A fast link with Paranal: new operational opportunities

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ABSTRACT

This paper elaborates on how ESO is looking forward to fully exploit all new opportunities that the high bandwidth communication link delivered by the EVALSO project will make available to the ESO Paranal Observatory. EVALSO, a project funded by the Framework Programme 7 of the European Union, stands for 'Enabling Virtual Access to Latin-american Southern Observatories' (more at www.evalso.eu). Its goal is to enable fast access to two European optical astronomical facilities in the Atacama Desert in northern Chile, namely the world-class ESO Paranal Observatory and the one run by the Ruhr Universität Bochum at the neighbouring Cerro Armazones. EVALSO plans to make available the still missing physical infrastructure to efficiently connect these facilities to Europe via the international infrastructures created in the last years with the European Commission support (ALICE, trans-Atlantic link, GEANT2) ESO, as member of the EVALSO Consortium, is involved in the implementation of the link and has already started together with the other members the analysis of the operational opportunities that this new capability will give the European astronomical community, not only in terms of faster access to the collected data, but also opening the door to new and more efficient ways of operating remote facilities.

Keywords: Communications, operations modes, remote observing

1. INTRODUCTION

The major contemporary or planned astronomical observatories are found at remote locations due to the need to exploit the rare confluence of atmospheric and environmental conditions that define an excellent astronomical site. Because of this, the operation of these facilities normally takes place in a geographically dispersed environment. The tasks of real-time operation of the facility, the support to such operations, and the data quality assessment and archive, to name just a few of the components of the end-to-end operations model of a modern astronomical facility, often take place at locations in different countries or even continents, with a stream of data containing scientific, calibration, environmental, and ancillary information flowing through all those locations. At the same time, astronomical instruments are equipped with increasingly large or multiple detector systems that output large data volumes, often at a high rate. The science and calibration data volume typically produced by a major optical/infrared astronomical facility like the Very Large Telescope (VLT) on Paranal is now of the order of several tens of gigabytes per day, a number that will increase in the next years with the arrival of new, higher multiplex instruments. Upcoming survey telescopes like VISTA and VST, and ultimately the LSST, promise to increase such numbers by orders of magnitude.

The sheer data rates pose a challenge to the need that all the different segments of operations, residing at different locations, have of being able to quickly access those data. A communications infrastructure linking the different operation centers that is able to support the transfer of such data volume on an acceptable timescale thus becomes an essential requirement for a major modern observatory to operate efficiently. The EVALSO project, described in this paper and where the European Southern Observatory (ESO) is a prominent partner, is designed to address such needs. EVALSO (for "Enabling Virtual Access to Latin-american Southern Observatories") is funded by the Framework Programme 7 of the European Union, and its goal is to upgrade the link to the optical astronomy facilities in the Atacama desert in northern Chile, concretely the facilities of the European Southern Observatory on Cerro Paranal and the observatory operated by the Ruhr Universität Bochum and the neighbouring Cerro Armazones. We outline here the rationale and expected benefits that the availability of the fast access capabilities offered by EVALSO will have on the end-to-end operations of the Paranal facilities, and on the possibility of exploring new observing modes that require those capabilities by providing fast access to scientific data to remotely located researchers.

2. INFRASTRUCTURE

At the moment, the Paranal Observatory is part of the ESO Wide Area Network (WAN), which provides connectivity between all ESO sites, namely:

- The Paranal Observatory is connected to ESO offices in Santiago de Chile via the MPLS network of ENTEL (Chilean provider), making use of microwave links to connect the Observatory to the Chilean fiber backbone, running about 100km away from the Paranal location. For redundancy, two two independent microwave paths are implemented.
- The connection between Garching and Santiago is using an IPsec tunnel built over the standard commercial INTERNET. In Germany, the ESO Headquarters are connected to INTERNET via DFN, the German National Research and Education Network (NREN).

The situation at the Observatorio Cerro Armazones (OCA) is logically similar, using a direct link to commercial Internet based on a Microwave circuit.

The use of microwave links has shown some disadvantages:

- The need to install active equipment outdoor in areas with difficult access and very extreme weather conditions (for imstance, one installation is located at a place called “El Viento”, literally “The wind”!). Because of the higher stress and the longer time to reach the locations, downtimes are more frequent and longer, decreasing the overall availability. The logs indicate the current availability at around 99%.
- The need of having line of sight between source of data and entry on the national network implies that more intermediate active repeaters are needed, thus decreasing the overall stability.
- Although capable theoretically to provide unlimited bandwidth, microwave links for private circuits are normally limited to few STM-1 channels (each 155Mbps), setting on some hundreds Mbps the future upper limit.
- Microwave technology is an established area and not much development or evolutions can be expected here.

To mitigate part of the negative effects, more channels on two different paths are used.

EVALSO aims at providing a solid and long-term-lasting infrastructure allowing enough capacity for today’s and future needs. It consists of installing an optic fibre facility running from the astronomical facilities to Antofagasta, the closest city where there is an already available communication infrastructure. With close cooperation with REUNA, the Chilean NREN, the project will create the needed connectivity from Antofagasta to Santiago to access there the International Research Network through RedCLARA, the Latin America Research network operated by CLARA, then via the trans-Atlantic link between Brasil and Spain, to the European GEANT2 infrastructure, and finally via DFN, the German NREN, to ESO. The project therefore will provide to the observatories a path at Gbps capacity between their sites and the scientific community in Europe.

The projected availability of such a high capacity link has already triggered several scientific activities to identify not only improvements on tasks currently done, but also opening the door to new operational ways. Such joint research activities, as they are called in FP7 terminology, are also part of the EVALSO project and some key aspects related to VLT operations are discussed in detail in the remaining sections of this paper.

More details on the projects, including links on the existing infrastructure and the project partners, can be found on the EVALSO Web site: www.evalso.eu.

3. DATA RATES

The data rate of the existing VLT first generation instruments, all of which are in regular operations at present, and of the VLT interferometer, is 14.9 compressed GBytes per 24 hours period, with a peak of 80 GBytes. It is possible at present to transfer this whole data rate over the existing network over a period of 24 hours using the current communications infrastructure, although in general near-real time (i.e. within some seconds) transfer of data obtained during operations would not be possible with it. In other words, although it is possible to close the operations loop in a short time, distributing the back-end processing of data in a smooth way, no significant change in the paradigm of interaction of the users with the facility is possible at the moment. This is not regarded as a major drawback, as the current operations model of the VLT, which combines classical visitor observing mode with an extensive and versatile service mode flexibly scheduled (both of which are described further in Section 5), is well able to absorb the operational demands from the vast majority of all the scientific observing programmes submitted each semester by the community of scientific users of ESO facilities. However, the benefits of expanding the offer of operational modes have been recognized for some time, as further described in Section 5.

The data rate from Paranal will increase substantially in the coming months as the 4m VISTA survey telescope enters operations. The single instrument of VISTA, VIRCAM, is a wide-field near-infrared imager that will carry out a variety of surveys. It is equipped with an array of 16 detectors of 2048 x 2048 pixels, involving data rates that will dominate the data stream from Paranal. Typical expected numbers (compressed) are as follows:

- Maximum data/night 450 GBytes/op night
- Typical high rate 210 GBytes/op night
- Mean data rate 105 GBytes/op night
- Average data rate 85 GBytes/calendar day

A second survey telescope, the 2.5m VLT Survey Telescope (VST), is also expected to enter operations within the next twelve months. Its instrument, the wide-field imager OmegaCam, has an even larger array of 32 detectors of 4096 x 2048 pixels, although given that it will operate in the visible the frame rate will be generally lower than that of VISTA.

4. CLOSING THE OPERATIONS LOOP

The successful scientific exploitation of the current world-class ground-based astronomical facilities heavily depends on the optimization of their operations. Such optimization takes place in the form of the ease and flexibility of access to the facility to its community of users, as well as in the form of a capable infrastructure. The ESO Very Large Telescope (VLT) offers at present the most advanced implementation of innovative telescope operations concepts, in particular the full implementation of the so-called Service Mode. The flexible scheduling capability offered by Service Mode has been a key ingredient in the recognized scientific success of the VLT[1], and it will be important for the success of new facilities currently under construction on Paranal such as the VST and VISTA survey telescopes, which will be operated exclusively in Service Mode.

While the scientific rewards of such an operations model have been amply demonstrated at the VLT, its successful implementation requires substantial complexity in the areas of data management and information and communications technology infrastructure. This complexity is driven by high-level requirements on operational efficiency and robust control of the data produced by the telescopes and their instrumentation, which have been described in detail elsewhere[2]. In practice, the operations model of the VLT and other ESO facilities is a complex network of interactions among groups based at widely separated geographical locations, which exchange large volumes of information. In this regard, VLT operations resemble those of other leading-edge astronomical facilities across the world and those of space-borne observatories. At the core of this network is the ESO Science Archive Facility, physically located at ESO Headquarters in Garching (Germany), which is used for the storage of all data obtained at the VLT and all other ESO telescopes, and also as an active tool for the preparation of data packages for users, retrieval of sets of observations by the ESO users community, data quality control, instrument health monitoring, and the distribution of processed, scienceready data products. The successful implementation of the state-of-the-art technology needed to support this operations model, which in many respects parallels the operation of space-borne observatories, is demonstrated by the increasing demand by the European astronomical community, the positive feedback received[3] and the high productivity as measured by the number of refereed publications of the VLT.

Given that the ESO archive and some of the groups managing segments of the operations of ESO facilities reside at the ESO Headquarters in Germany, communications with the mountain often represents a bottleneck in terms of operational efficiency and robustness. The extremely low percentage of downtime due to technical reasons at the VLT (currently below 3% of the time available for scientific observations) relies among other factors on the early identification of instrument under-performance and the need for preventive maintenance. Such identification can be carried out by detailed monitoring of the parameters characterizing the performance of the instruments. While basic monitoring does take place in near-real time on the mountain, a detailed follow-up and the detection of degradation trends can only be carried out off-line by dedicated personnel. In addition, the early identification of non-obvious malfunctions that have the potential of compromising the scientific usefulness of the data obtained is mandatory in order to avoid wasting telescope time on observations that may turn out to be flawed. One of the main motivations for EVALSO is to close the operations loop on a timescale dramatically shorter than possible today, thus bringing about the benefits in terms of reliability and robustness in the forms described above.

5. NEW OPERATIONAL POSSIBILITES

The current operations model of large ground-based astronomical facilities such as the ESO VLT is built around two modes:

In *Visitor or Classical Mode* fixed slots of time are allocated to a project long in advance. The researcher travels to the observatory and is in charge of adopting all decisions needed regarding instrument setup, exposure times, and sequencing of the observations. The advantage is the ability to adapt in real time to the external observing conditions, and to react to unforeseen results from observations just carried out, optimizing their follow-up. The main disadvantage is the need to cope with possible adverse atmosphere conditions that may render the quality of the data unsuitable for scientific analysis, or even prevent the acquisition of any data at all.

In *Service or Queue Mode* the researcher submits in advance to the observatory fully pre-specified instrument setup and exposure instructions in the form of Observation Blocks. The Observation Blocks will be executed only when the atmosphere conditions, and possibly others such as the lunar illumination, are suitable for the scientific goals of the observation. The advantage is the ability to ensure that the observations will be obtained under the proper external conditions, and the flexibility given to the observatory to allocate rarely occurring superb observing conditions to the scientific projects that really require them. The disadvantages are that it is in general not possible to predict when a given observation will be carried out, and that there is no possibility to react to unexpected findings in observations just executed or to fine-tune the parameters of the following observations based on results just obtained.

At present, real-time interactivity between the user and the observatory is ruled out in Service Mode, due to the lack of possibility of transferring the data resulting from one observation to the user sufficiently fast for the latter to decide among possible courses of action. Making use of Service or Visitor mode at a facility thus implies a trade-off between the need to guarantee the execution of observations under acceptable atmosphere conditions, and the need for real-time interaction with the facility.

Mixed operations modes that take advantage of the best of both schemes have been studied at some observatories and are currently considered as a possibility for the operation of the next generation of Extremely Large Telescopes. Perhaps the most attractive of these modes is one in which the observers can be remotely located in their offices or even at home, but retaining the possibility of real-time interaction with the observatory in both directions –receiving science data as they are obtained, and deciding on the course of action based on the results of observations just performed. In an ideal case the researchers would be contacted at short notice whenever the conditions were suitable for the execution of their programs. Given the number of teams using the VLT each semester, the implementation of the mode just outlined may be of interest to only a reduced subset of observing programmes, where some scheduling flexibility needs to exist in combination with the possibility of implementing real-time decisions. However, the high potential scientific return of some such programmes grants giving them serious consideration.

The programmes that may benefit most from the possibility of remotely interacting with the facility while being able to make real-time decisions are those having targets displaying transient unpredictable behaviors, and which fall under the category of Targets of Opportunity. Typically, such events happen in an unpredictable way and are detected by dedicated facilities, either on the ground or in space, which send immediate alerts to groups of researchers interested in carrying out follow-up observations. At the present, whenever such an event happens requiring follow-up observations at the VLT a request for observation at short notice is sent to the observatory requesting the execution of a predetermined set of observation blocks. However, the real-time interaction is restricted to the request to the observatory to start the observation, and no adjustment of the observations to the actual characteristics of the otherwise unique event (flux evolution, unexpected behavior, focus on a given spectral region...) is possible.

A fast communication channel enabling the transfer of just acquired data to the remotely located user would extend the real-time interaction to the entire process of data acquisition, quick-look analysis, and decision on how to proceed next. In this operational scenario, telescope time would be initially allocated to a project that intends to observe a certain type of unpredictable events, such as a gamma-ray burst, as they occur. Upon receiving an alert signaling the occurrence of such an event, the group conducting the project would rapidly contact the observatory in order to trigger follow-up observations. Once the first observation is concluded, the data would be immediately transferred to the requester, most probably after being processed by a data reduction pipeline that enables a quick-look assessment. Based on it, the requester would prepare the full definition of the next observation to be conducted and send it to the observatory, where it would be immediately processed in order to start the next observation of the target.

6. CONCLUSIONS

By providing a dramatic increase in the transfer speed of data between Paranal and Europe, EVALSO will make available the information and communications technology infrastructure that will become necessary in the near future to operate the ever-increasingly complex astronomical instruments in remotely located facilities. In this way, it will also anticipate technological solutions that will be needed by the future European Extremely Large Telescope (E-ELT). The fast fiber link not only addresses the logistics of data transfer from the mountain, even with the dramatic increase in data production expected with the beginning of operations of the survey telescopes on Paranal. It also provides near-real time capabilities to remotely located operations centers that allow increased operational robustness and a more convenient distribution of the tasks taking place at the different nodes of the end-to-end operations model. In addition, it opens the possibility of considering the implementation of new observing modes that combine the real-time decision capabilities offered by observing in visitor mode with the flexible scheduling that is offered by service mode, thus expanding the capabilities of the observatory towards the operational requirements set by prominent science cases of current astrophysics.

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