VISTA: Project Status

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ABSTRACT

VISTA is a 4-m wide field survey telescope with a near infra-red camera and a demanding f/1 primary design now well into its manufacturing phase. We contracted out major items, and generated a coordinated approach to the management of engineering budgets through systems engineering, risks through risk management, and safety through the generation of safety cases. Control of the interfaces and science requirements has been maintained and developed through the current phase. The project is developing the commissioning plan to deliver an effective and safe facility. The current status of VISTA is presented as we move towards the on site integration phase.

Keywords: VISTA, Infrared, Survey, Telescope, Wide Field Astronomy

1 INTRODUCTION

The Visible and Infrared Survey Telescope for Astronomy (VISTA) is a 4 metre class wide field telescope designed to conduct large-scale, surveys of the sky at near infrared wavelengths (0.9 to 2.5 μm). It could also operate at visible wavelengths (0.35 to 1.0 μm) if a second camera became available. VISTA will become a part of ESO's Cerro Paranal Observatory in Chile, and can in effect be considered as a single integrated IR camera with a field of view of 1.65 degrees, in which the "telescope" is really the fore-optics. From the outset, the project team approached the design with this concept i.e. we are not building a telescope we are building a 4 metre, wide field camera.

The VISTA project started in 2000 following a Joint Infrastructure Fund award to a consortium of 18 Universities within the UK led by Queen Mary University of London. Through competitive tendering the UK Astronomy Technology Centre (ATC) was contracted to act as VISTA Project Office (VPO) managing the project of developing and building the VISTA facility. In Phase A VPO validated the concept and identified what could be achieved with the available funding, and in Phase B the conceptual plans were converted into tenders and contracts placed for the development and manufacture of the component pieces. This phase will end with the commissioning of the telescope in Paranal and handover for operation by ESO.

A f/1 primary mirror design together with Cassegrain focus instrumentation offered the best solution to the difficult problem of combining a wide field with good image quality, and results in a large physical focal plane. The design is quasi-Richey-Chretien with a Cassegrain instrument rotator. The f/1 primary has resulted in a very squat and stiff mechanical structure, but demanding alignment constraints. The camera is a 3m, 3tonne instrument fitted with 16, 2048*2048 Raytheon VIRGO IR detectors. The telescope produces a f/3 beam, and the optics within the camera provide the corrections to maintain image quality across the large focal plane. The VPO has taken the approach of contracting out major elements for development and manufacture, and has been organised on a systems engineering and work package management based structure. The VPO retains systems engineering responsibility throughout the project, ensuring that the final delivered sub-systems will be integrated into a system meeting the project requirements. In all these areas development has been required to provide the necessary tools and structures. This systems approach naturally includes the requirements for verification and this has been planned, at component, sub-system and system level.

1.1 Status

Most sub-systems have been accepted at factory level and the test data from these tests is now available. The site work is now complete and the enclosure erected and tested on site. Full connections have been made to provide power to the

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telescope from the Paranal Power Station some 5.5km away and the fibre connections are in place to connect the telescope facility to the Paranal Control Room. The telescope structure, including the M1 cell, has been fully tested in the Vertex RSI factory in Mexia, Texas and is being shipped from Texas to Paranal during May 2006. The M2 Unit is completed in Barcelona at NTE and has been fully tested and is awaiting shipment to Paranal. The Coating Plant in UK is progressing well and testing should begin within the next weeks. The mirrors are both in L-ZOS in Russia where the final polishing is in progress, and these should be shipped later in the summer. The camera has completed most of its integration and test and is currently being prepared for its final 'all-up' camera test before shipping. Overall, the project is rapidly entering its final Integration and Test phase leading up to the commissioning phase and final acceptance at Paranal. The detailed status and testing of sub-systems will now be covered in some more detail.

2 TELESCOPE

The Telescope Work Package (WP), which is contracted with VertexRSI in Texas, includes both the Telescope Mount and the M1 cell and Support system. The majority of the factory testing was completed in November and December of 2005. The factory testing was the basis for factory acceptance of the Telescope WP and covered the following main areas:

- Telescope Tube relative deflections over altitude.
- Mechanical compliance which includes such areas as alignment, mechanical handling and mechanical operation.
- M1 support system functionality and performance.
- Axis Servo Control.

For more detail off the testing and results from the telescope tube deflections and the M1 support system see Jeffers et al 2006. The other major part of this testing that was conducted was the demonstration of the M1 removal and replacement processes & procedures. The M1 is removed using the enclosure crane prior to which the instrument, M2 and top end structure is removed. Figure 1 shows the top end structure being lifted off as per the procedure in preparation for M1 removal. Both the instrument, the M2 assembly and the top end structure are removed with the telescope horizon pointing before it is rotated back to zenith for M1 removal.

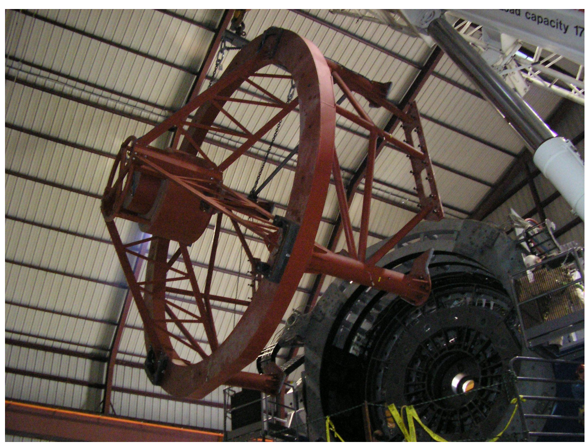


Figure 1 – Removal of the top end structure in preparation for M1 removal.

The M1 simulator (steel fabrication with precision machined interface) is shown in Figure 2 being lifted clear of the centre section. In the figure the support system can be seen quite clearly as the photograph was taken through the altitude axle.

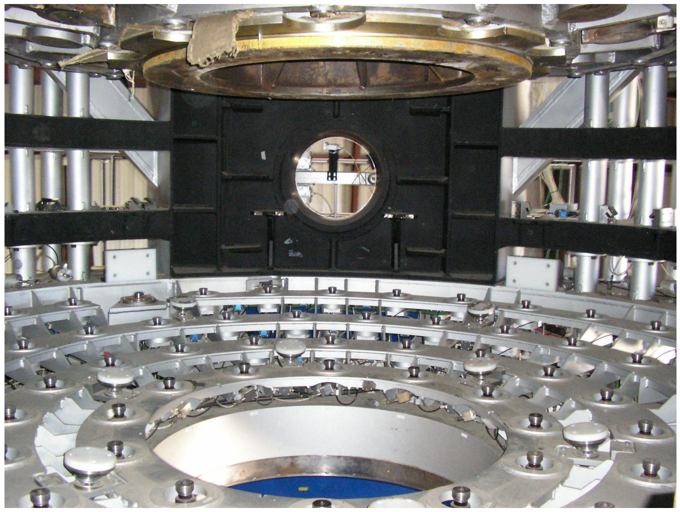


Figure 2– M1 Simulator removal through centre section.

The following table gives measured results with the vendor's position-loop electronics as a brief summary of the measured performance in some key areas of servo testing of the telescope. The VPO frequency-response parameters will be measured at Paranal, but system performance has been tuned for good position step responses at VRSI facilities in Wortham, TX. The VPO tuning parameters will then be optimised for minimum tracking error at Paranal.

Parameter	Value
Az Rate bandwidth	26.8 Hz
Az Pos bandwidth	2.04 Hz
AZ Pos gain margin	54 deg
AZ Pos phase margin	9.9 dB
Alt Rate bandwidth	11.5 Hz
Alt Pos bandwidth	2.47 Hz
Alt Pos gain margin	55.4 deg

Alt Pos phase margin	7.9 dB
Cass Rate bandwidth	33 Hz
Cass Pos bandwidth	1.5 Hz
Cass Pos gain margin	43.8 deg
Cass Pos phase margin	14 dB
RSS (Encoder) tracking error	0.025 to 0.084 arcsec rms, dependant on tracking dynamics.

The Telescope WP at time of writing is in transit to Cerro Paranal. It is anticipated that it will be ready for system integration in Paranal by late August.

3 M2 UNIT

The M2 Unit WP, which is contracted with NTE in Barcelona, underwent Factory Testing in September 2005. The testing consisted of:

- Safety inspections:
- Performance tests
- Software testing
- Mechanical inspections

The performance tests rigorously verified the performance of the system against the specification. The test set up involved a combination of Heidenhain Linear encoders, an Interferometer, a Newport rectitude sensor and Autocollimator. Figure 3 & Figure 4 show the M2 Unit under test in their two test configurations.

Figure 3: M2 Unit in Test Configuration 2

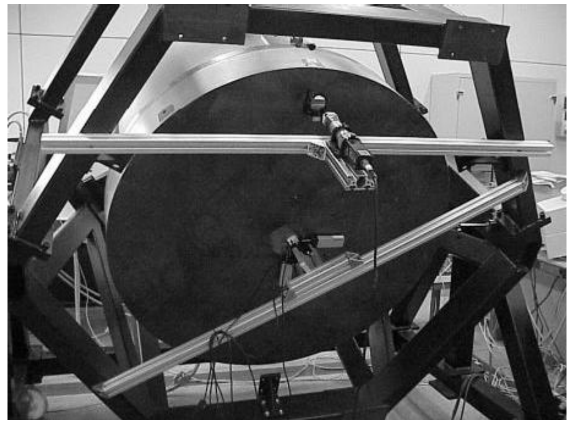


Figure 4: M2 Unit in Test Configuration 1.

The areas of performance testing were mainly relating to focus, centring and tilt accuracy and repeatability. Table 1 provides a brief summary of the tested performance of the M2 Unit. More details on this testing and the results can be found in Table 1.

Table 1 : M2 Unit performance test results

	Range	Speed	Abs Accuracy	Step min amplitude	Diff Accuracy
Focus	+/- 4 mm	0.26 mm/s	9.66 µm rms	1.49 µm rms	0.26 µm rms
Centring	+/- 4.423 mm	0.26 mm/s	28.1 µm rms	11.66 µm rms	2.6 µm rms
Tilt	**+/- 6 arcmin**	0.41 arcmin/s	0.79 asec rms	0.111 asec rms	0.1107 asec rms

The M2 Unit is now in NTE awaiting shipping and it is anticipated that integration onto the telescope will commence in early September.

4 MIRRORS

The mirrors for VISTA are 3.95m f/1 primary and a 1.24m secondary. The M1 blank was manufactured by Schott in Germany and transported to L-ZOS in Moscow for polishing[6]. The M2 is being fully manufactured by L-ZOS. The M1 is being polished on a replication of the M1 support system.

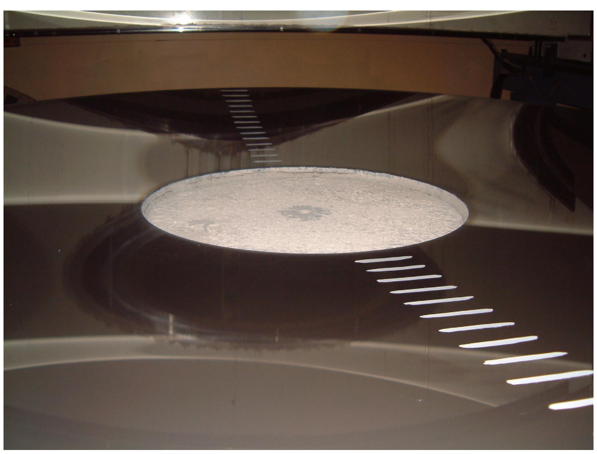


Figure 5: M1 at L-ZOS

Figure 6: M2 showing lightweighting

For M1 all of the Invar supports that interface the mirror and the support system have been attached to the mirror and checked for position whilst the bonding strength has been confirmed using test pieces. M1 is now undergoing polishing at the Moscow factory of LZOS. M1 has a challenging specification - it is less than 0.06 arcsecs r.m.s for the slope error and < 40nm r.m.s amplitude error of the wavefront, and several technical issues have had to be overcome as the challenges of producing a very fast (~f/1), 4m diameter mirror have become apparent. We have been fortunate that LZOS have a deep well of experience and fundamental knowledge of optics to draw upon - it has helped to counter the issues that have occurred such that the only penalty that has been suffered has been time - not sacrificed performance. Radial errors are being worked upon to achieve a 1~2 fringe surface finish prior to entering the final phase of polishing. Currently LZOS are removing somewhere between 15-25 fringes per week.

The M2 Assembly comprises of two main parts, the Support Cell and the Mirror. The Support Cell has been completed whilst the mirror has been light-weighted and is undergoing polishing. One of the key tests completed to date has been a vibration test of the assembled system to confirm that the 1st natural frequency met specification (40 Hz). M2 has a much simpler optical test setup (a large 2.4m Hindle sphere) but achieving the profile and finish of the mirror still poses a challenge. The mirror surface is at the micron level of accuracy and polishing will continue to take it down to the specification of less than 0.15 arcsecs r.m.s for the slope error and < 40 nm r.m.s amplitude error of the wavefront.

5 ENCLOSURE

The enclosure has been designed and constructed by EIE, Mestre Italy. It is a development of the VLT Enclosure design and is produced with a full environmental control system to ensure the telescope maintains the predicted overnight temperature during the day. The design incorporates two Observing Slit Doors, which move outwards to open and locks in both the open and closed position. In addition, the design incorporated three sets of double ventilation doors to allow control of air-flow and ventilation during the night. The slit is assisted by a windscreen that moves from floor level upwards in a number of steps and a moon-screen that can operate across the enclosure roof. The moon-screen doubles as a flat-field target. Attached to the enclosure is an auxiliary building which houses the coating plant as well as all the services required for the operation on the facility; power, chilled water and compressed air.

Figure 7: Enclosure from South

Figure 8: Enclosure looking through windscreen

The control system is integrated through a Seimans PLC which is turn is commanded by an ESO style LCU. The LCU will act as the interface between the enclosure and the telescope control system. The thermal control, which is controlled through the Seimans PLC, is in turn controlled by a Sauter PLC.

As well as acting as the building to house the telescope, the enclosure also houses the coating plant. This includes a mirror wash facility within the basement of the enclosure structure.

The building is now complete with only a few minor tasks, like painting, remaining. The verification process is almost complete and the performance of the enclosure is to specification. The outline characteristics are:

Slew speed	2° per sec
Maximum acceleration	0.5° per sec^2
Stop rotation	within 5 sec
Fine mode	0.28° difference
Max velocity limit	2.9° per sec
Max acceleration	0.75° per sec^2

6 CAMERA

The IR Camera is described in detail by Dalton et al 2006, but its current status is summarised here. The Camera has a 1.65º field of view and an array of 16 2k×2k Raytheon VIRGO HgCdTe detectors giving 0.34 arcseconds per pixel in the science focal plane with good imaging performance between 0.9µm and 2.5µm. The wide-field design of the telescope requires active control of the position and tilt of the secondary mirror, M2, and the Camera supports this with a pair of curvature sensors co-located on the focal plane.

The Camera is being built by a Consortium led by the Rutherford Appleton Laboratory (RAL), with the UK ATC and the University of Durham supplying some of its sub-systems. Over the last 18 months, the Camera has undergone an extensive assembly, integration and test (AIT) campaign in one of RAL's Clean Rooms and this is nearing completion with the Camera currently in its final pre-ship test phase. It will be shipped to Chile in July or August where it will undergo initial re-assembly and check-out in the Instrument Prep Room (IPR) before being mounted and checked out with the telescope in November / December.

One of the early tests in the AIT campaign was a sequence of flexure measurements using a fully assembled Camera with some subsystems represented by mass dummies. Measurements were made using an alignment telescope and fold mirror, shown in Figure 9, at various tilt and roll angles to compare with the Camera structure FE model. The Camera utilises a set of curved cold baffles with a specially developed coating which has a dual function: on the one hand to minimize any stray light by absorbing radiation in the science band; and also to reflect out-of-band radiation on to the front window of the Camera to assist in warming it to reduce potential window-misting problems. The baffle assembly is shown in Figure 10 prior to installation of the external cryo-tube, Figure 11.

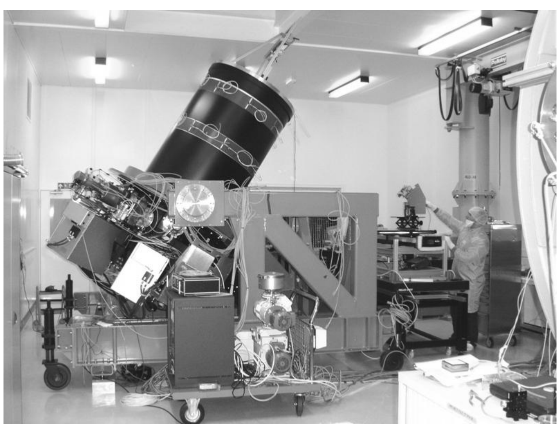


Figure 9: Flexure Measurements

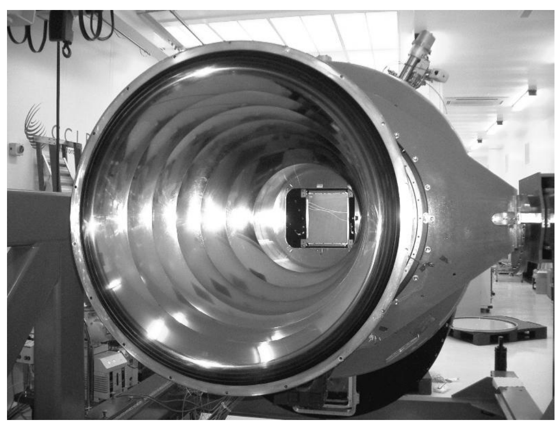


Figure 10: Cryo-Baffle Assembly

The focal plane comprises an array of 16 VIRGO IR detectors mounted on a molybdenum plate designed to ensure co-planarity of the detectors to ±25µm. The detectors are cooled to around 70K by three 2-stage closed cycle coolers connected to a thermal plate and thence to the detectors by a hybrid arrangement of rigid and flexible thermal straps. Much of the AIT programme has been designed to verify the performance of the detectors, their thermal control, and their co-planarity. It has been shown that two coolers are adequate to maintain the detectors at their operational temperature, thus providing a degree of redundancy. The detectors, their mounting plate, thermal plate, detector pre-amp electronics box and connector bulkhead collectively make up the focal plane assembly or FPA 'keg', shown in Figure 12. Co-planarity has been verified using a focused beam from an external optical test source scanned across the focal plane array. The measurements have included co-planarity of the IR focal plane with the wave-front sensors although, because of late delivery of the wave-front sensor optics, these have only recently been completed.

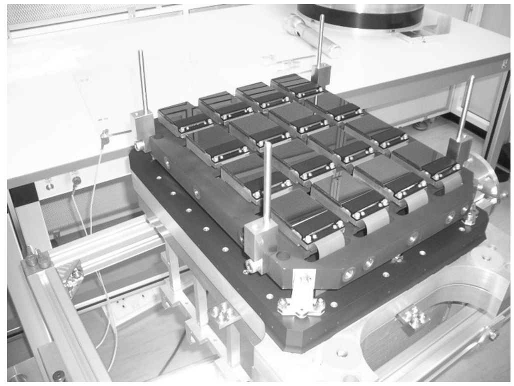
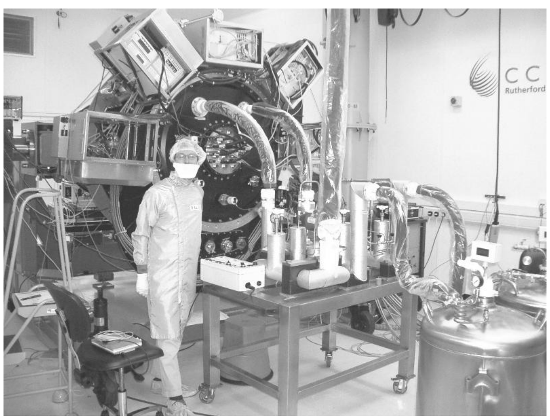


Figure 11 Cryo-Tube Installation

Figure 12 Focal Plane Assembly 'Keg'

The Camera thermal control system is designed to enable a 5-day turn-around which in turn requires the Camera to be cooled to operational temperatures in around 2 days and similarly for warm-up. Verifying the performance of this system has been another important aspect of the AIT campaign. The initial cool-down is assisted by a liquid nitrogen (LN_2) system with a sophisticated control system to ensure maximum cooling efficiency. The control system is mounted on the 'LN_2 trolley' shown in Figure **13**. During each cold run the IR detectors have been operated via the ESO-supplied IRACE controllers with a real-time display providing quick-look data from all 16 detectors, illustrated in Figure 14.



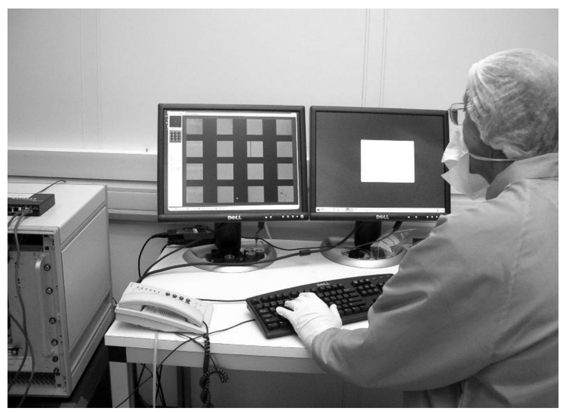
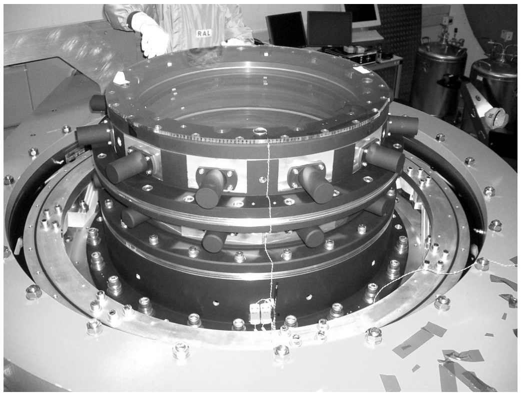


Figure 13 **LN2 Trolley**

Figure 14 IRACE Real-Time Display

The Camera image quality (CIQ) has been measured using a 'short cryostat' configuration, with the lens barrel installed, Figure 15, and focused spot images used to assess image quality at various roll angles and positions across the focal plane. Another critical subsystem is the front vacuum window of the Camera, made from 'Infrasil' fused silica, which has taken around 18 months to manufacture with different stages of the manufacturing programme taking place in 3 different countries. It is shown being taken into the Clean Room in Figure 16 prior to mounting its peripheral heaters and installation in its cell. Verification of the vacuum and thermal performance of the window assembly will be one of the last things to be tested in 'all-up Camera testing' which will take place during May.



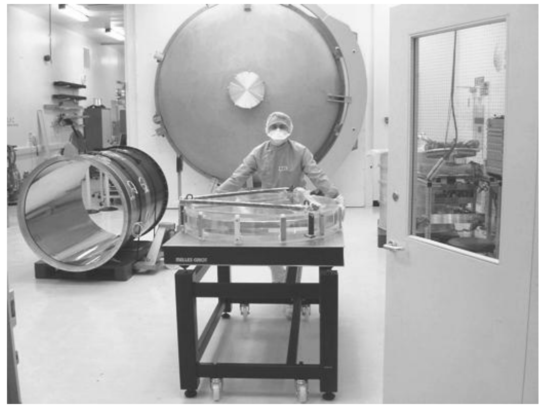


Figure 15 Lens Barrel Assembly

Figure 16 **Cryo-Window**

Another aspect of all-up testing will be a sequence of handling trials using the 3.5m long handling tool, which attaches at the rear of the Camera and has a cantilever arrangement to allow it to be lifted over its centre-of-gravity. The Camera will be de-mounted using a 10-tonne crane and then re-mounted on its handling frame using techniques very similar to those that will be used to mount and de-mount the Camera on the telescope in Chile, thus providing valuable experience of these procedures.

7 COATING PLANT

All the various components of the plant have now been assembled as a complete finished system at the factory in the UK in a fully mimicked layout of the plant as it will eventually be when installed on site at Paranal in the coating area within the auxiliary building of the VISTA enclosure.

Figure 17 **Coating Plant at factory**

Integration of the hardware with the PLC based control system to enable automatic control of the coating operations is all but complete with only the mirror rotation drive module to be finished.

Factory acceptance of the plant will be achieved by the contractor demonstrating deposition of both a thin film of bare Aluminium and a multi-layer coating of protected silver to the required specification for reflectivity throughout the spectral range from 0.3 to 3.3 microns. A uniformity of better than +/-5% on a nominal coating thickness of 140nm must also be demonstrated. This is particularly important around the area of the join overlap and at the ends of the magnetrons near the mirror inner bore and outer radii.

For the reflectance tests this will be done using small glass test pieces arranged on mounts at the height of the actual M1 and M2 mirrors along the arms of the mirror support structure within the vessel and for the uniformity over the join by

using larger test pieces. A high quality spectrophotometer will be used for measuring the reflectance of the coated samples and a hand held 4-pin probe resistivity meter to measure the coating thickness.
Due to the unconventional design of the coating plant vessel the pump down time to working pressure is well within the specified requirement of 2 hours.
As yet there are no results from the formal coating test program, however during integration of the three magnetrons in the factory some quite encouraging preliminary measurements of Aluminium coatings on a series of test samples were made. The detailed results of one of the test runs are included in Fig 18 for information, though it must be stressed that these are only preliminary results.

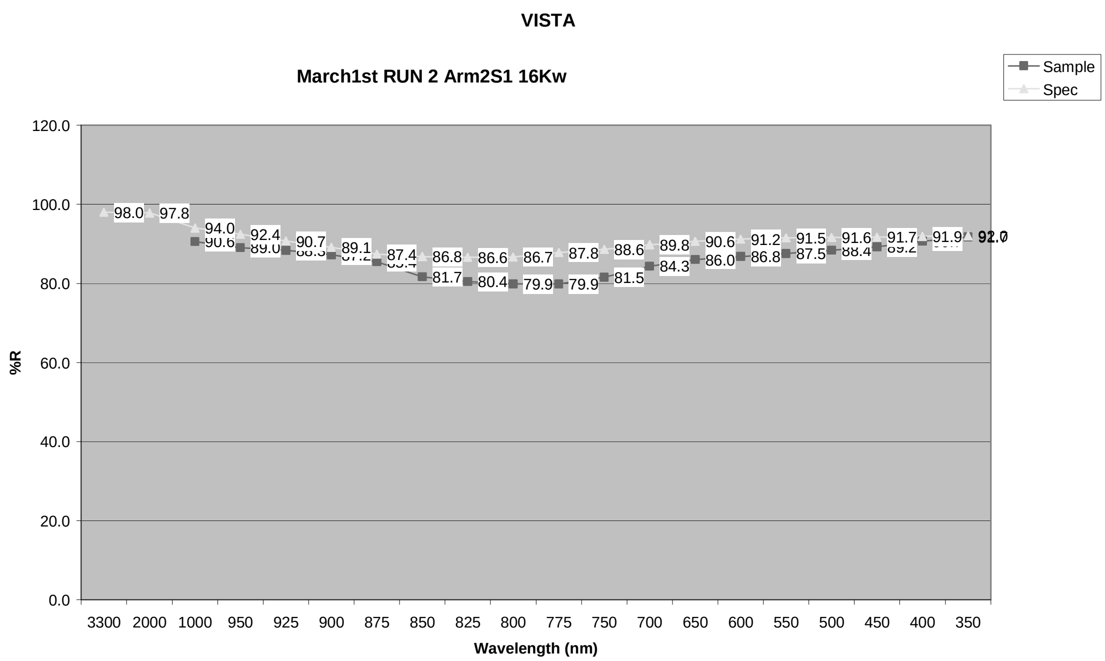


Figure 18: Reflectivity vs wavelength

The parameters used were:

Partial pressure water vapour 4.5x10^{-8} mbar
Magnetron Power 16kW
Rotation Speed 3rph
Deposition rate 1040nm/min
Thickness 160nm

8 SOFTWARE

Since VISTA will be located at ESO's Cerro Paranal Observatory and will be operated and maintained by the same staff who perform this role for the VLT, it was required at the outset to base VISTA's software on the VLT's. This approach also reduced development costs, since the volume of software that had to be written (both infrastructure and application) was significantly reduced. However this approach inevitably increased the VPO learning curve somewhat, but the effects of this were limited by developing collaborative working relationships with VLT software developers. A variety of techniques has been used to apply VLT software to VISTA, including use of the existing infrastructure software, hardware abstraction, inheritance and use of templates[1].

The basic computing architecture is identical to that of the VLT. Systems that interact with hardware devices or have realtime requirements run on Local Control Units (LCUs) i.e. VxWorks/VME systems programmed in C. Other systems run on workstations, all of which are likely to be Linux based when deployed, although much development was done using HP-UX systems. The VLT infrastructure software removes hardware and operating system dependencies from the applications, which are programmed in C++ with some use of Tcl. LCU's are located in the VISTA Enclosure and workstations in the Paranal Control Building. These two locations are connected by Gigabit Ethernet running on single mode fibre.

8.1 Telescope subsystems

The telescope mount is manufactured by Vertex RSI and will be tested and accepted using their standard control system with some VISTA-specific adaptations. To fit this into the VLT architecture, an interface was defined at the electrical level separating the low level control, which will be part of the operational system, and the higher-level software control, which will not. VLT-compliant LCUs running axis control software are then connected to this electrical interface, one LCU for each axis i.e. altitude, azimuth and rotator. This software includes the generic VLT axis control software, including servos, and the generic VLT tracking software that performs realtime astrometric and pointing model calculations. The hardware layer is abstracted and the details are handled in a VISTA-specific software layer using callbacks. The current status is that factory acceptance of the telescope mount has been completed using the contractor's control system. VISTA's axis LCUs have been integrated in the factory with the hardware using the electrical interface.

The M1 is supported on an active system comprising 81 axial actuators, 3 load-bearing axial definers and 24 lateral actuators with 3 lateral definers used to null the lateral forces. In order to counteract the effect of wind buffeting, assumed to tilt but not distort the mirror, the goal is to apply force corrections at a rate of 50 Hz to the axial actuators using reading from the definers. The lateral force servo is closed in software at a rate of 10 Hz. CANbus was selected as the medium for I/O with the interfaces being distributed across four separate CANbuses operating at 500 kbps. The hardware including the CANbus terminals are provided by the telescope mount manufacturer. Unlike the axis control, however, testing and acceptance are done using the M1 LCU, which runs a completely new application developed by Observatory Sciences Ltd. in the UK. Factory acceptance of the M1 support hardware has been completed using this LCU. The lateral loop has been closed at 50 Hz, but because of performance issues in the CANopen software communicating with the CANbuses, 50 Hz was not achieved in the factory. The performance issue is being addressed and it is expected that close to 50 Hz will be achieved. A notable feature of VISTA's M1 system, already verified in the factory, is that the force servos can remain closed while the telescope is slewing, a factor that will greatly improve observing efficiency.

The M2 Unit is a hexapod system, similar to that used on the VLT Auxiliary Telescopes and supplied by NTE in Spain. The LCU and control software were part of the same contract as the hardware, which simplified interfaces and testing. The software was adapted from the Auxiliary Telescope M2 software. Factory acceptance of the M2 Unit is complete. Enclosure control is implemented using PLCs provided as part of the hardware contract with EIE in Italy. The enclosure has been tested at Paranal using the VISTA LCU software, a new application written at the UK ATC.

8.2 Active Optics and Telescope Control

VISTA's active optics utilises two low order curvature sensors, which operate concurrently with science exposures, and a high order curvature sensor. These systems and their associated software have been provided by the University of Durham as part of the IR Camera[2], which is currently undergoing final tests before shipment. The software, including the analysis software using the simplex algorithm, is essentially complete but will be more extensively tested before deployment at Paranal. The higher level software[3], which uses the wavefront measurements to correct M1 and M2, is provided by the Rutherford Appleton Laboratory in the UK and is also functionally complete. This software uses inheritance techniques to extend the behaviour of the VLT's active optics software. Guiding and other higher level telescope control software is handled in the same way.

8.3 IR Camera and Data Handling

The software for VISTA's IR Camera[2] has been developed at the UK ATC in essentially the same manner as any VLT instrument, using the same templates and infrastructure. The software is complete and is part of the IR Camera undergoing final UK testing. At the start of the project, the performance requirements were challenging, 55 MBytes/s peak data rate and a maximum of 1.4 TBytes of data per night, but now they are fairly commonplace. The data rate will be achieved using fast RAID disks, under evaluation by ESO in conjunction with the VISTA IR Camera team. Data will be transferred from the IR Camera to the Paranal Archive using Gigabit Ethernet, ATM and high performance switches. The data will then be transferred to ESO, Garching by shipping magnetic disks. As for VLT instruments, an on-site Quality Control Pipeline will monitor performance of the instrument. A preliminary release of the associated Data Reduction Library has already been provided to ESO by the Cambridge Astronomical Survey Unit, a component of the UK-based VISTA Data Flow System[4].

9 SYSTEMS

A formal systems-engineering philosophy has been applied throughout the VISTA Project, from the early requirements capture and conceptual designs, through the specification development, workpackage tendering, and manufacturing phases, to the present stage of assembly, integration and verification.

VISTA is a dynamic project incorporating a number of high-risk technologies, required to deliver to fixed budgets and timescales – to achieve this, the Systems Engineering approach has been coupled to a Risk Management strategy, in order to target effort and resources to those areas most appropriate. The basis of VISTA risk management is unprejudiced identification and capture of potential risks, backed up by consistent assessment and scoring across the Project, with clear and traceable documentation throughout the "life" of the risk, from identification through to confirmed mitigation.

The cornerstone of VISTA Systems Engineering has been the construction, development and maintenance of a comprehensive set of engineering budgets, sufficiently comprehensive to address all key areas of system performance, but straightforward and robust enough to allow rapid assessment of the impact of low-level changes on top-level system performance. The budgets have been used throughout the project, key stages being the development of formal engineering specifications for workpackage contract tendering in order to identify potential cost/risk "drivers", and during the manufacturing phase, as system performance models evolve from "top-down/as-designed" to "bottom-up/as-built" forms.

The principal use of the engineering budgets in the latter phase has been to facilitate trade-offs – identifying those manufacturing areas where requirements of performance and tolerancing can be relaxed or waived to reduce cost or risk, without compromising the top-level performance of the delivered system or placing undue strain on other subsystems or workpackages. Contingency and margin within the engineering budgets has been allocated on the basis of risk and uncertainty; any requests for specification change or waiver are subject to a formal assessment and documentation process, with due consideration being given to assessment and mitigation of risk.

In the cases of both the M2 Hexapod and the Telescope Structure stiffness and alignment, comprehensive assessment of the performance and testing of the systems meant that waivers could be granted for certain aspects of as-built performance whilst still maintaining confidence in the top-level performance of the system as a whole.

9.1 Integration and Verification

The VPO was contracted to design, manufacture and deliver VISTA as a "turnkey" system, largely self-contained in nature albeit with links to remote power/control infrastructure; this is coupled with its "fully integrated" optical configuration - the telescope and mirrors are essentially the fore-optics to the camera, contrasting with the more familiar situation in astronomy where an instrument is commissioned to be installed on an existing telescope which is already working and characterised.

This quasi-indivisible nature has placed specific demands on the planning of the Integration, Verification and Acceptance processes – many high-level system performance parameters can only be quantified and characterised once the system as a whole is assembled. This unavoidably attaches a degree of risk and uncertainty to the Verification process whereby any deficits in the as-tested system performance may be attributable to shortcomings in one or more subsystems; it is critical to the success of the Verification and Acceptance process that the design of the test plans and procedures eliminates any such uncertainty wherever possible – this exercise is currently underway within the VPO.

It is essential that the technical performance requirements of the system are clearly encapsulated prior to planning the Verification and Acceptance phases, in a form that is strictly quantifiable and testable, and consistent with Customer expectations. This has been done for VISTA, and these specifications form the basis of the Technical Verification Plan currently under development. At each stage the Customer is involved, and given the opportunity to "buy in" to the Verification and Acceptance process.

10 LESSONS AND CONCLUSIONS

VISTA has been a challenge to develop through the design and manufacture phase. The time taken to procure any optics is far longer than anyone will admit during the early procurement phase. There is no doubt that the systems approach has helped and the flow down of testing from systems to sub-system and component has given confidence throughout the development. In fact, it is difficult to see how we would have any confidence integrating a telescope facility in Paranal if we had not followed a structured systems approach. This testing at factory level, and in some cases on-site, have gone well and have shown that the system should operate correctly to specification. We have gained greatly from using the standard ESO software which is well established and reliable and reduced the time of development and the risk. VISTA is now entering the demanding phase of integration and test, so it still remains to be proven that the completely integrated system functions as expected. We believe it will and that VISTA is in a good state to begin the Integration and Verification Phase and a hand-over for operation during 2007.

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