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The Role of ESO in European Astronomy

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Abstract

The evolution of ESO is briefly traced through its technical and managerial developments to today. Highlights of ESO activities in support of astronomical research by the member state community are given to emphasise the unique role of the Organisation in European astronomy, and the effectiveness with which it has carried out its mission, including the development of VLT/VLTI. This development is shown to be of crucial significance to permit forefront research in the global context. The need for continued support of this programme to permit full scientific exploitation is discussed. A continued role of ESO to support the study and the development of future facilities is advocated.

1. Introduction

The purpose of this paper is to clarify the context in which we are discussing the scope of ESO activities over the next several years. This appears both appropriate and necessary since by its recent accomplishments ESO's role has evolved significantly.

I do not wish to discuss ESO history in detail but I would like to distinguish (for the purpose of this paper) some different stages of its development.

1.1 The early years

The early years, 1962–1980, saw the development of the organisation and of its structure with the goal of establishing an observatory in the southern hemisphere. Particularly attractive was the possibility to study a region of

The Tarantula Nebula (30 Doradus) in the Large Magellanic Cloud as seen by SOFI, ESO's new 1–2.5 μm imager/spectrometer during its first test on the NTT telescope in December 1997 (see article on p. 9). The image is a colour composite of three ~ 5-min exposures made through narrow-band filters centred on the 2.166 μm Brγ hydrogen recombination; 1.644 μm [FeII] fine structure and 2.12 μm H_2 1-0 S(1) lines which have been coded blue, green and red respectively to reflect the ionisation state of the gas. Predominantly blue regions show where hydrogen is being photo-ionised by hot, massive, stars while red traces the sites of more recent and on-going star formation. The scale is 0.26″/pix. and the field is ~ 4.5′ × 4.5′ with N at the top and E to the left.

the sky not accessible to the major observatories in the north and containing the centre of our own galaxy and the Magellanic Clouds. The observatory did not compete directly with any member state facilities. The major technical accomplishment of this period was the construction of the 3.6-metre telescope, comparable in size to any of the generally available telescopes in the north and which achieved a performance equal to that of several telescopes in the world. More important in a sense was the development of an organisation with an identical structure to that of CERN for physics, which proved capable of constructing and operating substantial facilities.

1.2 The transition phase

A second phase (1980–1990) occurred with the design and construction of the New Technology Telescope (NTT). In this phase of its life ESO developed the technical capability which led to a new approach for telescope design. The actively controlled thin meniscus mirror was the prototype for the next generations of 8-metre telescopes such as the Very Large Telescope of ESO (VLT) and the American and Japanese 8-metre projects (GEMINI and SUBARU). Upon its completion, the NTT was the 4-metre telescope with the best optical performance in the world. It was fully competitive with any of the then existing telescopes, including Cerro Tololo, Kitt Peak, Palomar, AAT, CFHT, Calar Alto and WHT. Its observing capabilities when added to those of the 3.6-metre telescope made La Silla one of the major observatories in the world.

It should be noted that this major step was made possible, in part, by the strengthening of ESO resulting from the entrance of two new member states, Italy and Switzerland, in 1982.

ESO began in this period to carry out new functions in support of European astronomy. The development of MIDAS (a command language for scientific data analysis) was the only widely adopted European development of its kind. The creation of ECF (European Co-ordinating Facility) for the Hubble Space Telescope also gave ESO an additional responsibility for European astronomy. The major accomplishment of this period was, in addition to the completion of the NTT, the beginning of the VLT/VLTI project.

1.3 The current phase

A third phase is the current one (1990–2000). With the successful completion of VLT/VLTI, ESO's stature in the world scene changes from that of being one of the several European observing facilities of more or less comparable capabilities to (one of) the premier observatory(ies) in the world. **It is not just a Southern supplement to observatories by the member states in the north, but by far the most powerful observational capability available to European astronomers and the only one which permits them to compete in the world scene on a basis of parity in ground-based optical/IR astronomy.**

During this same period, ESO has undergone a major qualitative transformation. Its management structure, methodology and capabilities have greatly developed. Its engineering and contracting capabilities have been greatly strengthened. It has become an important focus of instrumentation and detector development for Europe. It has provided the European astronomical community with an institution capable of studying and elaborating future large-scale projects and to insure the participation of European astronomers in world-wide projects on a basis of parity with the USA and/or other countries.

1.4 The new role of ESO

The emergence of ESO as a European organisation capable to carry out in astronomy the role of leadership carried out by CERN in physics or by ESA in space science is a new development which is already widely recognised in the world.

VLT/VLTI is the only real competitor to Keck 1 + 2 (the twin ten metre telescopes in Hawaii).

The question which is implicit in many of the discussions about the future of ESO is whether this leading role in European astronomy should be continued in the future or whether the VLT/VLTI development should be considered a one-shot affair.

The Visiting Committee of ESO and its Science and Technology Committee have clearly taken the view that ESO should think about new missions well into the 2010–2020 time frame and have reaffirmed the ESO mission within the overall astronomical research programme of the member states. The mission of ESO is to "Provide facilities which will enable European astronomers to carry out outstanding science that can better be done in a global European context than nationally" (Report of the Visiting Committee and the Response of the Director General ESO/Cou-532 Conf.).

This view has been endorsed by Council and is in accordance with the Convention which assigns to ESO "projects that can only be accomplished through international co-operation".

In the last few years the VLT and VLTI projects and the development of the Paranal Observatory have been the clearest examples of what ESO as a unified force in European astronomy can do. These programmes are recognised to be beyond the capabilities of the individual national programmes in the member states.

It is clear that the need for large-ground based facilities in astronomy will continue to be present in the foreseeable future. Examples are the Large Millimetre Wave Array (LSA) and the new generation of Extremely Large Telescopes (single dishes $>$ 50 m diameter or extended arrays with comparable or larger collecting areas). Access to such facilities in the future will be essential to maintain competitiveness of European astronomy in the global context and thus we foresee a continued role for ESO in providing this.

The issue therefore is not whether there is a need for ESO in the future but rather what is the proper balance in the community of member states between programmes carried out at the national level and programmes which require international co-operation. Of course each nation will make its own decisions in this matter.

From a scientific point of view this balance should be based on a **strategic scientific plan for European Astronomy** which unfortunately does not yet exist. Rather than adopting either consciously or by default the planning for astronomy carried out periodically in the United States by the National Academy of Sciences, the scientific committees of ESO (VC, STC, OPC and UC) in co-operation with the Executive have developed mid-term and long-range plans which take into account scientific developments world-wide and establish priorities for the Organisation.

I would like in this essay to underline the importance of ESO's major current projects for European astronomy and the unique role played by ESO in this context. Further I would like to highlight less obvious but equally important contributions which ESO has given and should continue to give to the development of astronomy in Europe. Finally, I would like to make clear the high effectiveness with which ESO is carrying out its tasks and the importance of its European character as an intergovernmental organisation in accomplishing them.

2. Highlights of ESO's Current Activities

2.1 VLT/VLTI

Although most European astronomers realise the great importance of the VLT/VLTI development to permit the study of the most interesting astrophysical problems of today on a competitive international basis, the true significance of the advent of the Paranal Observatory is often not fully appreciated.

The flourishing of astronomy in the last century has been mainly due to the development of physics which has enabled us to understand the physical processes occurring in the universe and of observational capabilities capable of studying fainter sources and finer details of their spectra. To a considerable extent only those astronomers who had access to the largest telescopes could carry out frontier science. Since the 19th century, the United States has had this advantage, with the Mt. Wilson and then the Mt. Palomar telescopes dominating cosmological research in the first part of the 20th century, and the 10-metre Keck telescope and the Hubble Space Telescope in the last decade.

The situation has remained largely the same until now. In the document "A strategy for ground-based optical and infrared astronomy" of the Commission on Physical Sciences, Mathematics and Applications of the NAS of the USA published in 1997, a Table is prominently shown which summarises the telescope areas available to US astronomers (Table 1). Upon completion of current plans (including GEMINI, LBT, Magellan, Keck 2 and the MMT upgrade) there will be available to US astronomers 110.3 m^2 in public observatories and 400.7 m^2 in private observatories. (The computation excludes telescopes of less than 2 metre aperture

TABLE 1.

	Public Observatories			**Independent Observatories**		
	Telescope	Aperture (m)	Area (m^2)	Telescope	Aperture (m)	Area (m^2)
	KPNO	4.0	12.6	Keck 1	10.0	78.5
	CTIO	4.0	12.6	Palomar	5.0	19.6
	0,4 × WIYN	3.5	9.6	MMT	4.5	15.9
	KPNO	2.1	3.5	ARC	3.5	9.6
	0,9 × IRTF	3.0	7.1	0,6 × WIYN	9.6	3.5
				Lick	3.0	7.1
				Texas	2.7	5.7
				Dupont	2.5	4.9
CURRENT				MDM	2.5	4.9
				WIRO	2.4	4.5
				Steward	2.3	4.2
				Hawaii	2.2	3.8
				Texas	2.1	3.5
	SUBTOTAL*	14.2	38.9		44.8	167.8
		24%	19%		76%	81%
	0.45 × Gemini N	0.45 × 8	50.3	0.9 × Keck2	10.0	78.5
	0.45 × Gemini S	0.45 × 8	50.3	0.5 × LBT	2 × 8.5	113.4
	1/3 × Keck 1	1/3 × 10	78.5	0.5 × HET	~ 8	35.2
				Magellan I	6.5	33.2
				Magellan II	6.5	33.2
PLANNED				MMT Upgrade	6.5	33.2
				SDSS	2.5	4.9
	SUBTOTAL*	10.5	71.4		42.8	248.7
		20%	22%		80%	78%
	TOTAL*	24.7	110.3		83.0	400.7
		23%	22%		77%	78%

*The actual telescope apertures or areas are listed, but these values are multiplied by the fractions of time allocated to US astronomers to calculate the subtotals and totals. The sums in the independent observatories column do not include the University of Hawaii shares of international telescopes on Mauna Kea, such as Gemini North, the CFHT, the United Kingdom Infrared Telescope, and the Subaru Telescope. The MMT upgrade replaces the MMT, whose contribution has been subtracted from the total.

Quoted from: http://www.nap.edu/readingroom/books/gboi/chap2.html

TABLE 2.

Nation	Telescope	Diameter	Area m²
Belgium	—	—	—
Denmark	NOT (30%)	2.5	1.47
France	OHP	2	3.14
	OPM	2	3.14
	CFH (42%)	3.6	4.28
Germany	Calar Alto	3.5	9.6
	Calar Alto	2.2	3.8
	La Silla (50%)	2.2	1.9
	HET (10%)	9	6.36
	LBT (12.5%)	11.3	12.3
Italy	Galileo	3.5	9.6
	LBT (25%)	11.3	24.6
Netherlands	WHT (10%)	4.2	1.5
Sweden	NOT (30%)	2.5	1.47
Switzerland	—	—	—
TOTAL			83.2 m²
ESO	La Silla 3.6	3.6	10.2
	NTT	3.6	10.2
	2.2 (50%)	2.2	1.9
	VLT	4x8	201
TOTAL			223.3 m²

and takes into account appropriate fractions given to international partners.)

If we carry out the same computation for the ESO member states and ESO (Table 2) we find that, without the VLT, the combined area available (including all fractional participations in non-member states programmes) only reaches 105.5 m^2. The VLT adds 201 m^2 of observing area to European astronomy.

Therefore approximately 3/4 of all telescope area available to European astronomers will be provided through ESO.

It is only through the construction of the VLT that Europe will (for the first time in this century) become competitive with the USA in optical ground-based astronomy. No single European nation can by itself compete with even single US astronomical institutions such as Caltech, Carnegie, CFA, Texas and Arizona. The concerted effort of European astronomy through ESO is therefore much more important to European astronomy than public facilities are to US astronomy.

VLT/VLTI, when completed, will not only be fully competitive but may in fact become the most advanced observing tool in ground-based astronomy in the world. It is a matter of some pride that it has already become the mark against which all other facilities are measured. This is particularly true for the VLTI capabilities which should be superior to any other currently planned.

2.2 Development of optics and materials

The construction of the VLT/VLTI could not have been undertaken in the 90's without the technical and engineering developments which ESO carried out in Garching in the 80's. Of crucial importance was the design, development and implementation of the New Technology Telescope. This superb 4-meter telescope which has been in full operation since 1990 embodied for the first time the mirror design concept of a single thin meniscus whose configuration is actively controlled by computer-driven actuators. It is this technique which is the foundation of the VLT design.

To emphasise the importance of this technological advance we should remember that, until active optics was introduced, the rule of thumb for a rigid optical telescope of sufficient accuracy was that the thickness of the mirror blank should be approximately 1/6 of the diameter. This would have required 133 cm of thickness for an 8-metre mirror. In contrast, the thin meniscus approach permits us to use 17 cm thickness. The current VLT primary mirror weight of 20 tons would have become 160 tons in the classical design. It should be noted that this particular approach has been adopted by the US Gemini as well as by the Japanese Subaru 8-metre projects. While alternative new technology approaches such as adopted by Keck and LBT do exist, Europe is now considered a leader in this field.

This entire development included optics design studies at ESO Headquarters, research in alternate mirror materials and technology with the European industry and pilot programmes to test basic technological approaches spread over many years. The development of large Zerodur blanks at Schott, the construction of a new mirror polishing laboratory at REOSC, the development of new mirror coating systems at Linde, of high-precision encoders at Heidenheim, the design and development at GIAT of a new type of mirror support structure, the construction at Dornier of the M-2 mirror cell and of the 480-ton structure at Ansaldo have not only provided the tools needed for VLT but have also given European industries a competitive edge in international procurements. It is clear that no single institution in the member states could have produced these results. ESO must continue to provide the European astronomical community with this kind of technological resources for future programmes.

2.3 System engineering and modelling

The design, operation and optimum scientific exploitation of complex optical systems such as those used in VLT/VLTI require a highly sophisticated degree of computer modelling. Among the major telescope facilities in the world, VLT is unique in having a fully developed end-to-end computer model. The model takes into account all mechanical and optical properties of the telescope and its control system to predict the distortions produced by a number of effects starting from design characteristics to variable environmental stimuli including wind, temperature, humidity, seismic and microseismic disturbances, etc. Furthermore, by modelling the physical characteristic of the detectors and using its calibrations, we can predict the expected output from a given input flux and spectrum of radiation.

These models have proven invaluable in permitting effective trade-offs between required scientific performance of VLT and engineering and contractual specifications. Beyond these practical benefits, however, even more important has been the use of modelling tools to assess the requirements placed on individual elements of the array by the exquisite precision needed for interferometry. During operations, the models are essential to respond to variable seeing conditions with appropriate tactics for telescope use. The complex nature of active and adaptive servo control loops would make it difficult to design and operate them without appropriate simulation through the model. This overall capability has already been used by the ESO engineering groups in the Large Southern Array programme study.

2.4 Development of instrumentation and detectors

The development of instrumentation for the VLT/VLTI has been carried out in Garching in close collaboration with institutions of member states. 9 out of 11 instruments in the first-generation VLT complement are primarily built in member states with a number of major components, especially detector systems, built at ESO (Table 3). In addition, ESO has carried out a monitoring function, instituted planned management reviews (CDR, PDR and FDR) established hardware/software standards when appropriate, suggested remedial technical action when required and insured that the scientific purposes for which the instrument was built could be achieved with the hardware planned for delivery. A formal acceptance phase, commissioning phase and science verification are planned for all instruments.

Is this rigor required and is the instrument construction being done effectively? Of course, the proof will occur after commissioning of the VLT, however, a recent study of the Scientific-Technical Committee of ESO (Instrumentation Study of the Scientific-Technical Committee ESO/STC-223, 14.11.1997) pointed out the risks of an unstructured approach as followed by Keck where only some out of five instruments built in the first generation were actually useful at the telescope. This committee also found that the prices of the first VLT instruments were normally in line with those in the US. Substantial cost reductions in the near future will be obtained from commonality of designs and parts. The success of a new infrared imager and spectrometer (SOFI) built very quickly and inexpensively utilising ISAAC designs gives us confidence that we are on the right track.

2.4.1 Detectors

ESO's contribution is particularly important in the detector area, which is usually the single most critical item for the competitiveness of any astronomical instrument.

Europe had traditionally lagged behind the US in the development of visible light and infrared solid-state detectors and of their associated low-noise fast controllers. In the last few years, through association with US institutions, as well as with independent procurement, we are now receiving detectors which are equal to the best in the world. We have completed two inhouse controllers, the FIERA system for visible CCDs, IRACE for infrared arrays, which are at the forefront of performances in terms of low noise and high speed. In response to perceived need and to the recommendation of the technical committees, the ESO management created a new detector group with a critical mass of dedicated engineers and scientists to carry out this task. We believe that this has been the key to success.

As a result of successful laboratory and field tests of these new detector systems, ESO has taken responsibility for all detector systems on VLT(except on VISIR) and all the La Silla instruments.

At the moment 17 FIERA systems are being constructed for delivery to the instrument teams. The quality of the devices is such as to have raised the interest of the environmental sciences and defence communities in France (Onera) and Germany (Zeiss).

2.4.2 Operation of the instruments and calibration

A great deal of attention has been given to the maintainability and operability of the instrumentation associated with VLT/VLTI especially with systematic hardware and software standardisation. It should be remembered that our plan for operation on Paranal foresees a number of people comparable to those employed on La Silla. This goal would make Paranal perhaps the most effective facility in ground-based astronomy in the world. On the other hand, this requires strict planning, assembly and integration of instruments, the development of commissioning and verification plans, a plan for instrument maintenance and calibration which maximises scientific return within hard budgetary constraints. These stringent requirements have been made part of the deliverable items by individual institutions. Here ESO carries out a unique function in ensuring across the board uniformity to enable reliable high-level operation of the instruments.

2.5 Operations and data flow

The purpose of constructing the VLT/VLTI is to achieve scientific results which will be at the forefront of astronomical research in the world. To this end, particular attention has been given to the possibilities of new forms of observing such as service observing, variable queue and remote observing. All of these modes are intended to maximise the opportunity for the observer to carry out his/her observations under the optimum conditions. Extensive use of the modelling tools, mentioned above, is made to predict performance and modify telescope parameters to optimise its output, finally to ensure that the most suitable programmes for these conditions are carried out. This implies a great deal of attention to how the initial proposals are written, how they are further detailed after OPC approval, their division in observing blocks (the standard high level command unit to the VLT system) and the transfer of this information to the operators. Quick look data monitor capabilities are also provided.

The use of calibration data for the first cut reduction of the observed data permits the translation of signals in physical quantities which are then made available to the observers and stored in a long-term research archive. The development of this Data Flow System and of the VLT Archive will be one of the outstanding achievements of ESO and provide the European astronomer with the basis for further scientific elaboration of the data in a prompt and effective manner. I cannot more strongly emphasise the importance of this unique ESO contribution to ground-based astronomy in Europe.

2.6 The La Silla Observatory

La Silla was developed in the 70's and 80's to the point that it had become one of the important observatories in the world. It had a full complement of 15 telescopes (including two 4-metres) and it was thus fully competitive with Cerro Tololo, KPNO, Hawaii, etc. La Silla has provided for many European as-

TABLE 3.

In order to reduce as much as feasible the load on the in-house instrumentation staff and to profit from the available technical competence in the European astronomical community at large, ESO has adopted the policy of relying as much as possible on external national institutes in the member states for the construction of instruments.

At the moment only two instruments ISAAC (4.8 MDM 1996) and UVES (7.1 MDM 1996) are fully developed by ESO. Under the UVES programme there is a small contract (Only reimbursement of travel expenses) to the Osservatorio di Trieste for software developments. The other instruments currently under development are listed below with the responsible institutes and the ESO contract amounts. The leading Institute is underlined. It should be noted that in almost all cases ESO is providing the detector system, as well as a number of major subunits, e.g. motor controls, Real Time Display, etc.

FORS 1 and FORS 2
Institutes: Heidelberg Observatory, München Observatory, Karlsberg University (FRG)
Contract Value: 4.78 MDM (1997)

CONICA
Institutes: MPI-A Heidelberg, MPI-E Garching (FRG)
Contract Value: 2.57 MDM (1997)

NAOS
Institutes: ONERA, Meudon Observatory, Grenoble Observatory (France)
Contract Value: 7.61 MDM (1997)

VISIR
Institutes: CEA Saclay (France), ASTRON (The Netherlands)
Contract Value: 5.32 MDM (1997)

VIRMOS
Institutes: LAS Marseilles, OHP St Michel, OMP Toulouse (France), IRA Bologna, Observatories of Bologna, Milano and Napoli (Italy)
Contract Value: 10.22 MDM (1997)

FUEGOS
Institutes: Meudon Observatory, OMP Toulouse (France), Geneva Observatory (Switzerland), A.A.O. Sydney (Australia)
Contract Value: 4.4 MDM (1997)

Two new instruments, CRIRES and SINFONI, have been recently recommended by the STC, to fully equip the VLT with its first generation of instruments. We are currently exploring possible collaborations with the ESO member states in order to decrease the costs involved.

tronomers the major observational capability they could use.

Nearly 600 programmes of research on a vast range of scientific topics are carried out every year. The residence of astronomers from all member states at the observatory gives unique opportunity for fruitful interactions. Many young scientists have received their initial training in observing and data reduction through their involvement in the support functions. A vigorous Fellowship Programme (20–24 Fellows/year, ESO wide) has made this possible. La Silla also became the site of a number of national telescopes either fully funded and used by national groups or in a shared mode with ESO. Joint projects with Danish, French, German, Swiss and Swedish institutions are embodied in a variety of telescopes currently in use.

La Silla hosts a number of national experiments, such as CORALIE to search for exosolar-planets, EROS for the microlensing, DENIS for the IR survey of the southern sky. Also, individual institutes are providing additional money for specific projects (example: the 8k camera at the 2.2, SUSI2, etc.). La Silla was the site where Come-on-Plus and Adonis (the first adaptive-optics instruments) were offered to the community.

La Silla played a vital role during the development of the VLT as a site for early testing of technology and methodology. The VLT control software was implemented and tested on the NTT prior to its use on Paranal. The control consoles, operator stations, data-flow systems, etc., were also prototyped on the NTT. The SOFI infrared imager spectrometer for the NTT is a derivative of ISAAC for the VLT reduced in size as appropriate. It has already been commissioned with truly outstanding results on the NTT at the end of 1997. This will greatly facilitate the integration of ISAAC (planned for mid-1998) on the VLT. Finally, operational concepts such as service observing and calibration methodology were tested on the NTT.

The role of all smaller telescopes in the world after the arrival on the scene of the new generation of 8–10 metres has had to be reassessed. The ESO Scientific-Technical committee carried out a study which established priorities and was translated into an operation plan by the ESO Management (Scientific Priorities for La Silla in the VLT Era, ESO/STC-174 rev. 20.11.1995).

The resulting plan, approved by Council, detailed first the scientific priorities for medium-class telescopes operated along side an 8-m-class facility. Then a number of instrument upgrades were defined which were considered essential to support VLT programmes. These upgrades have been carried out with substantial long-term investment by ESO and several member states. Third, facilities and services that would not remain essential and competitive were identified for near- or medium-term closure. Finally, it was pointed out that space for medium-class facilities on or near Paranal is limited and expensive to develop. Furthermore the cost benefit of operating a given telescope on Paranal rather than on La Silla is doubtful at best.

By the year 2003, it is foreseen that only the two 4-metre-class telescopes would be offered to the astronomical community of the member states instead of the 15 utilised in 1993. It is clear that the 3.6-metre telescope and the NTT will continue to be important in conjunction with the VLT. Some programmes can be more effectively carried out with these telescopes, whose cost of operation is 1/10 of that of the VLT.

For some programmes the 4-metre telescopes may also be more suited. For example, a strategically important programme such as the search for extrasolar planets with high-precision (1m/sec) measurements of stellar radial velocities can best be done by the use of a dedicated 4-m-class telescope with the appropriate spectrometer. Similarly, wide-field surveys required to find targets for the VLT are most efficiently done at smaller telescopes with a wider field of view. Operational costs of such dedicated facilities will be appreciably lower than the multipurpose use of the same telescope.

We are currently reassessing the science role and operating plan for La Silla in light of the experience gained in the last few years and a new report will be presented to STC and Council. We foresee the possibility of further optimisation resulting in additional savings.

At reduced cost La Silla can continue to play a vital role in the ESO activities. Primarily its functions should be as follows:

(a) Continued use of upgraded, properly instrumented NTT and 3.6-m telescopes.

(b) Continued use during a transition period of the 2.2-m and 1.5-m telescopes and SEST.

(c) Infrastructure support for National Telescopes on a cost-reimbursement basis.

(d) A site for experimentation and tests of new instrumentation and technologies.

2.7 ESO-ESA collaboration

ESO Garching is the site of the HST European Co-ordinating Facility and its operation is jointly sponsored by ESO and ESA to support the Hubble Space Telescope Project and in particular to facilitate access by European astronomers to its data. ECF staff consists of a mixed team of ESO and ESA personnel. ECF is the only site in Europe where a full copy of the Hubble archive exists and is offered to the community with a unique set of tools for the recalibration and interpretation of its data.

The ECF staff was deeply involved in the design and execution of the Hubble data archive in collaboration with STScI and CADC. It also played major roles in the development of instrument calibration methodology. ECF has been recognised as one of the leaders in the techniques of image reconstruction and deconvolution, which were particularly important during the initial period of HST operation, when the telescope was affected by spherical aberration.

The expertise of ECF will continue to be used during the execution and later operations of the Next Generation Space Telescope (NGST). The expertise of ECF has been applied in the design of the VLT archive and in many other aspects of the data-flow system development. ECF plays a particular role in providing a synergism between ground-based and space-based astronomy programmes and between ESO and ESA, an activity clearly outside the scope of national institutions.

2.8 The role of ESO in international collaborations

ESO, as the largest single European Observatory, has acquired a stature which is recognised world-wide. Non member states are interested in entering in collaborative agreements with ESO or even to become members. Through these activities new concepts and technologies can be introduced into ESO for the benefit of European astronomers at a minimum cost.

Even more important for the future, however, may be the role of ESO in representing European interests in negotiations with the US or Japan. Just like ESA represents the European Community interests in its negotiations with NASA, ESO plays a similar role in negotiations with non member states consortia or institutions. Examples of such interactions which have already occurred are with NRAO, NOAO, STScI, and NASA in the US and with the Australian Research Council.

ESO provides a focus for discussions and agreements among European scientists about the proposed European roles in international ventures. It provides also the managerial and engineering support to support technical interactions with potential partners. It permits Europe to deal with the US institutions on a basis of parity rather than as perpetual minority partners. This is particularly important to allow European interests and points of view to influence in a positive manner the early conceptual phases of the programmes. It is clear that in the future the even larger facilities that will be needed in astronomy will require transcontinental scientific collaborations and ESO can play a unique role in these developments.

3. Future Programmes and the Balance between National and International Activities in Member States

From the above it should be clear that ESO should not be considered as simply an institution to construct VLT/VLTI and operate La Silla and Paranal on a one-shot basis but as an institution which will provide an important, continued contribution to European astronomy in providing technology and ground-based facilities beyond the reach of national groups.

Given the continued need for these facilities, the need for a continued role by ESO seems clear. The issue is then what would be an appropriate balance between national programmes and programmes done through ESO.

In order to successfully accomplish its task, **ESO's activities must reach the critical mass required to carry out those programmes which are beyond the capability of single nations but that are essential to maintain a competitive research level in the international context.** Among such programmes one can clearly include NTT, VLT/VLTI, a large millimetre/submillimetre array (beyond 2005) and any future large-scale optical telescopes (beyond 2015). One could also include many of the activities listed in the Highlights. Without these programmes European astronomy could not achieve the level of excellence required to place it in the forefront of research. The execution of these programmes would require an ESO budget which remains at least constant in purchasing power over the next decade, preferably with a few percent increase. This view is hard to reconcile with the current decline in funding for basic research in Europe but I hope that this crisis is temporary and will disappear as economic conditions improve.

What now of the balance between national and international enterprises? The level of this balance at this moment is very difficult to assess and it is certainly a prerogative of each member state. For some of the ESO member states the issue may be between the construction of major national facilities and the scientific utilisation of ESO facilities. For the majority of the ESO member states the issue is moot because they have chosen to make their investment in large facilities through ESO rather than nationally.

It would still be useful to compare expenditures from the point of view of scientific priorities. Unfortunately there are no complete figures to describe the national efforts in astronomy which can be directly used. Often the comparison is made between the expenditures for ESO and those for the discretionary part of the astronomy budgets in the nations. This of course ignores in the national programmes the cost of the institutional infrastructure and of the personnel salaries which constitute typically 80% to 90% of the expenditures in these disciplines. The ESO budget includes all expenditures. Also part of the ESO funds are returned for direct support of research and instrument development to the member states.

The only reasonable comparisons in absence of this financial material is for us to consider if ESO funding is too high for the tasks it is required to do in comparison with other known projects, in other words whether ESO is effective. We have compared the costs of development of VLT/VLTI with those of GEMINI, Keck and Subaru. Our costs are very close to American costs and a factor 3 below Japanese costs. Similarly with regard to operations we have compared our costs of operating our observatories and we find that they are quite competitive for a given level of performance. These findings have been reported to Council in the ESO document “Operation Plan/A Blueprint for ESO/CHILE in the 21st Century” (ESO/COU-534, 23.11.1994). We have already mentioned the instrument cost comparison which has been recently carried out by STC and has shown that ESO and the member states institutes are producing excellent quality instruments at reasonable costs. Thus ESO is fulfilling its role with a high level of competence and effectiveness. A detailed report was presented to Council in 1996 in the document “Management Approach, Policies and Cost Controls at ESO”, (ESO/COU-601 conf., July 12, 1996).

I would like to conclude this section by mentioning the role of science at ESO. ESO has provided the forum for the early studies and scientific debates by the community which have led to NTT, VLT, VLTI and may lead to the LSA. Both during these studies and in the conception, design, development and operation of the facilities, ESO has relied on its in-house scientific staff to draw upon the best expertise available in the community in order to define and direct its programmes. **The community of member states counts approximately 2000 astronomers; of these only 40 occupy positions at ESO** which are defined as requiring active research astronomers to fulfil ESO’s tasks. This represents only 2% of the European Astronomical Community dedicated to the service of the major facilities required by all of the community to succeed. It is clear that **ESO does not compete but complements national programmes** and will continue to do so in the future.

In order to accomplish its mission, however, ESO requires a strategic plan which is not subject to continued erosion. We carried out a full audit of ESO operations in 1993. We prepared a **long-range plan 1996 to 2003 in 1995** (ESO/COU-582 to 588, May 1996). This plan has been discussed extensively at STC, FC and Council and provides the technical basis of our activities. This plan has been reduced in cost three times in the last two years with overall cost decreases of more than 5% without any changes in scope. **We will still be able to complete VLT and VLTI within schedule and specifications**. **However we are now in great danger of diminishing the resources which are required both to fully utilise these wonderful new facilities and properly provide for the future.**

Over the next few years several 8–10-metre-class telescopes will enter in operation. The competition among them for new discoveries will be fierce. There is widespread perception that with this generation of big telescopes the basic tools are now in hand to map in great detail the formation and evolution of galaxies, clusters and large scale structures all the way to $z = 5$, i.e. back to when the universe was more than ten times younger than now. Several of the main open questions of observational cosmology may be closed within a few years. Leading ahead or lagging behind others in this effort, especially the US, will depend for Europe essentially on the quality and diversity of the VLT instrumentation, on the efficiency of its operations and data flow, and especially on their timely deployment. In all this ESO is now striving for the best, and we are confident we can actually lead. **A cut in the budget at this point in the project would impact inevitably the instrument plan and/or the operation efficiency, with the result of losing the margin of advantage over the competitors that we are trying to secure for the community, that will make the difference between being first in doing fundamental discoveries, or just confirm the results of others.**

Europe has made the capital investment to reach parity with the other major astronomical enterprises of the world. It would be a blow to European science if this effort was jeopardised now when success seems within reach.

4. Conclusions and Recommendations

Only through collaboration between nations can Europe hold its own in the arena of international scientific facilities.

ESO’s programmes are a necessary complement to national programmes and do not compete with them. National programmes benefit from access to ESO facilities, from opportunities for development of advanced technology in collaboration with ESO and from use of ESO infrastructure.

The successful completion of VLT/VLTI is providing European scientists with the only facility in ground-based optical and IR astronomy fully competitive on a world scale.

VLT/VLTI will provide most (75% in area alone) of all observational facilities available to member states in this field.

The continued support of a vigorous programme of instrumentation development, operation and data utilisation of the VLT/VLTI will be essential to achieve scientific success.

Continued operation of La Silla with a restricted number of high-quality telescopes will provide a low-cost but essential complement to the VLT/VLTI.

The on-going process of assessment of the role of La Silla should continue. This will include the utilisation of the infrastructure for national projects and the hand over of facilities to partners (in and out of ESO member states).

ESO has an important role to play in future large programmes starting from the leadership and co-ordination of early studies by the community to programme execution. ESO is uniquely qualified to carry out these programmes because of its technical and management experience and expertise and because of its effectiveness and cost competitiveness.

ESO-Garching should continue to study the conceptual definition, feasibility and implementation of the Large Millimetre Array (LSA). One of the aims of this study is to participate in discussions with the US and Japan to determine a possible basis for co-operation. New forms of co-operation with institutes in member states and non member states will also be considered.

ESO Headquarters should begin the study of scientific drivers and technology assessment for future ground-based optical telescopes of extremely large aperture which may come in existence in 2010 and beyond.

ESO can carry out its tasks within a budget constant in purchasing power or with small increases over the next decade. It is important, however, that a degree of stability should be achieved. The continued cuts over the last few years have gone as far as one can go without seriously jeopardising scientific success.

First Light at the VLT UT1 is now rapidly approaching. For the latest news about the various activities that will accompany this important event, please consult: http://www.eso.org/outreach/info-events/ut1fl/