VISTA

Visible & Infrared Survey Telescope for Astronomy

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Document Title:	**VISTA Software Architectural Design**
Document Number:	**VIS-TRE-ATC-00150-0001**
Issue:	**2**
Date:	**2 October 2001**

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Change Record

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
1	24 June 2001		Original presented for Close Out Review
2	26 Sept. 2001	4.5, 4.6, 4.7	Takes account of new requirements for guiding, focus, wavefront sensing. Fast M2 tip/tilt not required.

Table of Contents

1 Introduction

1.1 Purpose

This document describes the architectural design of the VISTA software system for use by software developers, hardware developers and package managers. It breaks the system down into modules that can be worked on independently. Interfaces between these modules and each other and between these modules and externals are identified.

1.2 Scope

The software described is that necessary to operate the VISTA telescope and its instruments i.e. that for which the VISTA Project Office is responsible. This comprises

- telescope control
- instrument control
- data acquisition
- data storage
- data reduction at the telescope site for quality assessment

It excludes software necessary for final data reduction and archiving, subsequent data analysis or software that could be used at the telescope for rapid detection of events

1.3 Applicable Documents

AD01 *VISTA Science Requirements*, VIS-SPE-VSC-00000-0001, V2.0, 26 October 2000.

AD02 *VISTA Operational Concepts*, VIS-SPE-VSC-0000-0002, V1.0, 28 March 2001.

AD03 *VISTA Technical Specification*, VIS-SPE-00000-0003, Issue 2, 26 September 2001.

AD04 *VLT Common Software*, VLT-MAN-ESO-17200-0888, Issue 1.0, 17 August 1995.

AD05 *VLT Instrument Software Specification*, VLT-SPE-ESO-17212-0001, Issue 2.0, 12 April 1995.

1.4 Reference Documents

RD01 *VISTA Computer Hardware Architectural Design*, VIS-SPE-ATC-00150-0002, Issue 2, September 2001.

RD02 *Final Layout of VLT Control LANs*, VLT-SPE-ESO-17120-1355, V1.2, 12 Jan. 1999.

RD03 *LCU Common Software User Manual*, VLT-MAN-SBI-17210-0001, Issue 3.5, 20 October 1999.

RD04 *Central Control Software User Manual*, VLT-MAN-ESO-17210-0619, Issue 1.9, 30 Oct. 1998.

RD05 *Broker for Observation Blocks User Manual*, VLT-MAN-ESO-17220-1332, Issue 1.5, 6 March 2001.

RD06 *Telescope Control System Requirements*, VLT-SPE-ESO-10000-0200, Issue 1, 29 June 1992.

RD07 *Telescope Control System Functional Specification*, VLT-SPE-ESO-11720-00001, Issue 1.1, 2 March 1995.

RD08 *Telescope Control System User Manual*, VLT-MAN-ESO-17230-0942, Issue 1.6, 12 Oct. 1999.

RD09 *TCS Preset Design Description*, VLT-SPE-ESO-17230-0797, Issue 1.0, 19 April 1995.

RD10 *ICD between Telescope Control Software and M1-M3 Unit*, VLT-ICD-ESO-11100-17210 Issue 1.0, 3 August 1993.

RD11 *ICD between Telescope Control Software and M2 Unit*, VLT-ICD-ESO-1100-11710, Issue 1.0, 3 August 1993.

RD12 *ICD between the VLT Control Software and the Observation Handling System*, VLT-ICD-ESO-17240-19200, Issue 1.3, 7 June 2000.

RD13 *ICD between Instrumentation Software and VLT Archive System*, VLT-ICD-ESO-17240-0415, Issue 1.0, 14 Sept. 1995.

RD14 *ICD between the Electro-Mechanical Hardware and the Control System of the Auxiliary Telescope System*, VLT-ICD-ESO-15100-1528, Issue 4.2, 22 January 2001.

RD15 *Template Instrument Software User & Maintenance Manual*, VLT-MAN-ESO-17240-1973, V2.0, 8 April 2001.

RD16 *Base Observation Software Stub*, VLT-MAN-ESO-17240-2265, Issue 1.1, 8 April 2001.

RD17 *Base ICS User Manual*, VLT-MAN-ESO-17240-0934, Issue 2.3, 8 April 2001.

RD18 *INS Common Software Base ICS User Manual*, VLT-MAN-ESO-17240-0934, Issue 2.3, 8 April 2001.

RD19 *Real Time Display User Manual*, VLT-MAN-ESO-17240-0866, Issue 2.8

RD20 *Motor Control- User Manual,* VLT-MAN-ESO-17210-0600, Issue 1.7.

RD21 *FIERA CCD Controller - Software User Manual*, VLT-MAN-ESO-13640-1388, Issue 1.3, 17 February 2001.

RD22 *IRACE-DCS User Manual*, VLT-MAN-ESO-14100-1878, Issue 1.3, 12 February 2001.

RD23 *Data Interface Control Document*, GEN-SPE-ESO-19400-794, Issue 1.1, 25 November 1997.

RD24 *An Assessment of the VLT TCS for Use on VISTA*, VIS-TRE-ATC-00150-0004, Issue 2, September 2001.

RD25 *ALMA Monitor and Control Bus, Interface Specification,* MMA Computing Memo #7, Rev. B, 5 February 2001.

RD26 *VLT Electronic Specification*, VLT-SPE-10000-0011, Issue 2.0, 6 March 2001.

RD27 *P2PP User's Manual*, VLT-MAN-ESO-19200-1644, Issue 2.1B, 2 August 2001.

1.5 Abbreviations and Acronyms

aO	active optics
ATM	Asynchronous Transfer Mode
CB	Control Building
CCS	Central Control Software
COTS	Commercial off the shelf
BOB	Broker for Observation |Blocks
ESO	European Southern Observatory
HOS	High level operating software
ICS	Instrument Control Software
INS	Instrumentation software (includes ICS and OS)
LAN	Local Area network

LANE	Local Area Network Emulation
LCC	LCU Common Software
LCU	Local Control Unit (a VME/VxWorks system)
MOU	Memorandum of Understanding
NA	Not available
NTP	Network Time Protocol
OH	Observation Handling (includes P2PP, OT and SCHED)
OLAS	On Line Archive System
OS	Observation Software
OT	Observation Toolkit
P2PP	Phase 2 Proposal Preparation tool
PSF	Point spread function
RTD	Real Time Display
SCHED	Scheduler
SLA	Service Level Agreement
SRD	Science requirements Document
TCP/IP	Terminal Control Protocol/ Internet Protocol
TCS	Telescope Control System
UT	Unit Telescope (of the VLT)
UTC	Universal Time Coordinated
VLT	Very Large Telescope
VME	A widely used computer bus (acronym is unimportant)
VPO	VISTA Project Office
VST	VLT Survey Telescope
VTS	VISTA Technical Specification
WS	(Unix) Work Station (and by implication Unix servers)

2 Overview

2.1 Background

The normal starting point for a software design is a Software Requirements Document. However the VISTA Project is unusual in that an existing design, that of the VLT, will be used so far as possible. This is an over-riding requirement not only for reasons of efficiency, e.g. software re-use, but because the system will be maintained and operated by ESO staff.

For these reasons the primary inputs to the design of the software architecture in the early part of the project are

- VISTA Science Requirements [AD01]
- VISTA Operational Concepts [AD02]
- VISTA Technical Specification [AD03]
- existing VLT software design and standards

Although there will be no overall VISTA Software Requirements Documents, there will be such documents for relevant subsystems, e.g. instrument and guide/focus control. Hardware and software architectural designs are clearly closely associated and so this document should be read in conjunction with the Hardware Architectural Design

2.2 Relationship to ESO VLT

VISTA will be sited close to the ESO VLT and will be operated from the Cerro Paranal Control Room by ESO staff. Various site services, provided by ESO, will be used, e.g.

- archiving
- local area network
- wide area network
- astronomical site monitor
- sysadmin
- maintenance

This means that the VISTA computer architecture must be closely based on the VLT architecture and must interact with it efficiently and reliably. These constraints are stated more formally in the SRD [AD01] and the VTS [AD03].

The degree of reuse will depend primarily on

- commonality of requirements between VISTA and VLT
- similarity of underlying hardware
- availability of VLT software (intellectual property, commercial contract conditions, etc.) - not expected to be an issue

The following sections give an assessment of the degree to which existing VLT application software can be used. In some cases it seems likely that the hardware will be very similar, e.g. for the axis controllers it should be able to use the same types of motors, encoders etc. even if they differ in detail like size. For others, e.g. M1 control, it may be possible to make major savings in hardware costs by adopting a completely different design. However in such cases it is important to account for software costs in the overall cost analysis.

VLT control software runs on VxWorks/VME systems called Local Control Units (LCUs) and Unix (HP-UX) workstations (WSs). A typical control system uses software on both platforms, the LCU for realtime and hardware interaction, the WS for a scanned status database and interfacing to other systems.

VLT control software relevant to VISTA includes the VLT Common Software [AD04 that provides the infrastructure for real applications. This common software includes components that run on LCUs [RD03], VME based computers and interfaces running VxWorks, and on workstations [RD04], HP workstations and servers running the HP-UX flavour of Unix. Other VLT control software relevant to VISTA includes actual applications, e.g. the TCS, its subsystems and instrument software.

The other body of relevant VLT software is the data flow system. This covers all aspects of data handling, e.g. archiving, processing and display, and also proposal preparation. This software runs on Unix workstations. Although this software is generally portable, it is only fully supported on HP workstations running the HP-UX flavour of Unix.

VISTA software can, like the VLT software, be considered to consist of the top level components as shown in Figure 1.

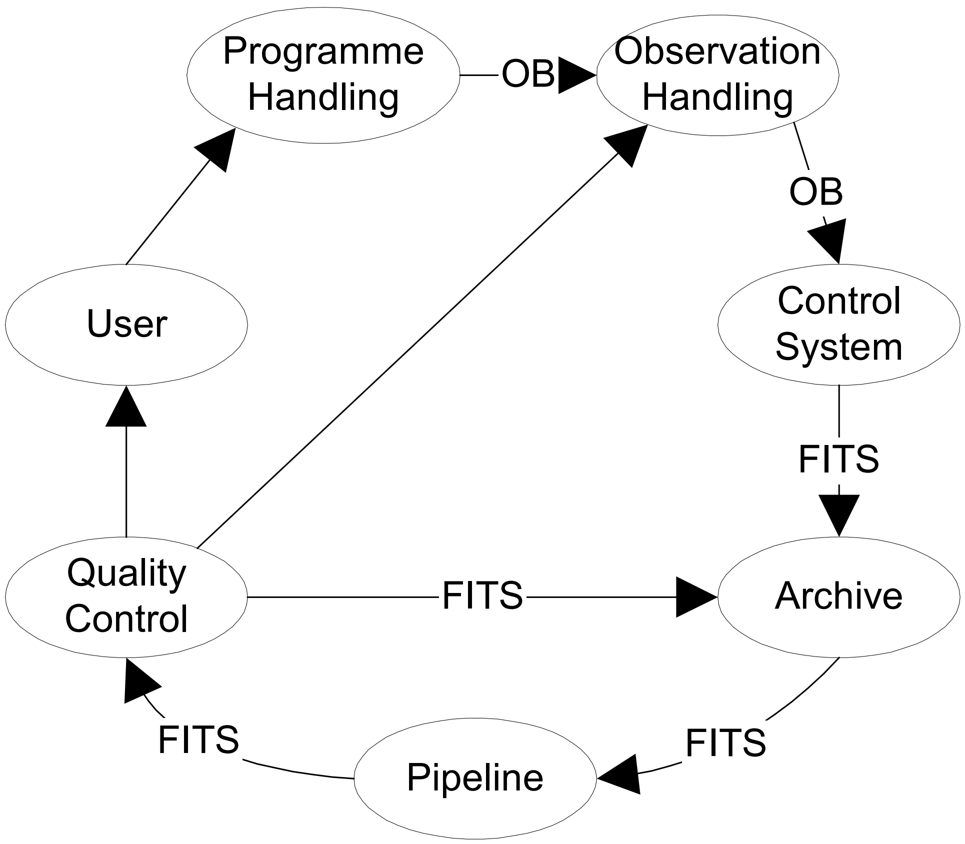

Figure 1. Dataflows between computer systems associated with VISTA.

2.3 Context

Given the scope of the VISTA software, the following externals (actors in UML) can be identified:

- VISTA hardware
- Paranal On Line Archive System
- Astronomical Site Monitor
- Catalogue System
- Telescope Operator
- Offsite staff (e.g. UK and ESO operational staff, archive staff and pipeline processing staff)

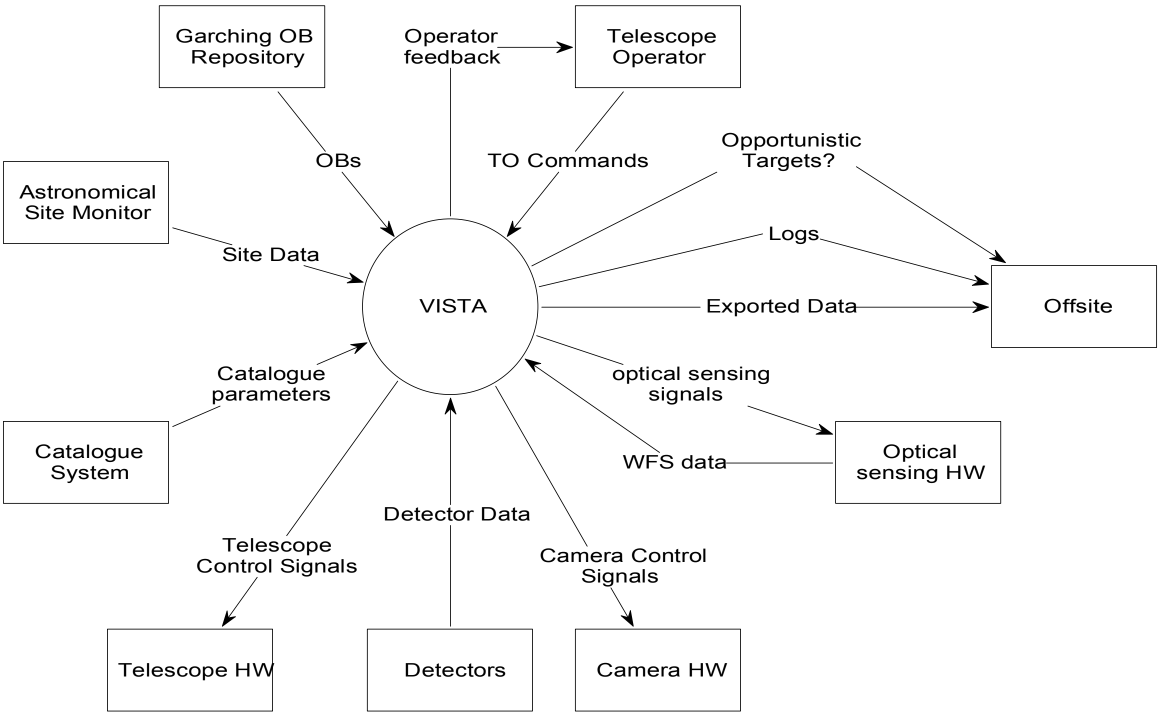

Figure 2. Context diagram for the VISTA computer systems.

2.4 General Software Architecture

The general hierarchy of the VISTA software is

- Control (inc. data acquisition)
  - Telescope
  - IR Camera
  - Visible Camera
- Data flow
  - observation planning and scheduling
  - data handling
  - pipeline processing

Control software will be VISTA specific, although reusing much VLT software and in some cases entire applications.

Data flow software, with the exception of pipeline processing, will generally involve deploying existing VLT application software or interfacing to it.

Telescope control comprises several subsystems, each associated with an identifiable hardware subsystem such as the altitude axis, and a higher level of co-ordination software, the Telescope Control Software [RD06], [RD08] and [RD07]. These systems are based on the Central Control Software (CCS) [RD04] and LCU Common Software (LCC) [RD03].

The hierarchies of the two instruments' software are essentially identical to each other and similar to the telescope control software. Mechanism control is performed by an LCU and associated workstation, operating as a single system as viewed by other systems. Similarly detector control and data acquisition are performed by an LCU/workstation combination, although the internal details are rather more complex. Like the TCS and its subsystems, these systems are based on the Central Control Software [RD04].

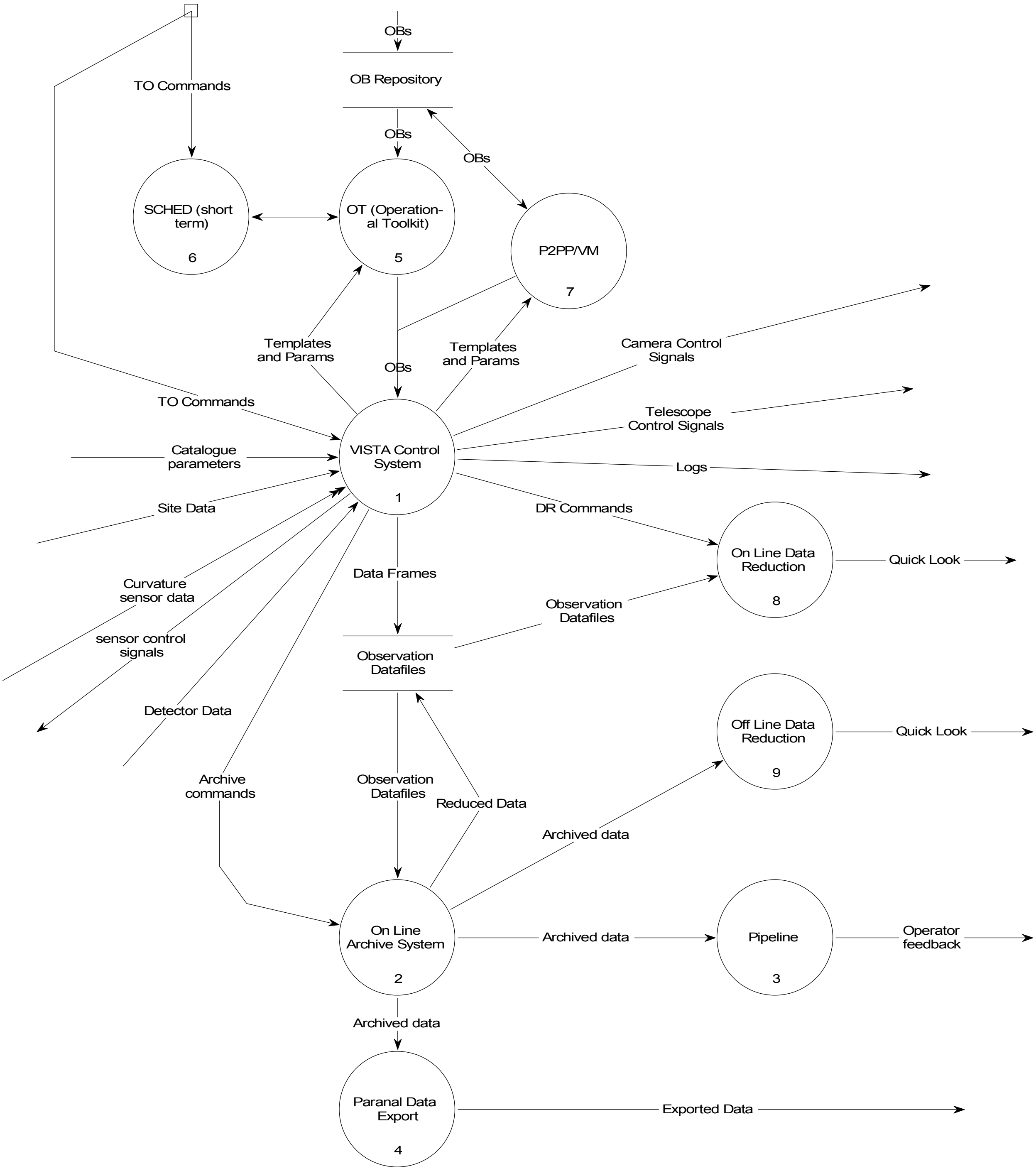

Figure 3. Data flows between the main VISTA control systems

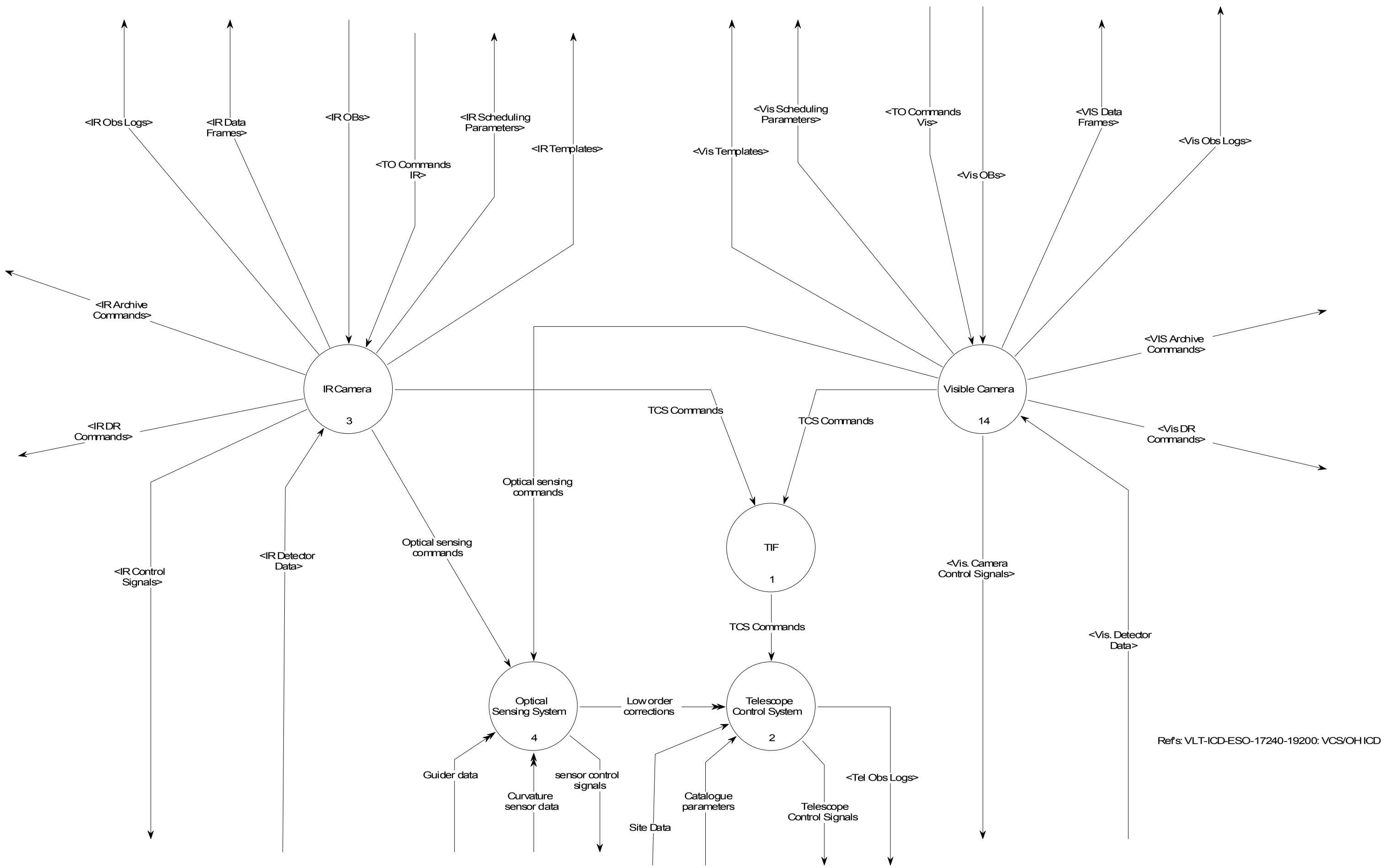

Figure 4. Data flows within the VISTA control systems

3 ESO Infrastructure Software

3.1 Overview

VISTA is constrained to comply with ESO standards, but this is a significant benefit in that infrastructure software already exists to provide services and interfaces that would otherwise have to be coded. An overview of the VLT Common Software (CCS) is available in AD04.

In addition to this infrastructure software, coding of VISTA specific software can be accelerated both by modifying existing VLT applications and by using ESO supplied template applications. For telescope subsystems, if a new software system is required, it should be possible to base this, whether closely or loosely, on the equivalent VLT system. For instrument systems, ESO provide a template Instrument Software System [RD15] and a Base Instrument Control System [RD18] including tutorials.

Until recently, the CCS used as a fundamental component a real-time distributed database package called RTAP, previously supplied by Hewlett Packard. A version of CCS, CCS-Lite, that did not use RTAP was available but with reduced functionality. In order to reduce dependence on niche commercial products and to avoid licencing problems, ESO have extended the functionality of CCS-Lite. In the March 2001 release of the common software it now has effectively all the functionality of CCS and is being used to run some of the UTs. It is planned to use this RTAP-free version for VISTA.

3.2 Common Software

The LCU Common Software (LCC) is the infrastructure software that supports applicaitons running on VME based VxWorks systems. The LCC User Manual [RD03] provides a full description and programmer's reference. The Central Control Software User Manual [RD04] similarly describes the workstation part of the common software.

Briefly the functionality it provides is:

- <u>LCU Management</u>
  e.g. start up, shut down, status, monitoring, self test, simulation control, management of software devices

- <u>Database</u>
  real time storage of and access to data, data sharing between processes, hierarchical

- <u>Scan System</u>
  scans remote databases for local use in order to reduce traffic and CPU loading

- <u>I/O Signal Handling</u>
  associates physical signals on I/O boards to the database, simulation mode

- Event Monitoring
  reports LCU status back to workstation's database, reports events to local and remote processes, event filtering

- Alarm handling
  "abnormal events", occurs when signal or database parameter goes out of range, monitoring, reported to local process to take appropriate action, displayed on engineering user interface, not yet fully supported in CCS-Lite

- Time Handling
  provides accurate system time for time-stamping observations and events and for synchronising the execution of processes, based on VME Time Interface Modules connected to a GPS receiver (workstations are synchronised to same time using NTP), used for interrupt routines

- LCU Access Control
  Prevents users and other processes accessing LCU processors used by others

- Logging
  automatic logging of events to support maintenance and debugging, user controllable, telescope and instrument operational logs in FITS format

- Error System
  reports errors to users, logs errors with tracing of related errors, browing tools

- Message System
  program to program communication at application level for control, not data exchange - on same or different CPUs

- Command Interpreter
  table driven command parser, checks syntax, checks static range of parameters

- Data Historian
  Collects and processes data for graphical representation and trending

- Plotting Tools
  Tools to read and display data, GUIs to configure tools, API

- Sampling System
  Samples high bandwidth data, e.g. in an LCU for plotting an a workstation

- Engineering User Interface
  development and debugging tools

3.3 Drivers

Drivers are provided and supported by ESO for VME interfaces in the LCUs. For engineering purposes engineering user interfaces are provided. Generally applications do not access drivers directly but do so through intermediate software, e.g. motion control.

3.4 Motor Control

The Motor Control Module provides software that sits between applications and drivers. To use this software the hardware must comprise specific types of motors and encoders. The software supports limit and datum switches in specific configurations [RD20].

4 Telescope Software

4.1 Telescope Control System

The TCS controls all aspects of the telescope relevant to normal observing and operations. The VLT TCS is a collection of HP Unix based software modules each implementing an area of functionality, e.g. tracking or presetting. It does not directly control any hardware, relying on LCU based subsystems for this purpose. The VLT's TCS is described in terms of requirements [RD06], functional specifications [AD03] and user manual [RD08]. In addition software design documents describe how specific areas of functionality are implemented, e.g. [RD09]. A formal ICD to the VLT TCS does not exist, but the corresponding information is fully described in the TCS User Manual [RD08].

VISTA's TCS will be a copy of the VLT TCS, which can be considered a generic site-wide TCS (and is in fact used on some ESO telescopes at other sites). Some minor additional functionality will be required by VISTA, but features used by the VLT will not be used by VISTA. This additional functionality, e.g. provision for external focus demands, will be provided by ESO in the generic TCS (subject to agreement).

Hardware requirements: - HP workstation

Software requirements: - Relatively minor enhancements to VLT TCS

Interfaces:
- Instrument software (generically defined in TCS User Manual RD08)
- VISTA's guiding, focus and wavefront sensing system
- LCU based telescope subsystems
- ESO interfaces, e.g. star catalogue and ASM, do not need to be explicitly considered for VISTA

4.2 Axis Control

The telescope axes are controlled by subsystems of the TCS. VISTA will have three main axes that must be controlled: altitude, azimuth and instrument rotator. In software terms these are separate systems, but with very similar architecture and internal details. Subject to any detailed hardware design issues, it will be possible to reuse the VLT's axis control software for VISTA [RD24]. Like the TCS, the axis control software can be considered to be generic to the site.

Hardware requirements:
- HP workstation (the TCS workstation)
- 3 LCUs: altitidue, azimuth, rotator
- VME interfaces and electronics

Software requirements:
- Configuration of existing VLT axis control systems (no new software)

Interfaces:
- Control hardware
- TCS

The interface to the hardware vendor can be specified at the hardware level, e.g. signals to servo amplifiers and from encoders. This approach is taken for the VLT auxiliary telescopes, whose ICD [RD14] can be used as the basis of a VISTA ICD.

The interface to the TCS is effectively described in the TCS User Manual [RD08]. Since this interface is between two ESO software systems, its exact details are not relevant to VISTA.

An LCU is mentioned about for control of the hydrostatic bearing, which is Requirements in this are TBD.

4.3 Hydrostatic Bearing Control

The VLT design includes an LCU that controls the hydrostatic bearing and cooling system. VISTA's requirements in this area are TBD. The function is associated with axis control, but the software that would run on the LCU is completely different to that on the three axis LCUs.

Hardware requirements:
- HP workstation (the TCS workstation)
- LCU
- VME interfaces and electronics

Software requirements:
- TBD

Interfaces
- TBD

4.4 M1 Control

M1 control is a subsystem of the TCS. Its most complex function is to control the surface of the primary mirror by acting on demands, i.e. a force vector, fed to it from the TCS. These demands could be generated from look up tables or they could be by generated by regular analysis of WFS data, but how the demands are generated is not the concern of the M1 control system. M1 control also includes lateral positioning and, potentially, temperature control.

Hardware will comprise an LCU with additional interface cards connected to custom and COTS electronics. The electronics design could be very similar to that of the VLT or it could be significantly different. The greater the similarity between VISTA and VLT M1 hardware, the cheaper potentially will be the software. On the other hand, overall costs could be less by using a different hardware implementation to the VLT, e.g. using CANbus rather than custom electronics and Profibus.

The interface to the TCS is described in outline form in the ICD [RD10]. Subject to the detailed design of VISTA's M1 support system, the exact details of this interface are not important to VISTA, since the VLT TCS and, at least, the upper levels of the M1 control software will be used on VISTA.

The interface between the LCU and the hardware is not described in a VLT ICD, since the LCU software and the control hardware were part of the same VLT contract. The supplied LCU software was modified by ESO and is now effectively ESO software that can be reused in whole or in part for VISTA. If the LCU software and the control hardware are in separate contracts an ICD will need to be written. It should be possible to do this at the hardware level, e.g. the exisiting VLT Profibus interface or a new Canbus interface. Defining interfaces on the Canbus is not fundamentally difficult, e.g. as demonstrated by the ALMA project [RD25].

Hardware requirements:
- HP workstation (for test purposes)
- LCU
- VME interfaces

Software requirements:
- Modification of VLT M1 CS, possibly a "new write" if this cannot be avoided.

Interfaces:
- TCS
- Hardware

4.5 M2 Control

M2 Control is a subsystem of the TCS. The system controls the position of M2 in 5 axes: X/Y lateral displacement, focus, tip and tilt. VISTA's M2 Control System can be simpler than the VLT's, since VISTA's design does not include fast tip/tilt (field stabilisation in VLT parlance) or a chopping capability. Because VISTA's M2 control requirements are a subset of the VLT's, the same interface from the TCS can be used but with the unused functions not being implemented.

The design of the control system depends in detail on the hardware design, but several possibilities exist. The VLT system (hardware and software) could be reused, but with field stabilisation and chopping omitted for economy. The control system being developed for the VLT Auxiliary Telescopes could be reused in large part. A new system could be written, conforming to the exisisting TCS interface.

Reusing the Auxliliary Telescopes' system is potentially the most economic, though the hardware implementation or other factors may mitigate against this. On the Auxiliary Telescopes the interface will be RS232 signals to Delta Tau PMAC cards (multi-axis programmable drive control cards) mounted in the LCU, but programmed by the M2 Unit vendor. (Although PMAC cards are not identified in the VLT Electronic Standards [RD26], they are specified in the Auxiliary Telescopes ICD [RD14].)

Hardware requirements:	- HP workstation (the TCS workstation) - LCU - VME interfaces
Software requirements	- Depends on M2 requriements, but possibly a "new write" of VLT M2 CS (could be a simple system if hardware vendor is made responsible for PMAC servo code)
Interfaces	- TCS (nominally defined in VLT ICD [RD11]) - Guide system (enhanced TCS User Manual [RD08]) - Focus system - Hardware

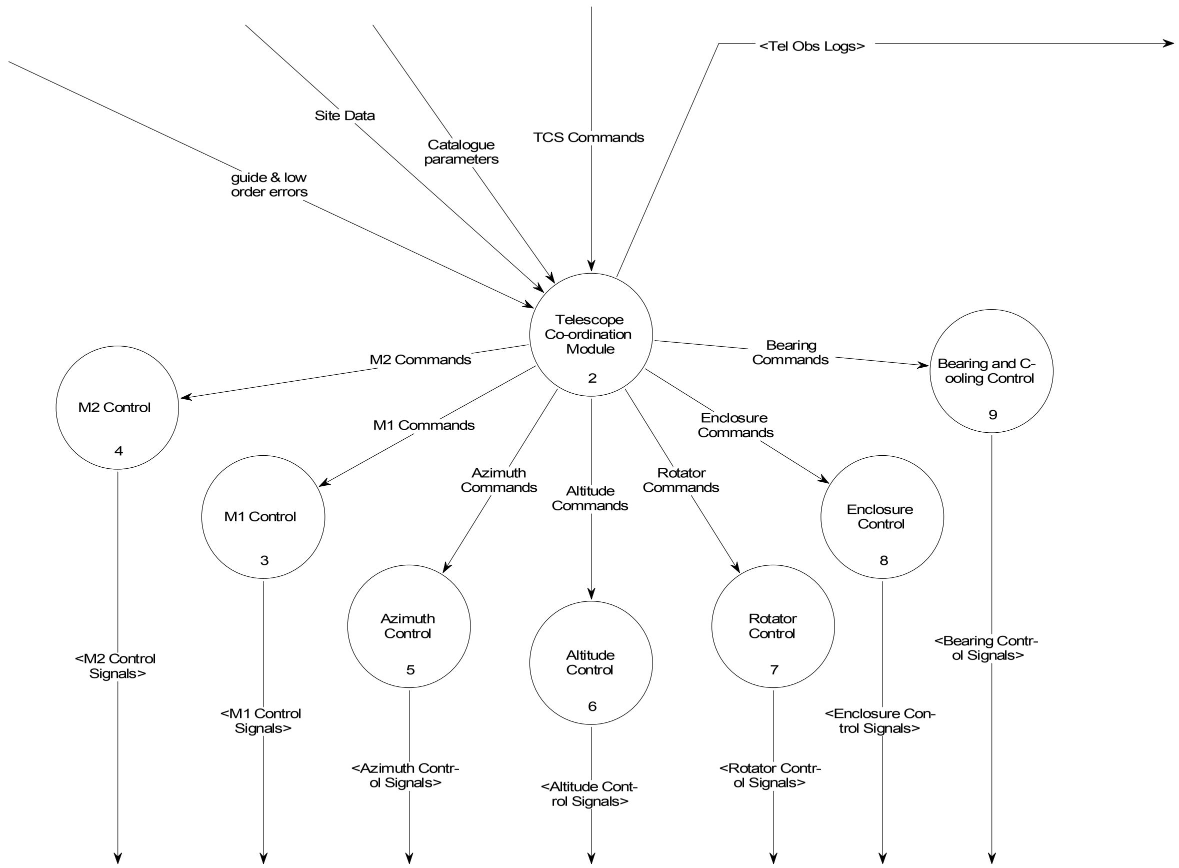

Figure 5 Data flows within the VISTA telescope control system.

4.6 Guiding and Lower Order Optical Corrections

Guiding is a complex function involving several hardware and software systems. VISTA will used fixed guide sensors with an area of interest containing the guide star. The basic tasks that must be performed are:

- select the guide stars (automatically with manual override)
- define the areas of interest and null position on the fixed CCD guide sensor
- acquire the data
- analyse the data (basically centroiding)
- send corrections to the Telescope Control System
- the TCS sends corrected demanded coordinates to the altitude and azimuth control systems at 20 Hz (and 100 ms in the future)

The rate at which guide corrections will be performed will be of order 10Hz.

The technique used to measure focus errors also provides lower order optical corrections, which can be used to correct the M1 figure and the M2 position. Fixed curvature sensors are located either side of focus. Areas of interest are defined on the CCD that contain the slightly enlarged intra- and extra-focal images of the selected focus stars. These images are analysed to determine the lower order Zernike coefficients. Two focus stars are required to separate out the effect of M1 astigmatism and M2 tilt astigmatism. The basic tasks are:

- select the curvature sensor stars (automatically with manual override)
- define the areas of interest on the fixed sensors
- acquire the data
- analyse the data
- send corrections to the Telescope Control System
- the TCS sends corrections to the M2 Control System
- the TCS updates the force vector sent to the M1 Control System

These corrections will be applied at a rate of about once per minute.

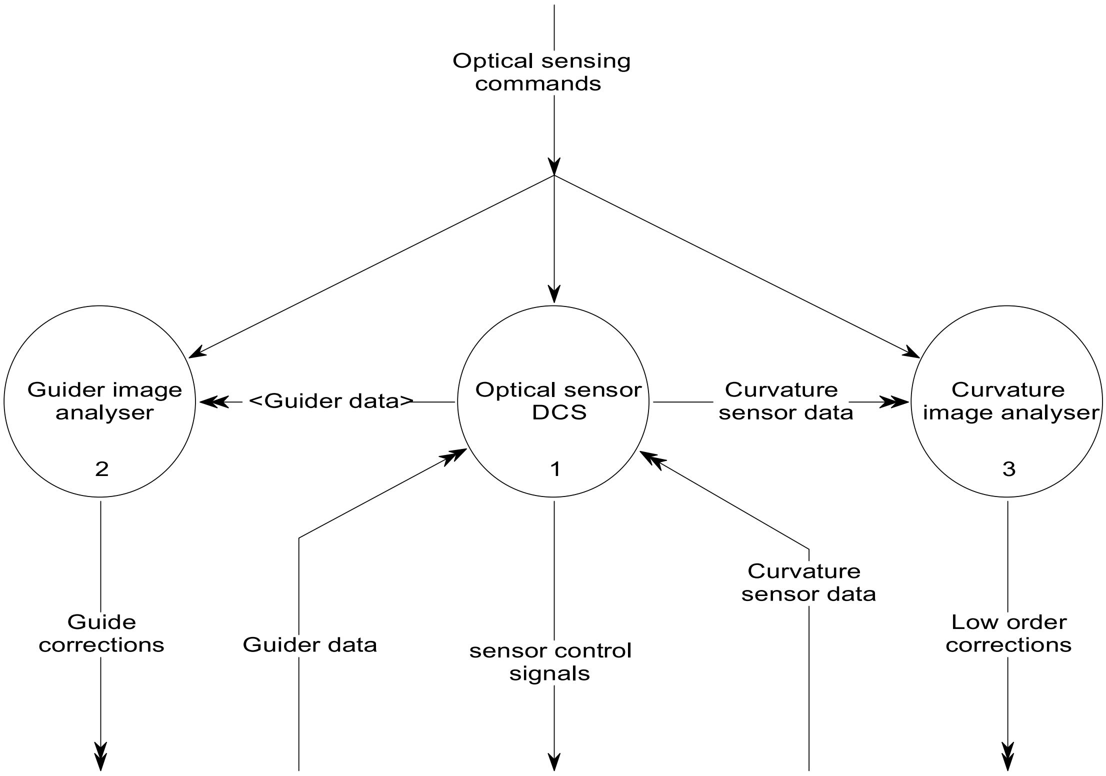

Figure 6 Dataflows within the systems that generate guide, focus control and wavefront information.

Unlike the VLT, but similar to the VST, guiding and focus control will be controlled by the instrument software. This is because the sensors will be integrated physically into the two cameras. This has the advantage that significant changes are not required in the TCS, allowing the continued use of a generic TCS across all ESO telescopes. The disadvantage is that it makes each instrument's software system more complex, but this is probably unavoidable.

Hardware requirements:
- HP workstation
- detector controller (FIERA)
- image analysis LCU

Software requirements
- New system including image analysis
- instruments' OS will have to take guide and focus control into account

Interfaces
- external guide and aO input to TCS (enhanced RD08)
- Observation Software
- Hardware

4.7 Higher Order Wavefront Sensing

A fixed Shack Hartmann wavefront sensor will be used to perform occasional recalibrations, typically once or twice a night, for the TCS active optics module. Since the telescope must be moved to position a star on the sensor, it is not possible (or required) to perform this higher order wavefront sensing concurrently with science observations.

These data will be analysed on the Image Analysis LCU, using software reused from the VLT, to feed corrections into the active optics module of the TCS. The Shack Hartmann WFS in this mode will perform a very similar function to the curvature sensor. The differences are the update rate (once or twice per night), the algorithms used to analyse the data and the order of the Zernike coefficients generated (higher than 3rd order astigmatism and trefoil).

Data from the WFS will also be analysed off-line to generate the look up tables used by the TCS. Data from the WFS will be acquired and stored like other science and calibration data, i.e. as FITS files that are archived and logged.

Hardware requirements:
- HP workstation
- detector controller (FIERA)
- image analysis LCU

Software requirements
- New system including image analysis
- instruments' OS will have to take wavefront sensing into account

Interfaces
- aO interface to TCS
- Observation Software
- Hardware

4.8 Enclosure Control

An LCU controls the VISTA enclosure, e.g. controlling the slit, and rotating the dome. It could also monitor and perhaps control or inhibit various parameters of interest to the rest of the control system, e.g. whether dome lights are on.

Hardware requirements:
- HP workstation (for test purposes)
- LCU

Software requirements
- New system depending on choice of hardware and design

Interfaces
- TCS
- Hardware

5 Instrument Software

5.1 Introduction

VISTA will have two instrument software systems, one for the Infrared Camera and one for the Visible Camera. These systems will use the same architecture as instrument software systems on the VLT, specified in AD05.

Software development will be accelerated by making use of template instrument software provided by ESO. (Template here has a different meaning to a template as used in OBs.) This template implements the functionality of an imaginary but realistic instrument software system and will provide a good starting point for a VISTA instrument software developer. Another benefit of this template is that it provides working examples of interfaces to other ESO systems, e.g. the TCS and archiver, important because such interfaces are not always fully described in ICDs.

5.2 Observation Handling

5.2.1 P2PP and Observation Blocks

For the VLT, the first point at which software becomes important in the observing process is the creation of Observation Blocks using the Phase 2 Proposal Preparation tool P2PP [RD27].

An OB is the smallest observational unit within the overall system and contains a complete specification of the observation required, e.g. target details, instrument configuration, observational constraints and exposure parameters. P2PP is the GUI tool usually used to create these OBs.

OBs can contain sequences of high level operations ("templates") that allow potentially quite complex control of the observing. Although an OB may make only a single target acquisition, it can, e.g., specify exposures at different offset positions in different filters. However a single OB should not take too long to execute, since if it fails in any way the whole sequence of exposures will be have to be redone.

For VISTA the concept of OBs is very useful and the VISTA software system will use them in the same way as the VLT. P2PP can be used to define each observation. If any small changes are needed, a request will be made to ESO to enhance P2PP in a generic way, such that it can continue to be used for all telescopes.

One fundamental shortcoming of P2PP for VISTA use is that it meets the requirements of individual observations, not the requirements of a survey. To plan efficiently a survey, it is desirable to have a tool that converts a survey specification into OBs. This set of OBs will take many nights (or years) to complete, but each OB will take of order an hour to complete.

The Project will investigate with others (e.g. ESO, the VST and UK wide field astronomy) groups) requirements for such a tool and ways by which it could be developed.

Hardware requirements: - None - performed at astronomers' institutions

Software requirements
- ESO will be requested to make small enhancements to P2PP if required
- Requirements for and implementation of a survey planning tool could be developed in collaboration with others

Interfaces: - OBs sent to Garching [RD27]

5.2.2 Scheduling

Scheduling of OBs is required before any observations are made. For the VLT, scheduling includes medium term scheduling performed at Garching and short term scheduling performed at the telescope. The information that goes into the scheduling process includes constraints, priorities (both contained in the OBs) and current observing conditions (available at the telescope both to software and the operator).

Standard ESO software will be used for scheduling VISTA observations. It is likely that improvements in efficiency, e.g. a reduced need for human decision taking, are possible by putting more functionality into the software. However such improvements will apply to all ESO telescopes.

Hardware requirements: - None

Software requirements - None. but VISTA developers and astronomers should collaborate with ESO.

5.3 BOB - Broker for Observation Blocks

BOB is the highest level component formally within the instrument control software (Figure 3). On one side it interfaces with the Observation Handling software (schedulers etc.) and on the other side it interfaces with the corresponding OS (described below).

As described in RD05, it operates on Observation Block Descriptions (OBDs), which it either reads from a disk file or receives from the Scheduling tool (OH/OT). These OBDs contain (or refer to) all the information needed by the VISTA control system to execute individual exposures. It is BOB's task to break these OBDs down, ending up with "units" of individual exposures, sending sequences of commands which are understood by the instrument OS. At the same time, BOB's GUI keeps the user informed of the contents of Observation Blocks plus Templates, and their status of execution, as high-level units.

If the OBDs have been received from the Scheduler, the status of execution of the individual templates etc. is fed back to the Scheduler as these events occur. This allows the Scheduler to take internal decisions, and also to inform its fellow processes on the OH side about relevant events.

For VISTA, each of the two instrument software systems will have its own instance of BOB, using configuration data and templates specific to that instrument. The BOB software itself can be considered generic to the site. If it is decided that some changes to the way BOB operates are desirable for VISTA, e.g. to reduce the need for human decision making, then these will be requested from ESO in such a way that BOB is still applicable to all ESO telescopes.

Hardware requirements:	-	Will run on instrument workstation
Software requirements	-	None - BOB is provided by ESO. VISTA may request some enhancements. VISTA will supply, e.g., templates, scripts and configuration files.
Interfaces:	-	Observation Handling [RD12]
	-	Observation Software [RD15]

5.4 *Observation System*

The Observation System is the highest level of software that must be implemented for a specific instrument. For those familiar with the Gemini architecture, it combines most of the functionality contained within the Observatory Control System and the Instrument Sequencer. The OS performs single observations, as requested by BOB, by coordinating lower level systems, e.g. the ICS, the DCS, the TCS and the Archiver. The OS can incorporate data display, e.g. using the Real Time Display (RTD) [RD19].

Hardware requirements:	-	Will run on instrument workstation
Software requirements	-	A new OS will be required for each of Infrared Camera and Visible Camera. Use will be made of the ESO supplied template instrument [RD15] and stub OS [RD16].
Interfaces:	-	BOB [RD15]
	-	Instrument Control System (internal to work package)
	-	Detector Control System (e.g. FIERA or IRACE)
	-	Optical Sensing System (yet to be developed)
	-	Archive System [RD15]
	-	TCS [RD08]

5.5 *Instrument Control System*

The Instrument Control System, one to be developed for each camera, is responsible for the control of an instrument's mechanisms, e.g. filters, shutters and ADC. In the Gemini architecture, the corresponding item is the Components Controller.

This system is very specific to the hardware that must be controlled, but the need for new software can be limited by making use of the template instrument [RD15] and base ICS [RD17].

Hardware requirements: - Will run on instrument workstation

Software requirements - A new ICS will be required for each of Infrared Camera and Visible Camera. Use will be made of the ESO supplied template instrument [RD15] and base ICS [RD17].

Interfaces:
- Observation Software (internal to work package)
- Camera hardware (internal to work package TBD)

5.6 *Detector Control System*

Requirements and choice of detector controllers are being dealt with separately. The baseline choices are ESO's detector controllers: FIERA for science CCDs [RD21], IRACE for infrared arrays [RD22]. The older ACE might also be required for the guide and curvature sensor CCDs, but FIERA will be used if possible.

Assuming ESO controllers are chosen, no completely new detector control software will be required, since they fully integrate into the VLT software architecture. If using another detector controller were to prove necessary, then the software would have to be packaged so that it interfaced to other ESO software in the same way as an ESO controller. Configuration data, e.g. waveforms, will have to be supplied by VISTA for the chosen CCDs and operational modes. The DCS can display data using the RTD tool [RD19].

Hardware requirements: - Will use a significant amount and variety of hardware as determined by the chosen DCS and the number of arrays

Software requirements - Configuration to VISTA's requirements.

Interfaces:
- Observation Software (defined in DCS Software User Manuals [RD21] and [RD22])
- File store on instrument workstation
- Detector interface electronics

5.7 On-Line Archive System

The archive system is responsible for recording archived observations in the database and for writing to physical media for storage and transport. One component of the archive system, OLAC the On-Line Archive Client receives commands from the OS and, when instructed to do so, transfers data to the On Line Archive Server (OLAS).

Hardware requirements:
- Archive server workstation (also client resides on instrument workstation)
- Disk storage
- Physical media writer

Software requirements
- Configuration only - all software is provided by ESO

Interfaces:
- Observation Software (RD13 and RD15)

5.8 On-Line Data Reduction

Data reduction may be programmed into an instrument's OS, but can be run semi-independently with a command interface from the OS [AD05]. On-Line Data Redution, being controlled by the OS, operates synchronously with the acquisition of the data. This means that if it does not operate quickly enough, it can cause inefficient use of observing time. On the other hand it potentially allows the observing process to be modified based on the analysis of previous data.

This type of data reduction requires the software to be integrated into the On-line MIDAS environment, similar to standard MIDAS but with a command interface. As this environment is rather mature and is not familiar to the likely developers of VISTA instrument software, it is planned not to use it unless there is a clear requirement to do so.

5.9 Data Reduction Pipeline

Data reduction may also be performed by a "pipeline". Basically this is an off-line data driven process that takes data from the on-line archive and reduces it according to previously specified recipes. It is data driven in the sense that the information to control the processing comes not from interactive user commands but from the data headers.

Because it is on off-line process, it cannot slow down the observing process. However it cannot really feed information back into the observing process, e.g. to redo an observation that has inadequate signal to noise or image quality. Within VISTA it is envisaged that a Data Pipeline will be used for data quality assessment, so that problems can be identified by the next day and, if appropriate, observations repeated the next night.

Another potential use of a data pipeline is the identification of objects such as near Earth asteroids, supernovae etc. for rapid follow-up observations on VISTA or elsewhere. (This is not part of the current project however.)

The development of pipeline environments is a very active area both within ESO and elsewhere. The infrastructure and framework are much less well defined than for control systems. Currently ESO's recommendation is for instrument teams to supply algorithms coded in C for ESO to integrate into a pipeline, particularly the final data reduction pipelines operated at Garching.

VISTA's Paranal data reduction requirements will in large part be met by such a pipeline. These requirements will essentially form a subset of the final data reduction requirements, both in terms of functions and the amount of data that must be so processed. (For example, it will be necessary to generate representative PSFs, but not the PSF of every object observed.)

It is potentially very efficient in terms of development effort (and therefore cost) to use the same software for both the off-site final data reduction and the on-site quality assessment. The Project will therefore endeavour to ensure that the final data reduction pipeline can, with some reconfiguration, run also at Paranal and so is not planning to write much new software. In order to achieve this, some challenges will have to be met, e.g. different compatibility constraints for the pipleines at the different locations.

Hardware requirements:
- Pipeline workstation (or possibly in the future a Beowulf cluster)
- Disk storage

Software requirements
- Configuration of final data reduction pipeline for Paranal use

Interfaces:
- On-Line Archive System

5.10 Observer Support Software

Observer Support Software (OSS) comprises programs written by the instrument software developers to assist observers prior to and during an observing run. In VISTA's case this would include those planning surveys, astronomers performing specific observations and telescope operators. OSS is specified in [AD05] and includes:

- Setup Files and checks of these
- Instrument configuration files
- Exposure Time Calculator

Hardware requirements:
- No specific hardware requirements

Software requirements
- Miscellaneous software items to be provided by instrument software developers

Interfaces: - An interface to the short term scheduler is referred to in [AD05], but the relevant document is not available from ESO

5.11 Maintenance and Verification Software

Maintenance and verification software is provided [AD05] by instrument software developers to enable engineers to perform low and high level tests and diagnostics on instruments. This software may use any of the instrument software modules from the OS downwards.

Hardware requirements: - No specific hardware requirements

Software requirements - Miscellaneous software items to be provided by instrument software developers

Interfaces: - Tests existing interfaces

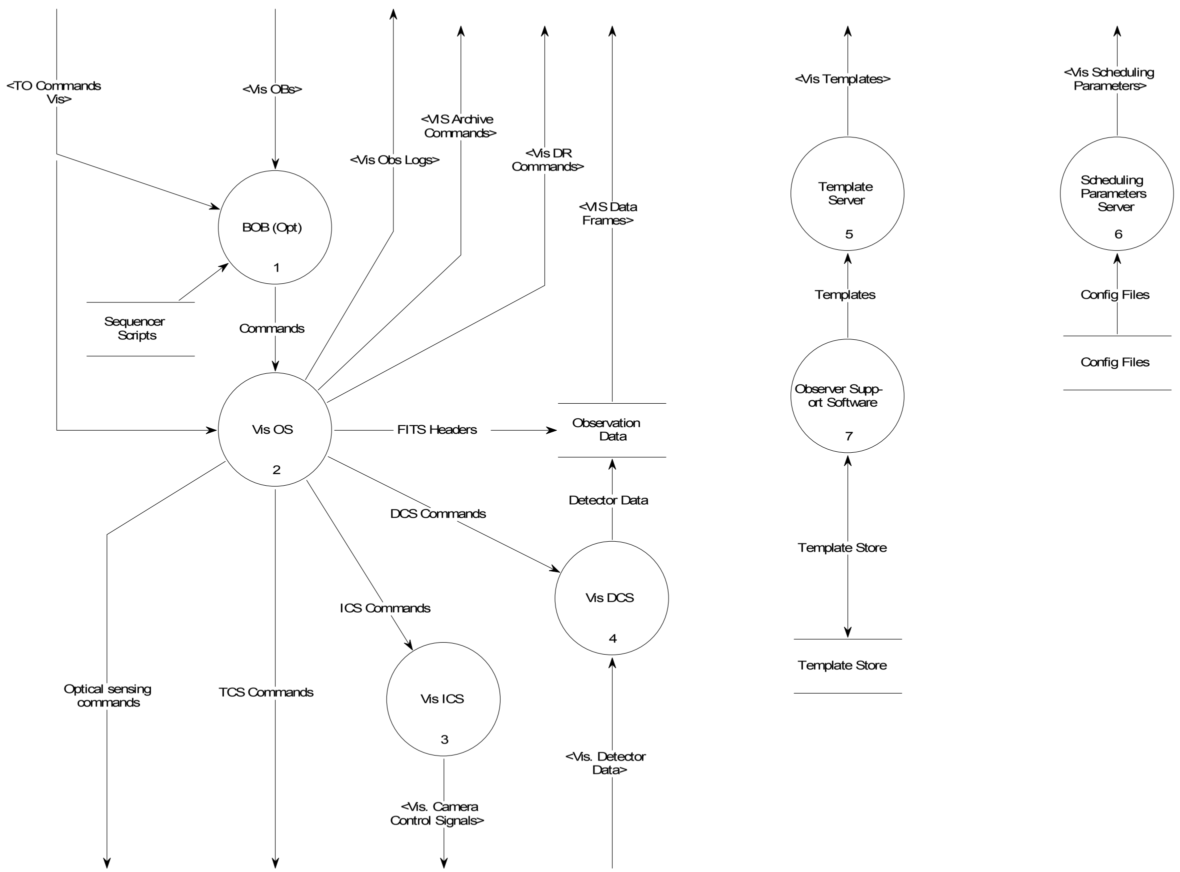

Figure 7 The Visible Camera Instrument software system. (There will be a similar system for the Infrared Camera.)

6 Work Packages and ICDs

6.1 *Potential Work Packages*

Table 1 lists potential software work packages. It is quite likely that many of these will not constitute individual work packages, but will be combined with each other or with hardware based work packages.

Package	WS/LCU	Likely VLT Reuse
Telescope Control System	WS	Little change
M1/M3 Control	LCU	Different in lower layers
M2 Control	LCU	Different in lower layers
Azimuth Control	LCU	Potentially little change
Altitude Control	LCU	Potentially little change
Rotator Control	LCU	Potentially little change
Enclosure control	LCU	Significantly different
Infrared OS	WS	Significantly different
Infrared DCS	(LCU)	Little change if IRACE chosen
Infrared ICS	LCU	Significantly different
Visible OS	WS	Significantly different
Visible DCS	(LCU)	Little change if FIERA chosen
Visible ICS	LCU	Significantly different
Infrared Pipeline	WS	Different (but potentially much reuse of final data reduction pipeline)
Visible Pipeline	WS	Different (but potentially much reuse of final data reduction pipeline)
Optical sensing software	WS/LCU	Significantly different but some reuse (also VST)

Table 1. Possible work packages. WS/LCU indicated where the software predominantly resides.

6.2 *Interface List*

Interfaces between packages and modules, whether software or hardware, assigned to different contractors are defined in Interface Control Documents. All interfaces involving VISTA software are listed below. At the architectural design stage, it is not known what potential packages may be combined in a single contract and so this list includes some interfaces that turn out not to be necessary contractually.

Table 2 List of software and software/hardware interfaces. Whether an ICD actually needs to be written will depend on the scope of contracts. Software ICDs may be combined with corresponding hardware ICDs.

Between system		and system	WBS	Corresponding VLT Interface	Comments
Instrument software		TCS		*TCS User Manual* [RD08]	Any changes to the TCS required for VISTA will be made to this generic TCS. The *VLT TCS User Manual* is the formal definition of this interface.
(generic to IR Camera and Visible Camera)		Optical Sensing software			This interface does not exist in the VLT architecture and will have to be written. Reuse of VST software and interfaces will be investigated.
		Observation Handling		*ICD: Control Software and Observation Handling Subsystem* [RD12]	Any changes to the observation handling (OH) subsystem required for VISTA will be made to the generic OH system. The VLT ICD is the formal definition of the VISTA interface.
		Star catalogue system		NA	In the VLT this is an internal ESO interface and is not formally defined. However it should be straightforward to document it.
		Archive System		NA	Although the VLT interface is not formally defined, it is effectively provided ready for use in the template instrumentation software [RD15].
		Data definitions		*Data Interface Control Document* [RD23]	VISTA data will be defined to conform with this ICD, which also describes control procedures.
IR Camera Software		IR Camera Hardware			This interface does not need to be defined by the VPO if the hardware and software are in the same contract.
Visible Camera Software		Visible Camera Hardware			This interface does not need to be defined by the VPO if the hardware and software are in the same contract.

Between system		and system	WBS	Corresponding VLT Interface	Comments
TCS		M1 Control System		*ICD: TCS and "M1-M3 Unit"* [RD10]	VISTA will use same interface. If this interface is part of a contract it will be rewritten, since the VLT ICD provides only an outline.
		M2 Control System		*TCS and "M2 Unit"* [RD11]	VISTA will use same interface. If this interface is part of a contract it will be rewritten, since the VLT ICD provides only an outline.
		Axis Control Systems		TBD	VISTA will use same axis control software and TCS. This interface, therefore, will not be required for contract purposes.
		Enclosure Control System		TBD	VISTA will use same interface, which will control only a subset of the enclosure functionality.
		Hydrostatic Bearing and Cooling Control System		TBD	Requirements for hydrostatic bearing control are TBD
		Star Catalogue			This is an interface from the generic TCS to another ESO system and so does not need to be considered.
		Site Monitor			This is an interface from the generic TCS to another ESO system and so does not need to be considered.
M1 Control System		M1 Hardware		NA	This interface will have to be written if it is part of a contract. It is likely to be defined at the field bus level (Profibus or Canbus).
M2 Control System		M2 Hardware		NA	This interface will have to be written if it is part of a contract. The Auxiliary Telescope ICD will serve as a guide [RD14].

Between system		and system	WBS	Corresponding VLT Interface	Comments
Enclosure Control		Enclosure Hardware		NA	TBD
Hydrostatic Bearing Control		Hydrostatic Bearing Hardware			TBD
Optical Sensing software		Optical Sensing Hardware		-	TBD
IR pipeline		Archive			A new system. Highly desirable to use a subset of final data reduction pipeline.
Visible pipeline		Archive			A new system. Highly desirable to use a subset of final data reduction pipeline.

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