Ensuring the Reliability and Performance of Instrumentation at the Paranal Observatory

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Instrumentation at the Paranal Observatory is currently composed of 18 scientific instruments (operational, in commissioning or on standby) and nine technical instruments (test camera, fringe trackers, adaptive optics modules, laser guide star facility, tip-tilt sensor). Over the 15 years since their first implementation and operation, enough information on their typical behaviour has been gathered to define a global plan for preventive maintenance and/or general refurbishment for each instrument in order to retain their reliability and performance. Several examples of monitoring of instrument performance are presented and reasons for failure are listed.

We describe the range of activities undertaken to ensure efficient and reliable Paranal instrumentation.

Introduction

Since the installation of the first test camera on the Very Large Telescope (VLT) Unit Telescope 1 (UT1) in 1998 at the Paranal Observatory, a full set of instruments has been installed and is in operation. A list of references for Paranal instrumentation is available[1]. Very few have been decommissioned (e.g., FORS [Rupprecht et al., 2010] and ISAAC [Spyromilio et al., 2014]). The instrumentation at the Paranal Observatory employs virtually all the possible technologies developed for the ground-based astronomical community over the last 20 years. Spanning a wavelength range from 0.315 μm to more than 20 μm, it includes adaptive optics (AO) and interferometric systems for high spatial resolution imaging and spectroscopy, large field of view imagers, multi-object spectrometers, integral field units (IFUs), high resolution spectrometers, etc.

Table 1. Scientific and technical instruments on the UTs.

Instrument name	First light	Current telescope	Status	Purpose
Test Cameras 1 & 2	1998		TC1 decommissioned; TC2 standby	Visible imaging for VLT integration, commissioning and Science Verification and later for various tests and commissioning
FORS 1	1998		Decommissioned in 2009	Ultraviolet–visible imaging and low/medium resolution spectroscopy; multi-object spectroscopy; imaging and spectropolarimetry
ISAAC	1998		Decommissioned in 2013	1–5 μm imaging; low- and medium-resolution spectroscopy; polarimetry; high time-resolution imaging
FORS 2	1999	UT1 Cassegrain	In operation	Ultraviolet–visible imaging and low/medium resolution spectroscopy with two exchangeable CCDs (blue and red sensitive); high time-resolution imaging and spectroscopy; multi-object spectroscopy; imaging and spectro-polarimetry
UVES	1999	UT2 Nasmyth	In operation	Ultraviolet and visible visible high-resolution spectroscopy
NACO	2001	UT1 Nasmyth	In operation	Near-infrared high spatial resolution imaging and low resolution spectroscopy with AO; polarimetry
FLAMES	2002	UT2 Nasmyth	In operation	15-arm IFU and fibre-fed multi-object visible medium- and high-resolution spectroscopy
VISIR	2002	UT3 Cassegrain	Upgrade ongoing; to be re-commissioned end 2014 and early 2015	Mid-infrared imaging and spectroscopy
VIMOS	2002	UT3 Nasmyth	In operation	Visible imaging; multi-object spectroscopy; IFUs
SINFONI	2004	UT4 Cassegrain	In operation	Near-infrared IFU spectroscopy with AO
CRIRES	2006		Taken out of operation in July 2014 for upgrade	1–5 μm long-slit high-resolution spectroscopy
LGSF	2006	UT4 M2	In operation	Laser guide star for SINFONI
HAWK-I	2007	UT4 Nasmyth	In operation	Near-infrared wide-field imaging
X-shooter	2008	UT2 Cassegrain	In operation	Ultraviolet to near-infrared medium-resolution spectroscopy
KMOS	2012	UT1 Nasmyth	In operation	24-arm near-infrared IFU spectroscopy
MUSE	2014	UT4 Nasmyth	In operation	24 IFU visible medium-resolution spectroscopy with Adaptive Optics Facility (AOF)
SPHERE	2014	UT3 Nasmyth	Commissioning	Near-infrared classical and coronagraphic imaging, polarimetry, low-resolution spectroscopy and IFU with extreme AO

Each instrument can be considered as a separate entity, but the instrumentation can also be viewed as a global system, implemented over a period of time. We present an overview of this global system of Paranal instrumentation.

The instruments

VLT instruments

Each of the four UTs hosts up to three scientific instruments. In addition UT4 hosts the laser guide star facility (LGSF). The location of an instrument has sometimes changed from one focus to another in order to optimise the observing time on sky for each telescope. Table 1 presents an overview of all the scientific instruments operated at the UTs. Figure 1 shows the current view of the UTs and their instrumentation, together with the two survey telescopes.

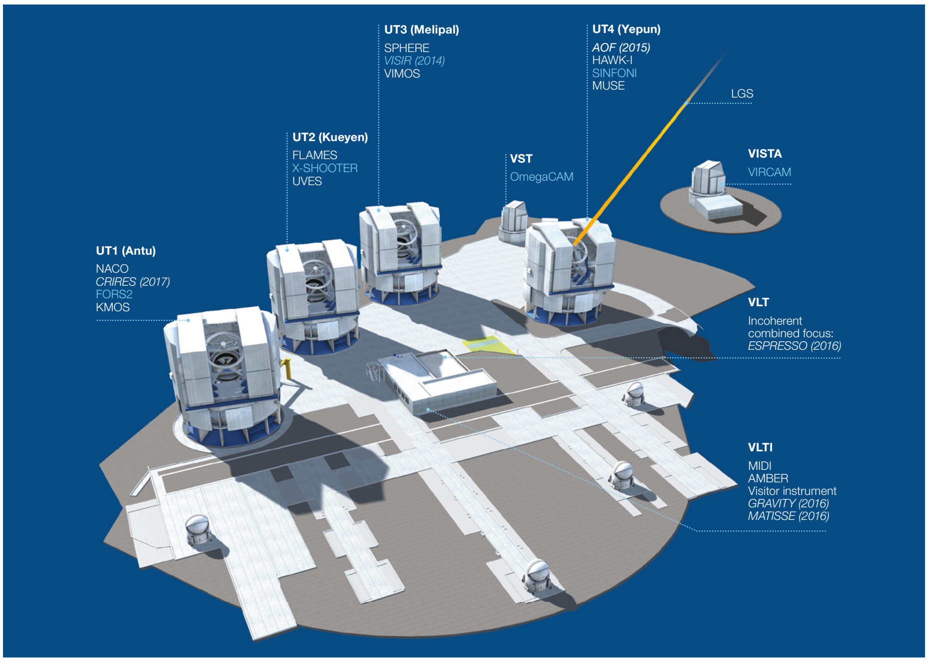


Figure 1. Paranal Observatory and its instrumentation. Instruments listed in blue are at the Cassegrain foci of the telescopes. Instruments listed in italics are not yet installed.

VLTI instruments

All the Very Large Telescope Interferometer (VLTI) scientific instruments are hosted in the VLTI underground laboratory on the VLT platform. Technical instrument systems (field stabiliser, fringe tracker and Multi-Application Curvature Adaptive Optics [MACAO] modules) are located in the VLTI lab or in the coudé path of the UTs. The instruments are fed by the UTs or by the Auxiliary Telescopes (ATs). Table 2 is an overview of all VLTI scientific and technical instruments operated at Paranal.

Survey instruments

Table 3 presents a summary of the Cassegrain cameras on the two survey telescopes, the VLT Infrared Survey Telescope for Astronomy (VISTA) and the VLT Survey Telescope (VST).

Average age of instrumentation

The first scientific instruments (FORS 1 and ISAAC) were integrated in 1998 at Paranal on UT1. In the whole history of Paranal, only VINCI (2004), FORS1 (2009) and ISAAC (2013) have been decommissioned, while PRIMA (2014) has been cancelled. CRIRES was taken out of operation in July 2014 for an upgrade to transform it to a cross-dispersed spectrograph (see Dorn et al., 2104; Follert et al., 2014). Thus a total of 21 scientific and ten technical instruments have already been installed, not including the visitor instruments or experiments, such as UltraCam, DAZLE (Dark Age *z* (redshift) Lyman-α Explorer), Multi-conjugate Adaptive optics Demonstrator (MAD), the Active Phasing Experiment (APE), etc. Figure 2 shows the growth in number of instruments and their average age by year.

The average age of the instrumentation in operation is currently 8.4 years. It will reach more than ten years by 2018, even

Instrument name	First light	Location	Status	Purpose
VINCI	2001	VLTI lab	Decommissioned in 2004	*K*-band VLTI commissioning instrument
MIDI	2002	VLTI lab	In operation	Mid-infrared two-beam combiner and spectrometer
MACAO-VLTI	2003–2005	UTs at coudé	In operation	Four AO modules for VLTI
AMBER	2004	VLTI lab	In operation	Near-infrared three-beam combiner and spectrometer
FINITO	2005	VLTI lab	In operation	Fringe tracker for AMBER and MIDI
IRIS	2005	VLTI lab	In operation	Four-beam tip-tilt monitor
PRIMA	2008		Cancelled in 2014	Phased referenced imager
FSU-A	2008	VLTI lab	In operation	*K*-band fringe tracker for MIDI, initially part of PRIMA
PIONIER	2010	VLTI lab	In operation	Near-infrared four-beam combiner (visitor instrument until P94)

Table 2. Scientific and technical instruments dedicated to interferometry.

Instrument name	First light	Telescope	Status	Purpose
VIRCAM	2009	VISTA	In operation	Wide-field infrared survey imager
OMEGACAM	2011	VST	In operation	Wide-field visible survey imager

Table 3. Survey instruments on the two survey telescopes.

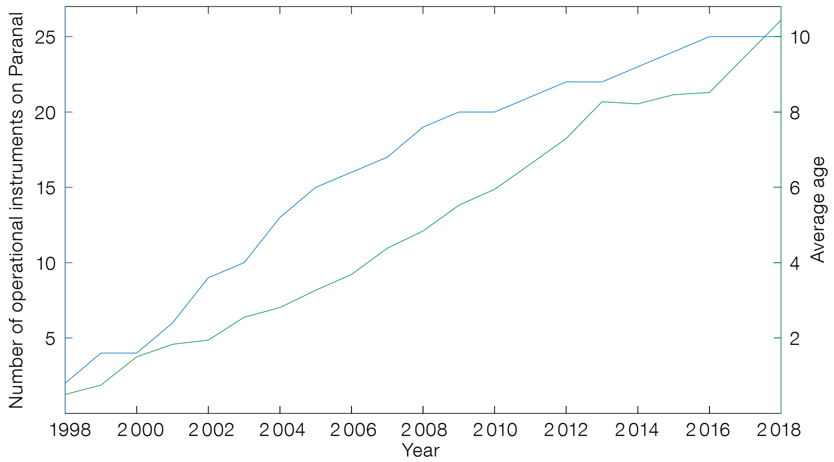


Figure 2. The number of operational instruments (in blue) and their average age (in green) are shown since the start of operation of the Paranal Observatory.

though the last of the second generation instruments will be installed over the next three years (Adaptive Optics Facility [AOF], ESPRESSO, GRAVITY and MATISSE; see Pasquini et al. [2013]). The number of instruments and their ages (Figure 2) allow us to deduce general statistics on their lifetime behaviour. It should be recalled that the lifetime defined at contract level is ten years for VLT instruments.

Monitoring of performance

An Instrument Operations Team (IOT) is associated with each scientific instrument. Its mandate and responsibility is to maintain the instrument operational environment to ensure the delivery of optimal quality science and calibration data, and science-grade data products whenever possible. The ultimate goal of its activities is to maximise the quality and quantity of the instrument scientific output.

In practice, a full set of tools has been implemented over the years in order to properly monitor the behaviour of both scientific and technical instruments. Some tools are used more frequently by the operator (astronomer and telescope and instrument operator), while others are used more by the engineer or instrument scientist responsible.

Paranal Problem Reporting System

The Paranal Problem Reporting System (PPRS) is a ticketing system designed to track all problems reported at the Paranal Observatory. Each ticket logs the affected system, type of failure, observing time lost on sky, workload necessary to recover the system and the eventual solution. The reporting system started at the end of June 1999; today nearly 57 000 tickets have been recorded, and of these, 22 000 (38 %) are dedicated to instrumentation. The PPRS allows us to easily track the observing time lost on sky and the number of tickets per instrument over the years, giving a good indication of the reliability of an instrument.

Quality control

A health check web page is associated with each instrument, maintained by the Quality Control Group in Garching[2], where the main performance data are logged every day after the calibration data are processed by their respective pipelines: typical applications include monitoring the zero point for the imagers, bias level, dark count rate, flat-field level, spectral resolution, etc. Plots reporting such quantities are updated with a frequency as high as once every 15 minutes and are publicly available. Flags are automatically raised when a measurement is outside a pre-defined range.

Such quality control plots allow daytime astronomers, operation specialists and quality control scientists to quickly spot problems easily (typically a failing function, such as that seen in plot 2 of Figure 3, which was traced to a failing power supply of a lamp) or to follow slow degradation, such as the decrease of the overall FLAMES–GIRAFFE blue transmission caused by the aging of the silver coating of the high-resolution grating (shown in Figure 11). Occasionally users spot issues with data quality that trigger actions on the Paranal side, e.g., with the UVES radial velocity accuracy or the CRIRES slit width repeatability.

Autrep

Autrep is an interface allowing engineers and astronomers to dive into all the data logged by the Paranal instrument and telescope control software. Graphics showing the evolution of the values of pre-defined or most useful parameters over a configurable period are automatically updated every day; all logged data can be retrieved using scripts and compared with other logged data. It is a powerful tool, as it provides easy access to the full data history.

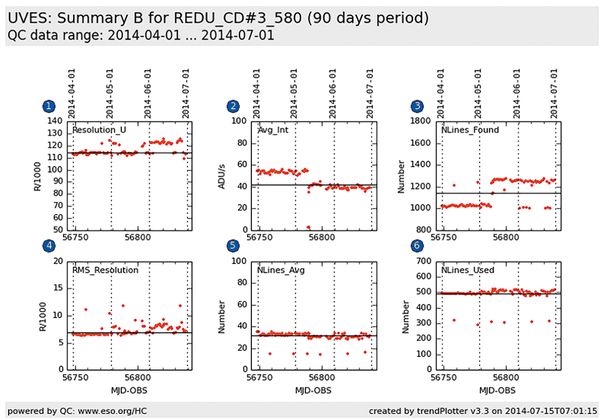


Figure 3. An example of one of the quality control plots obtained daily for UVES, showing the resolution and its root mean square (RMS) obtained on the upper CCD with the cross-disperser #3 for a central wavelength of 580 nm (plots 1 and 4), and associated quantities. Note the drop in the average intensity of the ThAr comparison lines on 10 May shown in plot 2, caused by an instability in the power supply.

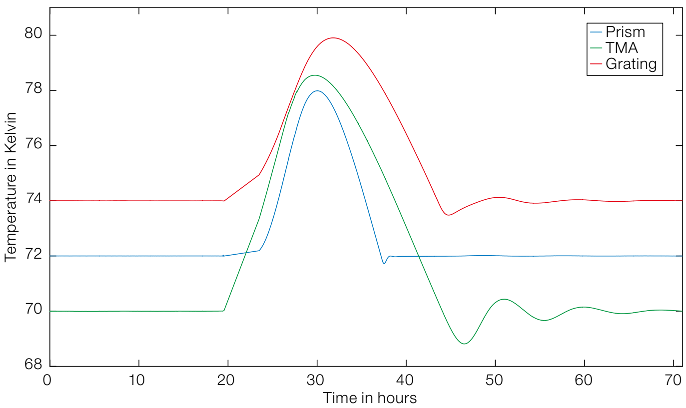


Figure 4. Autrep automatic monitoring of technical data for CRIRES is shown: temperatures for the pre-disperser prism (in black), three-mirror anastigmat (blue) and grating (red).

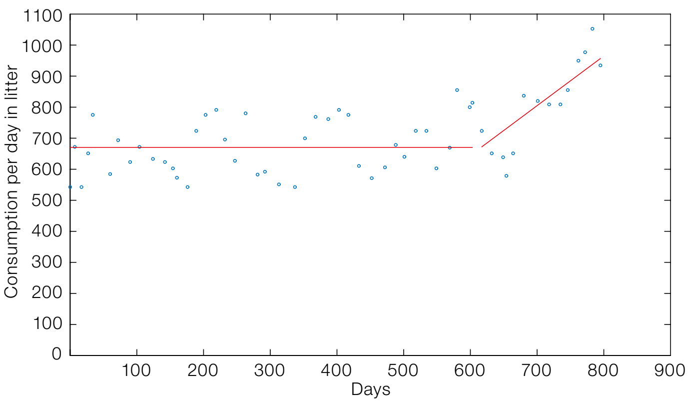


Figure 5. The liquid nitrogen consumption in litres per day on Paranal is illustrated between May 2012 and May 2014. The increase in consumption from late 2013 is due to the installation of KMOS, then MUSE and SPHERE.

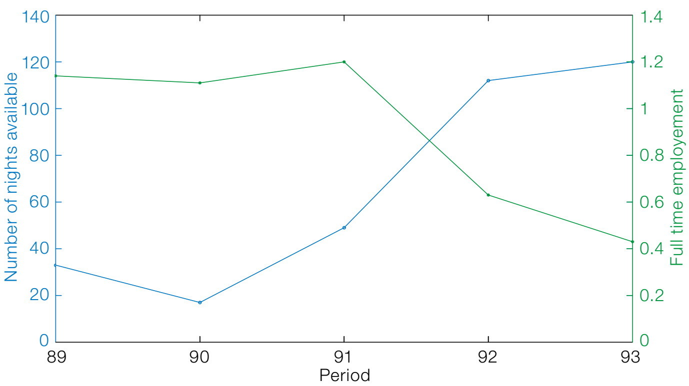


Figure 6. The effect of the LGSF upgrade on nights available (blue) and manpower (green) over the last five periods of observation (Periods 88 to 92). The upgrade from PARLA to PARSEC took place in Period 91.

Figure 4 shows as an example the measurements of the temperature of several components (the prism, three-mirror anastigmat and grating) inside the CRIRES cryostat before, during and after the last power outage on Paranal. Two days were necessary to bring these components back to the temperature stability required for normal operation.

Manual monitoring

Some systems do not have any automatic data logging, but must still be properly monitored. Important parameters are therefore manually logged during daily visual inspections. Figure 5 shows, for example, that the daily liquid nitrogen consumption over the last two years, as measured at the storage tank, has clearly increased significantly since the recent arrival of the three new instruments (KMOS, MUSE and SPHERE). The liquid nitrogen consumption will stabilise at around 1000 litres per day by the end of 2014. It will increase again when ESPRESSO, GRAVITY and MATISSE arrive.

Other analysis tools

Analysis tools can also be dedicated to management. Since 2011, working time in the instrumentation group has been logged: each member of the group reports the type of work (troubleshooting, planned maintenance, project, operation, etc.) spent on each system. From these statistics (e.g., Rabien et al., 2003) it is, for example, possible to extract the impact of the replacement of the dye laser (PARSEC) at the LGSF by a fibre laser PARLA (Lewis et al., 2014), on the manpower required for its maintenance in operational condition. Figure 6 shows the manpower per period of observation (six months) on PARSEC and PARLA. The gain with PARLA was not only a drastic reduction in the manpower needed by this system, but its availability on sky also quadrupled. The manpower saved by this upgrade has been directly re-assigned to implementing the second generation instruments and in making important refurbishments to the aging functions of some first generation instruments.

Monitoring of failures: PPRS and observing time lost on sky

The number of reported problems first increased with the number of instruments in operation, but then started to decrease in 2003 when teething troubles associated with the first instruments settled down. An average of around 70 problems is now reported per instrument per year (Figure 7). In other words, there is one problem every five days per instrument and around five PPRS tickets per day in total. The observing time lost on sky started to decrease later than the number of PPRS tickets, only setting in once the first generation instrumentation was fully implemented. Now, thanks to the presence of several instruments on each UT or at the VLTI, observations can continue with other instruments should one instrument fail. Around 20 hours are lost per instrument per year due to technical problems (Figure 8). This is equivalent to two nights of operation, or around 0.5 % of the available operation time.

The total number of problems and amount of time lost during the lifetime of each instrument are plotted in Figure 8. OmegaCAM should be considered sepa-

Figure 7. The average observing time lost on sky (blue) and the average number of problems reported (green) per year and per instrument from 1999 to 2013.

rately as it also contains the sensors for guiding and image analysis of the VST; thus all guiding and image analysis problems on the VST are accounted to OmegaCAM. It is also the only instrument on the telescope: hence a failure can impact a large part of the night. Since its commissioning in 2011, significant efforts at the hardware and control software levels have been made to reduce the observing time lost on sky.

The three instruments which have accumulated the largest amount of time lost and the greatest number of problems are VIMOS, X-shooter and NACO. These three instruments have a different history, but essentially their unreliability was due to design flaws.

Instrument lifetime reliability

The average number of problems per year and the average observing time lost on sky as a function of the number of years since the start of operation of the instruments at Paranal are shown in Figure 9. The plots span up to 11 years; since there are only three instruments older than 11 years, a longer time span would not be statistically representative. The lifetime of the instruments is clearly seen to be 11 to 12 years. This matches the expectation of a ten-year lifetime at

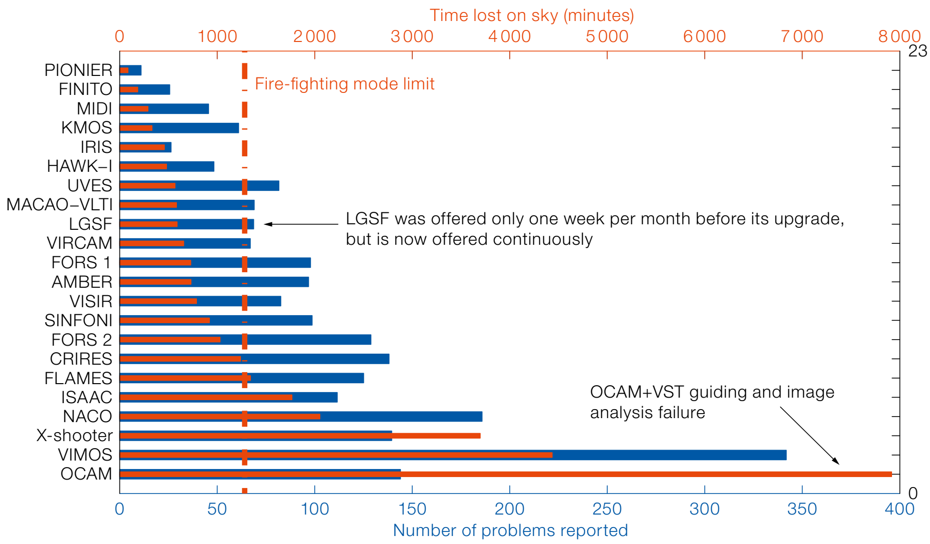
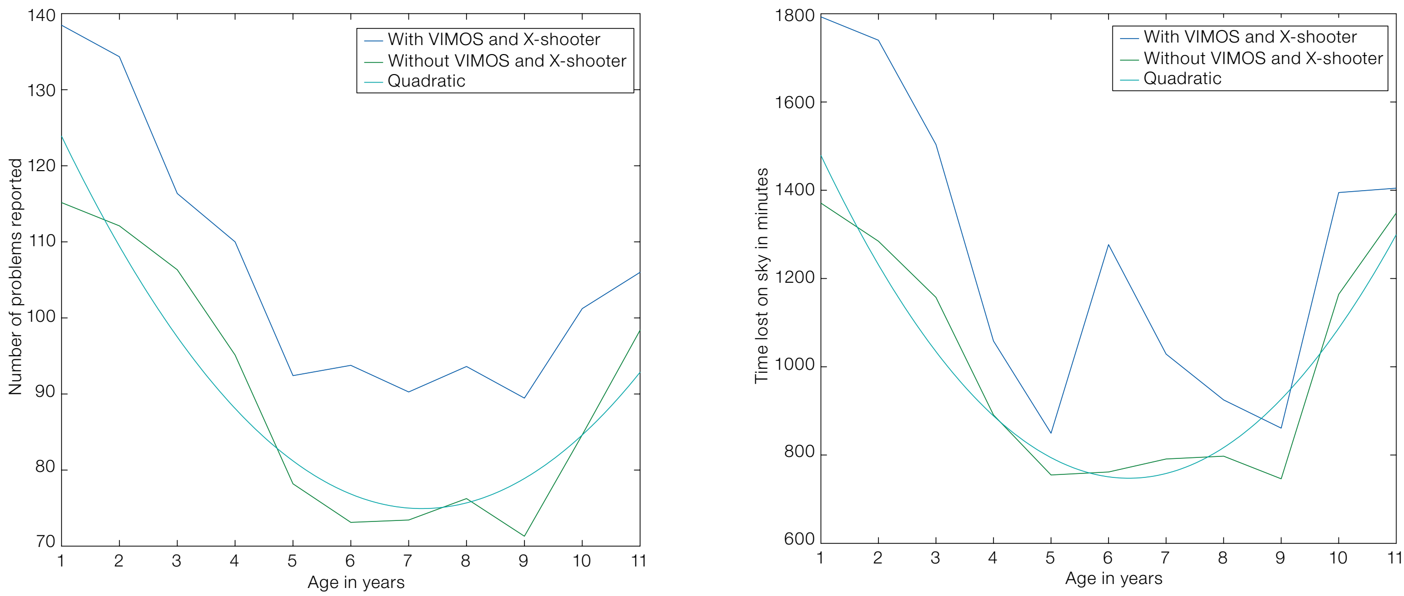


Figure 8. (Above) The observing time lost on sky (red bars) and total number of reported problems (blue bars) are plotted by instrument as an average per year since the start of the instrument operation. The fire-fighting mode limit is a threshold value above which the amount of observing time lost (and then of failures) strongly impacts the operation of the instrument.

Figure 9. (Below) The average number of problems (left) and observing time lost (right) per year is shown during the lifetime of all the instruments.



contract level. However a few instruments (VIMOS, CRIRES and X-shooter) have needed a substantial recovery action after just a few years of operation.

The green curves in Figure 9 were calculated excluding X-shooter and VIMOS, whose impact due to design flaws was far larger than the average behaviour. This curve was fitted by a quadratic polynomial. It shows that once initial problems have been solved (after around four years) the instrument is stable for four or five years; afterwards, the number of problems increases again due to aging and hardware parts becoming unavailable and obsolete. The amount of observing time lost due to technical problems affecting instruments follows the same curve. This pattern of behaviour is well known in system engineering.

The quadratic model describes the reliability of Paranal instruments. This is the result of all the work done in Europe, during their development and design, but also at Paranal to maintain them within specifications. One should wonder whether, and how, this curve could be improved, and whether, and how, this lesson could be applied to future instruments, such as for the European Extremely Large Telescope (E-ELT).

The evolution of instrument reliability can be compared to the one expected from the quadratic model by taking the ratio between the statistic for the instrument and the model as a function of time. An example is shown in Figure 10, using the instrument affected by the largest number of problems, VIMOS. The graph clearly shows its recovery towards normal behaviour after an important upgrade on the mask insertion units, detector shutters, flexure compensation system, between its sixth and eighth year of operation. It should be noted that the absolute reliability of the instrument, i.e., the ratio between the observing time lost on sky and the time available for science, is not given explicitly here. Instead, the observing time lost better represents the amount of work to be done, which is why this quantity has been chosen for this article.

Sources of failure

Instrument failures have many different sources. They are linked to different phases of development and operation and can be classified as follows, as can be seen by these few examples:

Top Level Requirements (TLR) and design phases:
– At TLR: The counter-chopping function implemented in NACO could never be used extensively, but it imposed such constraints on the field selector that it was unstable. Recurrent failure of the field selector represents 10 % of the total observing time lost on sky for NACO.
– At design: Examples are the mask exchange unit (MEU) of VIMOS, the atmospheric dispersion corrector (ADC) system of X-shooter and the opto-mechanical stability of AMBER. They all started to fail, or problems became apparent, as soon as the instrument entered into operation, or soon afterwards. The MEU of VIMOS has accumulated more than 300 hours of observing time lost on sky, corresponding to about more than 30 hours per year. Since its upgrade in 2011, the amount of observing time lost has decreased to around 8.3 hours per year. The total observing time lost due to X-shooter's ADCs is about 134 hours. The ADC system was therefore disabled, severely reducing the capability of the instrument; a refurbishment of the ADC system is under discussion. AMBER's warm bench thermal instability caused 16 % of all problems reported. The problem was solved after an upgrade to provide a more stable alignment unit and the implementation of a daily alignment verification procedure.

Manufacturing, integration and commissioning phases:
– At manufacturing: Poorly protected coatings can start to degrade as soon as the components arrive at Paranal; the specification of a component may not be well checked, for example, the transmission or the wavefront error of an optical element; or an element shows a higher failure rate than expected.
– At integration: Cables not well fixed; components not well screwed or glued, such as the filter carriage of OmegaCAM; leak of the cryostat, as on KMOS; software not well finalised and tested; or control loop of a motor not well tuned.
– At commissioning: Set-up not adapted to operational conditions.

Maintenance, operation and aging phases:
– Maintenance: Incomplete refilling with liquid nitrogen causing a cryostat to warm up.

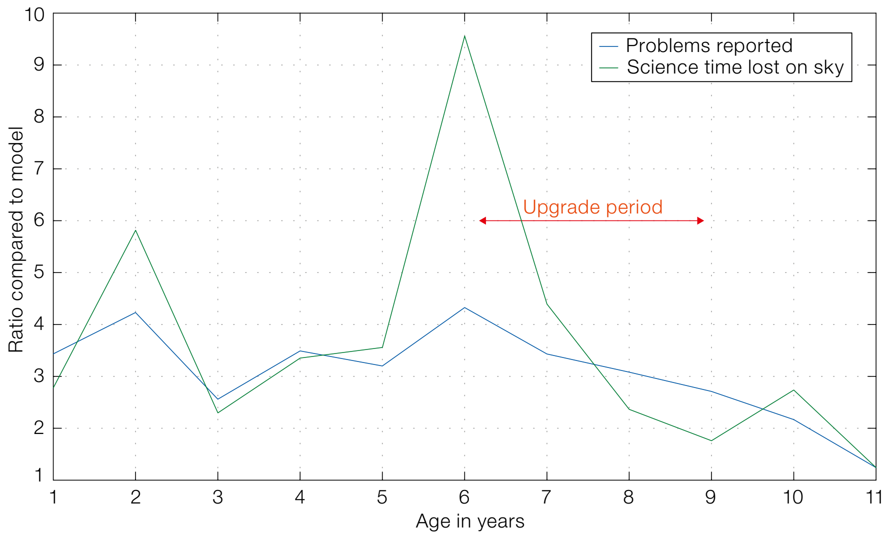


Figure 10. The ratio of the observing time lost (green line) and of the number of problems reported (blue) for VIMOS is compared to the quadratic model defined by the average of all instruments (excluding VIMOS and X-shooter).

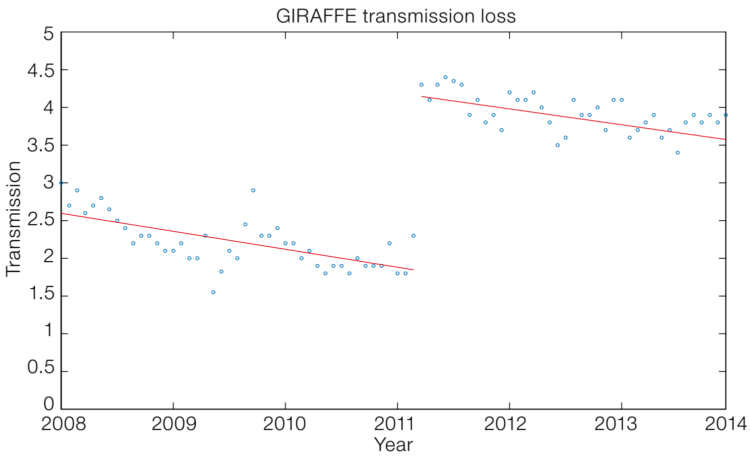


Figure 11. FLAMES-GIRAFFE transmission in the H447.1A setting is plotted before and after cleaning the high-resolution grating in May 2011.

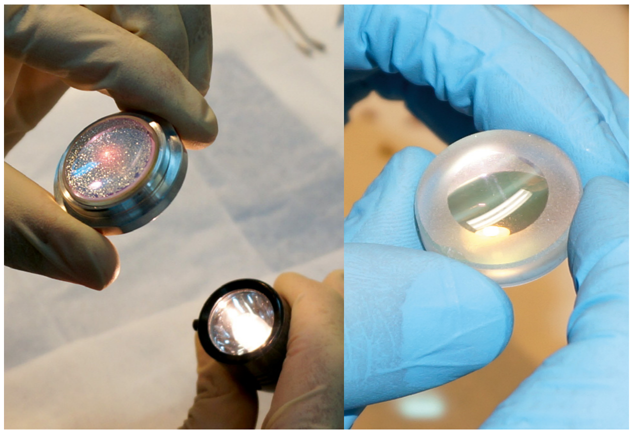


Figure 12. The damaged coating on a SINFONI lens (left) was discovered during inspection after a thermal cycle. The coating was polished away and the lens re-integrated (right).

- Incident: Power blackout resulting in the instrument warming up; earthquake upsetting the alignment.
- Aging: Hard point on rotation or translation stage, degradation of coating (as seen in Figures 11 and 12), burn out of a motor, failure of a drive or leak of a cooling system.

The correction process for problems originating from the TLR or design phases requires a redesign, replacement of the component or a change in the mode of operation. Such problems are the most difficult and expensive sources of failure to solve. They underline why every project should be extremely careful during the definition phase and refrain from shortening this crucial period or minimising its importance.

Problems occurring during manufacturing, integration and commissioning require a replacement, hardware re-integration and/or update and re-implementation (operation or pipeline). This is typically the kind of failure that prevents an instrument from entering operation or limits its capability to be in operation.

The process of correcting problems occurring during maintenance and operation first starts by defining the metrics to be followed. Then the maintenance procedure is corrected and steps taken to ensure adequate training and the availability of spare parts. A refurbishment plan is prepared when the instrument is aging or its components are becoming obsolete. Typical examples of the latter are: non-availability on the market of an electronic board, workstation, detector or version of software or hardware out of production.

Types of activities

Each instrument has been assigned an engineer responsible for its maintenance in operational condition: he/she is in charge of initiating and coordinating all the activities required for this goal, including maintenance. Activities can be divided into four categories: operation-driven, preventive maintenance, condition-based and corrective maintenance. Most of these activities are performed by technicians following a defined procedure established by the engineer responsible for the instrument. Examples of all four categories are presented:

Operation-driven activities

Operation-driven activities are required by the demands of science operations. Examples are:
- daily nitrogen refills for the instruments;
- insertion of mask in FORS or VIMOS;
- exchange of detectors for FORS (from blue to red sensitive CCD, or vice versa);
- development of new observation template software, or modification of existing software, which allows operations at a high level of automation in science service mode, calibration mode and routine tasks, such as daily start-up and shutdown of control software;
- changing the focal station of an instrument in order to optimise the overall science time for the observatory, such as recently carried out for NACO.

Preventive maintenance

Preventive maintenance activities are driven by the lifecycle of a component or by repetitive behaviour, for example:
- Regular software rebuilds are scheduled for each control workstation in order to ensure configuration control, which is the key to maintaining the instrument within operational conditions.
- Since the displacers of the closed cycle coolers have a lifetime of around two years, it has been decided to plan for their replacement after 18 months, i.e., sufficiently before the time of their expected failure, in order to avoid emergency interventions which are disruptive for both science activities and the overall scheduling of time for the observatory personnel.
- KMOS currently suffers from a vacuum loss. After analysis it was decided to pump it on average every week, keeping the instrument in operation, while reducing the impact on the engineers as much as possible. Figure 13 shows the effect of pumping on the KMOS cryostat pressure.

Condition-based activities

Condition-based activities are driven by a change of environmental conditions, such

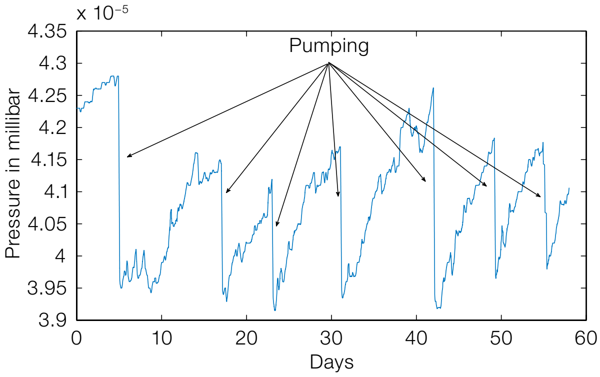


Figure 13. The pressure inside the KMOS cryostat is shown over a period of 60 days from measurements between mid-April and mid-June 2014. The effect of pumping on the cryostat pressure, is evident.

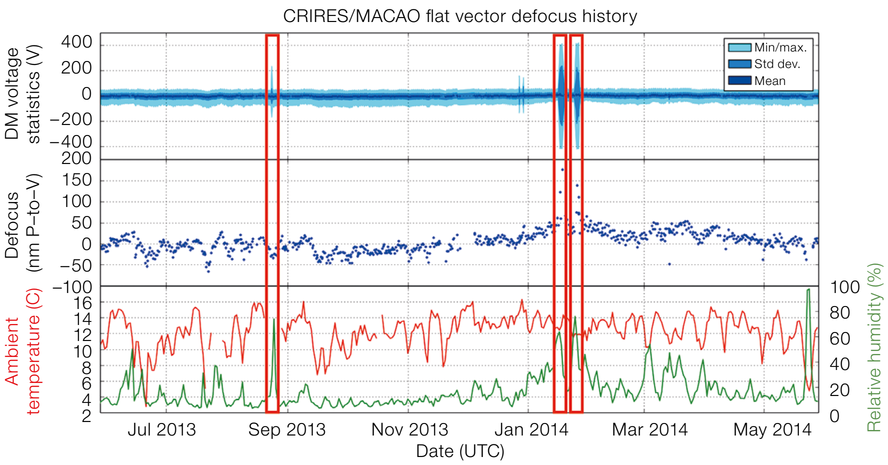


Figure 14. High-humidity events (red boxes) strongly affect the behaviour of the CRIRES MACAO adaptive optics module and prevent its use for operations. After such events, a new calibration and verification process are mandatory.

as the weather. For example, the MACAO systems cannot work properly at high humidity. After each high-humidity event (see Figure 14), a full verification of the performance and calibration of the system is performed.

Corrective maintenance

Corrective maintenance activities are triggered by failures detected during operation (night-time observation or calibration) or during technical verification. Each failure produces a report, which has been used for the statistics given in this article. A few procedures can generally be followed in the case of repetitive failures, like the replacement of a lamp, an avalanche photodiode (APD), a vacuum gauge or the reboot of a local control unit (LCU) or workstation.

Obsolescence and aging

A variety of other actions are required when, for example, an instrument is entering obsolescence, its scientific capability is to be extended or when it is decided that it must be decommissioned.

Refurbishment

Refurbishment of an instrument is necessary when too many functions are jeopardised by aging. Last year, for example, thanks to the help of the Max-Planck-Institut für extraterrestrische Physik, all the motors of SPIFFI (the Spectrometer for Infrared Faint Field Imaging), part of SINFONI, were replaced, as the failure rate was such that only one setting was possible for several weeks. NACO also underwent partial refurbishment, to recover fully the CONICA detector, increase the field selector reliability, replace the closed cycle cooler (CCC), and add a damping system to the CCC.

Upgrade

Reasons for an upgrade differ depending on the instrument. An upgrade is usually proposed when the instrument has completed most of its design science capability, as for VISIR (Kerber et al., 2012), when a real gain in performance is envisaged, such as for VIMOS (Hammersley et al., 2010; 2013) and CRIRES+ (Dorn et al., 2014), or it is becoming more difficult to maintain, as for PARLA (Lewis et al., 2014).

Control software is regularly upgraded following releases of the VLT software core. This activity sometimes includes the replacement of control workstations by more modern and powerful models, such as the current move towards 64-bit architecture.

Decommissioning

Decommissioning an instrument is the ultimate action. Pressure from the scientific community for the continuous use of even a severely aged instrument means that, so far, this situation has only occurred in order to free a focus for a new instrument. The next instrument to be decommissioned will be MIDI to allow for the integration of GRAVITY and MATISSE.

Global approach

The number of instruments for which no refurbishment, upgrade or decommissioning is planned is still large. As a consequence, we will be facing obsolescence and aging problems not only at the level of the electronics (boards, motors) and control software, but also at the level of mechanics (hard point, leaks) and optics (degradation of coatings). ESO is preparing an instrument obsolescence project to face this situation. It focusses on the first generation instruments that are still expected to be operational for at least the next five years, namely: FORS2, NACO, UVES, FLAMES, VIMOS, HAWK-I, OmegaCAM, AMBER and the LGSF.

Conclusions

The reliability and lifetime of the instruments on Paranal correspond on average to those requested at contract level (ten years, and less than 0.5 % of the scientific time lost). However, the operation and maintenance activities can only be organised with a good understanding of instrument behaviour. This understanding can only be obtained via an accurate and complete monitoring of the system. A methodical approach must then be applied to maintenance, finding the right balance between cost and manpower on the one hand, and the number of problems and amount of observing time lost on sky on the other hand.

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Links

[1] Reference list for Paranal instrumentation: http://www.eso.org/sci/facilities/paranal/instruments/InstrumentReferences.html
[2] Instrument quality control information: http://www.eso.org/observing/dfo/quality/

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Time-lapse image of the night sky over the Paranal Observatory. See Picture of the Week for 26 May 2014 for more information.