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Visible & Infrared Survey Telescope for Astronomy

IR CAMERA

Document Title:	**IR Camera Observation Software Design Description**
Document Number:	**VIS-DES-ATC-06084-0001**
Issue:	**2.1**
Date:	**11 October 2004**

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CHANGE RECORD

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
1.0	12/11/03		FDR version
2.0	14/04/04	1.4, 2.1, 3.1, 3.2, 3.3, 3.4, 4, 5.3, 5.6, 8	Updated for VDFS PDR.
2.1	11/10/04		HOWFS now controlled from sequencer scripts rather than from OS. Modification to templates and sequencer keywords, following experimentation by Alan Pickup. Changes marked by cyan highlighter.

NOTIFICATION LIST

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1 INTRODUCTION

1.1 *Purpose*

This document gives the detailed design of the VISTA IR Camera Observation Software. It follows on from the architecture described in the *"VISTA IR Camera Functional Specification"*, [AD2], and together with the detailed design documents of the VISTA IR Camera Instrument Control System, [RD5], and wavefront sensing system, [RD6], [RD7], [RD8], forms the Software Design Description of the VISTA IR Camera instrument software.

1.2 *Scope*

This document describes the detailed design of the VISTA IR Camera Observation Software, templates and sequencer scripts only. A complete software overview may be found in the "*VISTA IR Camera Software User and Maintenance Manual*", [RD10], and the "*VISTA IR Camera Software Functional Specification*", [AD2].

1.3 *Applicable Documents*

[AD1] *VISTA IR Camera Software Requirements*, VIS-SPE-ATC-06080-0010, Issue 2.2, 12 January 2004.

[AD2] *VISTA IR Camera Software Functional Specification*, VIS-DES-ATC-06083-0001, Issue 2.2, 5 February 2004.

[AD3] *VISTA Infrared Camera Technical Specification*, VIS-SPE-ATC-06000-0004, Issue 1.0, 28 October 2002.

1.4 Reference Documents

1.4.1 VISTA IR Documents

[RD1] *VISTA IR Camera System Design Description*, VIS-SPE-RAL-06013-0001, Issue 2.1, September 2004.

[RD2] *VISTA IR Camera System Block Diagram,* VIS-DES-RAL-06013-9001, Issue 1.3, 25 August 2004.

[RD3] *VISTA IR Camera Software Acronym and Abbreviation Glossary,* VIS-LST-ATC-06080-0030, Issue 1.4, 8 April 2004.

[RD4] *VISTA IR Camera Software Management Plan*, VIS-PLA-ATC-06016-0001, Issue 0.11, 29 April 2004.

[RD5] *VISTA IR Camera Instrument Control Software Design Description,* VIS-DES-ATC-06083-0001, Issue 1.8, 26 August 2004.

[RD6] *VISTA IR Camera Low Order Wavefront Sensor Software Design Description,* VIS-DES-UOD-06048-0001, Issue 1.0, 4 March 2004.

[RD7] *VISTA IR Camera High Order Wavefront Sensor Software Design Description,* VIS-DES-UOD-06048-0002, Issue 2.0, 4 March 2004.

[RD8] *VISTA IR Camera Autoguider Software Design Description (LCU part),* VIS-DES-UOD-06048-0003, Issue 1.0, 4 March 2004.

[RD9] *VISTA IR Camera Software Acceptance Test Plan*, VIS-PLA-ATC-06087-0001, Issue 1.1, 6 January 2004.

[RD10] *VISTA IR Camera Software User and Maintenance Manual*, VIS-MAN-ATC-06080-0020, Issue 1.3, 8 April 2004.

[RD11] *VISTA IR Detector Controller Technical Specification,* VIS-SPE-ATC-06020-0005, Issue 3.0, 23 April 2004.

[RD12] *VISTA IR Camera Focal Plane Subsystem Design,* VIS-DES-RAL-06031-0002, Issue 2.0, November 2003.

[RD13] *VISTA IR Camera Wavefront Sensors Subsystem Design,* VIS-DES-UOD-06042-0001, Issue 3.0, 8 March 2004.

1.4.2 VISTA Data Flow Documents

[RD14] *VISTA IR Camera DFS User Requirements,* VIS-SPE-20000-0001, Issue 0.5, 8 April 2004.

[RD15] *VISTA IR Camera Calibration Plan,* VIS-SPE-20000-0002, Issue 0.5, 8 April 2004.

[RD16] *VISTA DFS Data Reduction Specifications,* VIS-SPE-20000-0003, Issue 0.5, 8 April 2004.

[RD17] *Overview of VISTA IR Camera Data Interface Dictionaries*, VIS-SPE-IOA-20000-0004, Issue 0.1, 14 November 2003.

[RD18] *VISTA IR Observing Strategy*, VIS-SPE-IOA-20000-0005, Issue 0.1, 10 October 2003.

1.4.3 VISTA Documents

[RD19] *VISTA Instrument Software Requirements,* VIS-SPE-ATC-00150-0003, Issue 2.2, 25 July 2002.

[RD20] *VISTA Technical Specification,* VIS-SPE-ATC-00000-0003, Issue 2.37, 11 August 2003.

[RD21] *VISTA Software Management Plan*, VIS-PLA-ATC-00150-0006, Issue 2.0, 27 September 2001.

[RD22] *VISTA Software Architectural Design*, VIS-TRE-ATC-00150-0001, Issue 2.0, 2 October 2001.

[RD23] *VISTA Network Layout*, VIS-SPE-ATC-13040-0001, Issue 1.0, 1 September 2004.

[RD24] *VISTA Active Optics and Guiding Control Functional Specification,* VIS-SPE-ATC-13030-0002, Issue 1.1, 28 October 2003.

[RD25] *VISTA Active Optics and Guiding Workstation Software Detailed Design,* VIS-SPE-RAL-13030-0003, Issue 2.3, 28 May 2004.

1.4.4 ESO-VLT Documents

[RD26] *VLT Instrument Software Specification*, VLT-SPE-ESO-17212-0001, Issue 2.0, 12 April 1995.

[RD27] *VLT Software Programming Standards*, VLT-PRO-ESO-10000-0228, Issue 1.0, 10 March 1993.

[RD28] *VLT Software Management Plan,* VLT-PLA-ESO-00000-0006, Issue 2.0, 21 May 1992.

[RD29] *VLT Instrumentation Control Software — Relevant Documents (web page)*, see http://www.eso.org/projects/vlt/sw-dev/ins_doc/ins_doc.html.

[RD30] *VLT Software Requirements Specification*, VLT-SPE-ESO-10000-0011, Issue 2.0, 30 September 1992.

[RD31] *Data Flow for VLT/VLTI Instruments Deliverables Specification*, VLT-SPE-ESO-19000-1618, Issue 2.0, 22 May 2004.

[RD32] *VLT Common Software Overview*, VLT-MAN-ESO-17200-0888, Issue 1.0, 17 August 1995.

[RD33] *VLT INS Common Software Specification*, VLT-SPE-ESO-17240-0385, Issue 2.1, 15 July 1996.

[RD34] *VLT Guidelines for the Development of VLT Application Software*, VLT-MAN-ESO-17210-0667, Issue 1.2, 8 October 2001.

[RD35] *VLT Telescope Control System (TCS) User Manual*, VLT-MAN-ESO-17230-0942, Issue 2, 22 March 2002.

[RD36] *TCS AutoGuiding and Field Stabilisation Design Description*, VLT-SPE-ESO-17230-0933, Issue 3.0, 10 April 2000.

[RD37] *VLT Active Optics Design Description*, VLT-SPE-ESO-17210-1173, Draft, 20 October 1997.

[RD38] *VLT High Level Operating Software (HOS) / Sequencer User Manual*, VLT-MAN-ESO-17220-0737, Issue 3, 28 March 2002.

[RD39] *VLT High Level Operating Software (HOS) / Broker for Observation Blocks (BOB) User Manual*, VLT-MAN-ESO-17220-1332, Issue 4, 19 April 2004.

[RD40] *VLT Software Template Instrument Software User & Maintenance Manual*, VLT-MAN-ESO-17240-1973, Issue 4, 31 March 2003.

[RD41] *Base Observation Software Stub (BOSS) User Manual*, VLT-MAN-ESO-17240-2265, Issue 4, 5 April 2004.

[RD42] *VLT INS Common Software for Templates — User Manual*, VLT-MAN-ESO-17240-2240, Issue 4, 31 March 2004.

[RD43] *VLT INS Common Software Configuration Tool (ctoo) — User Manual*, VLT-MAN-ESO-17240-2235, Issue 4, 31 March 2004.

[RD44] *VLT INS Common Software Startup Tool (stoo) — User Manual*, VLT-MAN-ESO-17240-2153, Issue 4, 31 March 2004.

[RD45] *VLT INS Common Software / Base ICS (icb) User Manual*, VLT-MAN-ESO-17240-0934, Issue 5, 31 March 2004.

[RD46] *VLT Phase 2 Proposal Preparation Tool (P2PP) User Manual,* VLT-MAN-ESO-19200-1644, Issue 3, 30 January 2003.

[RD47] *IRACE-DCS User Manual*, VLT-MAN-ESO-14100-1878, Issue 1.4, 5 December 2003.

[RD48] *VLT Real Time Display — User Manual,* VLT-MAN-ESO-17240-0866, Issue 2.8, 16 May 1999.

[RD49] *VLT Central Control Software (CCS) User Manual,* VLT-MAN-ESO-17210-0619, Issue 2.4, 31 March 2004.

[RD50] *VLT Extended CCS User Manual*, VLT-MAN-ESO-17210-0770, Issue 1.8, 30 September 2001.

[RD51] *VLT INS Common Software / Setup Files and FITS Log Handling (SLX) User Manual,* VLT-MAN-ESO-17240-0726, Issue 2, 25 March 2003.

[RD52] *VLT INS Common Software / Objective SLX (OSLX) User Manual,* VLT-MAN-ESO-17240-0853, Issue 3, 26 March 2004.

[RD53] *VLT CCS Event Toolkit* — EVH User Manual, VLT-MAN-ESO-17210-0771, Issue 1.8, 6 October 2001.

[RD54] *VLT Tools for Automated Testing (TAT) User Manual,* VLT-MAN-ESO-17200-0908, Issue 1.4, 15 February 2001.

[RD55] *VLT Configuration Management Module (CMM) User Manual,* VLT-MAN-ESO-17200-0780, Issue 2.0, 22 October 2001.

[RD56] *VLT Software Installation Tool for VLT Software Packages (pkgin) — User and Maintenance Manual*, VLT-MAN-ESO-17240-1913, Issue 4, 31 March 2004.

[RD57] *Final Layout of VLT Control LANs*, VLT-SPE-ESO-17120-1355, Issue 2, 21 July 2003.

1.4.5 Interface Control Documents

[RD58] *ICD between the VLT Control Software and the Observation Handling System*, VLT-ICD-ESO-17240-19200, Issue 1.3, 7 June 2000.

[RD59] *ICD between Instrumentation Software and VLT Archive System*, VLT-ICD-ESO-17240-0415, Issue 1.0, 14 Sept. 1995.

[RD60] *Data Interface Control Document*, GEN-SPE-ESO-19400-794, Issue 2.0, 21 May 2002.

[RD61] *VISTA IR Camera to IRACE Software Interface Control Document*, VIS-ICD-ATC-06081-5001, Issue 0.5, 26 March 2004.

[RD62] *IR Camera to VISTA Telescope Control System Interface Control Document*, VIS-ICD-ATC-06000-13010, Issue 1.02, 16 September 2004.

1.4.6 OmegaCAM Documents

[RD63] Baruffolo, A, Bortolussi, A., De Pizzol, L. and Magagna, C., *"Design of the OmegaCAM Instrument Software"*, Proc SPIE 4848, 2002.

[RD64] Baruffolo, A, Bortolussi, A., Bagnara, P. and Magagna, C., *"OmegaCAM Instrument Software: implementation and integration"*, Proc SPIE 5496-12, 2004.

[RD65] *"OmegaCAM Instrument Software Functional Specification"*, VST-SPE-OCM-23100-3062, Issue 1.2, 31 October 2001.

[RD66] *"OmegaCAM Observation Software Design Description"*, VST-SPE-OCM-23100-3064, Issue 1.1, 31 October 2001.

[RD67] *"OmegaCAM Guide and Image Analysis Software Design Description"*, VST-SPE-OCM-23100-3065.

1.5 Abbreviations and Acronyms

To save duplication, all the VISTA IR software abbreviations and acronyms have been collected into one document, [RD3].

1.6 Glossary

To save duplication, all the VISTA IR software definitions have been collected into one document, [RD3].

2 OVERVIEW

2.1 Requirements and Constraints

The Observation Software has to coordinate the actions of all the other IR Camera software modules with the TCS and the data handling software in response to the commands and parameters that it receives from the higher level software. It has to:

- execute commands/parameters received from the Broker for Observation Blocks (BOB, [RD39]) or from the operator;
- allow an observation to be aborted, via a command received from BOB;
- coordinate the actions of the IRACE DCS, ICS and TCS;
- configure the instrument hardware via the ICS;
- configure the telescope (target coordinates, guide star and aO star information and LOWFS configuration information, etc…) via the TCS;
- control the acquisition of science and calibration data via the IRACE DCS;
- ensure ancillary data is included in the FITS headers;
- notify the VLT On-line Archive (VOLAC) of the availability of new data;
- provide a graphical user interface for the operator;
- generate observation logs.

The sequencer scripts provided as part of the Observation Software work package are executed by BOB. These scripts have to:

- extract configuration information from the parameters supplied with the Observation Block;
- configure the instrument and/or telescope by sending SETUP commands to the Observation Software;
- execute science observations by sending commands to the Observation Software and (occasionally) the TCS;
- execute HOWFS observations, by sending commands to the Observation Software, HOWFS image analysis subsystem and the TCS;
- forward HOWFS coefficients to the TCS;
- abort an observation when interrupted by the operator;
- use the template libraries described in [RD42] (see also [RD38]).

2.1.1 Software Requirements Traceability Table

The following tables associate design features described in this document with software requirements listed in [AD1].

2.1.1.1 General Software Requirements

Software Requirement	Design Feature	Reference
SWR 2.1.1.01 SWR 2.1.2.01 SWR 2.1.3.01 SWR 2.1.3.02	The software conforms to the standard ESO-VLT software architecture and ESO-VLT programming standards and guidelines, [AD1], [RD26] and [RD27].	Applies to all the Software.
SWR 2.1.2.01 SWR 2.3.02 SWR 2.4.02	Existing ESO-VLT software will be reused wherever possible.	Applies to all the Software.

SWR 2.5.03 SWR 2.7.1.05 SWR 2.7.2.03		
SWR 2.11.02 SWR 2.11.03	The software will be delivered with the required documentation.	Applies to all the Software.
SWR 2.1.2.02 SWR 2.2.1.01	The software design is compliant with existing ESO-VLT hardware and allows the instrument to be operated from the Paranal control room.	Section 6
SWR 2.1.4.01 SWR 2.1.4.02 SWR 2.1.4.03 SWR 2.5.09	The software will be designed to be robust and reliable and tolerant of faults.	Applies to all the Software.
SWR 2.7.1.01 SWR 2.7.1.02	The software will conform to ESO-VLT and VISTA safety requirements, [AD1], [AD3] and [RD19].	Applies to all the Software.
SWR 2.2.1.02 SWR 2.2.1.03 SWR 2.2.1.04	The VISTA IR Camera software is designed to be independent of any other instrument.	Applies to all the Software.
SWR 2.11.01	All external interfaces will be specified and conform to ESO-VLT requirements, [AD1], [AD2], [RD58], [RD59], [RD60], [RD61] and [RD62].	Section 3.2

2.1.1.2 Observation Planning and Scheduling Requirements

Software Requirement	**Design Feature**	**Reference**
SWR 2.2.2.01 SWR 2.2.2.05 SWR 2.2.2.02	The Observation Software will normally be operated automatically by commands and parameters sent from BOB and the scheduler. An Observation Block will completely specify an observation so that no additional information is required from the operator. Intervention by the operator will only be sought if something goes wrong (e.g. poor guide star signal detected or a critical device fails).	Section 8.
SWR 2.2.2.03 SWR 2.2.2.04	The Observation Software can also be controlled directly by the operator using the GUI. However, it is normal practice for BOB to be used to start or restart an observation. The operator can use the OS GUI to abort an observation once it has started. An automatic operation should be interruptable within the 10 minute goal, *depending on the interruption capabilities of the underlying subsystems*.	Section 3.2.1
SWR 2.2.2.06	The Observation Software will supply a template signature file stating the instrument's capabilities so	Section 8.

	the ESO-VLT scheduling software can check each Observation Block before submitting it.	
SWR 2.2.2.07	The Maintenance Software will include a self-test procedure which the operator can run at the beginning of each night to check that all systems are ready for science observations.	Section 3.4.1
SWR 2.2.2.09	The Observation Software will check that the camera and telescope have successfully reconfigured before starting an observation.	Section 3.4

2.1.2 Global operations

Software Requirement	Design Feature	Reference
SWR 2.2.3.01	The instrument engineering GUI will allow any single mechanism to be operated during detector readout for EMI noise pickup testing. *This is more of an engineering requirement on the ICS and DCS GUIs than an OS requirement.*	
SWR 2.2.3.02	The Observation Software will query the ICS for the focus adjustment necessary after placing a new science filter in the beam and will command the TCS to make the focus adjustment.	Section 3.4
SWR 2.2.3.03	The VISTA IR Camera software will be capable of synchronising the readout from the detectors so that (in the event of electromagnetic interference) the AG, LOWFS and science detectors do not read out at the same time. *Achieving the requirement depends on each detector controller (IRACE or TCCD):* • *providing a "reading out" signal* • *allow its readout to be suspended on demand.* *This requirement is TBC – pending an actual EMI measurement. See [RD13]for details.*	Section 3.4.5

2.1.3 Monitoring and logging

Software Requirement	Design Feature	Reference
SWR 2.2.4.01 SWR 2.2.4.02	The Observation Software will maintain a nightly log recording	Section 5.8

SWR 2.2.4.04 SWR 2.2.4.05 SWR 2.2.4.09 SWR 2.2.4.10	• all observations, including calibrations • telescope motions • camera configurations • faults • weather monitoring information (provided by the TCS). The ESO-VLT CCS logging facility, [RD49] and [RD52], will be used to write the logs. The log will record the effect of any faults (e.g. non-operating detectors), or the status of the data (e.g. record the area of sky not covered). Each nightly log is expected to be transmitted to Garching during the following day.	
SWR 2.2.4.03	The Observation Software will also maintain a nightly engineering log recording • significant camera parameters, such as detector temperatures, cryostat temperatures, cryostat vacuum and TTL signals (such as the power fail, cabinet cooler failure and UPS activated event) • any instrument faults The information will be sufficient for an engineer to be able to follow the instrument status through the night and diagnose any problems. It will also be sufficient to monitor the change of performance of the instrument from night to night.	Section 5.8
SWR 2.2.4.07	All faults will be reported to the telescope operator as soon as they are detected.	
SWR 2.2.4.11	The Observation Software GUI will allow the operator to access real time status displays giving - The instrument configuration, status and health. - Sky and environmental conditions. - A "quick look" display of the latest science data. *Achieving this requirement assumes that the ICS, TCS and DCS provide screens containing this information.*	Section 3.2.1

2.1.3.3 Observation Software Requirements

Software Requirement	Design Feature	Reference
SWR 2.4.01	The Observation Software will	Section 3

	(a) be controllable from BOB, via Observation Blocks, in the manner described in [RD38], [RD39] and [RD58]. (b) configure the instrument hardware via the ICS. (c) control the operation of the telescope via the TCS. (d) control the operation of the guider and LOWFS via the TCS (through sequencer scripts), supplying guide star candidates. (e) control the acquisition of science and calibration data via the IRACE DCS. (f) control the acquisition of high resolution wavefront sensor data via the IRACE DCS. (g) control the processing of HOWFS data and the transfer of wavefront coefficients to the TCS (through sequencer scripts). (h) ensure ancillary data is included in the FITS headers. (i) provide a graphical user interface for the operator. (j) generate observation logs.	Section 4
SWR 2.4.02	(a) The OS will be based on the Base Observation Software Stub [RD41] provided by ESO. (b) The OS will run on the Instrument Workstation.	Section 3 Section 6
SWR 2.2.2.10 SWR 2.4.04	The Observation Software will operate efficiently: (a) It (or the sequencer) will allow concurrent operations where these are sensible (e.g. filter wheel movement concurrent with telescope movement). (b) It will be designed so any software delays are much less than the instrument and telescope reconfiguration time and do not therefore drive the observation overhead time. (c) The Observation Software will be designed to maximise survey speed.	Section 3.4

2.1.3.4 Data Handing Requirements

Software Requirement	Design Feature	Reference
SWR 2.10.04	The Observation Software must be allow the IRACE DCS to achieve its performance target of sustaining the storage of one exposure to disk every 10 seconds for 14 hours. The OS must be capable of assembling and adding the FITS header information at the same	Section 7

	rate.	
SWR 2.10.05	The Observation Software will ensure adequate free disk space is available to store data before an exposure is initiated.	Section 3.4
SWR 2.10.06	The Observation Software will allow the storage of data from one observation to be overlapped with the configuration of the telescope and instrument for the next observation.	Section 3.4
SWR 2.10.09	The Observation Software will comply with the requirements stated in ESO's Data Interface Control Document, [RD60].	Section 5
SWR 2.9.02	The templates and sequencer scripts provided by the Observation Software will acquire and store all data necessary to reduce the data fully, as specified in the *VISTA IR Camera Calibration Plan*, [RD15].	Section 8.
SWR 2.10.10 SWR 2.2.4.06	The Observation Software will ensure that sufficient metadata is included for each exposure to be completely identified and its data reduced automatically, as specified in the Data Interface Dictionaries, [RD17]. This information will be provided in the data header and within the log files stored alongside the data. The log file belonging to each set of data will be identified. The existence of missing or poor quality data will be indicated in the data headers	Section 5

2.2 Observing Strategy

The Observation Software needs to control the instrument and obtain data in a manner that is compatible with the VISTA IR observing and data reduction strategy outlined by the Data Flow project and described in [AD2] , [RD18] and [RD14].

- The basic data unit is a single IRACE exposure[1] made at a single telescope "pointing".
- Multiple exposures can be taken at the same telescope position and coadded.
- Multiple exposures may be combined together while "microstepping" (i.e. shifting the telescope by an exact fraction of a detector pixel) to make a microstepped exposure (Figure 1 below). The observer can choose from a selection of microstep patterns.

[1] The exposure can itself be made from a series of coadded integrations, but any pre-processing of the data by IRACE is beyond the scope of the Observation Software.

Microstepping is used in exceptional seeing conditions to increase the sampling of the data, and frames taken with microstepping are designed to be interleaved together.

- Multiple exposures may be combined together while "jittering" (i.e. shifting the telescope by small amounts less than the field of view of the guide star) to make a jittered map (Figure 2 below). The observer can choose from a selection of different jittering patterns. Jittering is used to reduce the effect of bad pixels and cosmic ray events, and also used to determine the sky background.

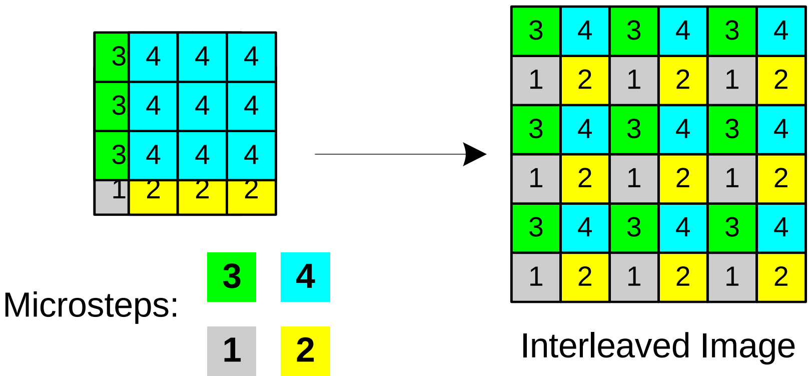

Figure 1 Combining Exposures with Microstepping

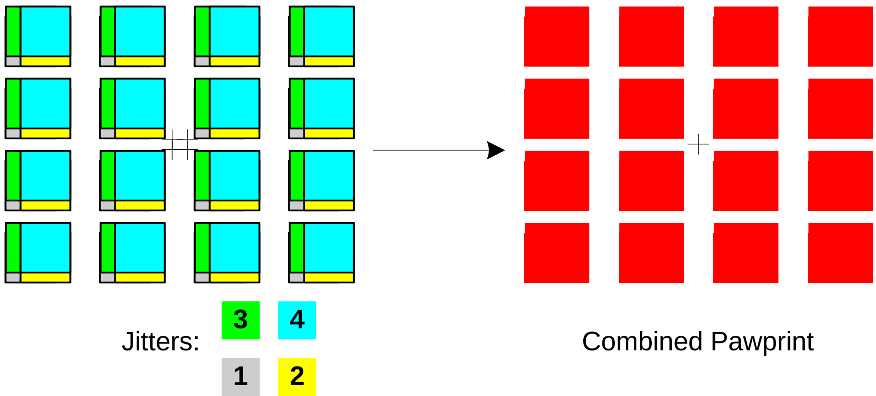

Figure 2 Combining Exposures with Jittering

- An observation that results in a non-contiguous image of the sky from the 16 detectors, made with or without jittering and microstepping, is known as a "pawprint". Six such pawprints may be combined together while offsetting the telescope by amounts which fill in the gaps between the detectors to make a "tile" (Figure 3 below).

- Observations can be made with different science filters.

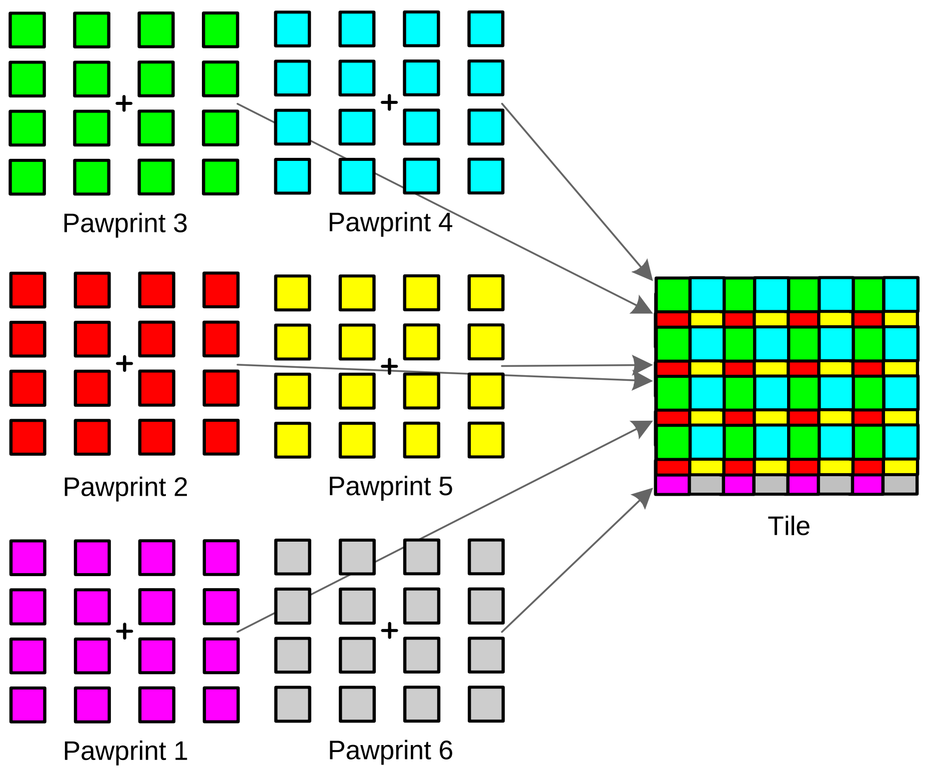

Figure 3 Combining Pawprints to make a Contiguous Tile

The VISTA IR Camera software allows all these operations to be nested together in different ways to support different observing strategies (see [RD14] for details). The most useful options are listed in Table 1 below, using the shorthand “F” to indicate a filter exchange loop, “T” to indicate a tile observation loop, “P” to indicate a pawprint observation loop, “J” to indicate a jitter loop, “M” to indicate a microstep loop and “E” to indicate an exposure loop. In practise “E” is always nested with “J” and “P” is always nested within a “T” (by definition). The most efficient observations are those with “JME” as the inner loop. Jittering and microstepping are optional, and there will normally be one exposure at the lowest nesting, so the entire “JME” loops can sometimes consist of just one exposure.

Nesting order	Description
• **FTPJME**	Make a survey from a series of tiles using one science filter, then change the filter and observe the same tiles again. Construct each tile from pawprints which may be jittered and microstepped. This is an efficient way of building up a survey. It is suitable for shallow surveys where variations in the colour of the sky background don’t require each field to be reobserved in different colours as quickly as possible, and you can afford to keep the science filter fixed.

	Procedure: For each filter (e.g. Y, J, H, Ks) Select filter For each tile Preset telescope to tile centre For each pawprint (e.g. 1 to 6) Offset telescope to pawprint centre Acquire new guide and aO stars For each jitter (1 to J) Offset telescope to jitter centre For each microstep Offset telescope to microstep centre For each exposure (1 to E, normally 1) Make exposure and save data Next exposure Next microstep Next jitter Next pawprint Next tile Next filter
• **TFPJME**	Make a survey from a series of tiles in which each tile is observed in all the required filters before moving on to the next tile. Construct each tile from pawprints which may be jittered and microstepped. This is also an efficient way of building a survey when you need each tile to be observed in several successive colours. Procedure: For each tile Preset telescope to tile centre For each filter (e.g. Y, J, H, Ks) Select filter For each pawprint (e.g. 1 to 6) Offset telescope to pawprint centre Acquire new guide and aO stars For each jitter (1 to J) Offset telescope to jitter centre For each microstep (1 to M) Offset telescope to microstep centre For each exposure (1 to E, normally 1) Make exposure and save data Next exposure Next microstep Next jitter Next pawprint Next filter

	Next tile

• **TPFJME**	Make a survey from a series of tiles, only this time repeat each pawprint making up the tile in all the required filters before moving on to the next pawprint.
	
	This is a less efficient way of building a survey because it involves more filter wheel moves, but it may be necessary when observing conditions are changing rapidly.
	
	Procedure: For each tile
	  Preset telescope to tile centre
	  For each pawprint (e.g. 1 to 6)
	    Offset telescope to pawprint centre
	    Acquire new guide and aO stars
	    For each filter (e.g. Y, J, H, Ks)
	      Select filter
	      For each jitter (1 to J)
	        Offset telescope to jitter centre
	        For each microstep (1 to M)
	          Offset telescope to microstep centre
	          For each exposure (1 to E, normally 1)
	            Make exposure and save data
	          Next exposure
	        Next microstep
	      Next jitter
	    Next filter
	  Next pawprint
	Next tile

• **TFJPME**	Make a survey from a series of tiles in which each tile is observed in all the required filters before moving on to the next tile, in the same manner as "TFPJME". This time put the jittering loop outside the pawprint loop, which means that each tile is constructed from a large number of pawprints whose positions are arranged to cover the required jittering pattern. Each pawprint can also be microstepped.
	
	This strategy is relatively inefficient, since the guide and aO stars need to be reacquired frequently, but it is useful for maintaining good spatial flatness when observing conditions are changing.
	
	Procedure: For each tile
	  Preset telescope to tile centre
	  For each filter (e.g. Y, J, H, Ks)
	    Select filter
	    For each jitter (1 to J)
	      Offset telescope to jitter centre

	For each pawprint (e.g. 1 to 6) Offset telescope to pawprint centre Acquire new guide and aO stars For each microstep (1 to M) Offset telescope to microstep centre For each exposure (1 to E, normally 1) Make exposure and save data Next exposure Next microstep Next pawprint Next jitter Next filter Next tile

Table 1 Alternative Strategies for Survey Observations

In practice, the procedures described in the above table will be optimised so that the selection of a science filter can be overlapped with telescope movements, and several successive telescope moves (e.g. for jittering and microstepping at the same time) will be made as one.

All the observing strategies are described by the same basic set of parameters:

- Number of tiles to be observed.
- List of filters.
- Pawprint pattern ID, giving the number and positions of pawprints, and size of pawprint pattern.
- Jitter pattern ID, giving the number and offsets of jitters, and size of jitter pattern.
- Microstep pattern ID, giving number and offsets of microsteps, and size of pattern.
- Number of exposures.

The camera software will have a number of pre-defined pawprint, jitter and microstep patterns from which the observer can make a selection.

3 ANALYSIS

3.1 *Context*

Data flow diagrams for the entire VISTA IR software may be found in [AD2]. Figure 4 shows the context of the Observation Software. Observations are made by executing sequencer scripts within BOB. The sequencer scripts normally result in commands being sent to the Observation Software, which in turn configures the TCS, ICS and DCS subsystems. In addition, the sequencer scripts can make small adjustments to the TCS (e.g. turning autoguiding on or sending a focus offset) by sending commands directly to the TCS. The sequencer scripts can communicate with an on-line data reduction process; the HOWFS image analysis system in the case of the VISTA IR camera. The telescope operator may interrupt the observing process through the GUI.

The raw data files from each observation are stored to disk by the DCS. The Observation Software collects FITS header information and adds it to the raw data. Observation logs are also written to disk. When each observation is complete a "newdata" signal is sent to the VLT on-line archive system (VOLAC), which makes the data available to the VISTA Data Flow System for processing.

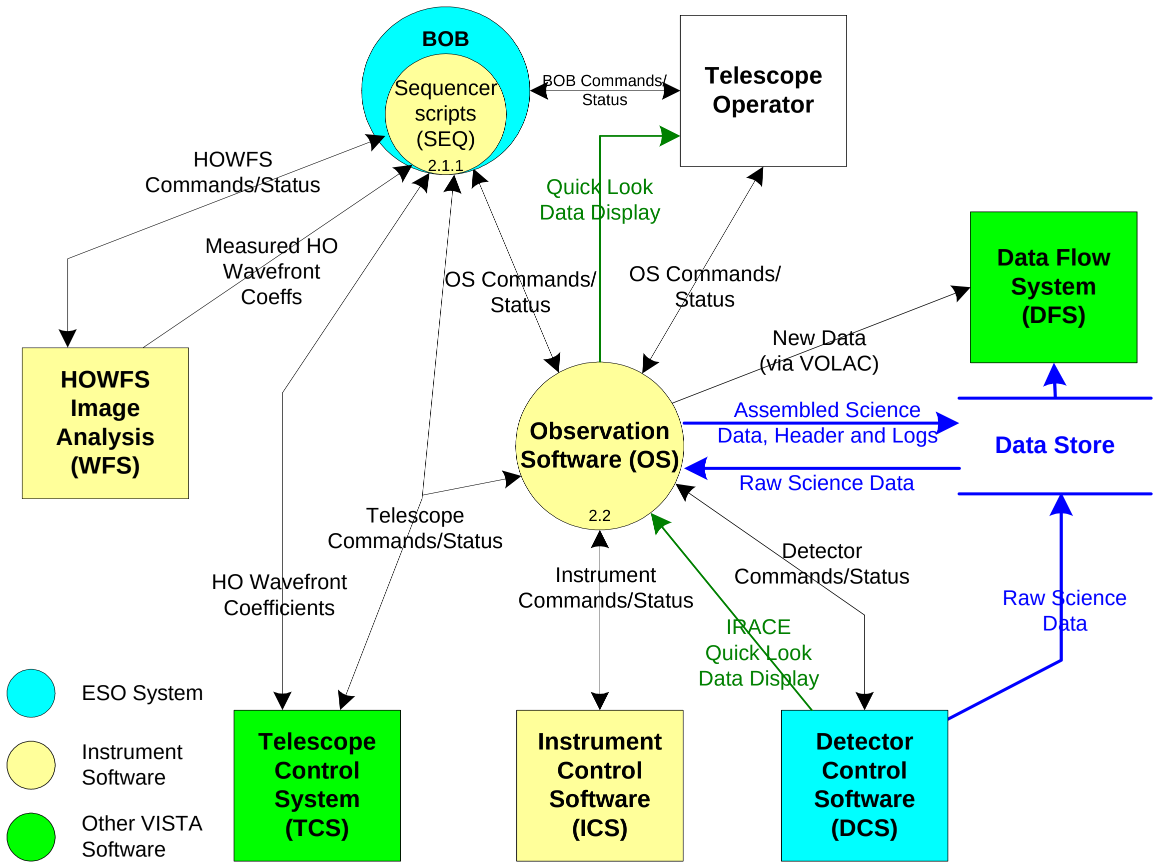

Figure 4 VISTA IR Camera Observation Software Context

The Observation Software decomposes into three parts, as shown in Figure 5.

- The OS GUI (module "vcopan") supplies the operator with a graphical user interface. It provides status information and allows the operator to issue engineering commands.

The other two processes are part of the "vco" module:

- The OS Server process (vcoControl) is based on the bossSERVER class supplied by the BOSS package. It is responsible for instrument configuration, state handling and command handling and for coordinating the underlying subsystems.

- The OS Archive process (bossArchiver_vco) is based on the BOSS archiver process[2]. This is responsible for collecting FITS header information and adding it to the raw data, signalling the on-line archiver (VOLAC) when the data are available for processing. It is also responsible for assembling the IRACE data for each observation and writing it into a single multi-extension FITS file.

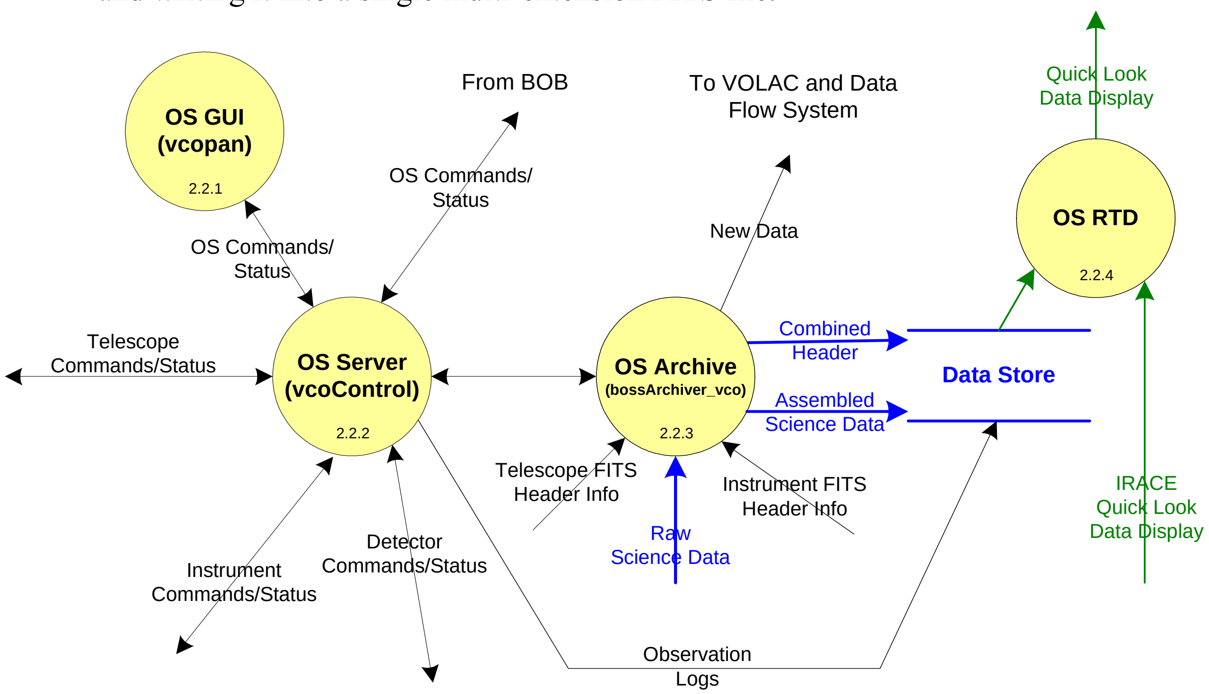

Figure 5 Decomposition of the VISTA IR Camera Observation Software

3.2 *Interfaces*

3.2.1 User Interfaces

The telescope operator interacts with the Observation Software using the OS GUI, through which OS commands can be executed and the status of the OS and its subsystems can be displayed.

3.2.1.5 OS Control Screen

The OS Control Screen is the top level control screen for the VISTA IR Camera. It should be a compact screen but have all the facilities a telescope operator would need frequent access to. The screen has to provide controls to allow the operator to:

- Change the overall state of the OS to "STANDBY" or "ONLINE" or cleanly shut down the software (OFF command).

[2] BOSS archiver is named this way for historical reasons but its real function is a file handler process.

- END or ABORT the current observation. (N.B. It is normal practice to start or restart an observation by interacting with BOB rather than the OS screen, see [RD39]).
- Add a comment to the observation log.
- Start up the OS engineering screen (which in turn leads to the ICS, DCS and HOWFS engineering screens and the TCS simulator screen).
  - Note that in normal operation ICS, DCS and HOWFS parameters are defined either in a configuration file read during software startup or in the templates processed by BOB. Adjusting instrument parameters by any other means is an engineering activity only.
  - The TCS simulator screen is used for testing the software in the absence of the real VISTA TCS. In normal operation the VISTA TCS screen will have been started separately on the telescope control workstation.
- Start up the ICS instrument status screen.
- Start up the DCS status screen.
- Start up the HOWFS status screen.
- Plus any other frequently used commands.

In addition, the OS control screen needs to display the following status items:

- The state, substate, access and simulation mode of all the instrument subsystems and TCS.
- The current instrument mode.
- The current exposure ID, exposure status, exposure time, remaining exposure time and data file name.
  - More detailed detector parameters can be queried by bringing up the DCS status screen.
  - Template information will be displayed on the BOB screen ([RD39]).
- A disk space monitor[3].
- The current telescope coordinates.
  - More detailed telescope information can be queried by looking at the TCS console running on the telescope control workstation.
- The currently selected filter.
  - Other mechanism details can be queried by bringing up the ICS status screen.
- The current cryostat window temperature (compared with current dewpoint) and focal plane temperature.
  - Other temperatures and instrument sensor readings cane be queried by bringing up the ICS status screen.
- Any alarms reported by the instrument.
  - There should be a means of finding out more about an alarm by bringing up a status screen.

[3] It has been suggested that the VISTA IR Camera disk space monitor should report the disk space available in terms of number of exposures that may be stored, as well as in Mbytes.

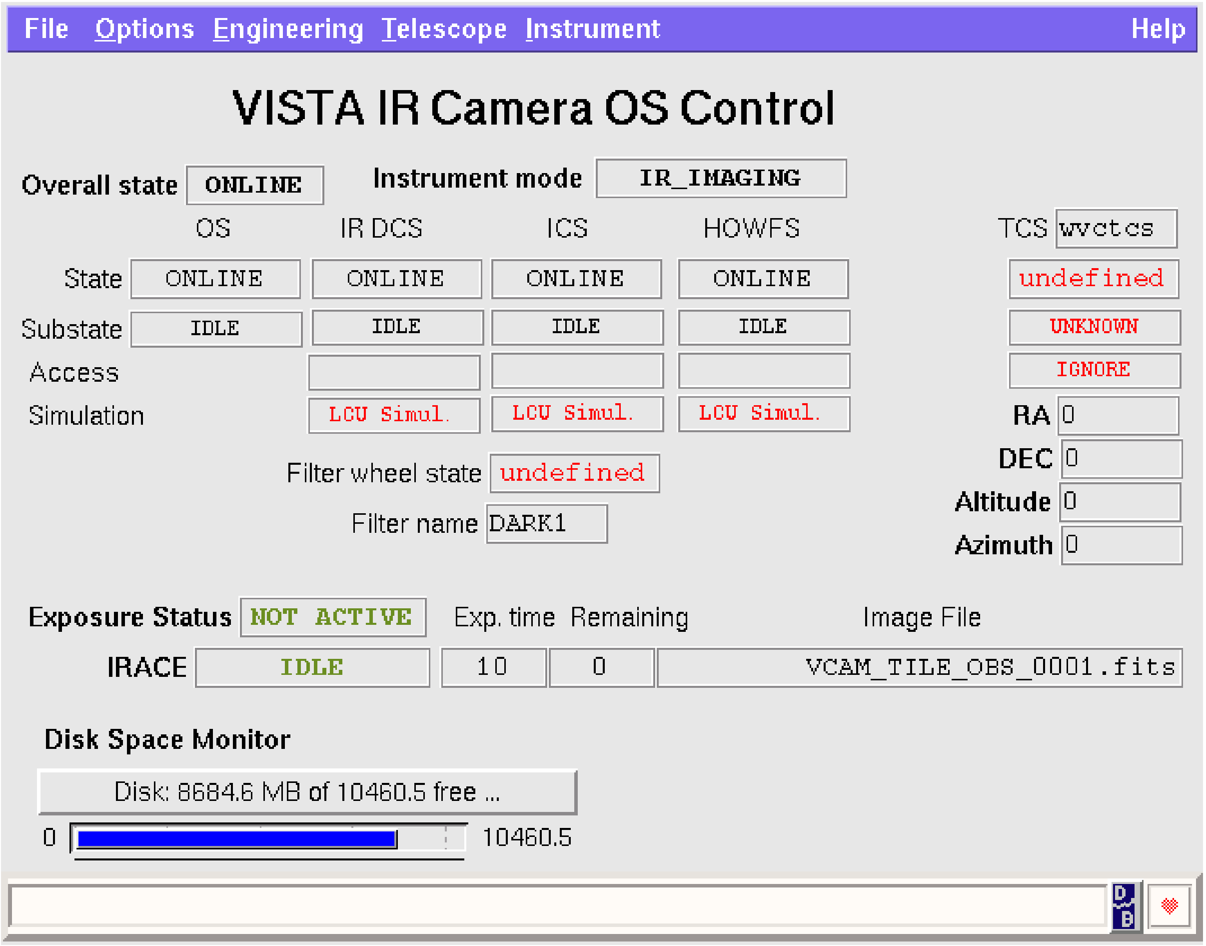

Figure 6 A Possible OS Control Screen

Figure 6 shows a possible OS control screen, based on the screen supplied by the ESO-VLT template instrument. The screen needs enhancing to include all the facilities mentioned above (and also needs updating to reflect the actual modes and templates described in this document), but gives the gist of what the OS screen will look like.

3.2.1.6 OS Engineering Screen

In addition to the standard OS Control Screen, there will be an OS engineering screen allowing access to the facilities needed for diagnosis, maintenance and testing of the instrument. The screen needs to provide controls or links to other screens to allow the operator or engineer to:

- Execute any OS command.
- Interrogate any database point.
- Check the instrument status in detail.
- Start up any subsystem status screen.
- Start up any subsystem engineering screen.
- Start up other VLT engineering screens.

- Interrogate the engineering log.
- Run a diagnostic test on the instrument.

3.2.2 Interface with BOB and Observation Handling System

The interface between the ESO observation handling software and instrument software is described in the "*ICD between the VLT Control Software and the Observation Handling System*", [RD58].

The Observation Software also supplies the ESO-VLT Observation Handling Software with the following files:

- **Instrument summary file** (VIRCAM.isf) containing a summary of the capabilities of the instrument (filters that may be selected, allowed ranges for detector temperature, readout modes of detector, etc.). This file will contain the lists of predefined tile, jitter and microstep patterns.

- For each instrument mode, a **reference setup file** (VIRCAM_<mode>_xxx.ref) giving all the parameter settings (for template xxx) necessary to make an exposure in that instrument mode.

- For each instrument template, a **template signature file** (VIRCAM_<mode>_xxx.tsf) describing the parameters and procedure necessary to execute that template.

- One or more **template sequencer scripts** (VIRCAM_<mode>_xxx.seq) associated with the instrument templates.

The Phase 2 Proposal Preparation Tool (P2PP) software, [RD46], allows an Observer to define observations to be made by the instrument by selecting templates and assigning values to the parameters associated with each template. The template signature files, instrument summary file and reference setup files are used to build an "Observation Block" describing each observation, as shown in Figure 7 below. More details about the templates supplied with the VISTA IR Camera may be found in Section 8 on page 50.

BOB receives Observation Blocks and executes the template sequencer scripts. BOB interacts with the Observation Software by sending standard commands and parameters as described in Section 3.3.

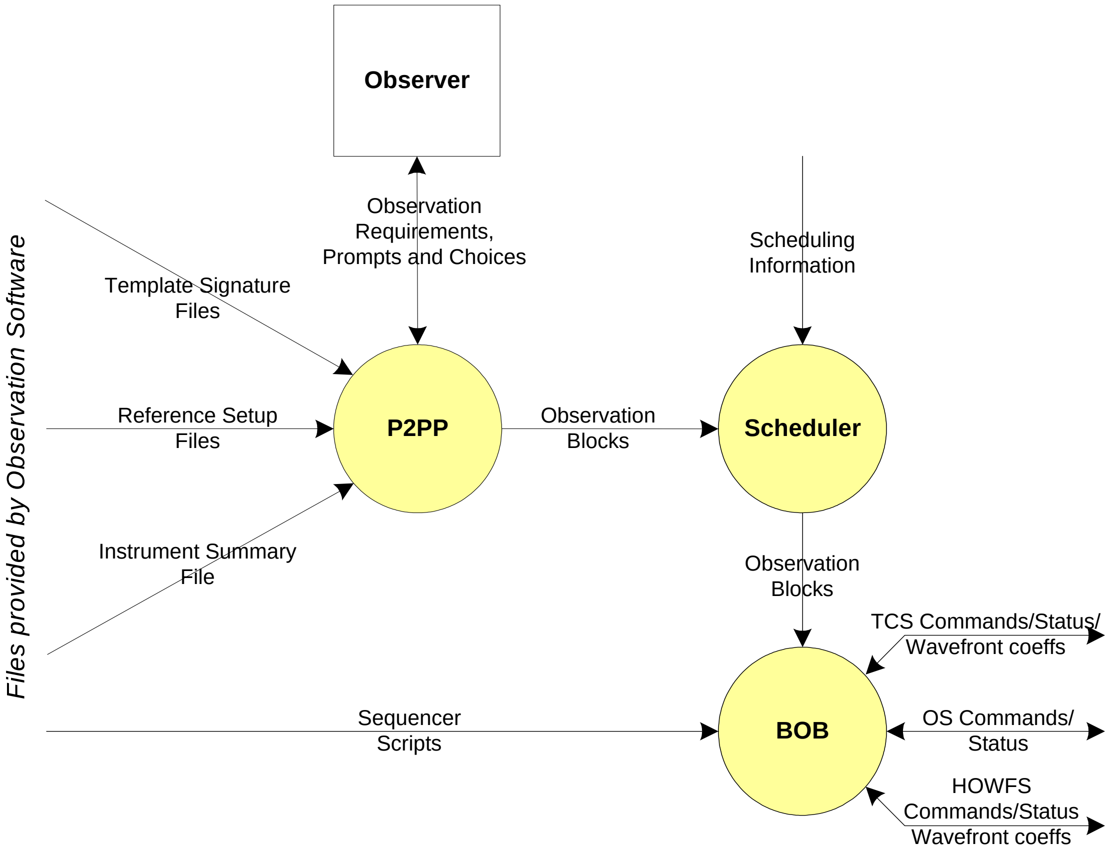

Figure 7 Use of Observation Software files by ESO-VLT Observation Handling System

3.2.3 Interface with TCS

The VISTA Telescope Control System (TCS) is based on the existing ESO-VLT TCS described in [RD35] and has very much the same interface with a science instrument. The interface is described in detail in the interface control document, [RD61]. Sequencer scripts implement the interface using functions in the “tplTCS” library described in [RD42] The Observation Software needs the following operations to be possible over this interface:

- Preset the telescope by supplying to the TCS the required [RA, Dec, Epoch, Equinox, Radecsys] of a pointing centre, plus the position angle of the instrument Y axis[4]. The TCS responds by pointing so the required field centre falls on the focal plane at the rotator axis.

[4] The exact definition of the position angle is outside the scope of the camera software but should be robust enough to be stable near the celestial poles. It is used to set the rotator angle so the observer’s image has the correct orientation on the sky. Default should be N at the top and E to the left on a detector image. The parameter will be extracted by the OS from each acquisition template and passed on to the TCS.

- Preset the telescope by supplying to the TCS the required [RA, Dec, Epoch, Equinox, Radecsys, Proper motion, Effective wavelength and (X,Y)[5] in the focal plane in instrument coordinates] of an object to be acquired. The TCS responds by pointing so the specified object falls at the specified (X,Y) on the focal plane.
  - This pointing method can be used to ensure that a guide star falls on a particular detector pixel.
- Preset the telescope to an altitude and azimuth suitable for taking a twilight flat-field.
- Present the telescope to point to the dome screen and switch on the required level of illumination.
- Offset the telescope by providing a [ΔRA, ΔDec], ensuring that the (X,Y) axes maintain the same position angle in focal plane coordinates so there is a seamless overlap (to allow accurate jittering and offsetting (see [AD2]). Getting the correct overlap will be especially important when observing near the celestial pole.
  - ~~The VISTA TCS receives offsets in terms of [ΔRA, ΔDec]. The camera software will need to convert [ΔX, ΔY] in instrument coordinates into [ΔRA, ΔDec] using a formula provided by the TCS work package.~~ ???
- Instruct the TCS to drift at a specified non-sidereal rate specified as a (ΔRA/s, ΔDec/s). This is needed for open loop tracking of a non-sidereal object.
- Offset the telescope focus by supplying to the TCS a focus offset for the currently selected science filter.
- Instruct the TCS to drift the rotator so that trailed exposures can be made for engineering purposes, to verify the location of the rotator centre.

The Observation Software will need to query the following status information from the TCS:

- Obtain from the TCS the current altitude and azimuth of the telescope (if required for flexure correction).
- Obtain from the TCS sufficient information (e.g. pointing direction, rotator angle, plate scale, etc.) to derive a mapping of each science detector pixel into (RA, Dec), and hence be able to store World Coordinate information along with the data.
- Obtain FITS header information (e.g. airmass at start, moon phase, angular distance from the moon) at the start of an observation (EXPSTART).
- Obtain FITS header information (e.g. airmass at end, average airmass, average seeing, guide and aO star quality measured during observation) at the end of an observation (EXPEND). This header information should flag whether there have been any periods of open loop active optics correction during the observation due to poor aO star quality.

There is a requirement to wait for a LOWFS measurement cycle to complete after moving the telescope by a “significant elevation change”. It is assumed that the TCS will handle this, since the OS does not know anything about previous observations or telescope elevations.

[5] (X,Y) coordinates in the focal plane are specified in instrument coordinates in millimetres, as described in the “Software Functional Specification”, [AD2]. The X axis points towards the central axis of filter wheel.

3.2.4 Interface with VLT On-line Archive (VOLAC) and Data Flow Software

The Observation Software will inform the VLT on-line archive (VOLAC) each time a new observation file is available. The standard BOSS interface described in [RD41] will be used, which consists of writing the name of the new file to a "newdata" database point. A full description of the interface is described in the "*ICD between Instrumentation Software and VLT Archive System*", [RD59].

Besides telling VOLAC when new data are available, the VISTA IR Camera also needs to provide information about the structure of the data and the information supplied, in the following categories:

- Format of raw data.
- Format of header information supplied with the raw data.
- Format of observing logs and any other ancillary information saved alongside the data.

Instructions for how to supply this information and described in the "*Data Interface Control Document*", [RD60]. The VISTA IR Camera data description will be documented in an VISTA IR Camera Data interface dictionaries, [RD16].

3.2.5 Interface with ICS

The VISTA IR ICS is described in detail in the *"IR Camera Instrument Control Software Design Description Document"*, [RD5], which contains a detailed list of the commands recognised. The following features are needed on this interface:

- Put a science filter in the beam.
- Put an intermediate filter in the beam at a specified angular offset.
- Put any filter in the loading position.
- Define the cryostat tube or detector target temperature, or put the ICS into "detector protection mode".
- Get FITS header items (e.g. name and ID of filter in beam, important instrument temperature and pressure readings) at exposure start (EXPSTART) and exposure end (EXPEND).
- Get the ICS status.

3.2.6 Interface with DCS

The IRACE detector controller software is described [RD46] and its requirements for the VISTA IR Camera are described in [RD11]. The IR Camera to IRACE software interface is described in detail in [RD61]. An overview is given here. The following features are needed on this interface:

- Specify integration time (DIT) and number of integrations (NDIT). The exposure time is DIT x NDIT.
- Specify readout mode and readout speed.

- Specify region of interest (window) to be read (from one or more science detectors – same window on each detector).
- Specify path and file name for data, plus file naming mode.
- Set a FITS header item.
- Get the DCS status.

The Observation Software is responsible for completing the FITS header and for:

- specifying the location of each science detector on the focal plane;
- specifying the World Coordinates coefficients for each detector (using information obtained from the TCS, as described in Section 3.2.3 on page 27).

Broken detectors must be identified by the IRACE DCS in the FITS header and the data saved in a format such that broken detectors do not cause a problem further down the data processing pipeline (see Section 5.6 on page 46).

3.2.7 Interface with HOWFS Image Analysis

The interface to the HOWFS image analysis system comes from the sequencer scripts rather than from the Observation Software itself. The HOWFS image analysis system is treated in a similar manner to an on-line data reduction system such as MIDAS.

The HOWFS image analysis system is described in detail in "*IR Camera High Order Wavefront Sensing Software Design Description*", [RD7]. The following features are needed on this interface:

- Define the files containing the current HOWFS bad pixels and flat-field measurements.
- Trigger a HOWFS image analysis measurement with the ANASTAR command, specifying the name of a file containing HOWFS data. This file should contain header information describing:
    - a unique ID for each exposure.
    - the location of the HOWFS star in the focal plane and the orientation of the HOWFS special filter.
    - the region of interest on the science detectors.
- Read back the HOWFS wavefront coefficients.
- Read back the HOWFS status (state, substate, health etc…).
- ~~Get FITS header items (if any) at exposure start (EXPSTART) and exposure end (EXPEND).~~

The HOWFS states are: OFF, LOADED, STANDBY, ONLINE (see the "*VISTA IR Camera Software Functional Specification*", [AD2]).

3.3 *Commands*

3.3.1 Standard BOSS commands

The VISTA IR Camera Observation Software is based on the BOSS and therefore obeys all the standard BOSS commands described in the following tables. These commands are described in detail in [RD37]. Some parameters that are irrelevant for the VISTA IR Camera (such as the detector controller ID[6], -detId, are not described here).

3.3.1.7 State changing commands

The standard instrument states are described in [RD32] and [AD1]. The STANDBY state is normally used during the daytime while the instrument is running but not operational and the ONLINE state is the night time operational state. The instrument can be monitored in the STANDBY or ONLINE state, but can only be controlled from the ONLINE state. The software is in the LOADED state when it has yet to be initialised or is about to be shut down.

Command	**Parameters**	**Description**
OFF	Change state of whole instrument or subsystem to OFF. Returns OK	
	-subsystem <string>	Subsystem to forward command to (optional)
ONLINE	Change state of whole instrument or subsystem to ONLINE. Returns OK	
	-subsystem <string>	Subsystem to forward command to (optional)
STANDBY	Change state of whole instrument or subsystem to STANDBY. Returns OK	
	-subsystem <string>	Subsystem to forward command to (optional)
STATE	Return the state/substate of the instrument or a subsystem. Returns state	
	-subsystem <string>	Subsystem whose state is to be examined (optional)

[6] Since there is only one science detector controller – the IRACE DCS.

3.3.1.8 Instrument configuration and observation commands

Command	Parameters	Description
ABORT	Abort all currently running actions as soon as possible. Exposures are terminated without saving data. A “WAIT” command is recommended after this command. (See also END). Returns OK	
	-expoId <integer>	ID of exposure to be aborted (optional). Defaults to current exposure.
ADDFITS	Add information to the FITS header. Returns OK	
	-expoId <integer>	ID of exposure whose header is to be modified (optional). Defaults to current exposure.
	-info <keyword> <value> [<keyword> <value>]	List of keywords and values to be added to the FITS header[7].
COMMENT	Add a comment to the FITS header. Returns OK	
	-expoId <integer>	ID of exposure whose header is to be modified (optional). Defaults to current exposure.
	-clear	If argument present, clear any previous comment strings.
	-string <string>	String to be added to FITS header.
END	End current exposure as soon as possible and save data. Cancels an exposure that has been set up but not yet started. (See also ABORT). Returns OK	
	-expoId <integer>	ID of exposure to be ended (optional). Defaults to current exposure.

[7] These keywords must have been defined in the IR Camera Data Interface Dictionary, which is where their data types are specified.

FORWARD	Forward command to subsystem. Returns <string> reply from subsystem	
	-subsystem <string>	Subsystem to forward command to
	-command <string>	Command to be forwarded
	-arguments <string>	Command arguments to be forwarded
SETUP	Configure the instrument. *(This is the main configuration command).* Returns expoId <integer>	
	-expoId <integer>	ID of exposure (compulsory!). New exposure defined if specified as zero.
	-function <keyword> <value> [<keyword> <value>]	Define a list of instrument keywords and values to be assigned (optional). In particular INS.MODE declares the instrument mode.
	-file <filename>	Define a file containing a list of keywords and values to be interpreted (optional).
	-noMove	If argument present, do not move?
	-check	If argument present, check configuration only. Do not adopt it.
START	Start or repeat exposure at an optional time. Returns OK	
	-expoId <integer>	ID of exposure to be started (optional). Defaults to most recently defined exposure.
	-at <string>	Time when exposure to be started (optional)
STATUS	Get the status of the functions specified in the list of arguments. Returns <string> containing list of <keyword1>,<value1>, <keyword2>,<value2>, etc…	
	-expoId <integer>	ID of exposure whose status is to be queried (optional). Defaults to current exposure.
	-function <string>	List of instrument keywords whose status is to be queried.
WAIT	Wait for specified exposure to finish. Returns expStatus <integer>	
	-expoId <integer>	ID of exposure to wait for (optional). Defaults to current exposure.

	-header	If argument present, wait only for the header to be collected, even if the detectors are still reading out.

3.3.1.9 *Miscellaneous commands*

Command	Parameters	Description
EXIT	Shut down the Observation Software control processes. Returns OK	
PING	Test presence of Observation Software. Does nothing except return a reply string. Returns OK	
SELFTST	Self-test the software without moving any mechanism (minor self-test). The subsystems are PINGed to ensure they are responding and then the SELFTST command is forwarded to them all in turn. Returns OK	
VERBOSE	Switch verbose mode on or off. Returns OK	
	ON/OFF	
VERSION	Return the OS software version. Returns the version string.	

3.3.2 Additional VISTA IR specific commands

None known.

3.4 Dynamic Model

The sequence diagrams show how the Observation Software will accomplish various tasks. The simpler tasks are described first in chronological order, building up to a description of the more complex tasks.

3.4.1 Beginning of night systems check

The beginning of night self-test is run by Paranal staff using the Maintenance Software supplied with the instrument. The Maintenance Software uses the INS.TEST parameters defined in the instrument configuration files (see Section 5.1 on page 43) to send a series of self-test commands to the ICS Server.

3.4.2 Instrument setup

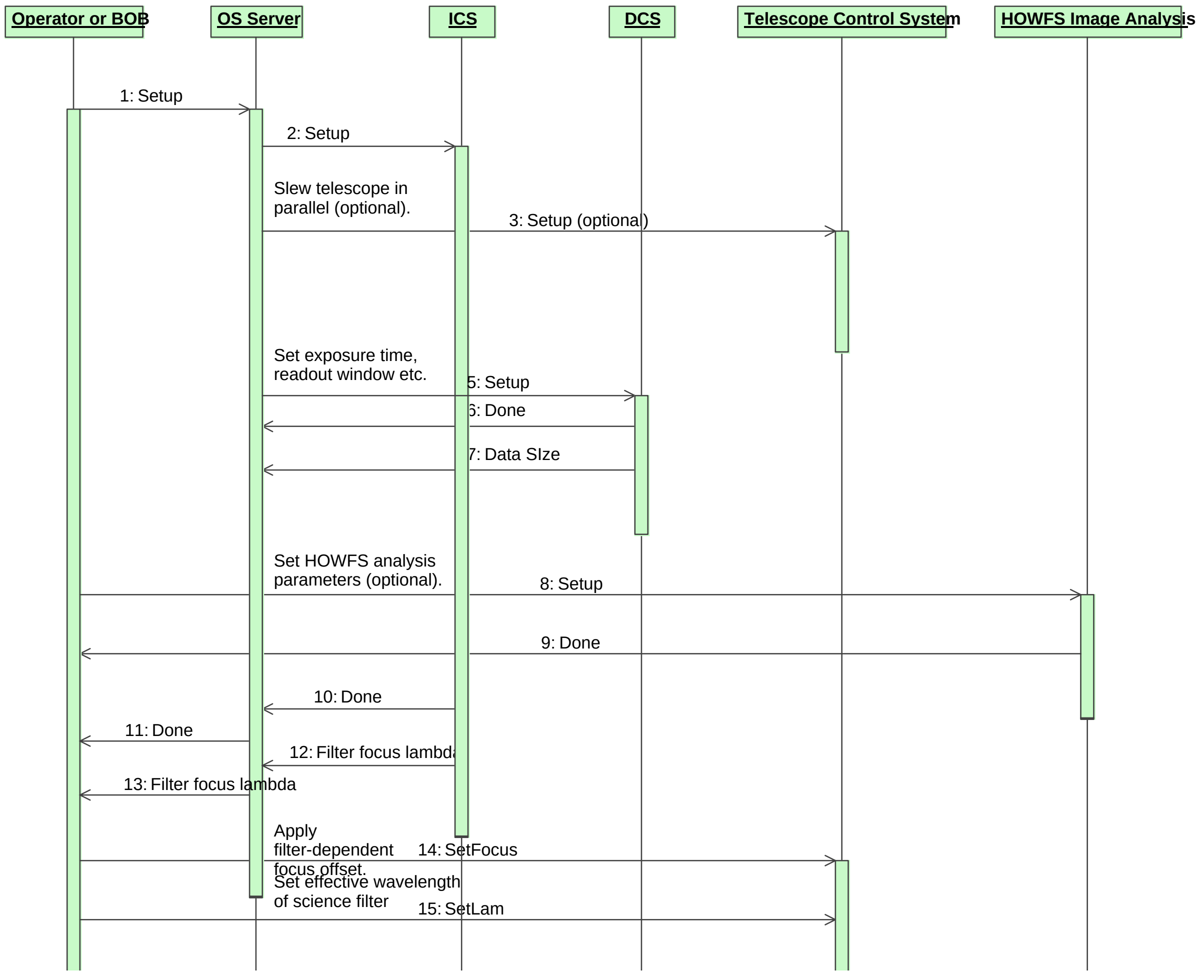

Figure 8 Sequence Diagram — Configure Instrument

Figure 8 above shows how the instrument is configured. BOB executes a template sequencer script which sends the OS a SETUP command with a complete set of parameters describing the new instrument configuration (using a variation of the "tplOBS" procedure described in [RD42]). The OS forwards the SETUP command to the ICS, along with an ICS subset of parameters, and the ICS starts reconfiguring. If the SETUP command contains TCS and DCS parameters, then the TCS and DCS are also reconfigured in parallel. When ready, the OS waits for the ICS, TCS and DCS to finish configuring, and when all its subsystems has successfully adopted the new configuration the OS reports a "Done". The ICS returns the focus offset and effective wavelength for the currently selected science filter, which the sequencer script forwards to the TCS. The detector controller returns a parameter indicating the size of a single exposure made at the current configuration parameters. If necessary, the sequencer script will configured the HOWFS image analysis system separately.

3.4.3 Acquire target — Preset

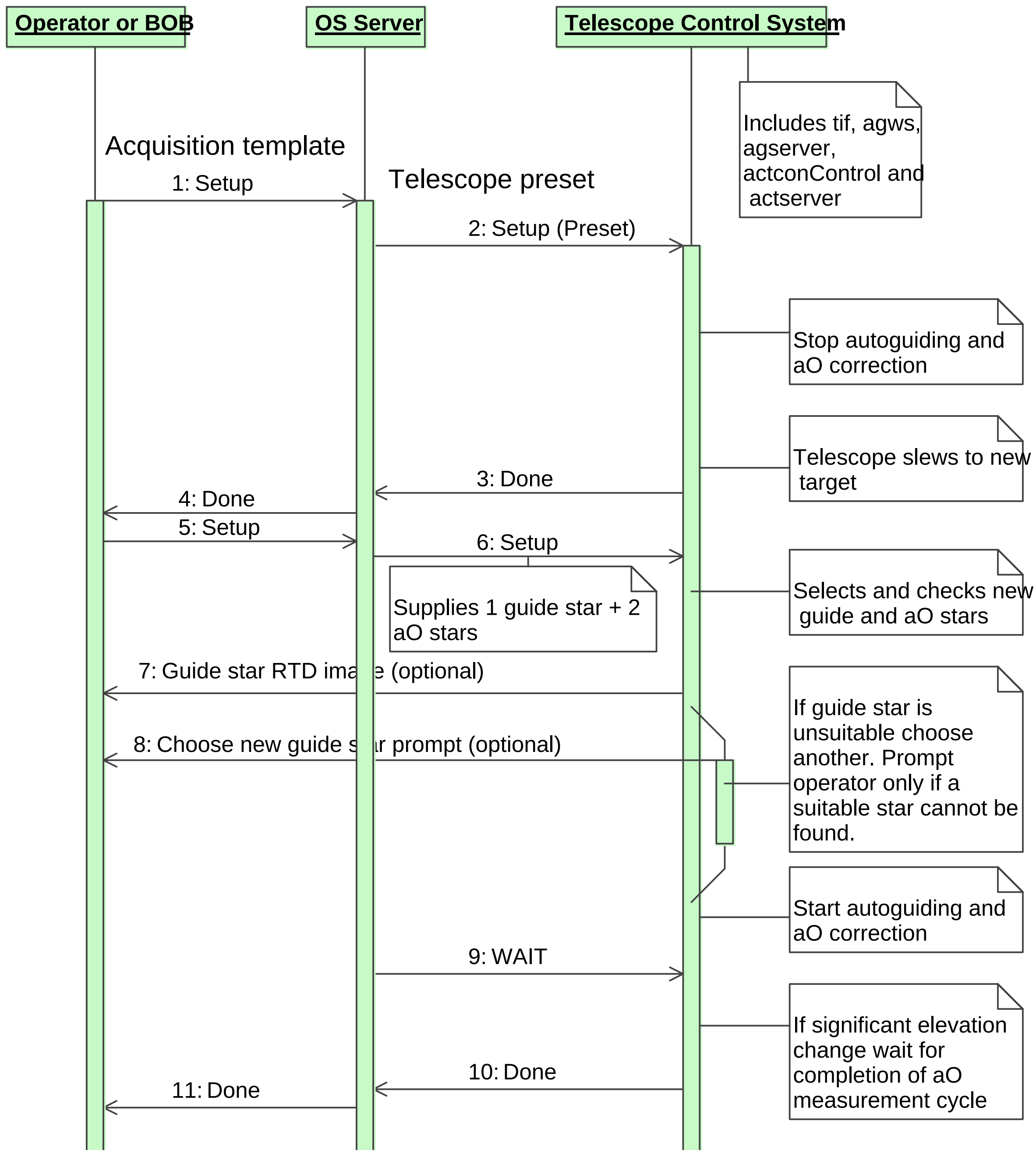

Figure 9 Sequence Diagram — Acquire Target with Preset

Figure 9 above shows the sequence of events the OS goes through to acquire a new target using a telescope preset (i.e. acquiring a target that requires a considerable slew of the telescope). (See also Section 3.2.3 describing the OS to TCS interface). While executing a "preset" acquisition template, BOB executes a template script with a set of parameters describing a new acquisition target (using a variation of the "tplTCS" procedure described in

[RD42]). The target coordinates are forwarded to the TCS as a "Setup" command and the TCS in turn configures its subsystems. The TCS slews to the new target. The TCS is then provided with the parameters describing the guide and aO stars, in a second "Setup" command, and automatically locks on to them. If the guide star is found to be unsuitable a new one is chosen. The operator may be interrupted if the TCS is unable to find a suitable guide star. Autoguiding and active optics correction are automatically started. If a significant elevation changes has taken place the TCS will automatically wait for an aO cycle to complete. When it is ready, the OS waits for the TCS to finish acquiring the target. and reports a "Done". See the *"VISTA Active Optics and Guiding Workstation Software Detailed Design"*, [RD25], for a detailed description of how the autoguiding and active optics is started by the TCS.

3.4.4 Acquire target — Offset and Jitter

An offset is a minor telescope pointing adjustment around an already-acquired target. This doesn't require a major slew and can therefore be carried out much more efficiently. There are two kinds of small telescope adjustments as far as the VISTA IR Camera is concerned:

- adjustments in which the telescope moves by an amount greater than the field of view (FOV) of the autoguider and LOWFS so new guide and aO stars need to be chosen.

- adjustments in which the telescope moves by an amount much smaller that the field of view of the autoguider and LOWFS so the same guide and aO stars can be used. Such a move is used for jittering and microstepping, as described in Section 2.2 on page 16.

Figure 10 and Figure 11 below shows the sequence of events for these two kinds of telescope moves while executing an acquisition template. The main difference is that when the telescope makes a large offset new guide and aO stars are provided and acquired in the same manner as a preset. Note that the sequencer script commands the telescope directly (missing out the OS) when telescope commands other than "Setup" are used.

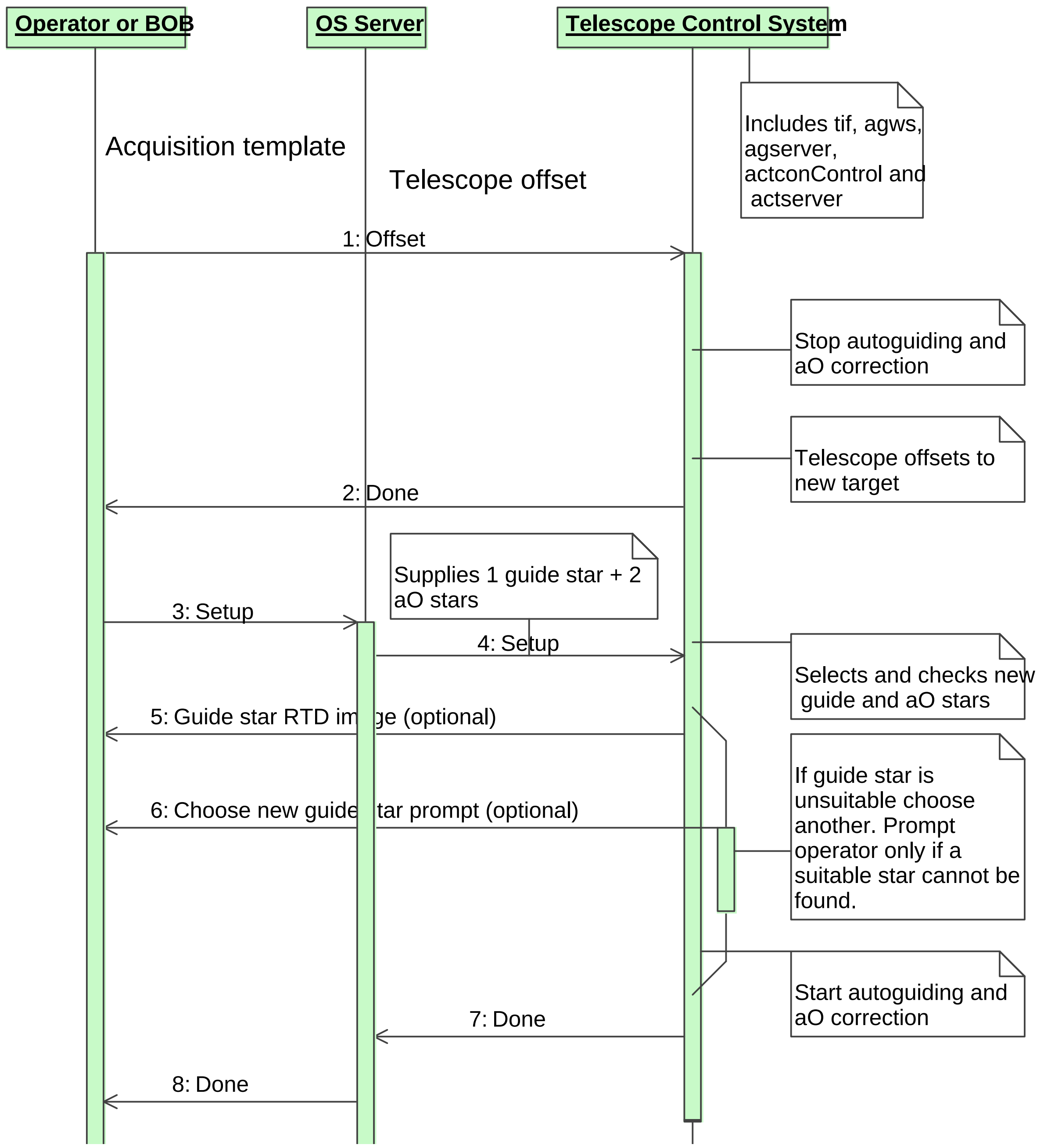

Figure 10 Sequence Diagram — Acquire Target with "Offset"

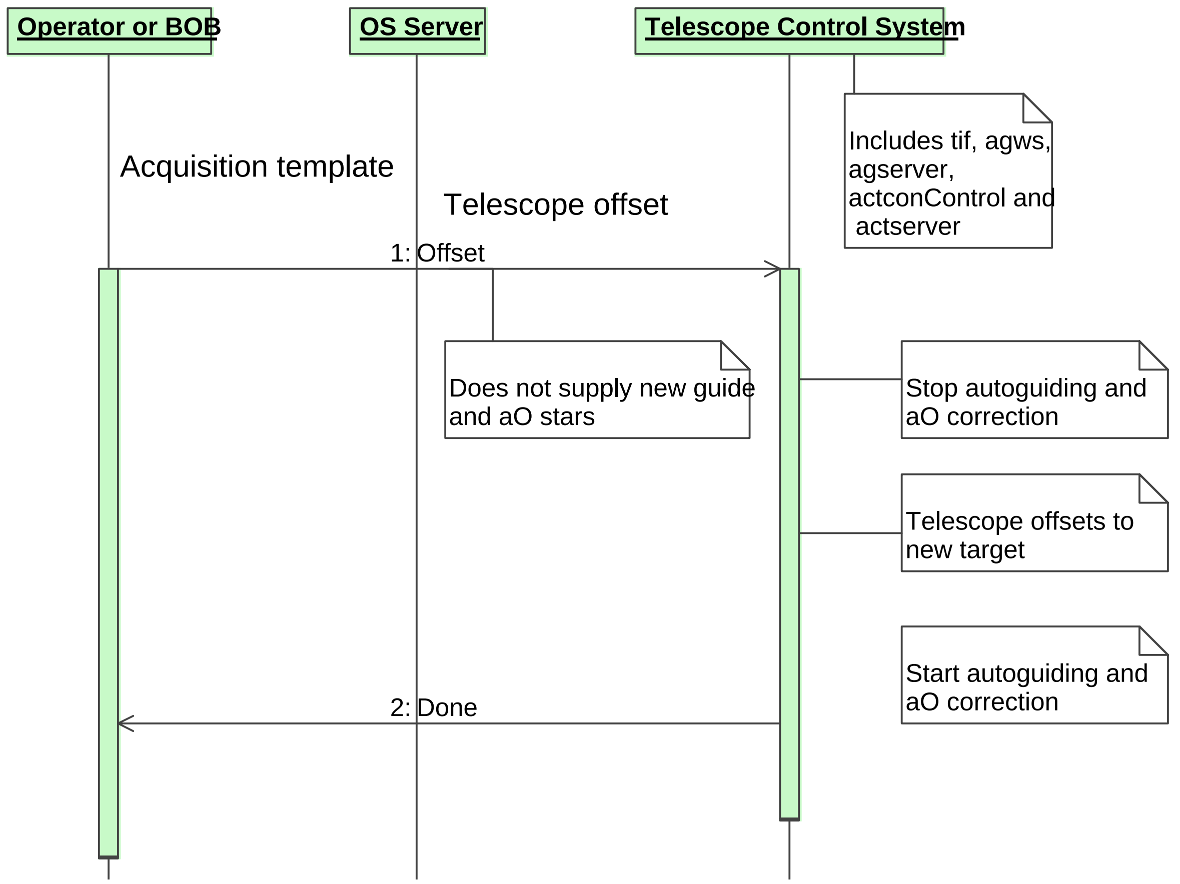

Figure 11 Sequence Diagram — Acquire Target with "Jitter" or "Microstep"

3.4.5 Autoguiding and Active Optics

Figure 12 below shows the sequence of operations during autoguiding and active optics correction, a process which happens in parallel with each science exposure. (The sequence for starting a science exposure is shown in Section 3.4.6.) Guide and aO stars will already have been acquired during a preset or offset (described in Sections 3.4.3 and 3.4.4). The sequence diagram shows how the IR Camera software systems interact with themselves and with the TCS[8] while autoguiding and active optics are operational. Details of the interaction between the TCS and agServer and actServer are not shown here, and the reader is referred to the *"VISTA Active Optics and Guiding Workstation Software Detailed Design"*, [RD25], for a complete description of how autoguiding and active optics is handled by the TCS.

Significant things to note on this diagram are that the agServer and actServer processes are constantly reporting the quality of the autoguider and LOWFS data to the TCS. If the quality falls below an acceptable threshold it is assumed the TCS will report this to the operator and will write a flag into the header it saves with the EXPEND command (Sections 3.2.3 and

[8] Note that in the context of this document "TCS" refers to everything in the TCS that is not part of the camera software — i.e. the tiff, agws and actconControl, etc.

5.6). Tracking will continue open-loop if the LOWFS data quality is unacceptable. The other significant thing is that the agServer and actServer are synchronising their readout with the IRACE DCS controller (with the DCS as master) to ensure they don't interfere with each other. *This synchronisation will only be necessary if there is electromagnetic interference (EMI) between these detectors. See [RD13] for a description of the readout synchronisation strategy*.

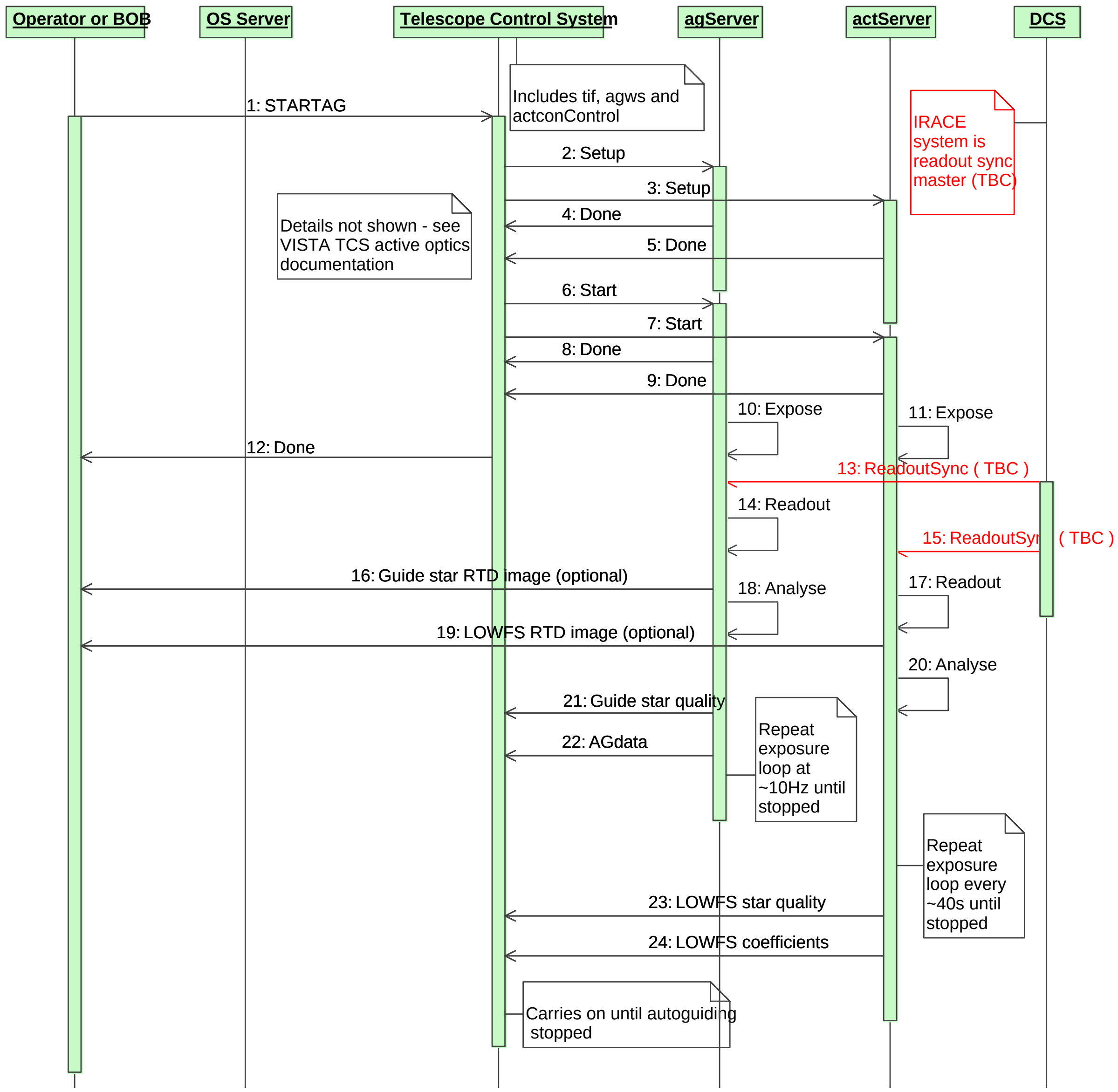

Figure 12 Sequence Diagram — Autoguiding

3.4.6 Science exposure

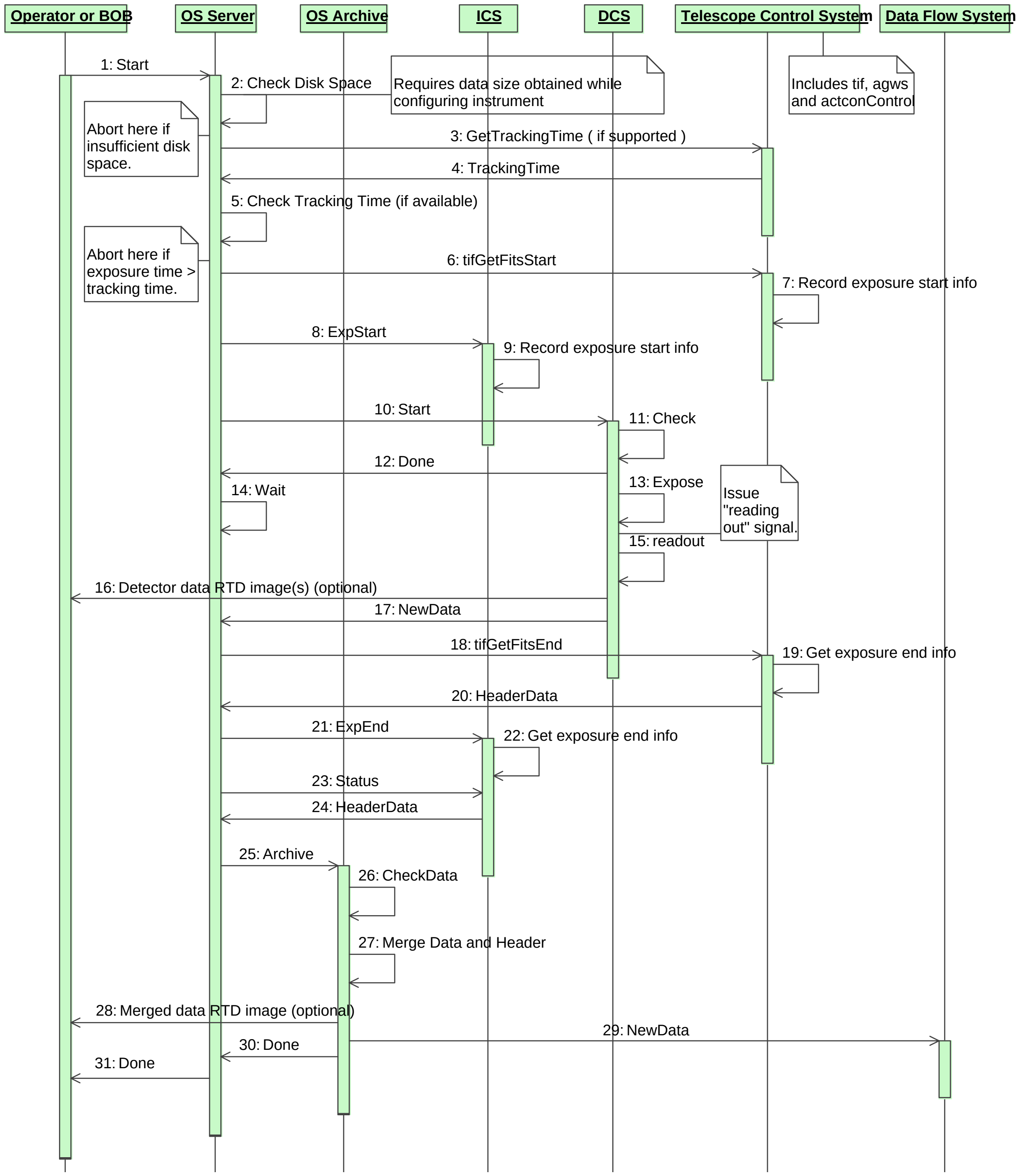

Figure 13 Sequence Diagram — Single Science Exposure

Figure 13 above shows the sequence for making a single science exposure. It is assumed that the target has already been acquired and autoguiding started as described in the previous sections. The Observation Software receives the START command and obtains the available tracking time for the current target from the TCS (if the TCS can do this). If the exposure time exceeds the available tracking time the exposure is aborted. The exposure is also aborted if there is insufficient disk space to store the data. Before starting the actual exposure, the TCS and ICS are instructed to save FITS header data. The DCS is then commanded to start the exposure. The Operator can monitor the exposure using the DCS real-time display. When the exposure completes the DCS saves the raw data and informs the OS the exposure has completed. The OS then instructs the TCS and ICS to save any FITS header information relevant to the end of the exposure. The OS Archive process is then instructed to process the data. The FITS header information is merged with the raw data and the combined data is passed on to Data Flow System (via the VLT on-line Archive, VOLAC).

3.4.7 HOWFS exposure

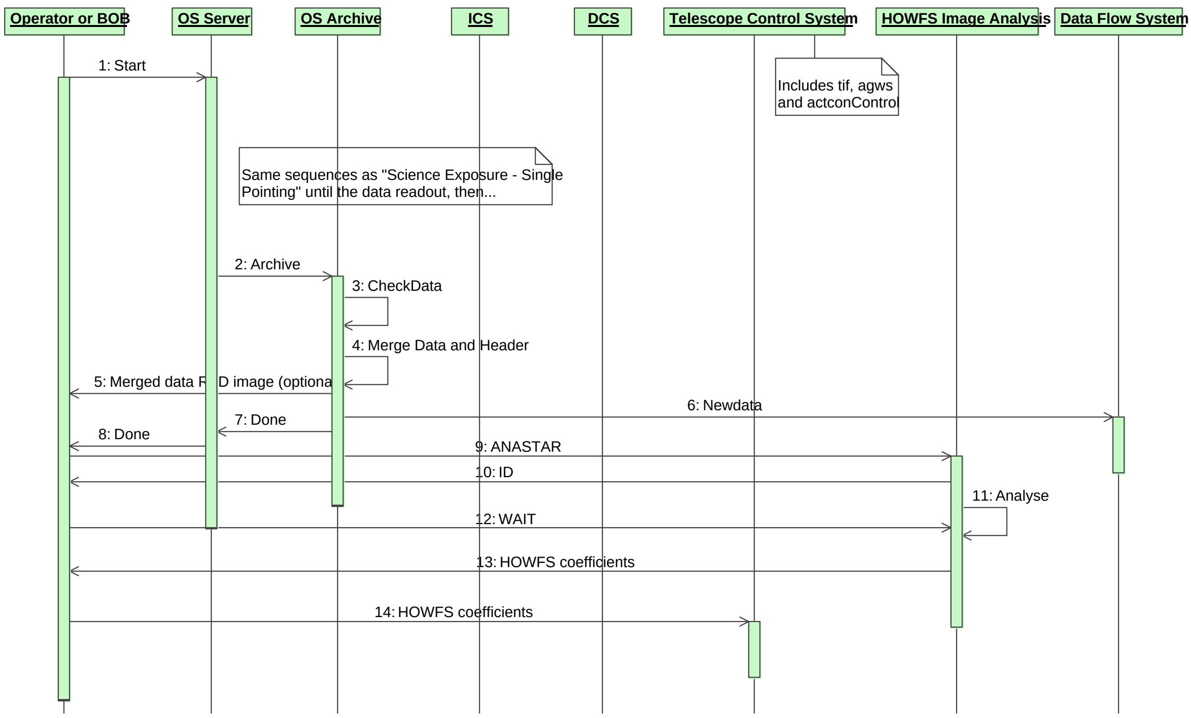

Figure 14 Sequence Diagram — HOWFS Exposure

Figure 14 shows the sequence of events that make up a HOWFS exposure. The sequence is exactly the same as for a science exposure, except that the sequencer script activates the HOWFS image analysis system after the exposure has completed; this system then processes the data and makes available the HOWFS coefficients, which are then forwarded to the TCS. The raw HOWFS data can be archived by the Data Flow System.

4 DETAILED DESIGN

The Observation Software decomposes into three parts, as shown in Figure 5 on page 23. The vcoControl process is based on the bossSERVER class supplied by the "Base Observation Software Stub" (BOSS) package [RD41].

4.1 Modules

The Observation Software breaks down into the following modules:

- **vco** — OS control module. This module contains the main control process (vcoControl) and the archiver process (bossARCHIVER_vco)
- **vcopan** — OS graphical user interface module
- **vcotsf** — OS template signature module
- **vcoseq** — OS sequencer script module
- **vcmcfg** — Instrument configuration module (for some reason classified as maintenance software)

4.2 OS Control (vcoControl)

This process is responsible for managing the subsystem interfaces. It receives commands from BOB, breaks the commands into those components targeted at the various subsystems and dispatches the commands to the subsystems. This process also listens to the underlying subsystems and generates a combined instrument status.

4.3 Archiver (bossArchiver_vco)

This process is responsible for dealing with the data generated by the IR Camera. It receives the raw data from the IRACE DCS, merges the header information saved by the subsystems with the data and notifies the VOLAC system of the availability of the new data.

This process also needs to manage a real-time display which presents a low resolution view of all 16 detectors to the observer. The ESO-VLT real-time display utility, [RD48], should be able to produce this display as long as the data header contains sensible World Coordinates information.

5 DATA DESCRIPTION

5.1 Configuration files

The VISTA IR Camera software is configured using the following configuration files, which are stored in $INS_ROOT/SYSTEM/COMMON/CONFIGFILES. See the configuration tool documentation, [RD43]:

- **vcmcfgCONFIG.cfg** — The top level configuration file, which defines all other configuration sets (i.e. configuration file and dictionary references) to be used with the instrument.

- **vcmcfgINS.cfg** — This file (and various others called vcmcfgICS_*.cfg) contains the main configuration keywords for the VISTA IR camera devices, described in detail in [RD5].

- **vcmcfgOS.cfg** — This file contains the configuration keywords describing the Observation Software interfaces, as listed in Section 5.2 below.

- **vcmcfgSTART.cfg** — This file contains the startup configuration keywords for the VISTA IR camera, such as the INS.CON.OPMODE simulation mode keyword. All the startup options are described in the BOSS documentation, [RD41], and startup tool documentation, [RD44].

The configuration files themselves contain comments describing all the configuration keywords.

5.2 Observation Software Configuration Keywords

The Observation Software uses the configuration keywords listed and described in the BOSS documentation, [RD41], and Template Instrument documentation, [RD40]. A full list is not repeated here but attention is drawn to keywords that have a special meaning for the VISTA IR Camera.

5.2.1 TCS subsystem configuration keywords

Keyword	**Type**	**Description**
OCS.TEL.NAME	string	Telescope name = 'VISTA' (not 'UT1', 'UT2', 'UT3' or 'UT4' as specified in the BOSS manual). 'UT0' is used for a simulated TCS.
OCS.TEL.FOCUS	string	Telescope focus position = 'CA' (VISTA only has a Cassegrain focus).
OCS.TEL.ID	string	TELESCOP FITS keyword defined by DICB (e.g. 'VISTA' – to be agreed).
etc…		

5.2.2 ICS subsystem configuration keywords

Keyword	**Type**	**Description**
OCS.ICS.NAME	string	Instrument control system name = 'ICS'.
etc…		

5.2.3 DCS subsystem configuration keywords

Keyword	Type	Description
OCS.DET1.NAME	string	Science detector controller name = 'IRDCS'.
OCS.DET1.TYPE	string	Science detector controller type = 'IRACE'
etc…		

5.2.4 HOWFS image analysis subsystem configuration keywords

Keyword	Type	Description
OCS.WFS.NAME	string	HOWFS image analysis subsystem name = 'HOWFS'
OCS.WFS.DICT1	string	HOWFS subsystem dictionary = 'VIRCAM_WFS'
OCS.WFS.KEYWFILT	string	Keyword filter = 'WFS.*.*.*.*.*.*'
etc…		

5.3 Instrument Operating Modes

The VISTA IR Camera will have the following instrument modes:

- **IMAGING** — An observation is made with the science detectors through any optically flat filter. This mode is used for most observations.
- **HOWFS** — An observation is made with the science detectors using a small beam-splitting filter for a HOWFS measurement.

NOTE: There isn't a separate mode for imaging with the autoguider or LOWFS detectors because in normal operation these detectors are controlled by the telescope software.

5.4 Instrument Path

ESO-VLT instruments define a path for each light path through the instrument leading to a unique detector (e.g. for instruments with separate visible and infrared channels). It is used along with the "STATUS" command for collecting the FITS header information relating to that path. The VISTA IR Camera has only one path:

- **INFRARED** — Light recorded on the infrared science detectors.

NOTE: There aren't separate instrument paths for the autoguider or LOWFS pre- and post-focus detectors because in normal operation these are controlled by the telescope software.

5.5 Database structure

Figure 15 shows the overall layout of the database structure for the VISTA IR Observation Software. The database follows the standard layout used by the Template Instrument and BOSS. The database contains the state, substate and status of all the subsystems. The "newData" database point is outside the scope of the Observation Software database but is shown here because it is used to inform VOLAC of the availability of new data files.

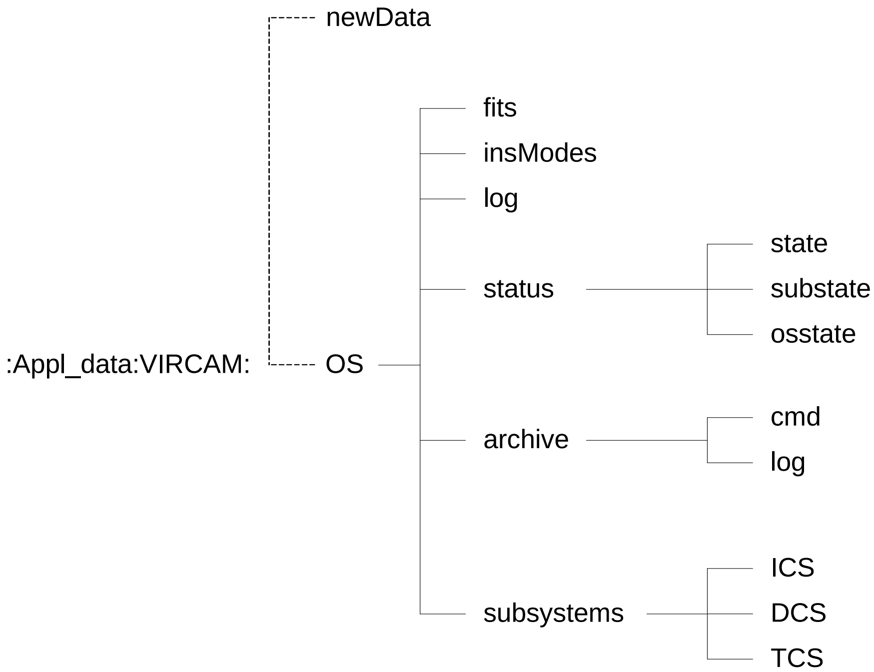

Figure 15 Top level database structure for the OS Control task.

5.6 *Data files*

Data files will be stored in $INS_ROOT/SYSTEM/DETDATA and will follow the naming convention described in *"Common Software for Templates"*, [RD42]. In general, file names have the form

<INST>_<mode>_<type>_<doy>_nnnn[_<extension>].fits

Where:

- <INST> = Instrument name (uppercase) ("VIRCAM" for the VISTA IR Camera)
- <mode> = Instrument mode (Section 5.3)
- <type> = type of observation as defined in keyword DPR.TYPE (e.g. DARK, FLAT, etc…)
- <doy> = sequential day of the year
- nnnn = unique sequential number
- <extension> = Optional file name extension.

Compare with template names in Section 8.1.

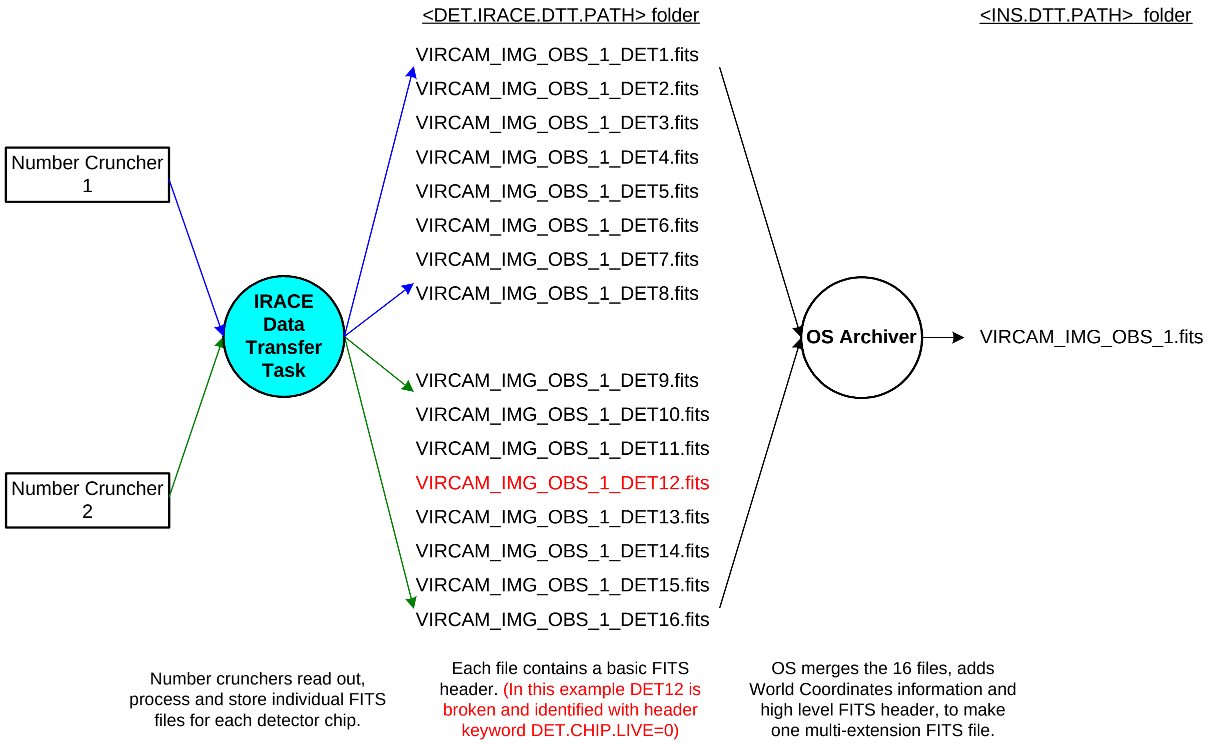

Figure 16 Data Files Merged by the Observation Software

5.6.1 Input files

The OS receives raw data as stored by the IRACE system (see the "*Detector Controller Technical Specification*", [RD11], and "*IR Camera to IRACE Software ICD*", [RD62]). The IRACE Data Transfer Task stores multiple FITS files, one for each detector, containing minimal header information stored by the IRACE software. Each file either contains the full (2028 x 2048 pixel) data array from each detector or a smaller array if a region of interest has been specified. All the detectors are read out, even if the OS is only interested in one, and all the detectors have the same region of interest and therefore data arrays of identical size and shape. All the data files must be readable even if one of the science detectors is broken. See Section 3.2.6 on page 29. A schematic view of the files received by the Observation Software is shown in Figure 16, above.

5.6.2 Output files

The OS archiver processes the raw data received from IRACE. It combines the individual files into one FITS file and adds the header information supplied by all the instrument subsystems in response to the EXPSTART, EXPEND and STATUS commands (see Section 3.2). The OS also adds World Coordinate information to the data. The result is a single raw science exposure, consisting of a multi-extension FITS file with complete header information added by the OS. The file has one extension for each detector, but for some (e.g. HOWFS) observations only one of the FITS extensions will contain useable data.

The data header is specified in the "*VISTA IR Camera Data Interface Dictionaries*", [RD16], and will conform to the requirements specified in the ESO-VLT *"Data Interface Control Document"*, [RD60]. A schematic view of the merging of the files by the Observation Software is shown in Figure 16, above.

5.6.3 Groups of files

Many of the files processed by the OS will be part of a group created by the execution of an observation block containing multiple templates, such as tile observations (Section 8.8.4). These files will be identified as being part of the group by means of these standard header keywords (see [RD17] for details).

RECIPE	Data Reduction Recipe to be used
STANDARD	Set TRUE if observation is a standard field
OBSNUM	Observation number (incremental count of exposures made this night, and also the number of the data file for this exposure).
GRPNUM	Group number (number applied to all members)
GRPMEM	Group membership (T/F)
~~NOFFSETS~~	~~Number of offsets in a pawprint~~
~~OFFSET_ID~~	~~Serial number of offset~~
NTILE	Number of pawprint positions in a tile pattern.
TILE_ID	Name of the tile pattern
TILE_I	Sequence number [1…NTILE] of this pawprint in the tile pattern.
TILENUM	Value of first OBSNUM in current tile pattern.
NJITTER	Number of positions in a jitter pattern
JITTRNUM	Value of first OBSNUM in current jitter sequence
JITTR_ID	Serial number (Name) of jitter pattern
JITTER_I	Sequence number [1…NJITTER] of this position in the jitter pattern.
JITTER_X	X offset in jitter pattern
JITTER_Y	Y offset in jitter pattern
NUSTEP	Number of positions in a microstep pattern
USTEPNUM	Value of first OBSNUM in current microstep sequence
USTEP_ID	Serial number (Name) of microstep pattern
USTEP_I	Sequence number [1…NUSTEP] of this position in microstep pattern.
USTEP_X	X offset in microstep pattern
USTEP_Y	Y offset in microstep pattern
OBS.GRP	Observation Block Group ID (if any)
OBS.ID	Observation Block ID
OBS.NAME	Observation Block name
OBS.TPLNO	Template number in Observation Block
TPL.ID	Template ID
TPL.MODE	Template mode (FTPJME, etc…)
TPL.NAME	Template name
TPL.NEXP	Number of exposures in template
TPL.EXPNO	Exposure number in template

DPR.CATG	Observation category (TEST, CALIB or SCIENCE)
DPR.TECH	Observation technique (HOWFS, SNAPSHOT, TILE, etc…)
DPR.TYPE	Observation type (BIAS, DARK, DOMEFLAT, etc…)

These parameters are either hard-wired into a template or are determined during the execution of the template sequencer script. The Observation Software is responsible for ensuring these parameters are written to the FITS header. The data flow pipeline can use these keywords to work out how to process the files.

5.7 *Dictionary*

The instrument dictionary is described in the "*VISTA IR Camera Data Interface Dictionaries*", [RD16].

5.8 *Log files*

The Observation Software generates the following log files:

- Nightly observation log, describing all the major events that happened during a night's observing, all the observations made, weather information and operator comments.

- Observation Software engineering log, reporting a more detailed list of events and fault reports with diagnostic information.

The logging is carried out using the CCS logging system, as described in the *"CCS User Manual"*, [RD48].

6 PHYSICAL DEPLOYMENT

The Observation Software runs on an ESO-VLT Instrument Workstation, as shown in the "*Software Functional Specification*", [AD2]. It requires a powerful version of the workstation to achieve the necessary data rate (see next section).

7 PERFORMANCE ANALYSIS

The VISTA IR Camera has to store each 268 Mbyte exposure within 5 seconds, leading to a peak data rate requirement of 53.7 Mbytes / second. It also has to be able to sustain an exposure every 10 seconds for 14 hours, leading to a sustained data rate requirement of 26.8 Mbytes / second and a total data storage per night in excess of 1.35 Tbytes (see [AD2] for details).

Most of the onus on achieving this data rate falls on the IRACE system, which is responsible for making the exposures and saving the raw data. Assuming that the delivered IRACE system achieves its performance requirement, the Observation Software must be capable of performing the following operations:

- Combining the 16 FITS files from IRACE into a single multi-extension FITS file;
- Adding the FITS header information (including World Coordinates information);
- Displaying the combined data (with World Coordinates information) to the operator via an ESO-VLT Real Time Display (RTD) [RD48], (if required);
- Passing the data to VOLAC;

at the maximum sustained data rate. This may entail the OS using the most powerful ESO-VLT Instrument Workstation available at the time. An analysis by the OmegaCAM project, [RD66], showed that the speed of the network and the speed of the disks were the most important factors in achieving their target data rate. The fastest data rate OmegaCAM could achieve on standard ESO-VLT equipment was about half the rate required by the VISTA IR Camera.

8 TEMPLATES

8.1 *Overview of Templates*

As mentioned in Section 3.2.2 on page 26, the camera Observation Software work package supplies the ESO-VLT Observation Handling software with:

- Template signature files
- Template sequencer scripts
- Reference setup files
- Instrument summary file

Figure 17 below shows the relationship between the various template files and the Observation Blocks processed by BOB. An Observation Block is the minimum schedulable unit (see the definition in [RD3] and [RD58]). It specifies a complete observation of a single logical target. It begins with an acquisition template describing the main target, followed by one or more other kinds of templates which make observations on or around that target.

There should be a template for each different kind of exposure (or pattern of exposures) that the instrument is capable of making. Each template is associated with an unique way of making an observation with the instrument, and is associated with a *reference setup file* that contains a list of the parameter keywords and values needed to set up the instrument for making that kind of observation. A template can incorporate one or more *template signature source files*, and these contain descriptions of the parameters associated with different instrument components (e.g. the filter mechanism). Template signature source files can refer to the instrument summary file, which contains a comprehensive description of the capabilities of the instrument — the allowed ranges for various instrument configuration parameters and the choices an observer can make.

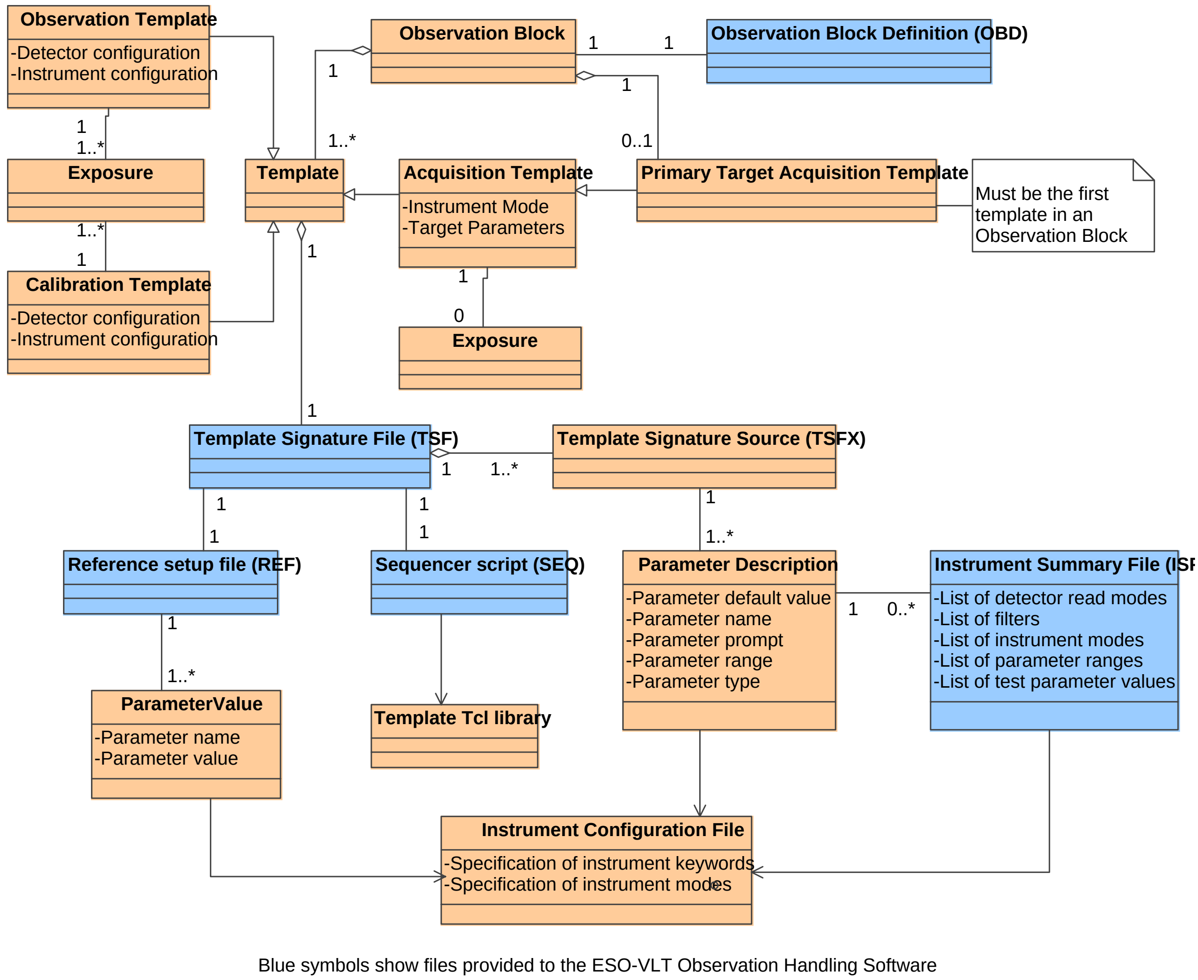

Figure 17 Relationship Between ESO-VLT Observation Block Entities

The naming convention for template signature files is defined in *"Common Software for Templates"*, [RD42]. Each file name has the form

<INST>_<mode>_<type>[_<description>].tsf

Where:

- <INST> = Instrument name (uppercase) ("VIRCAM" for the VISTA IR Camera)
- <mode> = Instrument mode ("gen" can be used for modeless or maintenance templates)

- <type> = type of template (acq – acquisition, obs – observation, cal – calibration, tec – technical)

- <description> = optional string of up to 16 characters identifying the purpose of the template, such as (bias - bias exposure, dark - dark exposure, domeflat - dome flat-field, twiflat – twilight sky flat-field, wave - wavelength calibration, exp - science exposure, std - standard star exposure, etc…)

Figure 18 below shows the hierarchy of the templates defined for the VISTA IR Camera, as listed in the "*IR Camera Calibration Plan*", [RD15]. There are a series of templates for each of the operating modes described in Section 5.3. In each mode there are three kinds of templates:

- Acquisition templates (*shown in blue italic*), which define the operating mode and telescope target parameters. Each Observation Block begins with an acquisition template defining the primary target to which that Observation Block refers. Acquisition templates do not generate exposures.
- Calibration templates (shown in red), which obtain exposures necessary for calibrating observations in a particular instrument mode. A calibration template can result in one or more exposures being made.
- Observation templates (shown in black), which obtain the exposures necessary to make science observations. An observation template can result in one or more exposures being made.

All modes

- VIRCAM_gen_cal_reset.tsf
- VIRCAM_gen_cal_dark.tsf
  - VIRCAM_gen_cal_darkcurrent.tsf

HOWFS mode

- *VIRCAM_howfs_acq.tsf*
- *VIRCAM_howfs_acq_domescreen.tsf*
- VIRCAM_howfs_cal_domeflat.tsf
- VIRCAM_howfs_obs_exp.tsf
- VIRCAM_howfs_obs_wfront.tsf

IMAGING mode

- *VIRCAM_img_acq.tsf*
- *VIRCAM_img_acq_twilight.tsf*
- *VIRCAM_img_acq_domescreen.tsf*
- VIRCAM_img_cal_domeflat.tsf
  - VIRCAM_img_cal_linearity.tsf
- VIRCAM_img_cal_twiflat.tsf
- VIRCAM_img_obs_paw.tsf
  - VIRCAM_img_obs_tile.tsf
  - VIRCAM_img_obs_offsets.tsf

Figure 18 Hierarchy of VISTA IR Camera Templates

The data reduction pipeline is designed to trigger whenever a template completes. The various templates will now be described in more detail.

8.2 General Templates

8.2.1 Calibration templates

- **VIRCAM_gen_cal_reset.tsf** — This template makes a reset (aka BIAS) exposure. The dark filter is selected and a single reset/read sequence executed by the detector controller. The observation made by this template can be used to calibrate HOWFS and IMAGING exposures.
  - **Parameters:** number of reset frames.

- **VIRCAM_gen_cal_dark.tsf** — This template makes a DARK exposure. The dark filter is selected and an exposure made at the same exposure time and integration time as the science observation it is intended to calibrate. The observation made by this template can be used to calibrate HOWFS and IMAGING exposures.
  - **Parameters:** integration time, number of integrations.

- **VIRCAM_gen_cal_darkcurrent.tsf** — This template makes a series of DARK exposures (as in VIRCAM_img_cal_dark.tsf) but at a variety of different exposure times. The resulting data can be used to determine the detector dark current.
  - **Parameters:** list of integration times and corresponding numbers of integrations.

8.3 HOWFS Templates

These templates will be used to collect HOWFS data.

8.3.1 Acquisition templates

Each of these templates may be used only once in an Observation Block and if used must appear at the beginning.

- **VIRCAM_howfs_acq.tsf** — Acquire a HOWFS source. This template sets the instrument into HOWFS mode and selects a HOWFS beam-splitting filter. It also points the telescope to a HOWFS standard star (using a “preset”), specifying the sky coordinates of the star, the required (X,Y) in the instrument focal plane, the position angle of the rotator and other target acquisition parameters described in Section 8.4 on page 55. If autoguiding and active optics correction are required one guide star and two aO stars are specified. The guide star is checked automatically and if found unsuitable the TCS selects a new one. The operator may be prompted if the TCS has problems finding a guide star.
  - **Parameters:** HOWFS filter,
    target coordinates and camera position angle,
    [optionally: guide star, two aO stars],
    focal plane X,Y.

- **VIRCAM_howfs_acq_domescreen.tsf** — This template sets the instrument into HOWFS mode and selects a HOWFS beam-splitting filter. It also moves the telescope to point at the flat-field screen in the dome (using a “preset”). Telescope tracking is turned off and the required illumination level is defined. The flat-field illumination source is switched on.

- **Parameters:** HOWFS filter, flat-field illumination.

8.3.2 Calibration templates

Note: The exposures generated by the VIRCAM_gen_cal_dark.tsf template can be used for HOWFS DARK calibration.

- **VIRCAM_howfs_cal_domeflat.tsf** — This template makes a flat-field exposure (or series of exposures) suitable for calibrating a HOWFS observation. It assumes the VIRCAM_howfs_acq_domescreen.tsf template has been executed and the telescope is already pointing at the dome screen with the calibration source turned on. The detector controller is configured with the same readout window as the target observation. A HOWFS beam-splitting filter may be selected (and positioned to the same orientation relative to the science detector as the observation to be calibrated). At the end of the template the flat-field calibration source is switched off.
  - **Parameters:** HOWFS filter,
    focal plane X,Y and detector window size,
    list of integration times and corresponding numbers of integrations.

  The data generated by this template can be compared with the data generated by VIRCAM_img_cal_domeflat.tsf to determine the transmission profile of the HOWFS beam-splitting filter.

8.3.3 Observation templates

- **VIRCAM_howfs_obs_exp.tsf** — This template makes a HOWFS wavefront measurement suitable for populating the active optics lookup tables in the TCS. The detector controller is configured with a suitable readout window and the HOWFS intermediate filter is selected and positioned over the required detector. A HOWFS observation is made and when completed the HOWFS image analysis system is triggered. The derived coefficients are used to generate the active optics lookup tables for the TCS.
  - **Parameters:** HOWFS filter,
    focal plane X,Y and detector window size,
    integration time, number of integrations,
    [optional: max iterations, number of coefficients, name of file]

- **VIRCAM_howfs_obs_wfront.tsf** — This template makes a HOWFS wavefront measurement suitable for measuring the current residual from the active optics lookup tables. It uses the same procedure as VIRCAM_howfs_obs_exp.tsf, with the addition that the derived coefficients are forwarded to the TCS when the analysis is finished.
  - **Parameters:** HOWFS filter,

focal plane X,Y and detector window size.
integration time, number of integrations,
[optional: max iterations, number of coefficients, name of file]

8.4 *Imaging Templates*

These templates will be used to make imaging observations with the VISTA IR Camera.

8.4.1 Acquisition templates

Each of these templates may be used only once in an Observation Block and if used must appear at the beginning.

- **VIRCAM_img_acq.tsf** — This template acquires a science target. It sets the instrument into IMAGING mode and selects a science filter. It also points the telescope to a new target (using a TCS "preset" command), specifying the sky coordinates of the field centre, the position angle of the instrument Y axis on the sky and other target acquisition parameters described in Section 8.4 on page 55. If autoguiding and active optics correction are required one guide star and two aO stars are specified. The guide star is checked automatically and if found unsuitable the TCS selects a new one. The operator may be prompted if the TCS has problems finding a guide star. See Section 8.9.3 on page 62.
  - **Parameters:** first science filter,
    target coordinates, camera position angle,
    guiding required flag: if set – [guide star, two aO stars],
    [optional: focal plane X,Y]

  This same acquisition template can be used to position the telescope before observing a single target, a single pawprint or a complete tile. For a single target or pawprint, the template is provided with the coordinates of the target to be observed and guiding is normally enabled. For a complete tile, the template is provided with the coordinates of the central null target; and guiding is not enabled until the telescope is offset to the first pawprint, which happens when the VIRCAM_img_obs_tile.tsf template is executed.

- **VIRCAM_img_acq_twilight.tsf** — This template is used to select a twilight sky field. It sets the instrument into IMAGING mode and selects a science filter. It points the telescope to the twilight sky by specifying an altitude and azimuth. The telescope is tracked but guiding is switched off.
  - **Parameters:** science filter,
    target altitude and azimuth,

- **VIRCAM_img_acq_domescreen.tsf** — This template sets the instrument into IMAGING mode and selects a science filter. It also moves the telescope to point at the flat-field screen in the dome (using a "preset"). Telescope tracking and guiding are switched off and the required flat-field illumination level defined. The flat-field illumination source is switched on.

- **Parameters:** science filter, flat-field illumination.

8.4.2 Calibration templates

Note: The exposures generated by the VIRCAM_gen_cal_dark.tsf template can be used for IMAGING DARK calibration.

- **VIRCAM_img_cal_domeflat.tsf** — This template makes a flat-field exposure (or series of exposures) suitable for calibrating an IMAGING observation. It assumes the VIRCAM_img_acq_domescreen.tsf template has been executed and the telescope is already pointing at the dome screen with the calibration source turned on. At the end of the template the flat-field calibration source is switched off.
  - **Parameters:** science filter,
list of integration times and corresponding numbers of integrations.

- **VIRCAM_img_cal_linearity.tsf** — This template makes a series of flat-field exposures (as VIRCAM_img_cal_domeflat.tsf) but at a variety of different exposure times. The resulting data can be used to determine the linearity of the detector response. At the end of the template the flat-field calibration source is switched off.
  - **Parameters:** science filter,
list of integration times and corresponding numbers of integrations.

- **VIRCAM_img_cal_twiflat.tsf** — This template makes a series of exposures sufficient to make a twilight sky flat-field suitable for calibrating an IMAGING observation. It assumes the VIRCAM_img_acq_twilight.tsf template has been executed and the telescope is already pointing at the twilight sky. The template can be requested to wait until the sky brightness achieves the desired level before proceeding.
  - **Parameters:** science filter,
optional: [required sky brightness],
Either:
    - list of integration times and corresponding numbers of integrations; or
    - required illumination level.

8.4.3 Observation templates

- **VIRCAM_img_obs_paw.tsf** — This template makes one "pawprint" observation using a selection of filter changes, jittering and microstep movements. It is assumed the telescope has already been positioned at the target using the VIRCAM_img_acq.tsf template. The detector controller is configured with the required readout and exposure time parameters and the following sequence executed:
FJME — Step through science filters in outer loop. At each science filter execute a jitter pattern (if specified), and within each jitter pattern execute a microstep pattern (if specified).
  - **Parameters:** list of science filters,

number of jitter positions, [optional: jitter pattern ID, jitter scale factor],
number of microstep positions, [optional: microstep pattern ID, microstep scale factor],
number of exposures, integration time, number of integrations

- **VIRCAM_img_obs_tile.tsf** — This template makes sufficient observations to generate a contiguous "tile", using a selection of pawprints, filter changes, jittering and microstep movements. It is assumed the telescope has already been pointed to the null target with the VIRCAM_img_acq.tsf template. The detector controller is configured with the required readout and exposure time parameters and one of the following sequences executed (c.f. the survey strategies described in Section 2.2 on page 16):
  FPJME — Construct the tile from a series of pawprints, repeating each pawprint with a different science filter. Within each pawprint execute a jitter pattern (if specified), and within each jitter pattern execute a microstep pattern (if specified) .
  PFJME — Construct the tile from a series of pawprints. Within each pawprint execute a jitter pattern, only this time repeat each jitter with a different science filter before moving on to the next. Within each jitter execute a microstep pattern (if specified).
  FJPME — Construct the tile from a pawprint and jitter pattern such that one jitter observation is made from each pawprint in turn. Within each jitter pattern there can be a microstep pattern. The whole sequence may be repeated with different science filters.
  Each time a new pawprint is selected, the TCS is provided with a new guide star and a new pair of aO stars, taken from the list provided with the template.
  - **Parameters:** nesting pattern (FPJME, PFJME or FJPME as above),
    list of science filters,
    tile pattern ID, tile scale factor,
    list of [guide star plus two aO stars] for each pawprint in the tile pattern,
    number of jitter positions, [optional: jitter pattern ID, jitter scale factor],
    number of microstep positions, [optional: microstep pattern ID, microstep scale factor],
    number of exposures, integration time, number of integrations

- **VIRCAM_img_obs_offsets.tsf** — This template makes a series of observations using a list of user-defined telescope offsets (suitable for making a one-off observation not covered by the pre-defined tile and jitter patterns). It is assumed the telescope has already been pointed to the null target with the VIRCAM_img_acq.tsf template. The detector controller is configured with the required readout and exposure time parameters and E exposures made at each of the specified telescope offsets.
  - **Parameters:** list of science filters,
    tile pattern ID, tile scale factor,
    list of [guide star plus two aO stars] for each offset,
    list of RA,Dec offsets,

number of exposures, integration time, number of integrations

N.B. Alan Pickup suggests that this template may be redundant, since we can always invent new kinds of tile pattern to use with VIRCAM_img_obs_tile.tsf.

8.5 *Technical Templates*

In addition to the templates described above, a set of technical templates may be used to carry out testing and engineering procedures:

- **VIRCAM_gen_tec_SelfTest.tsf** — A template that tests the operation of the instrument by exercising all the instrument modes. (It is expected this will be executed regularly by Paranal staff — see Section 3.4.1 on page 34).
- **VIRCAM_gen_tec_CheckFilters.tsf** — A template that checks the operation of the filter wheel by selecting in turn each of the filters currently installed in the instrument. (It is expected this will be executed regularly by Paranal staff — see Section 3.4.1 on page 34).
- **VIRCAM_gen_tec_CalibFilters.tsf** — A template that checks the accuracy of the filter wheel by making a series of repeated movements.
- **VIRCAM_gen_tec_LoadFilters.tsf** — A template that allows an engineer to load and/or remove one or more filters in sequence.
- **VIRCAM_gen_tec_crosstalk.tsf** — A template that makes a series of exposures for testing cross-talk between the detector controller channels.
- **VIRCAM_howfs_tec_CalibNull.tsf** — A template that makes a series of exposures for calibrating the HOWFS null wavefront.

Other engineering templates may be defined as the need arises.

8.6 *Sequence Keywords*

The IR Camera Templates will use the following sequencer keywords to describe the observing procedure.

Keyword	Type	Description
SEQ.NESTING	string	Nesting required: “FPJME”, etc…
SEQ.NFILT	integer	Number of filters
SEQ.FILTERS	string	List of filters
SEQ.TILE_ID	integer	Tile pattern ID
SEQ.TILE_S	float	Tile pattern scale factor
SEQ.JITTER_ID	integer	Jitter pattern ID
SEQ.JITTER_S	float	Jitter pattern scale factor

SEQ.USTEP_ID	integer	Microstep pattern ID
SEQ.USTEP_S	float	Microstep pattern scale factor
SEQ.NEXPO	integer	Number of exposures at each position
SEQ.TILE_ID	integer	Tile pattern ID
(The following keywords may not be required)		
SEQ.NOFFSETS	integer	Number of offsets
SEQ.OFFSETALPHA	string	List of RA offsets
SEQ.OFFSETDELTA	string	List of Dec offsets

8.7 Pattern Definition Keywords

These keywords are used to define the offsets associated with different kinds of tile, jitter and microstep patterns.

Keyword	Type	Description
TEL.TILEi.OFFSETALPHA	numlist	RA Offsets for pattern TILEi
TEL.TILEi.OFFSETDELTA	numlist	Dec Offsets for pattern TILEi
TEL.JITTERi.OFFSETALPHA	numlist	RA Offsets for pattern JITTERi
TEL.JITTERi.OFFSETDELTA	numlist	Dec Offsets for pattern JITTERi
TEL.USTEPi.OFFSETALPHA	numlist	RA Offsets for pattern USTEPi
TEL.USTEPi.OFFSETDELTA	numlist	Dec Offsets for pattern USTEPi

8.8 Typical Observation Blocks

The templates defined above may be combined together to make Observation Block which carry out standard VISTA IR calibrations and observations as follows:

8.8.1 VIRCAM_howfs_cal_domeflat.obx — Dome flat-field calibration for HOWFS

1) VIRCAM_howfs_acq_domescreen.tsf
   - Set mode to HOWFS.
   - Select HOWFS beam-splitter filter.
   - Move telescope to the dome screen.
   - Switch on illumination
2) VIRCAM_howfs_cal_domeflat.tsf
   - Select exposure time and make dome flat-field calibration exposures.
   - Switch off illumination.

8.8.2 VIRCAM_howfs_cal_lut.obx — Telescope HOWFS LUT calibration

1) VIRCAM_howfs_acq.tsf
   - Set mode to HOWFS.
   - Select HOWFS beam-splitter filter.
   - Move telescope to a HOWFS star and note elevation
2) VIRCAM_howfs_obs_exp.tsf
   - Observe and calculate wavefront

The OB is repeated at a variety of different elevations.
The observations are converted into a lookup table for the TCS.

8.8.3 VIRCAM_howfs_cal_wfront.obx — One-off HOWFS wavefront calibration

1) VIRCAM_howfs_acq.tsf
   - Set mode to HOWFS.
   - Select HOWFS beam-splitter filter.
   - Move telescope to a HOWFS star and note elevation
2) VIRCAM_howfs_obs_wfront.tsf
   - Observe and calculate wavefront.
   - Send the coefficients to the TCS

8.8.4 VIRCAM_img_cal_domeflat.obx — Dome flat-field calibration for science

1) VIRCAM_img_acq_domescreen.tsf
   - Set mode to IMAGING
   - Select science filter.
   - Move telescope to the dome screen and switch on illumination.
2) VIRCAM_img_cal_domeflat.tsf
   - Select exposure time and make dome flat-field calibration exposures.
   - Switch off illumination

8.8.5 VIRCAM_img_cal_linearity.obx — Linearity calibration for science detectors

1) VIRCAM_img_acq_domescreen.tsf
   - Set mode to IMAGING
   - Select science filter.
   - Move telescope to the dome screen and switch on illumination.
2) VIRCAM_img_cal_linearity.tsf
   - Make a series of exposures at a variety of exposure times designed for detector linearity calibration.
   - Switch off illumination

The exposures can be used to determine the linearity of the detector response.

8.8.6 VIRCAM_img_cal_twiflat.obx — Twilight sky flat-field calibration

1) VIRCAM_img_acq_twilight.tsf
   - Set mode to IMAGING.
   - Select science filter.
   - Move telescope to twilight sky.
2) VIRCAM_img_cal_twiflat.tsf
   - Wait for appropriate sky background level.
   - Select exposure time and make twilight sky flat-field calibration exposures.

8.8.7 VIRCAM_img_cal_illumination.obx — Map out illumination by internal scattering

1) VIRCAM_img_acq_offsets.tsf
   - Set mode to IMAGING.
   - Select science filter.
   - Move telescope to the first field.
2) VIRCAM_img_obs_offsets.tsf
   - Select exposure time.
   - Make a series of observations at various offsets designed to place bright stars on different parts of the focal plane.
   - Acquire new guide and aO stars when necessary.

8.8.8 VIRCAM_img_cal_persistence.obx — Calibrate image persistence on detector

1) VIRCAM_img_acq.tsf
   - Set mode to IMAGING
   - Select science filter.
   - Move telescope to a suitable target field of bright, saturated stars.
2) VIRCAM_img_obs_paw.tsf
   - Select exposure.
   - Make one exposure.
3) VIRCAM_img_cal_dark.tsf
   - Select DARK filter
   - Make a series of exposures.

8.8.9 VIRCAM_img_obs_tile.obx — Science survey tile observation

1) VIRCAM_img_acq.tsf
   - Set mode to IMAGING.
   - Select science filter.
   - Move telescope to the central null field.
2) VIRCAM_img_obs_tile.tsf
   - Select the exposure time.
   - Make a tile observation consisting of the required filter, pawprint, jitter and microstepping nesting sequence.

- Acquire new guide and aO stars when necessary.

See Section 2.2 on page 16.

8.9 *Target Acquisition Template Parameters*

The exact definition of the parameters contained in acquisition templates is to be specified by the data flow and telescope software groups. However, it is expected that an acquisition template will contain the following parameters describing the target to be observed:

8.9.1 Administrative Parameters

- Programme identification
- Name of principal investigator
- Unique science programme identifier
- Programme title string (defined by scientist)
- Observation description (optional)
- Unique observation identifier

8.9.2 Observation Scheduling Parameters

- Name of instrument to be used ("VIRCAM")
- Programme priority (assigned by committee)
- Observation priority (defined by scientist)
- Nightly priority (used to define the priority of this observation within a nightly schedule)
- Special priority (used for special purposes)
- Required limiting magnitude and signal to noise at specified colour/magnitude (for use by the ESO-VLT exposure time calculator).
- Range of acceptable phases of the moon
- Range of acceptable atmospheric seeing values in arcseconds
- Range of acceptable airmass values
- Range of acceptable atmospheric transparency values
- Required range of absolute date/times for each observation (if any)
- Required ordering and timing of observation blocks belonging to the same programme (if possible).
- Calibration requirements, such as
  - Whether this observation requires a dark frame.
  - Whether this observation requires a dome flat-field frame.
  - Whether this observation requires a twilight flat-field frame.

8.9.3 Acquisition Target Parameters (for preset)

- Standard name for the target being observed
- Description of target (defined by scientist)
- Celestial coordinates of the pointing target OR name of known telescope preset

corresponding to the target
- Proper motion of pointing target (if any)
- Epoch of target coordinates
- RADECSYS of target coordinates
- Equinox of target coordinates (when RADECSYS is not 'ICRS').
- Position angle of camera Y axis defined on the sky.
- Effective wavelength of the target.
- Focal plane (X,Y) coordinate (in instrument units, millimetres on the focal plane, as defined in [AD2]) on which target image should fall, defaulting to the optical axis (0,0).

8.9.4 Acquisition Target Parameters (for offset)

- Offset to be applied to the celestial coordinates OR offset to be applied to focal plane (X,Y) coordinate in millimetres (the camera software will convert an X,Y offset into celestial coordinates).
- New position angle of camera Y axis defined on the sky (if different)
- Whether a new set of guide and aO stars is required.

8.9.5 Telescope Tracking Parameters

- Whether the telescope is to be tracked or not.
- Required non-sidereal drift rate in arcseconds/minute (if any).
- Absolute Universal Time to which the non-sidereal tracking rate applies (if any)

8.9.6 Autoguiding Parameters

- Whether autoguiding is required or not.
- Name of guide star
- Celestial coordinates of star
- Magnitude of guide star
- Colour of guide star
- Proper motion of guide star (if any)
- Epoch of guide star coordinates
- RADECSYS of guide star coordinates
- Equinox of guide star coordinates (when RADECSYS is not 'ICRS')

8.9.7 Active Optics Parameters

- Whether active optics correction is required or not
- For each of the two aO stars:
  - Name of star
  - Celestial coordinates of star
  - Magnitude of star
  - Colour of star
  - Proper motion of star (if any)
  - Epoch of star coordinates

- RADECSYS of star coordinates
- Equinox of star coordinates (when RADECSYS is not 'ICRS')

8.10 Observation Template Parameters

The following parameters need to be specified within the observation templates

8.10.1 Data Handling Requirements

- Description of the type of observation to be made (e.g. dark, flat-field, twilight sky, science).
- Observation ID (used to tie together multiple files belonging to the same observation).
- Offset number (if this observation is part of tile).
- Jitter number (if this observation is part of a set of jittered exposures).
- Microstep number (if this observation is part of a set of microstepped exposures).

8.10.2 Instrument Parameters

- Name of science filter OR name of intermediate filter/position combination.

8.10.3 Detector Parameters

- Total integration time required in seconds.
- Region of interest on each detector (if any, otherwise assume whole detector surface).
- IR detector readout mode (raw data, read-reset-read, coadded or differenced).
- Number of integrations to coadd.

9 PROCEDURES

9.1 Installing and building the software

The ESO Configuration Management Module (CMM), [RD55], will be used for software configuration management and software installation.

The software can be built using the pkgin utility, [RD56], with the commands

```
cmmCopy vcins
pkginBuild vcins –env wvcam lvcics1
```

The procedures for installing and building the software are described in the "*User and Maintenance Manual*", [RD10]

9.2 *Testing the software*

The ESO-VLT Tools for Automated Testing (TAT) package, [RD54], will be used for checking the correct functioning of the software. In addition there will be a set of maintenance templates for exercising all the possible instrument observing modes (as listed in Section 8.5 on page 58).

See the Acceptance Test Plan, [RD9], for a list of instrument tests.

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