simulation mode, the generation of automatic observing sequences, maintenance checks and status display. MIDAS will also be available on-line for image display and quick-look analysis.

Development Status

Detailed design work started after the Preliminary Design Review in April 1992 and is scheduled to be completed with the Critical Design Review in summer 1993. ISAAC is a technically complex instrument. Exploiting large array detectors on a large telescope requires a large instrument which has also to be operated at cryogenic temperatures but still meets the stringent flexure requirements imposed by its rotation on the Nasmyth adapter. Because of this rotation not only control and signal cables but also the high pressure helium lines for the closed-cycle coolers and fluid lines for the electronic cooling circuit have to be routed via a cable wind system which allows for the rotation and minimizes torque on the adapter. The high background modes of ISAAC also place difficult demands on the speed of the data-acquisition system. In order to meet these various requirements, the preliminary design of ISAAC incorporates a variety of technologies for which little practical experience is available and for which sound design and analysis alone is not considered sufficient. These include the use of diamond-turned metal mirrors, stepper motors, position sensors and large-diameter bearings at cryogenic temperatures and under vacuum. In order to minimize risk therefore, we are currently prototyping the most critical functions for test in a specially designed cryogenic test facility before finalizing the design and starting the manufacture which will be largely contracted to industry.

Project and Science Teams

The ISAAC Project Team within ESO is:
A. Moorwood, Instrument Responsible/Scientist
P. Ballester, MIDAS reduction software
P. Biereichel, Control and data acquisition software
J. Brynnel, Control electronics
B. Delabre, Optical design
G. Finger, Detectors and system performance
G. Huster, Mechanical design
J.-L. Lizon, Cryogenics, integration, tests.
M. Meyer, Detector electronics
A. van Dijsseldonk, Instrument Manager and procurements

Members of the ISAAC external Instrumental Science Team which reports to the VLT Programme Scientist are G. Miley (Leiden, Chairman), R. Chini (Bonn), E. Oliva (Florence) and J.-L. Puget (Paris).

UVES, the UV-Visual Echelle Spectrograph for the VLT

H. DEKKER and S. D'ODORICO, ESO

Overview

UVES is one of the two instruments in the VLT Instrumentation Plan being designed and built by ESO. It is a crossdispersed echelle spectrograph with a nominal resolution of 40,000 with a 1 arcsec slit. This double-beam instrument uses 22×85 cm mosaic echelle gratings, grating crossdispersers and thinned CCD detectors with 2048^2 pixels each, one for each arm. It will be mounted at the Nasmyth platform on a horizontal optical table inside a protective enclosure (Fig. 1). We are now in the preliminary design phase following the approval of the Design and Implementation Plan by the Scientific Technical Committee and Council in their May/June 1992 round of meetings. The Preliminary Design Review is planned for 20/21 April 1993. UVES will be built in two copies; the instrument schedule foresees the installation of UVES1 at the Nasmyth focus of Unit Telescope 2 in the second half of 1997, of UVES2 at UT3 about 12 months later.

Observing Capabilities

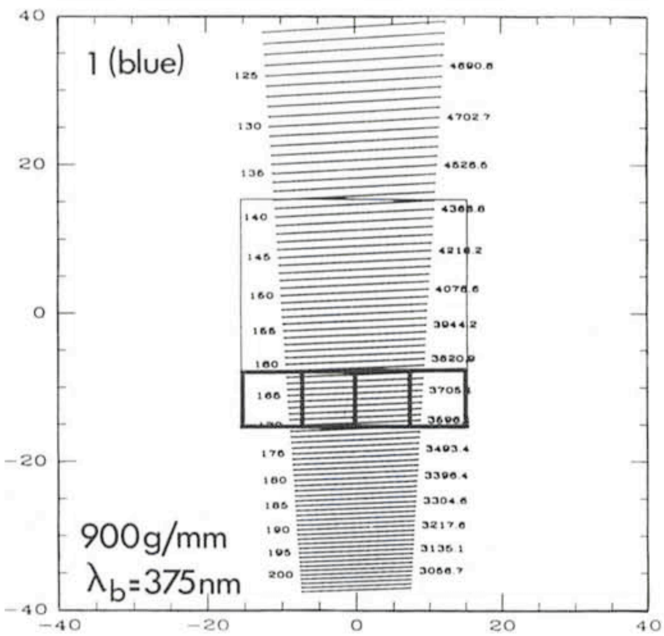
Echelle spectrographs are instruments of highest priority in all of the large telescope projects because high resolution spectroscopy is one of the observing modes which benefits most from the larger collecting area. The stellar flux is dispersed over a large number of detector elements and for objects of faint magnitudes the shot noise of the signal is comparable to the detector read-out and dark current noise. In this regime, the S/N ratio increases with the second power of the telescope diameter, and the gain in using the VLT becomes very significant. In the observations of brighter objects where the photon statistics is dominating other sources of noise, the large aperture of the telescope is still needed to achieve in reasonable exposure times very high S/N ratios and to follow spectral variations on short time scales. It is also

Figure 1: *3-D view of UVES with most of the enclosure panels removed for clarity.*

essential to include in the design provisions for accurate wavelength and intensity calibration and to minimize the amount of scattered light in the spectrograph.

The report of the VLT Group on High Resolution Spectroscopy (VLT Report No. 50, 1986) includes a review of the scientific programmes which require observations with spectral resolutions in the range 10^4–10^6. They concerned basic studies of the physical conditions and chemical composition of matter in stellar or gaseous bodies. The data to be obtained are relevant to any modelling of the past history and the future evolution both of our galactic environment and of the universe as a whole. The goals of this observing mode remain essentially unchanged today. In a first approximation two types of programmes and corresponding requirements on the instrument can be identified. First, those which call for observations of the faintest objects over a wide spectral range with low to medium S/N ratios and at resolution in the range 10^4-10^5. Examples of this category are the studies of abundances in galactic and extragalactic stars and of the primordial gas in the universe through QSO absorption lines. They require an instrument of high efficiency to take full advantage of the larger telescope size with a wide spectral coverage to observe lines spread over a large spectral interval. At the magnitudes that one is likely to observe, the possibility of accurate sky subtraction also becomes essential. A second category of programmes calls for spectral resolution higher than 10^5, in more restricted wavelength regions, and generally, but not always, with very high S/N ratios. Examples are the studies of the physical conditions in the interstellar clouds through the observations of the equivalent widths and the profiles of lines of atoms like Na and Ca and molecules as CN and CH, of the abundance of Lithium isotopes in the interstellar medium and studies of stellar oscillations from the observed variations in the profiles of lines originating in the stellar atmospheres.

In UVES which offers a nominal resolution of 4×10^4 for a 1 arcsec slit in a crossdispersed format, the first category is well covered by the instrument equipped with the standard camera/detector combinations. However, the concept permits to also attain the higher resolutions required by the second category by using a long camera combined with image slicers. In this case the separation of the orders is not required for sky subtraction, but to accommodate the long exit slit of the image slicer. In order to have stable, well characterized instruments, the most attractive option seems to be to replace the blue camera on UVES2 by a high-resolution camera. The tradeoff is still being analysed and will be decided upon in 1993. Factors affecting the decision are on the one hand a detailed investigation of the optimum spectrum extraction methods and the final S/N ratio that can be achieved in this mode (which will be



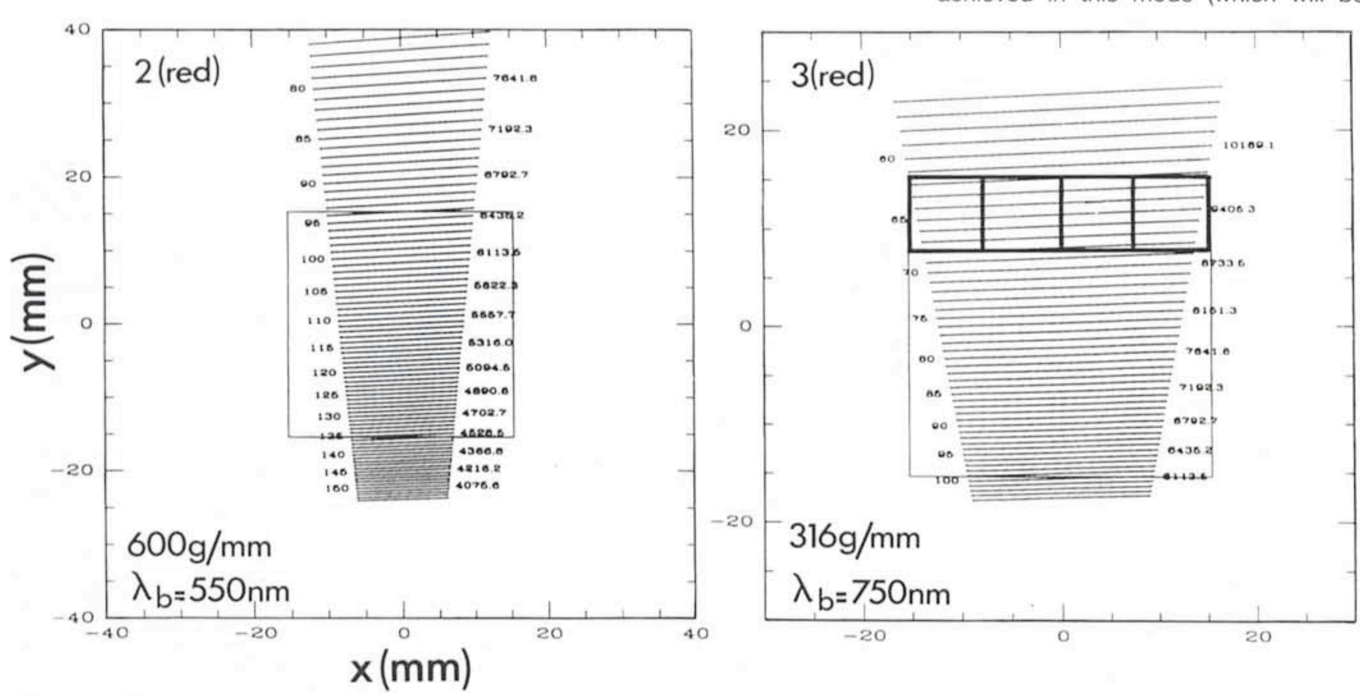


Figure 2: *Spectral formats with the crossdisperser gratings. These are mounted on turntables so the central wavelength can be set by the user. The thin-line square the field of the CCD detector with the F/2 (blue) and F/1.25 (red) cameras respectively. The heavy-line rectangle shows the field of the 4×1-CCD mosaic with the F/5 camera.*

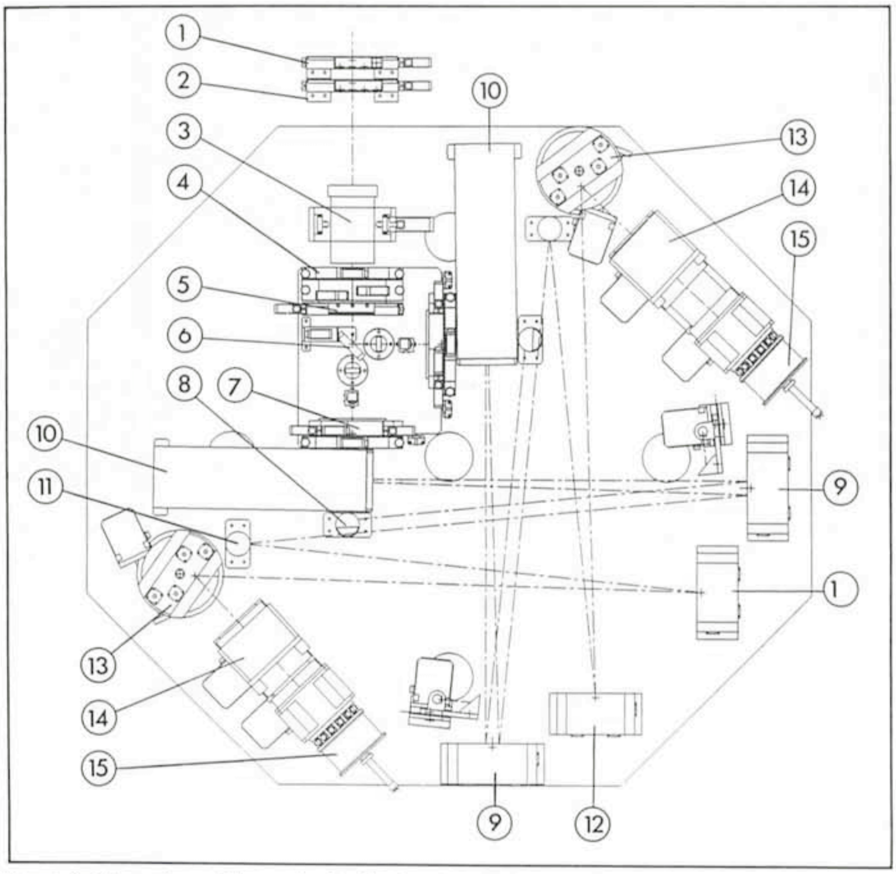


Figure 3: *Plane view of the optical table showing the layout of UVES. Legend: 1 = calibration system. 2 = image slicer unit. 3 = image derotator. 4 = filter wheel. 5 = pupil stop. 6 = mode selector (blue/red/dichroic). 7 = slit. 8 = folding mirror. 9 = main collimator. 10 = R4 echelle. 11 = intermediate spectrum mirror and stray light stop. 12 = pupil transfer collimator. 13 = crossdisperser grating unit. 14 = camera. 15 = CCD detector head and continuous flow cryostat.*

affected by the spectral format peculiar to image slicing, wavelength calibration, detector noise considerations, frequency of radiation events, etc.), the expected demand of the blue and long cameras and the properties and expected performance of the high resolution spectrograph for the incoherent combined focus. The expected performance that UVES would have with the different camera options is summarized in Table 1 while the spectral formats are shown in Figure 2.

Optomechanical Design

The instrument functions are placed on a horizontal optical table with a height of 1.7 metres above the Nasmyth platform. Figure 3 shows a plane view of the layout on the optical table. Advantages of a table are good accessibility and ease of handling of functions and flexibility in view of possible future changes, for instance in the area of CCDs and cameras. Only the calibration unit, image slicer and image derotator are mounted on the rotator. We plan to use an optical table with super-Invar top and backing sheets. Since Invar has an expansion coefficient much lower than that of steel, this will reduce the sensitivity to vertical temperature gradients that might cause the table to bend, which is important since the main dispersion direction is perpendicular to the table surface. The table is supported by a welded frame on three spherical supports. The frame itself rests on three pads on the Nasmyth platform. The control and CCD electronics are located in a temperature controlled cabinet outside the enclosure.

The enclosure consists of a welded steel frame and isolating panels mounted on the frame. Thermal stability is essential to achieve good radial velocity accuracy and a stable focus of the lens cameras. A preliminary calculation shows that without any active temperature control, the temperature of the instrument will change by not more than 0.05 deg C/h during typical observing conditions, which we consider sufficient. The instrument is equipped with temperature sensors at various locations on the table and the enclosure.

The calibration unit, containing a 45-degree mirror, flatfield and ThAr lamps, is mounted before the F/15 Nasmyth focal plane. The mirror slide also mounts an Iodine cell which – when inserted into the telescope beam – produces a dense forest of absorption features in the object spectrum in the region 4800–6000 Angstrom and provides a very stable reference for radial velocity measurements. Bowen-Walraven image slicers mounted on a motorized slide can be placed in the F/15 focal plane.

UVES uses an imaging derotator that is shared by both arms. The user selects the arm(s) used with a 4-position slide that can move from the free (red) position to a blue mirror or one of two dichroics with two different cross-over points. The collimated beam is focused by red or blue doublets on the corresponding slits that are each equipped with slit viewing cameras. We are investigating the implementation of Atmo-

Table 1: *Main parameters of UVES*

	Red	Blue	High Resolution
Wavelength range	0.42–1.1 μm	0.3–0.52 μm	0.3–1.1 μm
Resolution-slit product	4 x 10^4	4 x 10^4	4 x 10^4
Camera	dioptric F/1.25	dioptric F/2	reflective F/5
CCD	2048^2, 15 μm (thinned)	2048^2, 15 μm (thinned)	2048^2 x 8192, 15 μm (thinned mosaic)
Typical wavelength range/frame	2500 Angstrom in 35 orders	900 Angstrom in 40 orders	600 Angstrom in 8 orders
Pixel matching	.31 arcsec/pixel	.19 arcsec/pixel	.06 arcsec/pixel
Max. resolution	~5 x 10^4 (slit .6″)	~7 x 10^4 (slit .4″)	~1.5 x 10^5 (slicer slit .2″)
Slit height	15″ typ.	10″ typ.	10–15″ (slicer 1.7 x 1.7″)
Detection efficiency (incl. telescope and slit)	10% at 600 nm	9% at 400 nm	10% at 600 nm
Magnitude limit	19–20 in V (S/N=10, 3 h)		14–15 in V (S/N=100, 3 h)

spheric Dispersion Compensation prisms and a Polarization analyser in the preslit optical train.

The collimator is a new design developed at ESO that is very well suited for crossdispersed echelle spectroscopy and which in the meantime has also been adopted by the Munich Observatory and the Nordic Optical Telescope Group for their fiber-fed echelle spectrographs. The collimator mirrors are off-axis parabolas. From the slit which is mounted at its focus, the first parabola delivers a collimated beam on the echelle which operates in Quasi Littrow Mode with only a small off-plane angle. The dispersed beams are again collected by the main collimator and focused at an intermediate focal plane, after which the pupil transfer collimator recollimates the beams, at the same time delivering a second "white" pupil where the crossdisperser and camera are placed. This type of collimator is free of aberrations while the control over the second pupil offered by it eliminates vignetting at the crossdisperser and camera. The near-Littrow illumination improves echelle efficiency and reduces problems associated with using the echelle off-Littrow. A stray light diaphragm placed at the location of the intermediate spectrum reduces interorder stray light.

The echelle is unusually steep (for astronomy) and has 31.6 g/mm and a blaze angle of 76 degrees with dimensions ~ 220×850×125 m. Since the maximum ruled length that can be obtained is 408 mm (determined by available grating ruling engines), a mosaic is required. The usual technique that has been employed at ESO and elsewhere is to mount two single 408 mm gratings on a common substrate. For this instrument we intend to use another mosaicking technology which involves replication by the grating manufacturer of two gratings on common substrate with inherent advantages of simplicity and robustness. Figure 4 shows a photograph of a prototype grating that was recently delivered to ESO.

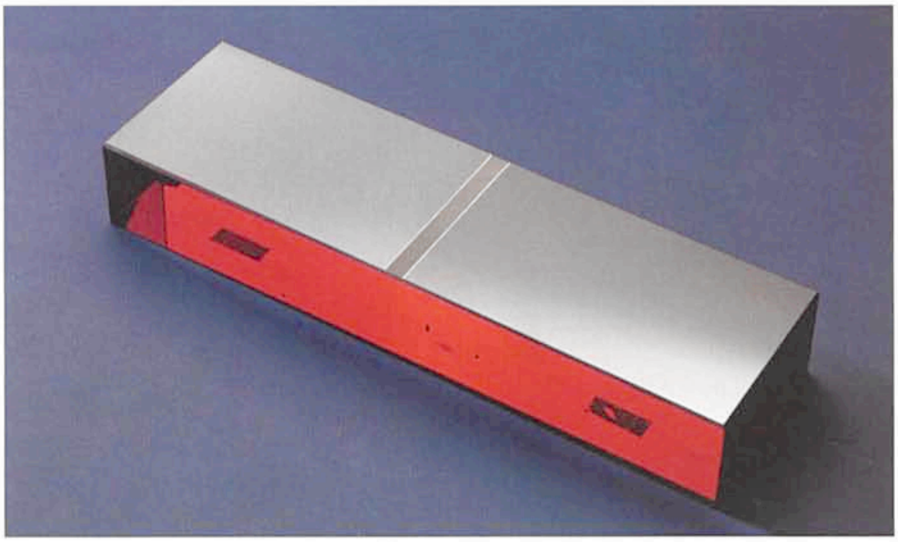


Figure 4: *Photograph of a recently delivered prototype echelle grating with dimensions 450×130×70 mm. The 14-mm gap between the two segments is due to the manufacturing procedure followed and would lead to a 2.2% light loss if also present on the full-size grating. The measured resolution of this grating is $7 \cdot 10^5$, close to the theoretical resolution of a single segment.*

We have extensively investigated prism/grism crossdisperser combinations but prompted by the need for large-order separation have finally settled for standard first-order reflection gratings. These are mounted back to back on a grating turntable.

The regular short cameras are fast dioptric designs offering a wide field, good imaging quality, high optical efficiency and an external focus, important to interface new detectors. Their field size and image quality is compatible with 2048^2 CCDs with 15 μm pixels. The long camera employs 4 mirrors of which 3 are off-axis aspheres and accommodates a mosaic of 4 of these chips in a row. Compared with the red F/1.25 camera, the long camera has a 4 × larger focal length so the angular fields of long camera and red camera in the dispersion direction are identical. In the crossdispersion direction the field and hence the number of orders and wavelength range covered is reduced by a factor 4. Data of the cameras are given in table 2.

Table 2: *Basic camera data*

	Red short camera	Blue short camera	Long camera
Type	dioptric	dioptric	off-axis aspheres
F/no	F/1.25	F/2	F/5
Focal length (mm)	250	400	1000
Field (mm)	43.4 mm diam.	43.4 mm diam.	30 x 120 mm
Wavelength range (nm)	420–1100 nm	300–520 nm	300–1100 nm
Back focal distance (mm)	4	4	~30
Scale (μm/arcsec)	48	78	240
Efficiency	~90%	~90%	~85%
Image quality (E_{80})	~10 μm	~10 μm	~15 μm

Detectors

The baseline detector foreseen is a 2048×2048, 15 micron square pixel detector in a thinned, backside illuminated version. The specified performance calls for a typical ron of 4 electrons, full well capacity of more than 10^5 electrons, and a QE of >30% at 350 nm and >60% at 600 nm. The device should be buttable on at least two sides to be able to build up a row of 4 which would cover the 30×120 mm field of the long camera. Such a CCD is not an off-the-shelf product. ESO has started two development programmes to obtain the required CCD within 1993. One contract with Thomson CSF in France calls for the development of a backside-illuminated version of the Thomson 7897M device. A second agreement with the Steward Observatory of the University of Arizona foresees the thinning of devices of the same format as produced by LORAL. Another thinned CCD which should be available on the market in 1993 is the 2048×2048, 24 micron square pixel CCD from Tektronix. This device would require slower cameras than the Ford or Thomson chips with a curved field matching the bow of the TEK chips. Butting of the back-up Tektronix detectors is presently not possible and we might have to reconsider the high resolution camera if the baseline CCD cannot be obtained. We will actively follow the developments in the detector area with the aim to make a final selection of the detectors for UVES towards the end of 1993. The single chips will be

Table 3: *Composition of technical project teams at ESO and Trieste Observatory*

ESO	
H. Dekker	Instrument responsible, gratings procurement and instrument testing
H. Kotzlowski	Mechanical engineering and technical coordination
P. Ballester	MIDAS reduction software
S. Deiries	Detector assembly/test
B. Delabre	Optics design and procurement
S. D'Odorico	Commissioning at the telescope
G. Hess	CAD design
O. Iwert	CCD detectors
J.L. Lizon	Component testing and optomechanical integration/test
A. Longinotti	Overall software and liaison with Trieste
W. Nees	Instrument control electronics
R. Reiss	CCD control electronics
E. Zuffanelli	Secretary
Trieste	
P. Santin	Coordination at Trieste and liaison with ESO
A. Balestra	Observation Software
M.G. Franchini	Observer Support Software
C. Vuerli	Maintenance Software

mounted in the standard ESO dewar that is being developed for a number of VLT instruments while the CCD mosaic requires the development of a dedicated dewar. The dewars will be cooled by a continuous flow of liquid nitrogen that is pumped from a nearby large vessel through flexible LN2 lines. The autonomy time of the system is expected to be on the order of weeks.

Electronics and Software

While the preceding description is very specific to UVES, the electronics and software architecture will be common to many VLT instruments so the following description reflects the overall control philosophy of the VLT, not just that of UVES. Only a brief description will be given here.

The function control and detector electronics will use intelligent VME-based Local Control Units (LCUs) housed in temperature controlled cabinets outside the enclosure. The control and detector LCUs communicate via the VLT Ethernet LAN with the Instrument Workstation. Its physical location is typically the main VLT control room but it could also be placed next to the instrument during the testing phase.

The main software modules at LCU level are *Instrument Control Software* responsible for communication with the instrument workstation and controlling all instrument functions and *Detector Control Software* to control all detector related LCUs, respectively.

Modules resident in the Instrument Workstation are *Observation Software* which is responsible for controlling observations, from the instrument setup to the storage of the data on tape, *Observer Support Software* which assists the observer to check important parameters relevant to the observation like resolution and expected S/N and *Maintenance Software* to assist the maintenance staff in documenting instrument configuration changes, aligning and doing detailed performance checks. *MIDAS* will be available as well for online data analysis. There will be special MIDAS procedures for image display, calibration and quick-look data analysis.

While in stand-alone mode, these modules will provide for simple tasks like the execution of single observations. Embedded in the whole VLT software, the UVES software will be able to take advantage of many common facilities like the *Sequencer*, which allows to define a sequence of observations corresponding to a complete night off-line, or the *Scheduler*, which allows to switch automatically from one observing programme to another if certain conditions (e.g. seeing) change during the night.

The *VLT User Interface* provides to the user, who may be a service technician, an on-site or remote observer or a service observer, a transparent communication interface with all of these modules at various selectable levels of access authorization, interactivity and automation.

ESO has recently signed an agreement with the Observatory of Trieste under which the latter will contribute 3 man-years in 1993 and 1994 to develop the Observation, Maintenance and Observer Support Software for UVES in collaboration with ESO. The agreement may later be extended to the phase of integration, testing and commissioning of the instrument if this will be in the interest of both parties.

Project and Science Teams

The composition of the technical project teams at ESO and of the software group at Trieste is given in Table 3.

S. D'Odorico is the instrument scientist at ESO. The project relies also on a team of internal scientists composed of D. Baade, Ph. Crane, G. Mathys, L. Pasquini and J. Wampler for advice on specific scientific/technical issues.

As for the other VLT instruments, UVES has a science team composed by external scientists who are kept informed of the status of the project and whose advice is sought every time a decision has to be taken which has an impact on the scientific capabilities of the instrument. They report to the VLT project scientist J. Beckers. Members of the team are B. Gustafsson (Uppsala), H. Hensberge (Brussels), P. Molaro (Trieste) and P. Nissen (Aarhus).

The Choice of the Telescope Enclosures for the VLT

L. ZAGO, ESO

1. Introduction

The final choice of the type of telescope enclosure for the VLT unit telescopes was probably one of the most critical decisions taken in the course of the VLT project up to now.

Back in 1984, at the start of the project, the work on the definition of the VLT enclosures started with the objective to study and design an "open" type of enclosure, in which the telescope would be largely exposed to the undisturbed windflow during observations. This option of envisaging an open-air