THE VLT SURVEY TELESCOPE: A STATUS REPORT

THE VLT SURVEY TELESCOPE (VST) IS NOW A FEW MONTHS FROM ITS COMPLETION. THIS PAPER BRIEFLY REVIEWS THE PROJECT, ACCOUNTS FOR ITS CURRENT STATUS, ANTICIPATES THE CALENDAR OF FUTURE MILESTONES UP TO FIRST LIGHT, AND LISTS THE SCIENTIFIC PROGRAMMES FOR THE OBSERVING TIME GUARANTEED TO THE OAC BY ESO FOR PROCUREMENT OF THE TELESCOPE.

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THE VLT SURVEY TELESCOPE (VST; Capaccioli et al. 2003a,b) is a 2.61-m diameter imaging telescope conceived for the Paranal Observatory to support the VLT through its wide-field capabilities and to perform stand-alone survey projects. It features a f/5.5 modified Ritchey-Chretien optical layout, a two-lens wide-field corrector, with the dewar window acting as a third lens and an optional atmospheric dispersion compensator, an active primary mirror, a double-hexapod driven secondary mirror, and an alt-azimuth mounting. It will operate from the UV- to the *I*-band, preserving, within a corrected field of view of 1° × 1°, the excellent seeing conditions achievable at the Cerro Paranal site. The telescope will be equipped with just one focal plane instrument, OmegaCAM, a large-format (16 k × 16 k pixels) CCD camera built by an international consortium of the same name. Fruit of a joint venture between ESO and the Capodimonte Astronomical Observatory (OAC) of Naples, now research centre of the newly established Italian National Institute for Astrophysics (INAF), the VST (Figure 1a + 1b) is expected to become operational at Paranal in the spring of 2006.

A BIT OF HISTORY

The opportunity to undertake a major scientific and technological venture was offered to OAC by the assignment of an unexpectedly substantial grant in the framework of resources reserved by the Italian Government to promote southern regions. Such funds had been previously solicited to further develop the observing station implemented at Toppo di Castelgrande with a 1.5-m alt-azimuthal telescope (TT1). In 1996 the OAC director set a commission of experts with the task of updating the programme with ideas for a > 5 Mega-Euros observing facility, leading in science and capable of boosting the growth of the OAC community. A constraint to be duly considered was the *una tantum* nature of the grant, which strongly suggested that it would not support a regular flow of resources for operations and maintenance.

As a result, in July 1997 the Capodimonte Observatory was able to present to ESO a scientific and technical proposal envisaging the design, construction, and installation at the Cerro Paranal Observatory, of a new technology telescope with a medium aperture, specialized in, and entirely devoted to wide-field (WF) imaging at optical and infrared wavelengths. The goal was to ensure, by this instrument, its camera and the seeing qualities of the Paranal site, a more than tenfold increase in the scientific output with respect to the combination of the ESO/MPG 2.2-m reflector with WFI. Named VST for VLT Survey Telescope, the instrument was intended to complement the VLT with wide-angle imaging for the detection and pre-characterisation of sources to be further observed with the larger telescopes, but it was also meant for non-VLT related stand-alone survey programmes.

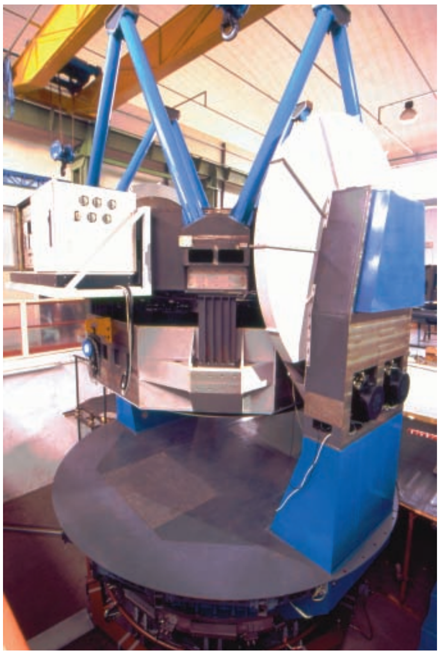

Figure 1a: The VST mounted up to the top ring, in the assembly area at Scafati (Naples).

Figure 1b: The VST top ring with the M2 cell.

The principles of the VST project were accepted by ESO a year later (Arnaboldi et al. 1998). A Memorandum of Understanding (MoU) between ESO and OAC, subscribed in June 1998, assigned to the Neapolitan observatory the procurement of the telescope, and to ESO the realization of the enclosure and the responsibility for operations and maintenance of the instrument for a minimum of 10 years. In return of its contribution, OAC was entitled to receive a share of the total VST observing time (GTO) of the order of 15–20 % (to be re-evaluated at the end of construction on the ground of the actual costs of the various components of the project), and a number of hours at one VLT UT equivalent to 50 observing nights distributed over time, with a maximum of 6 in one semester.

At its conception, the telescope was planned to support at most two instruments: a CCD camera for the optical domain (first priority), and a second camera for the non-thermal infrared domain. Technological and budget limitations, together with the appearance of another WF telescope (VISTA), led to specializing VST to the wavelength range from UV to I. The design and manufacturing of the optical camera (OmegaCAM), with a mosaic of 32 CCDs for a total of 256 Mpixels mapping the field of view of VST at a scale of 0.21 arcsec per 15 µm pixel, was contracted by a European consortium which includes the Netherlands, Germany, Italy, and ESO. The MoU was signed in January 2000.

The performance of the VST/OmegaCAM system, computed with reference to the properties of the optical components and of the CCD camera, is expected to exceed 50 % efficiency across the whole spectral range from UV- to *I*-bands. A conservative estimate of the signal-to-noise ratio of the VST system on point sources observed in 5 bands with 30 minutes exposure time gives a limiting value of ~ 26 AB mag/arcsec^2 (Figure 2).

The expected data rate for the scientific projects of the Capodimonte GTO will be nearly 5 TB/year of non-compressed data. This flow raises the need of suitable HW/SW facilities. The hardware endowment at OAC consists of two Beowulf clusters: one is made of 17 dual Opteron CPU servers, to be used for data reduction; the second is a set of 10 dual Pentium servers that will be dedicated to data analysis. Concerning the management of the VST data, software to archive fits files which uses http as transport protocol has been developed along with the *fitshdr* package, a tool for fits header manipulation. The hardware for the massive data storage will be acquired in time for the start of VST operations.

Since the beginning of the VST project, in order to adjust to the logic of surveys and to create the needed expertise, the OAC team started gathering know-how on the processing of wide-field images. This has been done through the involvement in several national and international dedicated projects which led to the following main results:

– the completion of the OAC Deep Field (OACDF), a multi-band pilot survey over 0.5 square deg conducted with the ESO/MPG 2.2-m WFI camera in cooperation with the observatories of Bologna, Padua, and Rome (Alcalà et al. 2004);
– the creation of astrometric and photometric software tools in the context of a collaboration with TERAPIX at the Institut d'Astrophysique de Paris (Radovich et al. 2004). A porting to C++ of these tools, which were initially developed in PERL, is now in progress;
– the participation within the ASTRO-WISE consortium, an EU project funded through the FP5 RTD programme. In this framework, a first version of a pipeline for the processing of wide-field images has been released. In the same context OAC is developing a tool for photometric variability, which will be mainly used for SN searches, stellar variability studies, and discovery of exoplanets.

Design

The design of the VST has been the responsibility of the Technology Working Group (TWG) of OAC in coordination with ESO for the validation of consistency to the VLT standards (Mancini et al. 2000). The project strategy was defined in order to guarantee the optimization of the whole system in terms of mechanical design and optical interfacing by the use of finite element analysis and computer modelling. The mechanical design is driven by the positioning accuracy and stability required by the optical design of each element for each optical configuration, considering the detector and its optical elements as a part of the telescope, and so improving the integrated system design. The VST basic specifications are summarized in Table 1 and the expected operational image budget is reported in Table 2 (next page). The VST enclosure at Paranal Observatory has been realized by ESO as a facility integrated into the VLT system (Figure 3, next page).

The VST optics were procured through a contract with Carl Zeiss Jena GmbH, with the Russian firm LZOS JSC as subcontractor. The primary (M1) and secondary (M2) mirrors are made from Sitall, an optical glass produced by LZOS JSC and similar to Zerodur. The lenses for the WF correctors are of fused silica produced by Schott (Figure 4, next page). The prismatic lenses for the atmospheric dispersion corrector (ADC) are made from special glasses, also by Schott. In 2002 the primary mirror was destroyed in an accident during shipment from Europe to Chile. This enforced a series of emergency actions to resolve the problem with minimum impact on the final VST schedule. The new

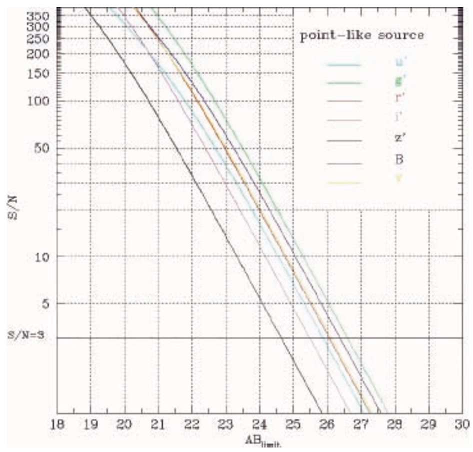

Figure 2: Example of the VST performances on stellar sources (exposure time = 30 min, seeing = 1″, airmass = 1, and no moon). The calculator is available at the address: *http://www.na.astro.it/~rifatto/vst/vocet_2.htm*.

Table 1: VST telescope basic specifications

Telescope aperture	2 610 mm	
Image scale	0.214 arcsec/pixel	
Pixel reference size	15 µm	
Unvignetted field of view	1.47° diagonal, 1° × 1° square format	
Detector	16 k × 16 k pixels CCD mosaic	
M1+M2 EE (80 %)	< 0.3 arcsec (basic)	
M1+M2 EE (80 %)	< 0.15 arcsec (intrinsic)	
Image quality (EE)	required	80% within 2 × 2 pix at *z* = 0°
	two-lens corrector (worst case)	80% in 1.7 pix at *z* = 0°
	ADC + one-lens corrector (worst case)	80% in 1.9 pix at *z* = 0° 80% in 2 pix at *z* = 50° 80% in 3 pix at *z* = 70°
Ghost sky concentration	0.0004	

Table 2: VST image budget

	EE (80 %)	worst case
Two-lens wide-field corrector	$z = 0°$	$z = 50°$
no wind, no seeing	2.0 pix	n.a.
wind 6 m/s, seeing 0.4″	3.2 pix	n.a.
wind 12 m/s, seeing 0.4″	3.7 pix	n.a.
ADC + one-lens wide-field corrector	$z = 0°$	$z = 50°$
no wind, no seeing	2.1 pix	2.4 pix
wind 6 m/s, seeing 0.4″	3.3 pix	3.5 pix
wind 12 m/s, seeing 0.4″	3.8 pix	4.1 pix

contract with the LZOS JSC envisages the supply of the replica mirror at the end of August of 2005. It is expected that the new M1 shall maintain the outstanding quality figures measured on the original mirror. M2 was also slightly damaged during transportation to Chile, and has been returned to LZOS JSC for repair.

The VST is optimized for seeing-limited spatial resolution over a field of view of 1° × 1° matched to a 16 k × 16 k pixels CCD mosaic camera. It operates two different correctors: the first, consisting of two lenses, works in the range from 320 nm to 1 014 nm for observations at small zenithal distances; the second, composed of a rotating ADC coupled to one lens only, operates in the same wavelength range but to an elevation of 30° (Figure 5). A mechanical switching unit allows the appropriate corrector to be selected.

An active-optics system controls the shape of the primary mirror and the position of the secondary. M1 is supported by 84 axial actuators distributed on four rings of 12, 18, 24, and 30 elements (with a force resolution of 1 N), and by 24 radial actuators (5 N resolution) (Figure 6). The M2 position is controlled by a double-stage system, a classical hexapod and a piezo-based fine positioning device, capable of a tilt resolution of 10^{-3} arcsec and a linear resolution of ~ 1.2 nm. They allow the control system to preset and track the position of M2 in advance of and during the scientific exposure. The major aberrations corrected by the active-optics system include defocus, coma, spherical, astigmatism, quad-astigmatism, and tri-coma. The wave-front analysis is obtained by a Shack-Hartmann unit included in the probe, sensitive enough to work on guide stars of 14 mag for integration times of ~ 30s. Given the number of active systems on board of VST and the compactness of the telescope, distributed intelligence solutions have been implemented through the design and realization of embedded controllers connected to the high level control system through a CAN BUS solution.

The VST design follows the concepts used by ESO for the VLT: maximization of general reliability in terms of quality and continuity of the telescope service. It is also compliant to the VLT standards for integration at Paranal and service. The telescope azimuth and elevation axes are controlled by four pre-

Figure 3: The VST dome at Paranal, in between the VLT domes and two auxiliary telescopes.

Figure 4: One of the VST corrector lenses inspected at LZOS JSC.

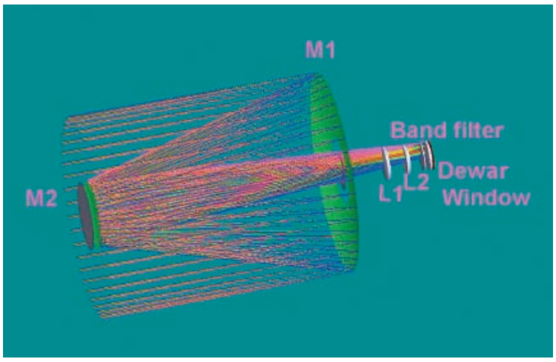

Figure 5: VST optical design.

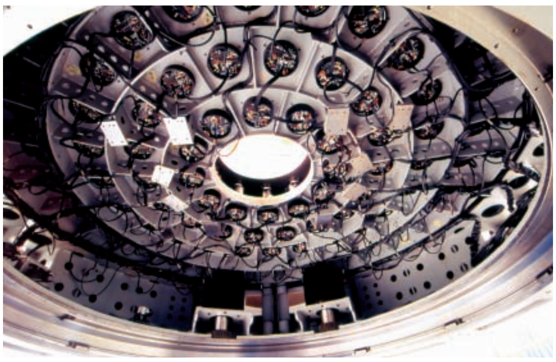

Figure 6: M1 cell seen from the back, showing the four rings of axial actuators.