VLT/I Instrumentation: Lessons Learned Forum

This paper is the result of a joint effort by ESO and its Scientific and Technical Committee (STC) to extract the main lessons from last April's "VLT/VLTI Instrumentation: Lessons learned" Forum and start applying them, in particular in the framework of the development of second generation VLT –and soon VLTI– instruments. This is but one step in a continuing effort to optimize these complex and challenging developments which involve a significant fraction of Europe's astronomical instrument builders in the near-UV to mid-IR range. With a major effort in the European radio community to build multiple receiver systems for ALMA now being pursued at an accelerated pace, it was also vital to revisit very quickly our whole procurement strategy in this area.

G. Monnet *(ESO)* and R. Bacon *(STC; CRAL)*

The Forum was held at ESO-Garching over three consecutive half-day sessions on 8–9 April. To ensure maximum feedback from the ESO user community, the event was sandwiched between the regular User's Committee (UC) and Scientific and Technical Committee (STC) spring meetings. The purpose was to review with the external Consortia how the first generation instrumentation has been developed and the lessons of its successes and failures. The main objectives were: *i*) to produce a better common understanding among the instrument builders both from the Community and from ESO and the members of the ESO Committees (UC, STC, Council); and *ii*) to get the necessary input to improve ESO's procedures and policies, in particular for second Generation VLT/I instrumentation development and ALMA.

The Forum embraced both analytic and synthetic approaches. The analytic approach featured individual presentations by the external PIs on the instruments developed in the last decade for Paranal and La Silla, supplemented by two presentations by ESO on its experience. The synthetic approach included two panel discussions, one on "Procedures" (Contracts, Design Reviews, Progress Meetings, Reporting, PAE, Commissioning, GTO, ESO roles) and one on "Science Operations" (Observing modes, Templates, Quality Control, Pipelines, Data Access), followed by concluding presentations on behalf of the UC, STC and ESO executive.

Invitations were extended to the Consortia that were involved in first generation instrument projects and their ESO counterparts, the potential PIs of second generation instruments, the STC/UC/Council representatives, the panel members and a number of ALMA representatives. Attendance was high with more than sixty non-ESO staff participants. All external Consortia were duly represented, except for the Australian Oz-Poz Team, which unfortunately could not attend the Forum but sent comments in advance.

Membership for the Panels was as follows:

-Panel #1 (Procedures): S. D'Odorico, ESO (moderator); A. Blécha, Observatoire de Genève; W. Boland, NOVA-Leiden; F. Casoli, INSU; J. G. Cuby, ESO;

Forum Agenda

Instrument Procurement History & Evolution	C. Cesarsky	ESO
Lessons learned: FORS 1 & 2	I. Appenzeller	LSW-Heidelberg
Lessons learned: CONICA	R. Lenzen	MPIA-Heidelberg
Lessons learned: NAOS	G. Rousset	ONERA
Lessons learned: VIMOS & NIRMOS	O. LeFèvre	LAM-Marseille
Lessons learned: Giraffe	F. Hammer	Obs. Paris
Lessons learned: SPIFFI	F. Eisenhauer	MPE-Garching
Lessons learned: VISIR	P.O. Lagage	CEA-Saclay
Lessons learned: OmegaCAM	K. Kuijken	Leiden SW
Lessons learned: HARPS	M. Mayor	Obs. Genève
Lessons learned: MIDI	U. Graser	MPIA-Heidelberg
Lessons learned: AMBER	R. Petrov	Nice University
What went right and What went wrong?	G. Monnet	ESO
Panel #1: Instrument development Procedures	Panel #1	
Perspective from the Users	H. van Winckel	UC
Panel #2: Science Operations	Panel #2	
What Shall We Change? ESO Perspective	G. Monnet	ESO
What Shall We Change? STC Perspective	R. Bacon	STC
General Discussion & Conclusions	All	

F. Eisenhauer, MPE-Garching; A. Russell, ATC-Edinburgh; P. Vettolani, INAF.

-Panel #2 (Science Operations): P. Quinn, ESO (moderator); M. Bremer (Bristol University); C. Cacciari, (Bologna); B. Garilli, (IASF-Milano); D. Minniti, Chile; D. Silva, ESO.

Forum Agenda

The Forum Agenda is given in the Table on the previous page. All Presentations are accessible from the Web at *http://www.eso.org/~gmonnet/llforum* (username: *llforum*; password: *UR32Cthem!*).

Lessons Learned and Applied

We received considerable feedback both from the Principal Investigators of some twelve instrumental projects led by external groups and from ESO project managers from Garching, La Silla and Paranal. As expected, no complete consensus could be reached from such a diverse set of individual experiences, but a number of common threads clearly appeared during the Meeting. All steps of instrument development were addressed, from the initial evaluation and decision process through instrument design, fabrication and integration and finally reintegration and commissioning in Chile. Most of these points were related to contractual and management aspects, but there were also some important technical issues. All require a closer look on how instrument projects are handled at ESO and how we can improve.

Management and Contractual Aspects

Schedule, Performance & Cost: revisiting the "fast-track" approach

"Schedule, performance, cost: pick any two". The extensive instrument programs for the present generation of Very Large Telescopes certainly offer a good opportunity to check the validity of this Dilbert-like saying. In ESO's case, experience so far shows that: *i*) hardware costs are as a rule accurately predicted; *ii*) manpower predictions are less accurate, with systematic underestimation factors ranging from slightly larger than 1 to 1.5; *iii*) performance specifications are mostly met, with the painful exception of (mechanical) reliability for many projects and *iv*) schedules consistently tend not to be met, with typical 1 to 2 year delays. Overall, both Gemini and Keck found similar patterns in spite of large differences in their respective procurement policies.

Thus, schedule is the main "free" parameter in the equation. This would appear therefore to put into question the usefulness of the so-called "fast-track" approach, used with varying degrees of success in recent years for numerous ESO projects (NAOS, VIMOS, FLAMES, SPIFFI, HARPS). In retrospect, however, it appears to have been a useful tool, especially for faster contracting, early purchases and relatively quick design. On the other hand, time pressure generated during the crucial Assembly, Integration and Testing phases has been sometimes detrimental, e.g. for NACO and especially VIMOS. However, as counterexamples, the complex FLAMES facility was "only" a year late on an extremely challenging original schedule. The technically complex, if operationally simpler, SPIFFI spectrometer was even closer to meeting its original schedule. The HARPS Planet Searcher project for the La Silla 3.6 m telescope even succeeded in making its original 3-year schedule to the day. Based on our experience, developing a full-fledged VLT facility would "normally" take about 5 years. This can be significantly accelerated, but with a special concerted effort and then only if in addition all eventual R&D issues have been solved upfront, a lesson certainly learned *a contrario* on some first generation instruments, e.g. VISIR and NIRMOS.

Consortium-ESO relationship

Almost fifteen years ago, when the VLT first generation instruments effort was launched, a simple and neat model was adopted with, basically, a customer (ESO) to industrial-like supplier (Consortium) relationship. A more complex situation evolved in the following years as the need to apply rigorous hardware and software standards was recognized – at first rather reluctantly on both sides, and, ultimately, fully embraced by both sides. The *quid pro quo*, however, was that the corresponding systems, in particular instrument control and detector assemblies, were delivered, documented and maintained by ESO for the vast majority of the instruments. This played a large role in the evolution towards the present, sometimes confusing, situation in which ESO increasingly plays the dual role of a "subcontractor" to the Consortium – required to deliver goods within time, cost & performance – and of the "client", monitoring the instrument contract. In some cases, the ESO contributions have been seen as outsiders compared to the "real" Consortia. This too has led to problems in understanding the implications of resource limitations within ESO and in evaluating the rate of progress in some areas.

Perhaps even more importantly, with the delivery so far of the first seven VLT instruments, it has become clear that, at the end of the day, ESO bears the ultimate responsibility for operating these scientifically competitive new facilities for its community. The relationship with Consortia has thus evolved quite naturally towards a partnership with a common single goal, rather than the previous client to customer model. This remains a somewhat entangled scheme as, at the same time, ESO is responsible to its own community for the guaranteed time granted to external Consortia in exchange for manpower and, possibly, cash (e.g. OmegaCAM, MIDI, AMBER), assuming the instruments are delivered on time, within budget, and according to performance specifications. This aspect necessarily retains a contractual nature.

The Gemini Observatory is engaged in similar soul-searching. However, in its case, there is much less technical contribution to the projects on the part of the Observatory and, in particular, little standardization. Moreover, in contrast to ESO, it bears the full cost (hardware plus manpower) of the instruments. One year ago, their "lessons-learned" solution was to adopt from now on a full partnership model until Critical Design Review (relatively close to ESO Preliminary Design Review), followed by the usual client role until full delivery of the instrument. In the case of ESO, we should distinguish between instrument building, which is inherently done in partnership, and the contractual aspect, whose *raison d'être* is to cover the guaranteed time allocation in exchange for the Consortia contributions.

Above all, both the ESO and the community instrument builders recognize the need to continue applying proper project management tools, in particular, Instrument Specifications and Statements of Work, Progress Reports and Reviews, as well as maintaining a living Management Plan for every project. This view, which started at a very early phase of the VLT project, is now shared by virtually all instrument teams at every large telescope.

Analysis and Decision Phase

First generation instrument definitions and procurement schemes ranged over the whole gamut, from competing proposals (e.g. the two FORS, CONICA and VIMOS) to single source procurements (e.g. ISAAC and UVES for internal ESO instruments, VISIR after an extensive, competitively selected Phase A study and FLAMES for external procurements). With the present second generation start, there is a clear demand for a more unified scheme. We are thus instituting systematic Phase A studies to establish the instruments' top level scientific goals, their

technical feasibility and the aptitude of the teams – including the possible ESO contributions. These studies are conducted in partnership and, ideally, we are already able to build at this early phase a full ESO project team covering all instrumentation and operational aspects, including a Paranal contribution.

The Phase A studies will lead to Reviews by ESO, with the help of external reviewers, in which the project concepts, performance and feasibility are covered, as well as results of critical R&D and provisional contributors, to conduct the projects within acceptable schedules, cost and management plans, costs and schedules. This phase is also crucial to recognize any further R&D effort, which should be completed before any project enters into an "irreversible" state. It is worth noting that there are currently two cases, viz., KMOS and the Planet Finder, with two teams in direct competition with each other during this phase, and ESO will make every effort to treat them on an equal footing.

These Phase A Reviews will be the basis for ESO evaluations transmitted to the Consortia for comments. These elements, together with the Review documents, will be communicated to the STC for recommendations on the individual projects, for resolving cases of competing projects, and on the relative scientific priorities of the different instrumental avenues explored. This scheme should make the decision making process more transparent to our community.

Recently, steps have been taken to strengthen the final decision phase for the launch of instrument projects. In parallel with the Forum, we have established within ESO a "Project Definition & Approval" (PDA) Committee, composed of representatives of Instrumentation & Systems Development and Paranal & Garching Operations, which endorses proposals to the Executive for all new projects, including instrument upgrades. This integrated approach is essential to ensure that all project aspects are addressed in a coordinated way and to develop full project "ownership" inside ESO.

It should be noted that so far the second generation Phase A studies have been handled through formal Contracts with the Consortia. This is a slow and time-consuming process, somewhat disproportionate to the relatively small sums involved in each of the cases (50 to 150 k), and even more so with respect to their short timescales (1 to 2 years). We are looking to implement a much simpler procedure, e.g. through direct purchase orders issued by ESO, at least below a certain financial cap.

Development phase: Design; Fabrication; Assembly, Integration & Testing

Both Gemini and ESO have expended huge efforts to establish proper contracts with external Consortia in order to start the development phase. There is relatively little we can do about the efforts required, given the usually large number of actors involved, but we could save time by starting actual design (and when appropriate, initiating some time-critical procurements) right after selection while, in parallel, negotiating the contract for guaranteed time allocation, which requires approval by the ESO Council. We would obviously then run a (small) risk on both sides by investing in a project that could eventually be cancelled some 6 to 9 months later. This is however more than counter-balanced by the certainty otherwise of losing momentum, including, at the very least, a full semester delay in every schedule, as was experienced on first generation projects with some damaging impact on ESO competitiveness.

During all this development phase, the key management tools are the progress meetings, which involve the whole Consortium, including of course the relevant ESO team. Building this combined team approach, involving not only ESO "hardware" divisions but also operational ones (Paranal & DMD), is crucial to the success of the partnership model.

As originally put into place for the VIRMOS contract, all instrument contracts should be framed in two successive steps: First, instrument design up to the project Final Design Review (FDR) and second, fabrication up to the instrument reintegration and Commissioning in Chile. The FDR is a crucial event whose purpose is to firmly establish the technical, financial and human capacity to actually develop the facility within schedule, performance and cost or, barring that, to terminate the project in an efficient and amicable way (with some contractual guaranteed time attached to the Consortium efforts up to FDR). There has been some lively discussion on the Review process carried out by ESO on more than 20 instrumental projects. Some Consortia have found the ESO approach too formal and occasionally inefficient. There has been a rather large consensus that the fundamental approach looks right, but also that we must revisit the issue, in particular, to give clearer definitions of the objectives of the various reviews and that we must ensure that these reviews remain conducted in a professional way, but at the same time within a fully cooperative atmosphere.

Many of the instrument delays occurred between FDR and Preliminary Acceptance in Europe (PAE), and closer involvement of ESO staff and improved communication would be of great benefit in this phase. The instrument development phase ends with the PAE, another crucial event, which requires stepping up Paranal involvement, ideally months before the actual acceptance tests. In the last two years, we have experienced some rather painful PAE, where an instrument finally got a go-ahead to Paranal (partly) out of desperation from all actors involved. This, however, did not appear to be directly connected to a major management or procedure failure, but to sheer technical complexity instead (see below).

Commissioning and Start of Operations

Even with due allowance for the finite capability of Paranal compared to the present avalanche of instrument and telescope systems installations, the current commissioning scheme appears sub-optimal, both practically and psychologically, due to the complex and sometimes confusing responsibility sharing between the Consortium P.I., the ESO-Garching project manager and instrument scientist, and the Paranal responsible. Granted, partly because some instruments were not fully completed before moving to Paranal, we sometimes went through protracted commissioning extending over 3-4 periods instead of the canonical two phases: Commissioning I, devoted to instrument technical evaluation, and Commissioning II for integration in the VLT operation flow. This is an experience that neither the Consortia nor ESO would like to repeat.

We need to move to a clearer scheme, strictly linked to the absolute first priority goal to characterize the instruments and finalize the deployment of their observing modes. The intent is to retain an overall Paranal-led commissioning under plans drafted by the combined Consortium-ESO team, with the goal of sticking to the two-phase model. Early involvement of Paranal staff in the program definition should help reduce the sense of "Them" and "Us" that has developed. In addition, for the subsidiary but nevertheless important goal of early scientific evaluation of the instrument capabilities, a separate short observing program should be carried out jointly by the Instrument PI and the Instrument Scientist(s) under the supervision of the VLT Program Scientist. The observational data

will immediately become public. At the same time, we will continue with the recent practice of allowing Consortia to make use of some of their Guaranteed Time very early in the deployment of the instrument.

Technical Aspects

Instrument Complexity

In the fully integrated "operation flow" concept of the Paranal Observatory, operational complexity has been a limiting factor in our capacity to put a given facility on the air. In this respect, the multi-mode first generation instrumentation, with many different "internal states" (in other words, a very high instrumental entropy) to be integrated, commissioned, evaluated, documented and calibrated, has presented an enormous burden. In retrospect, we all have largely underestimated this kind of complexity and at the same time overestimated the capabilities of the Consortia and of ESO. In parallel, this operational complexity is linked to an equally large technical complexity, with many moving functions and all too often serious reliability problems that are exacerbated by the particularly demanding Paranal observation scheme, especially in service mode.

For second generation instruments, the crucial time window to avoid repeating this mistake is right now, when projects are still at the conceptual level. The fine point is to balance the scientific usefulness of adding another sub-mode or another function to a given instrument to the additional burden it would create. Such a pruning is essential to avoid revisiting the *Via Crucis*, viz. the painful phase from PAE to Commissioning in Chile that has been walked through too often in the recent past.

The VLT standards

Once (almost) a dirty 12 letter expletive, the concept of "VLT standards", which has applied across the board, and in particular to all instrument control HW/SW and detector systems, has now gained respectability as these standards have matured and are now systematically provided by ESO to the Consortia. While there were growing pains in that process, ESO is now able to deliver a number of building blocks that speed up and simplify the development efforts of the Consortia. We are considering possible extensions e.g., providing a common Real-Time Computer platform for the Adaptive Optics systems as well as providing all Observing Software (OS) top layers.

We should not be blind to the shortcomings of this approach. Standards are notoriously difficult to maintain and especially to upgrade in a fully backward compatible way, and they usually carry significant penalties in volume, weight, heat dissipation and production cost, albeit with big savings in spares and maintenance costs. On the Consortia side, there is also a clear risk of loss of competence in strategic instrumental domains for the Laboratories across Europe. However, all this pales in comparison to the sheer chaos we would be in if we were to operate and maintain dozens of incompatible systems in the Chile Observatories.

Instrument Pipelines

During the first generation phase, ESO has built a common data flow infrastructure that addresses basic end-to-end needs for data acquisition and archiving. Observatory pipelines have so far been mainly restricted to the operational needs of quick-look and quality control, which are vital to the VLT operational model. Evolution of this infrastructure has sometimes been painful for external Consortia but this should be largely avoided in the near future with the ongoing development of a Common Pipeline Library.

There is an urgent need to move now in the direction of pipelines that provide more science-ready products to the users; i.e., with the astronomical objects automatically extracted and the instrumental signature removed from the data. In that sense, the UVES pipeline is a precursor that has largely contributed to the scientific success of the instrument. We plan to move steadily in that direction. The first step will be to cover multi-slit spectrometry, with the even bigger challenge ahead of integral field spectroscopy. In this endeavour, external Consortia have much to provide in terms of algorithms, as does Paranal (and La Silla) Observatory in terms of observing procedures. These contributions will have to be integrated, under the control of the corresponding instrument scientists, and within the ESO common infrastructure, in order to maintain reliability, scalability and predictability – admittedly, at the expense of flexibility and responsiveness.

There is a much larger issue on the horizon, viz., eventually going beyond science-ready products to scientifically led, full data analysis pipelines. It is presently unclear if and how the numerous efforts in the ESO community, in particular from the various national data centres, could –or even should – be coordinated with the goal to increase our scientific productivity. This needs to be addressed in the near future.

Conclusions and Perspectives

The deluge of self-criticism above should not obscure the bright silver lining. ESO and its community, through dedicated and competent Consortia, have produced a challenging instrumentation complement in roughly one decade, at an affordable cost, with state of the art performance at the cutting edge of present technology and offering a staggering variety of observing modes. This instrumentation has been integrated end-to-end into the powerful VLT -and VLTI- Machine. In parallel, La Silla instrumentation and telescopes have been modernized and their operation increasingly brought under the VLT paradigm. Global success can be measured objectively: technically, from the low rate of downtime and the high shutter open efficiency, and scientifically, from the high publication rate and citation index of the ESO Observatories. As a result of this whole effort, and for the first time in a century, the observational capabilities of European ground-based astronomy have overtaken the other side of the Atlantic.

At first sight, our common challenge ahead with second generation instrumentation may appear somewhat less formidable than it has been for the first instrument complement. In a couple of years, the VLT/I Infrastructure should be largely complete, from the Telescopes themselves to the instrument standard HW & SW sub-systems, to data handling and analysis pipelines. This will ease the instrument builders' work, whether at ESO or in external Consortia. We certainly should not repeat the painful stories of the early VLT instruments, e.g. the two FORS for which the Consortium had to go repeatedly through vastly different versions of the Instrument Control System! This, hopefully, will also translate into somewhat easier instrument handovers to the Operation Divisions. However, the burden of the remaining infrastructure tasks – in particular VISTA and PRIMA – as well as putting the VLTI facility into full operation, should not be underestimated. We are now largely free from the panic mode in which some first generation instruments were installed in order to provide a long-needed, sorely-lacking capability (e.g. Adaptive Optics with NACO) and/or to be able to fully use a Unit Telescope (again the case of NACO for bright time periods at UT4). Finally, there is now an extensive knowledge base in Europe on how to build – and how not to build – instruments for 8-10 m class telescopes.

This does not mean, however, too much of a free lunch ahead. In this era of fully

This cartoon illustrates the race between present builders of large telescopes and their instrumentation, put in order of first light on the sky. It may also help to remind us of the point made by the red Queen to Alice: 'HERE, you see, it takes all the running YOU can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that.' (Lewis Carroll; Through the Looking Glass)

international competition, delivering facilities tuned to urgent new scientific drivers in a timely way through brand-new instruments or upgrades of existing ones, or using a "friendly" visitor focus in order to keep at the frontier of astrophysical research, remains crucial. Also, while the second generation projects so far tend to feature "almost" single mode instruments with fewer mechanisms, they nonetheless present some formidable technical challenges such as the KMOS multiple cryo-mechanisms, the MUSE 24 (!) spectrometers *cum* image slicers, and the extreme Adaptive Optics system required for the Planet Finder. Some of the suggestions above in our global approach for instrument procuring have already been transformed into policy. We will be working on more in the coming months to improve the overall process. It is clear that every attention should be given to ultimately make the second generation developments an unqualified scientific success. In that respect, the Forum has been both timely and useful.

As for ALMA, many of the lessons learned with the first generation VLT/I instruments apply. Institutions or Consortia of institutions in the community are responsible for major ALMA work packages in the areas of front-end and back-end electronics. While these are integral components of the overall facility, rather than instruments in the VLT/I sense, the relationship between ESO and the institutions is very similar, and the approach to ALMA largely derived from this instrumental experience. Two distinct differences are that ALMA will bear the full costs including labour, and that no guaranteed time will be granted to the contributing institutions. The relationship between ESO and the participating European institutions during design and development (the so-called ALMA Phase I) was essentially the full partnership model. As we move now into construction and series production to equip the 64 antennae, it is shifting to the customer–supplier model with correspondingly more formal contracts and active monitoring and management by ESO. In all these contractual aspects, the ALMA project is in fact much closer to the Gemini Observatory approach than the ESO one; it may be interesting to note that Gemini has however recently introduced a relatively small amount of guaranteed time observing to better motivate the instrument Consortia. Extensive "ALMA standards" are applied across the project, especially in software. Integration and Commissioning is an overall project responsibility with support to be provided by the sub-systems suppliers. Hence, any confusion due to shared responsibilities should be avoided.

Finally, we would like to extend warm thanks to the speakers, the panel members, and all participants from ESO and its Community. Such an event is not an easy one to tackle and could have easily degraded into a blame storming session. *Au contraire*, the maturity of all actors was impressive and reflects the increasing professionalism that is key to successfully developing ever more powerful scientific facilities.

L. GERMANY, *SciOps*

3.6M CONTROL ROOM HAS MOVED!

Finally, those who dwelt at the very top of La Silla have come to join the rest of us in the common control room of the RITZ. On June 19, the 3.6 m control room was moved into the RITZ and has been operating successfully from there ever since. Congratulations to all those involved in the move, all of the careful preparation and planning paid off with no time lost at all! 3.6 m observers can now enjoy the community atmosphere of the RITZ along with observers at the 2.2 m and NTT.

HARPS 2ND COMMISSIONING

This was scheduled for between the 5th and 21st of June but was unfortunately severely hampered by bad weather (eleven nights lost out of sixteen). Although we were not able to fully characterise the instrument due to lack of time, we were extremely happy with how the instrument performed, with *P*-modes from a pulsating star clearly observed. More tests will be conducted before the instrument is offered to the community at the start of Period 72.

NEW IR STAFF ASTRONOMER

We welcome Ivo Saviane as the new IR staff astronomer on La Silla. Ivo has been a La Silla fellow for the past two years working within the 2p2 team and assumed his new role for the observatory on July 1st.