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The VLT Survey Telescope (VST) Project: a progress report

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Abstract. This is a report on the status of the VLT Survey Telescope (VST) project, a joint venture between ESO and the INAF - Capodimonte Astronomical Observatory, Naples, for the design, construction, and operation at Cerro Paranal of a 2.60 m wide-field imaging facility to support VLT as well as to carry on stand-alone observing programs. VST is not a traditional telescope; it is rather a highly specialized instrument, and cannot be considered disjointed from its camera. This is why some information will be also provided on the status of OmegaCAM, which is however an independent activity of ESO with the homonymous Consortium.
Lacking space to illustrate this text, we refer to the collection of images about VST and its camera in the original Power Point presentation of this contribution downloadable at the address:
http://www.na.astro.it/oacweb/oacweb_ ricerca/vst_ site.

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1. Introduction

The VLT Survey Telescope (VST) project, originally named TT2, was conceived with the aid of a selected group of Italian senior astronomers, called by the Director of the Capodimonte Astronomical Observatory (OAC) to devise an idea matching at best the following requirements and constraints:

1. a major project (> 5 M€);
2. the *una tantum* nature of the funds, preventing long-term commitments;
3. a general goal: a high standard and a scientifically significant output;
4. a local goal: the growth of the OAC scientific and technological community.

The opportunity had been created by the extraordinary assignment to the Capodimonte Astronomical Observatory (OAC), Naples, of special funds of the kind

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allocated by the Italian Government to support the Southern regions of the Country.

In 1997 the VST project had been grossly sketched: its aim was the design and construction of a 2.6 m aperture, wide-field (WF; $1^\circ \times 1^\circ$, i.e. $1\overset{\circ}{.}46$ corrected FoV diameter), high resolution (80% encircled energy [EE] in 0.4), UV to I facility, to be installed and operated at the ESO Observatory on the Cerro Paranal, Chile. The goal was to ensure by the VST and its CCD camera a more than tenfold increase in the scientific output relatively to the MPI/ESO 2.2 m telescope & WFI. VST was primarily intended to complement the observing capabilities of VLT with wide-angle imaging for detecting and pre-characterizing sources for further observations with the VLT. But the VST was also designed for stand-alone survey projects. A few obvious targets for VST, as well as for the other WF facilities, were indicated in the outer Solar System bodies, exo-planets, Milky Way objects, nearby galaxies, extragalactic and intracluster PNs, weak and micro-lensing phenomena, high redshift supernovae, AGN and quasars, degenerate objects.

A major strategic decision was to design the telescope in house at Capodimonte, and either to build the various (hard and soft) components/parts directly with OAC manpower or if contracted outside, maintain the supervision of the OAC Technology Working Group (TWG) led by Dario Mancini. The plan was to go beyond a simple testing of the individual parts and instead, to avoid compatibility problems at Paranal, perform a preliminary integration of the telescope in Naples.

Besides obvious technical and economical reasons, the choice of this approach was dictated by the desire of providing an opportunity for an international level training to several young engineers and physicists in Southern Italy, thus fulfilling the original aim of the money assigned to OAC by the Italian and Regional Governments. This approach was acknowledged in 2002 with the assignment to OAC of the prestigious *Roberto Cortese Prize* (cf. http://www.na.astro.it/oacmedia/news/cortese/premio2002.htm).

At the moment the OAC-TWG consists of 4 staff engineers, 5 technicians, and 12 engineers/physicists on temporary positions. The general management of the project was assumed by Giorgio Sedmak.

The VST project as devised by OAC was accepted a year later by ESO at the end of a careful and severe scrutiny.

A MoU between ESO and OAC, signed in June 1998, assigned to OAC the procurement of the telescope, and to ESO the realization of the dome and the operation of the telescope for a 10 years instrument lifetime. In exchange for the procurement of the telescope, OAC was entitled to receive a fraction of the VST observing time, and some VLT nights. The share of the VST time for Italy (including OmegaCAM) will be of the order of 20-25%, leading to 550-600 VST nights in 10 years and 70 VLT nights.

The VST was originally planned to support two instruments: a CCD camera for the optical domain (first priority), and another camera for non-thermal infrared domain. Technological and budget limitations, as well as the proposal for a specialized infrared WF telescope at Paranal (VISTA), induced to specialize VST for the optical, with a $16k \times 16k$ CCD camera covering the entire 1 squared degree FoV. The MoU between ESO and the OmegaCAM Consortium (involving institutes from Germany, Italy and The Netherlands) for the procurement of the VST optical CCD camera was signed in January 2000.

The expected performances of VST may be summarized by the AB magnitudes per square arc-second reached with 30 min exposures under optimal sky conditions at Paranal: from 25.0 in the I-band to better than 26.5 in the B-band at S/N= 3.

2. The VST project

The main steps of the program so far accomplished are listed in Table 1.

Table 1. VST milestones. The past

Date		Action completed
October	1997	OAC proposal to ESO
June	1998	ESO-OAC MoU & project kick-off
June	1998	OAC contract for the optics with CZJ/LZOS
September	1998	Inclusion of ADC in the optical design
January	1999	Preliminary Design Review
February	2000	Final Design Review no. 1 (excluding mechanics)
September	2000	Final Design Review no. 2 (mechanics)
June	2002	M1 replacement contract

Table 2. VST milestones. The future

Date		Action programmed
July/August	2003	Acceptance of the telescope in Europe
December	2003	Start of re-assembly of VST at Chile Paranal
Summer of	2004	Acceptance at Chile Paranal

Originally it was planned to have the telescope accepted in Europe at the beginning of 2003 and to start the re-assembly at Paranal in April of 2003, with the goal of starting regular observations in October of the same year. Unfortunately, for a number of reasons this schedule had to be revised as indicated in Table 2.

2.1. VST calling for a house

The civil work on the Paranal plateau has been almost completed by ESO with the erection of the dome, a high building in the VLT style, placed between VLT Melipal and Yepun units. It will be ready to host VST from June 2003.

2.2. VST optics

The VST has been optimized for a modified Ritchey-Chretien configuration, with an active 2.65 main mirror (M1) and a secondary (M2) which can be adjusted by an exapode coupled with a sliding table. VST M1 is moved by 84 active axial pads and 24 radial, all of them with on-board control electronics. The wide field is flattened by a two lenses corrector plus the cryostat window which is also an active optical element. In order to compensate the atmospheric dispersion (particularly severe in the blue side of the VST WF), the first lens of the corrector may be replaced by a pair of prismatic lenses (ADC).

The optical components of VST were procured by Carl Zeiss Jena, mostly through a subcontract placed with the Lytkarino Glass Factory (LZOS), Moscow. The main characteristics of M1 and M2, both on astrositall glass-ceramics, are presented in Tables 3 and 4.

The main optical components were accepted at the LZOS factory, Lytkarino (Moscow) on September 7, 2001, and then shipped to Jena, to be handed out by Zeiss to ESO for the transportation to Paranal. Unfortunately, during the sea journey the VST optics got into an accident which caused the complete destruction of M1 and some damage on M2.

The bad news reached OAC at midnight of May 6, 2002 and, already in the following morning, the ESO Director General had

Table 3. VST mirrors characteristics

	M1	M2
Mirror diameter	2650 mm	938 mm
Hole diameter	600 mm	—
Mirror thickness	140 mm	130 mm
Curvature radius	9509 mm (f/3.6)	4374 mm (f/4.7)
Conical constant	−1.139899	−5.421864
Basic quality	< 80 nm	< 80 nm
Intrinsic quality	< 20 nm	< 20 nm
Encircled Energy (80%)	0.15 (meas. 0.12)	—

authorized the action by the OAC director to provide a replica of M1 at the expenses of ESO (to be in turn reimbursed by the insurance company).

The contract between INAF-OAC and LZOS for the supply of a new M1 was signed in Naples on June 14, 2002. It was based on the only blank of the proper size available to LZOS. The hope was that the new mirror could be produced in about 18 months, i.e. within January 2004. Unfortunately, however, after milling the blank showed up some defects that had to be properly investigated prior to the final acceptance. As a consequence, the starting of the polishing has been delayed in order to provide the ESO Director General with all the elements to decide on the safety of the operation. At the time of writing (June 2003), it seems that the blank meets all the safety requirements and that the polishing may start (still pending the ESO DG decision). If so, the expected delivery of the new M1 at the Moscow airport is June 2004.

VST M2 has also been returned to LZOS factory in Moscow for repair and if no additional problems will appear, it should return to Paranal at the end of 2003.

The characteristics of the corrector and of the ADC are illustrated in Table 5.

The components, manufactured and integrated in the holding barrels by Zeiss, will be delivered in September 2003, with a major delay with respect to the contracted delivery time.

Table 4. Characteristics of M1 + M2 combination (f/5.5)

		Required	Measured
Quality	basic	< 114 nm	31.0 nm
	intrinsic	< 29 nm	17.1 nm
EE(80%)	basic	< 0.30	0.28
	intrinsic	< 0.15	0.15

In conclusion, at the end of 2003, when we plan to start the integration of the telescope at Paranal, all the optical components but M1 should be there.

2.3. The telescope

So far all the mechanical components of the telescope have been produced but the M1 cell, which was delayed by the mirror crash and is presently under fine machining. The various components are being pre-assembled in a special area provided at the Mecsud, a mechanical factory located at Scafati (SA), about 45 minutes from OAC by car. The hydrostatic system for the rotation in azimuth was completed and tested in March 2003. Then the azimuth box was placed over the base-plate, which was equipped with the floor needed for the integration of the motors. At the moment the arms and the center-piece are

Table 5. VST corrector & ADC

Two-lens corrector		
Zemax EE(80%)	focal plane	1.80 px
	actual, passive	1.93 px
ADC + one-lens corrector		
Zemax EE(80%)	focal plane	1.87 px
	actual, passive	2.00 px

also in place and, aside, it has been assembled the structure holding M2. The motors, the exapode, designed in house and already tested, the pads etc. are ready for integration. The electronics is ready. The control software is written, though not tested yet. And the budget is under control. In absence of unforeseeable major problems, the telescope should be ready for the acceptance by ESO in August of 2003. Then it will be dismounted, packed and shipped to Paranal for the re-assembly.

2.4. The cost

At the end VST will cost about 7 millions of Euros. OAC has received funds for VST by the Italian Government ("otto per mille" + CIPE: 3.000 k€), the Ministry of University and Research (2.250 k€), the Regional Government of Campania (1.500 k€), CNAA-INAF (350 k€).

3. OmegaCAM: the VST camera

VST will be equipped with a $16k \times 16k$ pixel CCD camera named OmegaCAM. The instrument, which is built by a Consortium of European institutes (cf. http://www.astro.rug.nl/∼omegacam/), will cost $\sim 3,500k$€ and require ~ 50 man-years. The field of view of $1^\circ \times 1^\circ$ will be covered by a mosaic of 32 CCDs with a 2048×4096 pixels format, for a total of $\simeq 0.268$ Gpix, with a filling factor of 95% and major gaps of $\sim 1.5'$. The scale is 0.21 arcsec/pix The spectral range spans from 320 to 1000 nm. The camera will be equipped with 10 on-line filters (Sloan *ugriz*, Johnson BV, Strömgren v, H_α [FWHM=10nm] at cz = 0, 2280, 5570, and 9910 km/s). The absolute accuracy of the astrometry is expected to be $0\farcs3$ rms, with an internal accuracy of $0\farcs02$ rms.

The characteristics of the CCDs (Marconi CCD 44-82, 4-side buttable) are a pixel size of $15\mu m$, a QE peaked at 550nm (80%), a R.O.N. of $5e^-$, and a read out time of 30 s.

At the moment the non-official plan is to have the camera delivered at Paranal in September of 2004.

4. VST-OmegaCAM data flow

Since one image of $268,435,456$ pixels $\simeq$ 0.5 Gbyte, the output of one typical observing night with 50 science frames + 50 calibration frames is of the order of 50 Gbyte. A reasonable estimate of the VST data volume in one year is detailed in Table 6. It is a rather impressive amount, which poses problems for the reduction (particularly in those cases when real-time is needed) and archiving. The problems have already been addressed in various ways and places.

In particular, over the last years the Capodimonte Observatory has devoted a great deal of energy and resources towards the development of the know-how and the creation of the hardware and software tools thereby assuring an optimal scientific exploitation of the VST data. The scientific exploitation of the WFI data, to which the VST data belongs, requires fast and efficient solutions for three different but closely interrelated problems which are:

a) archiving and distribution (data management);
b) reduction and calibration (data reduction);
c) extraction of the scientific content (data mining).

For all these three aspects existing technologies are only in part satisfactory (in

Table 6. VST-OmegaCAM data flow

Data type	Tbyte/year
Raw calibration data	8
Reduced calibration data	4-5
Raw science data	20-30
Descriptor data	1
Reduced image data	15
Astronomical source list data	3-5

terms of computational and storage capabilities) and call for an entirely new approach. The strong interrelations are self-evident if one considers, for example, the impact of data mining on the calibration and structure of the archive.

In preparation of the initial processing of the first VST data, OAC is training young researchers through collaborations with both national and international institutes via MURST COFIN-1999 and COFIN-2001 national grants in the framework of item a) and c) as well as through the European project ASTRO-WISE related mainly to implementation of a pipeline to process and calibrate the VST data. Within this same program, by using the OAC guaranteed time at the ESO 2.2m Wide-field Imager, OAC astronomers have built a the so-called OAC Deep Field (OACDF), (cf. http://www.na.astro.it/oacdf-bin/cdfcgi?imgal).

5. Conclusions

The VST and its camera should be full-time operative at Paranal in the fall of 2004. This specialized instrument will be for a while the largest facility in the world fully devoted to WFI in the optical. Synergy and competition are expected by MegaCam, the Canadian-French WF camera at the CFHt (http://www.cfht.hawaii.edu/Instruments /Imaging/Megacam/), by Suprime-Cam at the Subaru telescope (http://www.naoj.org/Introduction/instrument.html), and, in 2004, by LBC at the Large Binocular Telescope (http://susi2.mporzio.astro.it/WFI-LBT/).

Time has come for the Italian community to think of how to use VST. For now the only project considered for the OAC guaranteed time is a 200 squared degree extragalactic survey ($0.2 < z < 0.8$) requiring about 80-100 nights in a period of 2-3 years.