does not correspond to the aim of this team and be the counterparts of Garching/Durham astrometeorologists with knowledge of operations to provide input, requests, and feedback.

This group will define the different training activities towards the full awareness and correct understanding of the different weather, atmospheric and meteorological parameters necessary to provide the information and enable the different observational modes for a given moment during observing, while also promoting and helping in development towards implementation of more accurate measurements and forecasts necessary for the best-informed assessment for the operations.

7. CONCLUSION

Construction activities at the ELT site are ongoing while also different parts of the telescope are either in studies or being built by different consortiums around the world. At Paranal, the staff is very interested in working for an early stage in the different areas of this development. Identifying the areas of concern along the different groups and sharing this information with the ELT group is a mature and also a very necessary process.

Make the best use of the existing know how, and also prepare all the staff in advance regarding the training needs or the operational changes is something the observatory is seriously working on. A new office of project has been created in order to take control of the integration of different new areas, like the ELT, to the current Paranal site is something is helping to understand in a more comprehensive way about all aspect that would help in a seamless connection.

Since parallel activities for different projects are evolving in time, ESO is also open to integrate others facilities to the current Paranal scheme in the future. Be prepared to hold additional and maybe more complex systems is something is worth to be taken seriously in a deeper analysis.

The current array of the control loop seems not to be prepared for these future integrations, not only because of the space of the control room, but for the interactions needed for newer instruments and subsystems.

Integrating the ELT, requires that all existing VLT facilities and the ELT be aware of all each other, especially when using the laser systems, but also in terms of the weather parameters of the different sites, visitor mode observations performed and several other factors which are of interest of the different telescopes and sites.

In case of Paranal, also newer instruments which can be used by different UTs or by all of them (ESPRESSO) also changed the operational paradigm about operating in cluster or operating like a whole array.

Looking at these needs, it seems reasonable to upgrade the current operational array in order to generate a centralized control system in a different concept more connected with open control centers, where the control room allows more interaction and the important information is displayed for all the systems. During this period, several groups are interacting to define how this can be achieved and the way to implement such a change, ideally, without affecting the operations of the observatory.

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