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4	8 Apr 2008	All	"Guidelines" replaced with RFC2119
			Multi-HDU files support
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			Other minor corrections
5	8 July 2011	All	External data products
			Compound file types
			Specs for header dumps
			Guidelines for instrument names
			ARC category deprecated
			Archive file name convention
			Other clarifications/corrections

Items To Be Resolved

Major issues to be resolved in future versions of this document:

- Handling of long strings in ESO FITS files.
- Spectroscopy units in ESO FITS files: wavelength vs. frequency.
- Time definitions for IR instruments.

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Chapter 1

Introduction

1.1 Purpose and scope

This document summarises the ESO official data interface specification. This specification applies to all data structures produced or used by the ESO optical telescopes since 1997. A description of the term *Data Interface* is given in Chapter 2 below, together with a summary of when and how such an interface is used.

The data structures mentioned in this document reflect the concepts and objects developed for the VLT Data Flow System (DFS) as implemented in the VLT2009 release of the VLT Common Software.

This document is issued and maintained by the ESO Data Interface Control Board (DICB). The DICB Terms of Reference are given in [AD1].

This document is meant as a technical reference and therefore its intended main audience is engineers and/or scientists who develop software to either produce, analyse or handle data files conforming to this specification.

The detailed data interface specifications are described in *data dictionaries*. There is one dictionary for each context, i.e. instrument, telescope system, observatory, etc.

The DICB issues and maintains a dictionary (`ESO-VLT-DIC.PRIMARY-FITS`) containing the definitions of all non-hierarchical keywords used anywhere at ESO. A template for Instrument Control Software (ICS) dictionaries (`ESO-VLT-DIC.XXX_ICS`) is also available. All new ICS instrument dictionaries should be based on this one. The format of the ESO Data Dictionaries is given in Chapter 7 on page 63.

In addition to data dictionaries, the Data Interface Control Board also releases and maintains specifications describing the layout of FITS frames and other file structures used by the observatory.

Examples in this document have been included for explanatory purposes only. The authoritative reference for keyword specifications are the ESO Data Dictionaries.

The on-line version of this document, the Data Dictionaries and other DICB information are located on the ESO Archive server at `http://archive.eso.org/DICB`. Facilities for searching and selective display of keywords are also available.

Requests for changes or additions to this document or any of the ESO Data Dictionaries must be submitted to the Data Interface Control Board for consideration (`dicb@eso.org`). Please refer to [AD1] for details.

This document and the DICB data dictionaries supersede the older Archive specification, *Data Interface Requirements*, Ref No. ARC-SPE-ESO-00000-1/1.4 which becomes hereby obsolete.

1.2 Applicable Documents

[AD1] ESO. *Terms of Reference of the ESO Data Interface Control Board, GEN-TRE-ESO-19400-1138/2*, December 2010.

[AD2] ESO. *Data Flow for VLT/VLTI Instruments, Deliverables Specification, VLT-SPE-ESO-19000-1618/2.0*, May 2004.

[AD3] ESO. *VLT On-line Data Flow, Requirement Specification, VLT-SPE-ESO-19000-0749/1.11*, June 1996.

[AD4] FITS Working Group, Commission 5: Documentation and Astronomical Data, International Astronomical Union. *Definition of the Flexible Image Transport System (FITS), Version 3.0*, July 2008. `http://fits.gsfc.nasa.gov/fits_standard.html`.

[AD5] N. Zarate and P. Greenfield. FITS Header Inheritance Convention, April 2007. Available at `http://fits.gsfc.nasa.gov/registry/inherit.html`.

[AD6] N. Zarate, R. Seaman, and D. Tody. FITS Foreign File Encapsulation Convention, September 2007. Available at `http://fits.gsfc.nasa.gov/registry/foreign.html`.

[AD7] International Organization for Standardization, Geneva, Switzerland. *ISO 8601:2004. Data elements and interchange formats — Information interchange — Representation of dates and times*, December 2004.

[AD8] R. L. Seaman, W. D. Pence, and A. H. Rots. FITS Checksum Proposal, May 2002. Available at `http://fits.gsfc.nasa.gov/registry/checksum.html`.

[AD9] R. L. White, P. Greenfield, W. Pence, D. Tody, and R. Seaman. Tiled Image Convention for Storing Compressed Images in FITS Binary Tables, November 2006. Available at `http://fits.gsfc.nasa.gov/registry/tilecompression.html`.

[AD10] International Organization for Standardization, Geneva, Switzerland. *ISO 80000. Quantities and Units.*, 2006-2009.

1.3 Reference Documents

[RD1] S. Bradner. RFC 2119: Key words for use in RFCs to Indicate Requirement Levels, March 1997. `http://www.ietf.org/rfc/rfc2119.txt`.

[RD2] Optical Research Associates. *Code V Reference Manual, Version 8.0*, February 1995.

[RD3] ESO. *VLTI Data Interface Control Document, Version 1.0, VLT-SPE-ESO-15000-2764/1.0*, May 2002.

[RD4] ESO. *VLT Science Operations Plan, VLT-PLA-ESO-10000-0441/2.0*, May 1997.

[RD5] IEEE Std 1003.1, 2004 Edition. The Open Group Technical Standard. Base Specifications, Issue 6.

[RD6] E. W. Greisen and M. R. Calabretta. Representations of world coordinates in FITS. *Astronomy & Astrophysics*, 395:1061–1075, December 2002.

[RD7] M. R. Calabretta and E. W. Greisen. Representations of celestial coordinates in FITS. *Astronomy & Astrophysics*, 395:1077–1122, December 2002.

[RD8] E. W. Greisen, M. R. Calabretta, F. G. Valdes, and S. L. Allen. Representations of spectral coordinates in FITS. *Astronomy & Astrophysics*, 446:747–771, February 2006.

[RD9] European Southern Observatory. *ESO External Data Products Standard, GEN-SPE-ESO-33000-5355/2*, March 2011. `http://www.eso.org/sci/observing/phase3/p3edpstd.pdf`.

[RD10] ESO. *VLT Paranal Network / Computers / Consoles Specification, VLT-SPE-ESO-17100-3439/6*, March 2009.

[RD11] ESO. *INS Common Software, Specification, VLT-SPE-ESO-17240-0385/4*, January 2005.

[RD12] ESO. *INS Common Software, Common Software for Templates, User Manual, VLT-MAN-ESO-17240-2240/5*, December 2005.

1.4 Glossary

Calibration Frame A frame used in the process of data reduction to remove instrument or athmospheric signature from observations. Also a frame taken to obtain information about the performance of hardware components, e.g. telescope, instrument or detector.

Calibration product (also called master calibration) A pipeline-processed frame made of an input set of raw calibration frames. It typically provides instrument signature (like detector read noise level, fixed-pattern noise, dispersion relation etc.).

Data Interface Set of definitions that describe the contents of data files (see Chapter 2 for a detailed discussion).

(VLT) Data Flow System The system that handles the flow of scientific and calibration data and information for the ESO VLT. It includes subsystems for proposal handling, observation handling, science archiving, data pipeline and quality control (see [AD2] and [AD3]).

Data File This term describes all data files resulting from the execution of ESO observing programmes or files created by pipeline processing. Data files include: raw observation frames, processed (by the pipeline) observation frames, observatory calibrations.

Flexible Image Transport System (FITS) A standard data format widely used in the astronomical community. FITS is defined in [AD4]. A FITS file consists of one or more Header + Data Units (HDUs), where the first HDU is called the 'Primary HDU' or 'Primary Array'. Any number of additional HDUs may follow the primary array; these additional HDUs are called FITS 'extensions'. Three types of extensions are currently defined by the FITS standard: images (N-dimensional data arrays), binary or ASCII tables. Each HDU consists of a ASCII header unit and an (optional) data unit. The primary HDU must be of image type, but can contain no data. The header part consists of parameter `keyword = value` records. The FITS header describes the structure of the data part and also includes the description of the performed observation. The headers of ESO FITS files deviate from the FITS standard laid out in [AD4] because of using hierarchical keywords (see Sec. 4.4 on page 34).).

FITS Keyword A string consisting of groups of maximum 8 alphanumeric characters, separated by blanks, used in FITS headers to encode parameter information related to the data formatted in the FITS file.

Graphical User Interface (GUI) A user interface based on the presentation of data and command options via graphical panels and user selection via mouse and keyboard data entry.

Log File A computer readable file containing log records. Log files are written by handlers that receive log requests from distributed applications running in the on-line environment. Typically, log handlers will record major normal operations as well as unforeseen events and errors. The format of log files is defined in Section 5.1 on page 55.

Observation Block The smallest schedulable observational unit for the ESO VLT. An observation block contains a sequence of high level operations, called *templates* that need to be performed sequentially and without interruption in order to ensure the scientific usefulness of an observation. Observation blocks may include only one target acquisition.

Observation (Raw) Frame The data file containing the result of an observation. In general, different instrument modes produce different observation frames.

Observing Programme A list of observation descriptions and targets to be observed to achieve a scientific aim. Observing programmes are proposed by a PI and are granted observing time by a time allocation committee (e.g. the ESO OPC). For the VLT, observing programmes will be formulated during *Phase 2 Proposal Preparation* in terms of *Observation Blocks*. Observation programme may consist of one or more *Observing Runs*.

Observing Run Observation or set of observations, performed in unique telescope/instrument configuration, constituting a logical unit item of the observing programme, as specified by the proposer.

Phase 2 Proposal Preparation Detailed preparation of observations. This phase is used by astronomers who have been granted observing time in order to provide the detailed observation setup for each target within their *Observing Programme*.

Phase 3 Process in which principal investigators of ESO observing programmes return their reduced data products to ESO for storage in the ESO archive and subsequent data publication to the scientific community. ESO's policies governing Phase 3 are specific to the type of observing programme. Phase 3 is mandatory for ESO Public Surveys and for ESO Large Programmes; voluntary for other ESO programmes.

Pipeline The software system used to process VLT raw data into calibration or science products. Pipelines consist of recipes which typically process a certain type of raw data. Pipelines require infrastructure for classification, grouping and association of data. They are running in on-line mode on Paranal, and in off-line mode by the Data Processing and Quality Control group in Garching. The main purpose of pipelines are the extraction of instrument quality information, and the extraction (calibration data) or removal (science data) of instrument signature.

Quality Control The VLT Quality Control process comprises the following tasks: visual checks of observed science and calibration data, checks of ambient conditions for science observations against user-specified constraints, checking the formal correctness of the data files, creating master calibration data, extracting quality parameters for quality assessment of data files and of the instrument status, populating the master calibration archive and performing instrument trend analysis.

Quality Control (QC) Level 0 Quality control during or immediately after the execution of the observation. Involves monitoring of ambient parameters (e.g. seeing, humidity) against user constraints, and checking of flux levels. QC level 0 is typically done on-site.

Quality Control (QC) Level 1 Off-line quality control using the pipeline. Involves extraction of QC1 parameters (e.g. read noise, grating position, zero points) and comparison to reference and historical data (trending). Initial QC Level 1 is done on-site. The final QC1 is done by the Data Processing and Quality Control team of the Data Products Department of the ESO Data Management and Operations Division.

Processed Frame The result of a pipeline data processing applied to either raw science or calibration frames.

Setup File A computer readable file containing configuration information for either telescope, instrument, detector, etc.

Template High level VLT operation procedure. Templates provide the means to group commonly used procedures in a well defined and standardised unit. Templates have input parameters described by a template *signature*, and produce results that can serve as input to other templates. As an example, an *Acquisition Template* takes target coordinates and produces through an interactive procedure the precise positions used later, e.g. to place the slit.

Translation/Alias Table A table containing alternative names for ESO standard keywords. This table is used by data delivery tools or control software to translate short names into ESO standard parameter keywords. ESO Archive can deliver FITS files with non-ESO keyword headers by translating the ESO standard into an external specification defined through a translation table.

VLT Control Software (VCS) The software tools and systems that are directly involved in the control of VLT instruments, telescopes and related hardware. It enables and performs the acquisition of scientific data. VLT Control Software should not be confused with VCS Common Software.

1.5 Abbreviations and acronyms

ASCII	American Standard Code for Information Interchange
APEX	Atacama Pathfinder Experiment
CCD	Charge Coupling Device
DEC	Declination
DET	Detector Subsystem
DFS	(VLT) Data Flow System
DIC	Data Interface Control
DICB	(ESO) Data Interface Control Board
DID	Data Interface Dictionary
DMD	Data Management Division
EDP	External Data Product
ESO	European Southern Observatory
FITS	Flexible Image Transport System
GUI	Graphical User Interface
HDU	FITS Header + Data Unit
HST	Hubble Space Telescope
IDP	Internal Data Product
INS	Instrument Subsystem
IOT	Instrument Observing Template
LCU	(VCS) Local Control Unit
NTT	(ESO) New Technology Telescope
OPC	Observing Programmes Committee
OST	Observation Summary Table
PI/CO-I	Principal Investigator/Co-Investigator
QC1	Quality Control Level 1
RA	Right Ascension
STSDAS	Space Telescope Standard Data Analysis Software
TCS	Telescope Control Software
UTC	Universal Time Coordinated
VCS	VLT Control Software
VLT	(ESO) Very Large Telescope
VLTI	(ESO) Very Large Telescope Interferometer
WCS	World Coordinate System

1.6 Conventions used in this document

The following conventions are used throughout this document:

- The key words "must", "must not", "required", "shall", "shall not", "should", "should not", "recommended", "may", and "optional" in this document are to be interpreted as described in RFC 2119 [RD1].
- Keyword names appear in monotype font (e.g. `NAXIS`).
- Keyword data types are given in the tables of FITS keywords (e.g. Table 4.1) in the leftmost column with the following codes:

  (L) Boolean/logical
  (I) integer
  (S) character or string
  (R) double precision

- Character strings in keyword values are left justified, and trailing spaces are not significant.
- Angles are measured in degrees, the convention for optical elements is summarised below:

  Grism Angle The angle of grisms is defined as the angle between the grooves and the alignment pin on the front face of the instrument. The alignment pin is duplicated on the rotator and the instrument.

  Slit Angle The angle of a slit is defined as the angle between the slit and the alignment pin on the front face of the instrument. The alignment pin is duplicated on the rotator and the instrument.

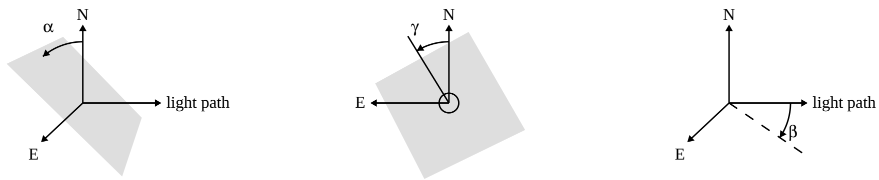

Figure 1.1: Conventions for angles related to the projected sky plane.

- Angles that relate to the projected sky along the light path are measured with a right-hand orientation as shown in Figure 1.1. The position angle γ is measured East of North. Two tilt angles are needed to describe elements that are not perpendicular to the optical axis: α and β. They give respectively the tilt against the plane perpendicular to the optical axis along the celestial East-West axis and along the celestial North-South axis.

- Other angles follow the conventions given in [RD2].

1.7 Acknowledgements

The following persons have contributed to the definition of the Data Interface specification: M. Albrecht, E. Allaert, D. Baade, P. Baksai, P. Ballester, S. Bogun, N. Delmotte, A. Dobrzycki, P. Grosbøl, R. Hanuschik, H.-U. Käufl, J. Knudstrup, B. Leibundgut, C. Melo, F. Ochsenbein, B. Pirenne, J. Retzlaff, G. Rupprecht, R. Slijkhuis, A. Wicenec and A. Zijlstra.

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1.8 Release notes

The current release of this document is issued to document the features implemented in the VLT Common Software VLT2010 release. There are, however, issues that have been discussed and agreed upon by the Data Interface Control Board, but which are not yet fully implemented in the software.

Comments to this document will be greatly appreciated. Please send them to `dicb@eso.org`.

Chapter 2

Overview

Well defined data specifications are fundamental for the operation of large observing facilities. In a Data Flow System, data structures and parameters are used by a large number of people and systems at different places and times. Ensuring that parameters are given the same meaning and are used in a coherent way throughout the observatory is essential for a seamless flow. In fact, in the context of the Paranal Observatory, in which up to 14 instruments will be offered to the community, the task of defining, maintaining and controlling data flow structures and parameters becomes a key to the success of science operations.

The *data interface* of the observatory comprises the definition of:

- all data files that ESO delivers to or requires from its users community and
- data and parameters that are exchanged across modules of the VLT Control Software and the Data Flow System.

Among other, such data structures include observation input data, acquisition data, instrumentation characteristics, and setup files and parameters.

The specifications included in the data interface give the syntax rules (file formats) and the semantic conventions (names, meaning, physical units) used to generate and handle data files.

In order to ensure stability and consistency in the long term, data interface specifications are put under configuration control. This is achieved by defining and maintaining *data dictionaries* that define in detail all parameters used in a given context, e.g. for a given instrument (see Chapter 7). Changes and additions to these dictionaries are made only after all parties involved (instrumentation, data acquisition software, reduction software, archive, observatory operations) have screened the request and its execution throughout the data system is coordinated. The vehicle used at ESO to implement this is the Data Interface Control Board, a committee that brings together representatives from all groups involved (see the DICB Terms of Reference, [AD1]). The Data Interface Control Board reviews new specifications and/or additions and changes to them, validates data files during the commissioning of instruments and their modes and coordinates the implementation schedule of data files.

The present document describes the specifications for the structure of the data frames (Chapter 3), the use of keywords in ESO FITS files (Chapter 4), the content of the log files (Chapter 5), the VLT parameter files (Section 6) and the structure and contents of the data dictionaries (Chapter 7). The ESO usage convention for physical units is given in Chapter 8. The naming convention for optical components is given in Chapter 9. The rules for instrument identifiers and propagation of those identifiers, as well as ESO file naming conventions are given in Chapter 10.

Chapter 3

Data structures

The general philosophy followed in the definition of data files created at ESO can be summarised as follows:

- Frame headers contain only information that is relevant to data reduction and analysis and are recorded in astronomy-oriented units, such as arcseconds for slit widths, etc. (see Chapter 8, p. 68).
- Frame headers contain the non-standard hierarchical keywords (Section 4.4, p. 34), but ESO provides a tool, called *hierarch28* (HIERARCH-TO-EIGHT), to translate headers from one semantic specification to another (e.g. hierarchical keywords with ESO names to e.g. IRAF-STSDAS naming conventions). Please consult `http://archive.eso.org/saft/hierarch28/` for information about *hierarch28*.
- A number of log files record all information relevant to science operations; in particular, telescope operations, instrumental configuration, standard reduction steps and atmospheric conditions are recorded (see Section 3.2 on page 22).
- A number of auxiliary files/tables provide a user-friendly view of the data harvest both at the telescope and at home during post-observation data analysis.

This section describes the rules and guidelines applicable to data files covered in this document.

3.1 Raw observation and processed frames

The ESO data acquisition system and pipeline processing deliver observations in FITS format (see [AD4]). They shall conform to the following rules:

Storage Format Each observation frame includes data from one exposure. A processed frame contains data from one or more exposures.

Multiple-window and multiple-chip data shall be stored in different image extensions of the same FITS file, with the data pixels belonging to one window/chip stored in one image extension. In those cases the primary Header-Data Unit (HDU) data array shall remain empty.

Exceptions to this requirement may be granted by the Data Interface Control Board following the request from the instrument and/or software team if considerations such as hardware or system setup, system performance, data transfer or data storage make following this requirement impractical. If this request is approved, all individual files must still comply to the rules set forth in this document.

The data from single chip instruments shall be stored in the primary HDU of the FITS file. This also applies to cases in which the file contains extensions with supporting data/information. An example of this situation is a file consisting of a data image and, e.g., exposure map, detector map, listing of MOS slits, etc. In this case, the data image shall be stored in the primary HDU, and the supporting data in the extension HDUs.

Ordering of HDUs Non-test multi-HDU FITS files, i.e. files created in the process of regular observatory operations in supported instrument configuration, must have extension HDUs ordered in a sequence which is pre-defined for each such configuration.

This requirement applies to files delivered to the end-users; internal data flow (in particular data acquisition process) can, for efficiency reasons, use uncontrolled HDU order.

It is recommended, but not required, that extensions HDUs be ordered in an intuitively easy sequence (e.g. row-by-row with the first extension containting data from the “top-left” chip).

All auxiliary and/or optional HDUs shall follow the HDUs containing data.

Headers The headers of FITS files delivered by ESO shall consist of the following groups of keywords: primary keywords, world coordinate system (WCS) keywords, ESO hierarchical keywords, selected operations log entries and, optionally, comments. Each of these keyword groups is described in detail in the following sections.

Unless the keyword is explicitly defined to reflect the requested setup value, the keyword value shall reflect the actual setting of the parameter or function.

If a FITS file consists of more than one HDU, and the primary data array is empty (i.e. for multi-window or multi-chip data), then keywords related to the data in a particular extension shall be written into the header of that extension, while keywords describing the dataset as a whole shall be written into the primary header and shall be assumed to apply to the extensions as well (this concept is known as “keyword inheritance”). Keyword inheritance shall apply by default, unless explicitly specified otherwise by setting Boolean keyword `INHERIT` in the extension HDU to `F`. See [AD5].

Keyword inheritance must not be used for keywords directly related to the data contained in the extension HDUs (e.g. an instrument consisting of two identical chips should write keywords from the `DET` category into the extension HDUs, even though they could be put into the primary HDU and inherited).

The required FITS keywords (`SIMPLE`, `NAXIS`, etc.) and the commentary keywords are not inherited.

If a keyword appears both in the primary header and in the extension header, then the value in the extension header shall apply in the extension.

If a file modification results in a change of an inherited keyword, then such change shall appear only in the header of the extension HDU and not in the primary header. I.e. the inherited keyword shall appear in the extension header with its new value and the primary header value shall remain unchanged.

It is recommended that all extension headers contain Boolean keyword `INHERIT` explicitly specifying whether keywords are inherited into the extensions.

At acquisition time, the FITS header of a given frame is assembled by the instrument Observation Software (OS) by collecting the contributions to the header from the different subsystems (TCS, INS, DET, etc). Each of these subsystems may contribute primary and/or hierarchical keywords.

Only optical elements intersecting the light path in a given exposure shall be recorded in the header.

Header records should be ordered such that primary keywords are listed first (at the header top), followed by hierarchical keywords (see Section 4.4, p. 34) sorted by category in the following order: `DPR`, `OBS`, `TPL`, `GEN`, `TEL`, `ADA`, `INS`, `DET`, any other category.

The data description for VLTI frames is given in a separate document [RD3].

The file names of FITS frames shall contain extension '`.fits`'. For historical reasons it is permitted, but not recommended, to use '`.tfits`' as a file name extension for FITS files for which all non-empty HDUs are binary tables.

3.1.1 Text dumps of FITS headers

This format may be used for:

- Internal metadata transfer;
- External display of the contents of FITS headers.

Files used for the above purposes shall follow all rules applicable to FITS frames as described in the present document, with the following changes:

- The entire data parts of all HDUs, including the padding, shall be discarded;
- Unix end-of-line characters ('`\n`') shall be inserted at the end of each eighty-character header card;
- The trailing spaces in the resulting records can, but do not have to, be preserved;

It is recommended that the text dumps preserve the blank header cards.

The file names of text dumps of FITS headers shall preserve the original frame's file name, with '`.[t]fits`' extension replaced with '`.hdr`'.

3.2 Log files

The following log files are produced during telescope operations:

- The *operations* log: records all major operations performed and their results (e.g. telescope presets, instrument operations, detector readouts and possible preprocessing); the operations log starts everyday at noon (UTC) and includes actions, acknowledgements, events and comments throughout the night.
- The *configuration* log: records the overall configuration in effect during operations such as pointing models, mounted filters, adaptive and active optics parameters; configuration log entries are written at the start of operations (usually at the beginning of the night) to record the configuration in place, and during operations when configuration parameters change.
- The *conditions* log: records main meteorological and seeing measurements, both ambient and within the dome; typically, ambient conditions would be checked by sensors periodically and their readings recorded in the log every n minutes.
- The *QC1* log: records all Quality Control parameters determined by the pipeline.

All log files shall be stored and archived in the VLT Archive Facility. From there they shall be available for engineering monitoring and any other needs. Extracts from each of the logs shall be stored on the medium handed over to the PI's as part of the standard data distribution procedure. Some log records may also be included in the headers — this is governed by the 'class' attribute of a keyword in the corresponding dictionary (see Section 7.3 on page 65 for more details).

By convention, all keywords that identify the configuration in place on a given night should be recorded in the *configuration* log at the beginning of the night and whenever the configuration changes.

A detailed description of log files is given in Chapter 5, p. 55.

3.3 Observation preparation data and VLT parameter files

The preparation of observations, also called *Phase 2 Proposal Preparation* is supported by tools that assist the user in defining target and instrument requirements (see [RD4]). This information is grouped in units called *Observation Blocks*.

The format and syntax of the VLT *Parameter Files* is used by the VLT Control Software (VCS) to store Setup files.

The format of VLT Parameter Files is described in Chapter 6, p. 60.

3.4 Compound file types

3.4.1 TAR (“Tape Archive”) files

The TAR format may be used to combine sets of logically related files for the purpose of operational transfer, archiving and external delivery.

The TAR file structure must conform to the specifications described in [RD5]. All individual components of a TAR file must follow the standards described in this document.

The TAR files shall use ’.tar’ as the filename extension. For each type of TAR files, the relation between its components and the naming convention must be properly documented and submitted to the DIC Board for approval.

3.4.2 FITS files encapsulating non-FITS files

This format can be used for packing into single FITS file, for the purpose of archiving, of non-FITS files.

The frames constructed in that way shall follow the convention described in [AD6].

Chapter 4

Keyword Description

This chapter describes keywords used by ESO in FITS headers, log files and other data files. The main purpose here is to provide the overall structure of the keywords and their value/usage conventions. The precise specification for each keyword is given in separate data dictionaries (see Chapter 7, p. 63).

Some of the keywords will be used only in headers, some in headers and setup files and again some other only in log files. The specification of where a keyword is included is given through the data dictionaries (see Section 7.3 on page 65).

A list of mandatory keywords is given in appendix A, p. 77. Keywords are mandatory in the sense that they must be included if the information contained in them is applicable to the file in question; for example, RA and DEC keywords are not mandatory in a bias frame.

4.1 Primary FITS keywords

The FITS format, header syntax and standard keywords are described in [AD4]. In addition to the required FITS standard keywords, ESO uses a set of *primary* keywords in its data file headers. For those keywords, ESO follows common conventions for value formats and units. A dictionary containing the definitions of those primary keywords (`ESO-VLT-DIC.PRIMARY-FITS`) is available from the DICB.

Keyword values can be either decimal integers, double precision floating point numbers (allowed notations: `1.`, `1.0`, `1.E+00`, `1E+00`), strings (enclosed within single quotes, i.e. `'string'`) or Boolean, in which case the value can be either `T` (true) or `F` (false).

- Values of the mandatory FITS keywords `SIMPLE`, `BITPIX` and `NAXIS`, and, if applicable, `NAXISn`, `XTENSION`, `PCOUNT`, `GCOUNT` and `EXTEND` must be written in FITS fixed format (see Section 4.2 of [AD4]).

- `EXTEND` set to `T` is mandatory in the header of the primary HDU if the file contains extensions. It is not mandatory in single-HDU files, but it is recommended to include this keyword and to set it to `T` also in this case. This keyword must immediately follow `NAXIS` and (if applicable) `NAXISn` keywords.

Table 4.1: Primary FITS keywords used at ESO in primary HDU and extensions

Type	Keyword	Example	Explanation
(L)	SIMPLE	T	Standard FITS format (NOST-100-2.0)
(I)	BITPIX	16	# bits storing pix values
(I)	NAXIS	2	# of axes in frame
(I)	NAXIS1	2080	# of pixels/row
(I)	NAXIS2	2048	# of rows (also # of scan lines)
(L)	EXTEND	T	Extensions may be present
(R)	BZERO	32768.0	real = fits-value*BSCALE+BZERO
(R)	BSCALE	1.0	real = fits-value*BSCALE+BZERO
(S)	BUNIT	'adu '	Physical unit of array values
(I)	BLANK	0	Value used for NULL pixels
(S)	ORIGIN	'ESO-PARANAL'	Observatory
(S)	DATE	'2001-08-19T09:34:52.676'	Date the file was written
(R)	DATAMAX	43212.0000000	Maximal pixel value
(R)	DATAMIN	323.0000000	Minimal pixel value
(S)	TELESCOP	'ESO-VLT-U3'	ESO Telescope Name
(S)	INSTRUME	'FORS1 '	Instrument used
(S)	OBJECT	'NGC1234'	Target designation as given by the user
(R)	RA	21.955217	01:27:49.2 Pointing (J2000.0)
(R)	DEC	-1.88210	-01:52:55.5 Pointing (J2000.0)
(R)	EQUINOX	2000.	Standard FK5
(R)	RADECSYS	'FK5 '	Reference system
(R)	EXPTIME	100.000	Exposure time (s)
(R)	AIRMASS	1.145	Averaged airmass
(R)	MJD-OBS	52140.39805498	MJD start (2001-08-19T09:33:11.950)
(S)	DATE-OBS	'2001-08-19T09:33:11.950'	Date the exposure was started (UTC)
(S)	TIMESYS	'UTC'	Time system used
(R)	UTC	34391.000	09:33:11.000 UTC at start (s)
(R)	LST	9766.777	02:42:46.777 LST at start (s)
(S)	PI-COI	'SCIENTIST'	Name of the PI/Co-I
(S)	OBSERVER	'OBSERVER'	Name of the observer
(S)	ORIGFILE	'FORS1-IMG231.19.fits'	Original file name
(S)	ARCFILE	'FORS1.2001-08-19T09:33:11.951.fits'	Archive file name
(S)	CHECKSUM	'CYMRAEGLLENYDDOL'	HDU checksum
(S)	DATASUM	'1123581321'	data unit checksum
	COMMENT		Comments
(S)	XTENSION	'IMAGE '	FITS Extension first keyword
(I)	BITPIX	16	# bits storing pix values
(I)	NAXIS	2	# of axes in frame
(I)	NAXIS1	2080	# of pixels/row
(I)	NAXIS2	2048	# of rows (also # of scan lines)
(I)	PCOUNT	0	Parameter count
(I)	GCOUNT	1	Group count
(I)	TFIELDS	13	number of fields in each row
(S)	EXTNAME	'WIN1.CHIP1.OUT1'	FITS Extension name
(S)	CHECKSUM	'BADAKIZUEUSKARAZ'	HDU checksum
(S)	DATASUM	'3141592653'	data unit checksum
(L)	INHERIT	T	Primary header keywords are inherited

- BZERO and BSCALE give, respectively, the offset and the scale factor for data pixels when required. The principal use for those keywords is to store unsigned 16-bit integer data in HDUs with BITPIX=16, in which case BZERO=32768.0 and BSCALE=1.0 are specified. Note that BZERO and BSCALE are, per FITS Standard requirement, always interpreted as floating point numbers.
- BUNIT describes the physical unit of the array value. The value of this keyword should conform to the recommendations outlined in Chapter 8 on page 68.
- ORIGIN specifies the site where the file was generated. ESO uses either 'ESO-LASILLA' or 'ESO-PARANAL' for data obtained at the respective observatories, and 'APEX' for data obtained with the APEX telescope. 'ESO-GARCHING' shall be used for simulation data produced in Garching.
- DATE gives the UTC date when the FITS file was created. The value string for date uses the YYYY-MM-DDThh:mm:ss.sss format, following the FITS standard restriction of the ISO 8601 format (see [AD7] and Section 4.4.2.1 of [AD4]). Note that the value of this keyword describes the file, not the observation.
- DATAMAX and DATAMIN give the maximal and minimal pixel value across the image (excluding special values, i.e. BLANK).
- TELESCOP provides a standard designation of ESO telescopes.

Table 4.2: Usage of the TELESCOP keyword at ESO

Value for TELESCOP	**Telescope**
ESO-NTT	ESO 3.5m New Technology Telescope
ESO-3.6	ESO 3.6m Telescope
MPG/ESO-2.2	MPI 2.2m Telescope
ESO-1.5	ESO 1.5m Telescope
DK-1.5	Danish 1.5m Telescope
NL-0.9	Dutch 90cm Telescope
ESO-CAT	ESO coudé 1.4 Auxiliary Telescope
ESO-1.0	ESO 1.0m Telescope
ESO-VLT-Ui	ESO VLT, Unit telescope i
ESO-VLT-Uijkl	ESO VLT, incoherent combination of Unit Telescopes ijkl
ESO-VLTI-Uijkl	ESO VLT, coherent combination of Unit Telescopes ijkl
ESO-VLTI-Amno	ESO VLT, coherent combination of Auxiliary Telescopes mno
ESO-VLTI-Uijkl-Amno	ESO VLT, coherent combination of Unit Telescopes ijkl and Auxiliary Telescopes mno
ESO-VLTI-Sij	ESO VLT, coherent combination of test siderostat telescopes ij.
ESO-VST	ESO VLT Survey Telescope
ESO-VISTA	ESO 4-meter Visible and Infrared Telescope for Astronomy
APEX-12m	Atacama Pathfinder Experiment

- INSTRUME provides a designation of the instrument used (see Chapter 10 on page 10).

  The complete identification of the instrument is described in the Instrument category (see Section 4.4.2, p. 44); the instrument mode used, when several observing modes are available, is also to be found in this category.

- OBJECT is either the target designation (as given by the astronomer) for science exposures or the exposure type for non-science frames. It should contain the value of OBS TARG NAME for observations of celestial objects and the value of DPR TYPE for all other exposures.
- RADECSYS gives the frame of reference for the equatorial coordinate system. ESO uses FK5 for mean place coordinates system; moving to ICRS is planned.
- RA and DEC report the telescope pointing in mean places of equinox given in EQUINOX. RA is given in degrees without applying any $\cos\delta$ factor.
- EQUINOX contains the epoch of the mean equator and equinox of the coordinate system used to express the WCS mapping. This keyword shall have the value of 2000.0 for data referred to FK5. This keyword must not be present in the data referred to ICRS.
- EXPTIME provides the exposure time in seconds; it may have decimals. When the exposure is made of several periods, EXPTIME time is the sum of the exposure periods, and not the difference between end and start of exposure.

  Subintegrations, i.e. multiple exposures before a readout of the detector are described by the DIT and NDIT parameters, see Section 4.4.2 on page 47.

  For several IR instruments, where the end raw product is an averaged (rather then cumulative) exposure, EXPTIME describes the averaged exposure time.

  For description of the use of keyword EXPTIME in External Data Products, see Section 4.8 on page 53.
- AIRMASS should give the average airmass for the optical axis during the exposure computed for the time while the shutter is open.
- MJD-OBS is the modified Julian Date ($JD - 2400000.5$) of the *start* of the observation. Two resolutions will be supported depending on the capabilities of the instrument: seconds and milliseconds. Five decimals are required for an accuracy of one second and 8 decimals for one millisecond. The reference frame for MJD-OBS at ESO is UTC (unless keyword TIMESYS specifies otherwise) and is given as known to the detector control system local control unit (LCU). The time on the LCU is synchronised with the observatory time system via the Network Time Protocol (ntp).
- DATE-OBS gives the date in which the exposure was started. The value string for date uses the restricted ISO 8601 format, YYYY-MM-DDThh:mm:ss.sss. This keyword repeats the value of MJD-OBS and is included mainly for human readability. The reference frame for this keyword is the same as for MJD-OBS.
- TIMESYS lists the standard abbreviation of the principal time system used for the time-related keywords and the data. This keyword needs to be present only if the system used is other than UTC. Allowed values are listed in http://tycho.usno.navy.mil/systime.html.
- UTC and LST give the time in seconds elapsed since midnight of the start of the exposure as known to TCS. The time on TCS is synchronised with the observatory time system via a

dedicated time module. In principle, `UTC` and `LST` should correspond, within a second accuracy, to the UTC time given by the detector control LCU in `MJD-OBS`. In practice, `MJD-OBS`, `UTC` and `LST` provide for a redundant consistency check mechanism in case of malfunction.

- `PI-COI` The PI or Co-I's initials followed by his/her surname. The primary keyword `PI-COI` should repeat the value of `OBS PI-COI NAME`.
- `OBSERVER` The observer's initials followed by his/her surname.
- `ORIGFILE` records the original file name, as assigned at the instrument workstation.
- `ARCFILE` provides the name under which the file is stored in the archive.
- `CHECKSUM` provides a Cyclic Redundant Check (CRC) calculation for each HDU. It uses the ASCII encoded 1's complement algorithm, see [AD8].
- `DATASUM` gives the checksum calculated for the data sections only. For dataless records this keyword should be set to `'0'`. See [AD8].
- `COMMENT` reports any comments associated with this frame.

The following keywords are used exclusively in FITS extensions:

- `XTENSION` indicates start of an extension block in the FITS file. This keyword is mandatory for an extension header and must not appear in the primary header. Possible values are: `'TABLE'` for ASCII tables, `'BINTABLE'` for binary tables and `'IMAGE'` for image extensions.
- `PCOUNT` is mandatory in the extension header. It contains the number of bytes that follow the table in the associated extension data. In image and standard binary table extensions it should be set to `0`. For variable-length-array binary tables (e.g. tile-compressed FITS files) it will be non-zero. This keyword must immediately follow `NAXIS` and (if applicable) `NAXISn` keywords.
- `GCOUNT` is mandatory in the extension header, and should always be set to `1`. This keyword must immediately follow the `PCOUNT` keyword.
- `EXTNAME` is a string used to distinguish different extensions of the same type in the FITS file. `EXTNAME` should uniquely describe the detector/chip/window combination used.
- `INHERIT` is used to indicate that the keywords from the header of the primary HDU should be inherited into the extension.

The following keywords are mandatory in `'BINTABLE'` extensions:

- `TFIELDS` is a non-negative integer showing the number of fields in the table. This keyword must immediately follow the `GCOUNT` keyword.
- `TFORMn`, with the integer index `n` ranging from 1 to the value of the `TFIELDS` keyword, which show the format of individual fields in the table. The format of the values of those keywords must follow the rules specified in the FITS Standard document [AD4], Section 7.3.1).

4.2 Coordinate system keywords

The coordinate system keywords used at ESO are based on the World Coordinate System (WCS) as described in [AD4] Keywords CRVALna, CRPIXna, CDn_ma, CTYPEna and, optionally, CUNITna, CRDERna and CSYERna describe the coordinate system frame on which the data pixels are to be interpreted.

The CDn_ma keywords replace CDELTna, CROTAna and PCnnnmmm, CDELTi and CROTAi, the use of which is deprecated in files generated at ESO. Use of CDELTna keywords with either CROTAna or PCn_ma keywords, as described in [AD4], will be allowed for External Data Products, but no file shall utilise more than one rotation/skew convention (i.e. it is not allowed to use both the CD matrix and the CDELT keywords).

The WCS keywords must be included in every HDU containing data. In all WCS keywords, the index n ranges from 1 to the value of the NAXIS keyword.

As necessary, each HDU may contain one or more alternate coordinate systems (see below). The alternate systems are labeled with index a at the end of the keyword name. The index can be empty (i.e. no index) or an uppercase letter, ranging from A to Z. The WCS indexes can be used out of order, i.e. presence of WCS keywords indexed with B does not require that the file also has a system indexed with A.

It is recommended that the WCS indexes used are, if possible, related to the coordinate systems they describe, e.g. index P can be used for pixel coordinates, index S for spectral coordinates, etc. (see below).

The unindexed WCS keywords provide what is considered the principal coordinate system for the data. The principal system may be a copy of one of the indexed systems.

Three commonly used WCS coordinate systems are described below. The full list can be found in [RD6], [RD7] and [RD8].

4.2.1 Pixel coordinates

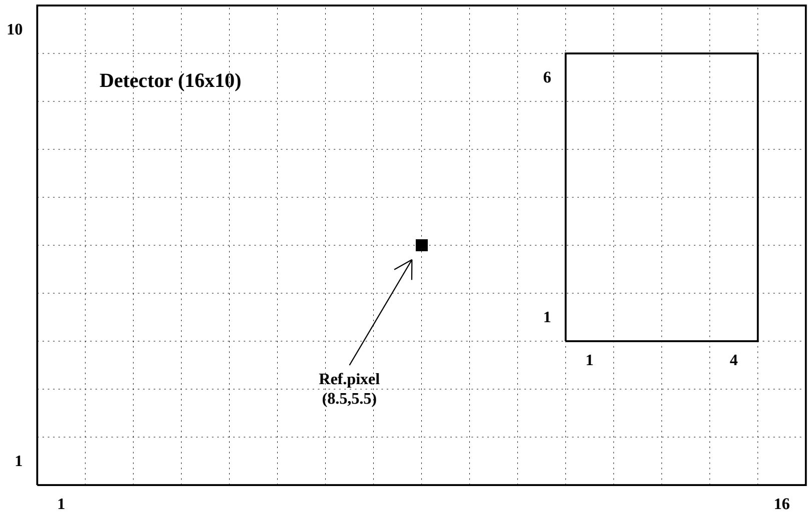
The usage of detector coordinate system is shown in Table 4.3 and explained below. The example shows unindexed WCS keywords.

Note that coordinates in FITS frames refer to the center of pixels, i.e. pixel 1 would integrate flux between 0.5 and 1.5 if the chip had uniform sensitivity.

Table 4.3: Usage of WCS keywords for pixel coordinates

Type	Keyword	Example	Explanation
(S)	CTYPE1	'PIXEL'	Pixel coordinate system
(S)	CTYPE2	'PIXEL'	Pixel coordinate system
(R)	CRPIX1	315.	Value of X ref. pixel
(R)	CRPIX2	325.	Value of Y ref. pixel
(R)	CRVAL1	1020.	X ref. pixel of center of rotation
(R)	CRVAL2	1025.	Y ref. pixel of center of rotation
(R)	CD1_1	1.00000	1 image pixel per detector pixel
(R)	CD2_1	0.00000	no rotation, no skew
(R)	CD1_2	0.00000	no rotation, no skew
(R)	CD2_2	1.00000	1 image pixel per detector pixel

- CRVALn give the reference pixel of the full detector matrix. When possible, it is recommended to define the reference pixel (possibly with fraction if the accuracy is achieved) at the point where the telescope's optical axis intersects the detector.
- CRPIXn give the position of the reference pixel of the detector matrix (CRVALn) relative to the coordinate frame of the readout window. The following picture illustrates the use of CRVALn and CRPIXn for a window readout:



When the complete detector is read out, CRPIX1/CRPIX2 are equal to CRVAL1/CRVAL2, i.e. 8.5 and 5.5 respectively. In the case a window only is readout, CRPIX1=-2.5 and CRPIX2=2.5 while CRVAL1/CRVAL2 remain the same.

- CDn_m give the elements of the coordinate translation matrix. For the detector coordinate system no rotation is applied, hence the non-diagonal elements of the matrix are 0. CD1_1 and CD2_2 give the number of detector pixels per data pixel in x- and y-direction, respectively. They are also known as the binning factors.
- CTYPEn gives the coordinate system for CRPIXn. CTYPEn for raw frames is the string 'PIXEL' indicating that coordinate system refers to detector pixels.

  Coordinate keywords shall describe the coordinate system for each chip. In case of a multi-chip instrument the coordinate keywords are therefore written to the header of each of the image extensions.

4.2.2 Celestial coordinates in imaging data

In order to obtain celestial coordinates for a given image, a mapping is required between the sky and the physical layout of the detector while making use of the VLT field astrometric calibration and detector orientation (see Section 4.4.2).

With the help of WCS keywords, analysis software can establish the celestial coordinates corresponding to any pixel in the frame. In the general case, WCS keywords will account for translation, rotation, mirroring and projection functions to accurately describe the mapping. However, in the case of the VLT it is expected that a simple tangential projection will provide the required transformation under normal conditions.

When the mapping has been applied, the coordinate system keywords have to be interpreted differently according to the value of `CTYPEn` (see [RD6, RD7, RD8] for details).

Table 4.4 gives the ESO usage for WCS keywords when they describe the mapping of detector pixels to celestial coordinates. The example shows unindexed WCS keywords.

It is recommended that raw imaging data include mapping to celestial coordinates in the WCS keywords whenever this information is available with reasonable accuracy, utilising the `CRDERi` and `CSYERi` keywords (see below) when appropriate.

Table 4.4: Usage of WCS keywords in imaging data

Type	Keyword	Example	Explanation
(S)	CTYPE1	'RA---TAN'	TAN projection used
(S)	CTYPE2	'DEC--TAN'	TAN projection used
(R)	CRPIX1	1029.2	reference pixel in X
(R)	CRPIX2	1017.8	reference pixel in Y
(R)	CRVAL1	21.95522	RA at reference pixel in degrees
(R)	CRVAL2	-1.88210	DEC at reference pixel in degrees
(S)	CUNIT1	'deg '	Unit of coordinate transformation (optional, default: degrees
(S)	CUNIT2	'deg '	Unit of coordinate transformation (optional, default: degrees)
(R)	CD1_1	-0.00277	10.0 arcsec per pixel
(R)	CD2_1	0.00000	no rotation, no skew
(R)	CD1_2	0.00000	no rotation, no skew
(R)	CD2_2	0.00277	10.0 arcsec per pixel
(R)	CSYER1	0.00014	(optional) systematic error of 0.5 arcsec
(R)	CSYER2	0.00014	(optional) systematic error of 0.5 arcsec
(R)	CRDER1	0.00056	(optional) random error of 2 arcsec
(R)	CRDER2	0.00056	(optional) random error of 2 arcsec

The `CDn_m` keywords express the transformation matrix to correct for scaling, rotation and skew (please refer to the FITS standard document [AD4] and WCS documents [RD6, RD7, RD8] for more information).

4.2.3 Spectral coordinates

The wavelength solution for spectroscopic data may be presented with the help of the WCS keywords.

Table 4.5 shows the usage for WCS keywords in spectral data. The example shows the mapping of detector pixels to a simple case of longslit spectrum dispersed linearly along the x-axis of the detector, binned by 2 in the cross-dispersion direction.

Other tranformations are possible (logarithmic, velocity, etc.), depending on the value of the `CTYPEn` keyword (see [RD6, RD7, RD8] for details).

It is recommended that raw spectroscopic data include mapping to spectral coordinates in the WCS keywords whenever this information is available with reasonable accuracy, utilising the `CRDERi` and `CSYERi` keywords (see below) when appropriate.

Table 4.5: WCS keywords in spectroscopic data

Type	Keyword	Example	Explanation
(S)	CTYPE1	'WAVE '	wavelength in X
(S)	CTYPE2	'PIXEL '	pixel coords in Y
(R)	CRPIX1	1.0	reference pixel in X
(R)	CRPIX2	1.0	reference pixel in Y
(R)	CRVAL1	2164.546	wavelength at reference pixel in nm
(R)	CRVAL2	1.0	Y at reference pixel in degrees
(S)	CUNIT1	'nm '	Unit of coordinate transformation
(S)	CUNIT2	'pixel '	Unit of coordinate transformation
(R)	CD1_1	0.0104268	nm/pixel
(R)	CD2_1	0.00000	no rotation, no skew
(R)	CD1_2	0.00000	no rotation, no skew
(R)	CD2_2	2.0	binned by 2 in Y-direction
(R)	CSYER1	0.00050	(optional) systematic error of 0.0005 nm
(R)	CRDER1	0.00010	(optional) random error of 0.0001 nm

4.2.4 Coordinate transformation uncertainties

If random or systematic errors in coordinate `i` are known, they should be recorded in keywords `CRDERi` and `CSYERi`, respectively, in units shown in relevant `CUNITi` keyword. They give a representative average value of the error over the range of the coordinate in the data file. The total error in the coordinate would be given by summing the two errors in quadrature.

4.2.5 Example of use of alternate coordinate systems

Table 4.6 shows the use of alternate coordinate systems in a single file. Three hypothetical coordinate systems are shown, labeled with:

P: "pixel" coordinates. In this example the WCS keywords show that the data are unbinned in the x-direction and binned by 2 in the Y-direction.

F: "focal plane" coordinates. In this example the WSC keywords map the location of the considered chip on the detector's focal plane, with milimeters as units.

S: "spectral" coordinates. In this example the WCS keywords show a linear wavelength solution with 0.0104268 nanometres per pixel in the x-direction and binning by 2 in the y-direction. The wavelength coordinate has a known systematic error of $\sim$20 pixels and an unknown random error.

In the example, the spectral coordinates are also the principal coordinates of the frame and are therefore repeated in the unindexed WCS keywords.

Table 4.6: Sample use of alternate WCS keyword sets in spectroscopic data

```
COMMENT        ##### pixel coordinates #####
CTYPE1P = 'PIXEL   '          / Coordinate system of x-axis
CTYPE2P = 'PIXEL   '          / Coordinate system of x-axis
CUNIT1P = 'pixel   '          / Units of x-axis
CUNIT2P = 'pixel   '          / Units of y-axis
CRPIX1P =                 1.0 / Reference pixel in x
CRPIX2P =                 1.0 / Reference pixel in y
CRVAL1P =                 1.0 / Value in reference pixel in nm
CRVAL2P =                 1.0 / Value in reference pixel
CD1_1P  =                 2.0 / binned by 2 in x-direction
CD1_2P  =                 0.0 / no rotation, no skew
CD2_1P  =                 0.0 / no rotation, no skew
CD2_2P  =                 2.0 / binned by 2 in y-direction
COMMENT        ##### focal plane coordinates #####
CTYPE1F = 'LINEAR  '          / Coordinate system of x-axis
CTYPE2F = 'LINEAR  '          / Coordinate system of x-axis
CUNIT1F = 'mm      '          / Units of x-axis
CUNIT2F = 'mm      '          / Units of y-axis
CRPIX1F =                 1.0 / Reference pixel in x
CRPIX2F =                 1.0 / Reference pixel in y
CRVAL1F =             105.894 / Value in reference pixel in mm
CRVAL2F =               15.25 / Value in reference pixel in mm
CD1_1F  =               0.027 / mm per pixel
CD1_2F  =                 0.0 / no rotation, no skew
CD2_1F  =                 0.0 / no rotation, no skew
CD2_2F  =               0.027 / mm per pixel
COMMENT        ##### spectroscopic coordinates #####
CTYPE1S = 'WAVE    '          / Coordinate system of x-axis
CTYPE2S = 'PIXEL   '          / Coordinate system of x-axis
CUNIT1S = 'nm      '          / Units of x-axis
CUNIT2S = 'pixel   '          / Units of y-axis
CRPIX1S =                 1.0 / Reference pixel in x
CRPIX2S =                 1.0 / Reference pixel in y
CRVAL1S =            2164.546 / Value in reference pixel in nm
CRVAL2S =                 1.0 / Value in reference pixel
CD1_1S  =           0.0104268 / nm per pixel
CD1_2S  =                 0.0 / no rotation, no skew
CD2_1S  =                 0.0 / no rotation, no skew
CD2_2S  =                 2.0 / binned by 2 in y-direction
CSYER1S =                0.22 / syst.err ca.20 pixels
COMMENT        ##### principal system, equal to spectr.coords #####
CTYPE1  = 'WAVE    '          / Coordinate system of x-axis
CTYPE2  = 'PIXEL   '          / Coordinate system of x-axis
CUNIT1  = 'nm      '          / Units of x-axis
CUNIT2  = 'pixel   '          / Units of y-axis
CRPIX1  =                 1.0 / Reference pixel in x
CRPIX2  =                 1.0 / Reference pixel in y
CRVAL1  =            2164.546 / Value in reference pixel in nm
CRVAL2  =                 1.0 / Value in reference pixel
CD1_1   =           0.0104268 / nm per pixel
CD1_2   =                 0.0 / no rotation, no skew
CD2_1   =                 0.0 / no rotation, no skew
CD2_2   =                 2.0 / binned by 2 in y-direction
CSYER1  =                0.22 / syst.err ca.20 pixels
```

4.3 Keywords in tile-compressed files

ESO utilises FITS tile compression for storage and transfer of image data. ESO tile-compressed files shall follow the convention described in [AD9]; this reference contains definitions and descriptions of all keywords mandatory in such files. Those keywords are also listed in Section A.9, page 82.

4.4 Hierarchical keywords

The FITS Format standard has been used largely by the astronomical community primarily as a format to transfer data. When it comes to use FITS as format to also archive observational data, the first question that arises is how to use FITS keywords to describe the parameters (instrumental, temporal, etc.) that define the configuration leading to the actual observation. In the absence of a widely accepted *semantic* standard, some communities have developed their own conventions. In the Optical and the Infrared astronomy communities, however, different projects have diverged quite considerably, making the re-use of software packages for data reduction across observatories difficult.

One of the main drawbacks of FITS keywords is that they, being limited to names of 8 characters, do not provide enough name space to describe the sometimes hundreds of parameters required to describe the configuration of modern observing facilities.

ESO uses hierarchical keywords as a means to manage a structure of domain names, i.e. to group keywords that belong to the same logical entity. More generally, hierarchical keywords in FITS implement *a domain naming convention* allowing the definition of context-dependent keywords[1]. The advantage of hierarchical keywords is that they provide readable headers and support an easy to manage data interface based on context instead of managing keywords with cryptic names.

The main disadvantage of hierarchical keywords is that they are not a FITS standard and therefore only ESO data reduction software will be able to interpret parameters recorded in this way. This effectively limits the choice of software packages that ESO users can utilise. As a strategy to overcome this shortcoming, ESO has developed the *hierarch28* tool, which allows translation of hierarchical keywords into FITS standard, eight-character keywords (see Chapter 3 on page 19).

In 2006, the FITS Working Group of the International Astronomical Union began maintaining the *Registry of FITS Conventions* (`http://fits.gsfc.nasa.gov/fits_registry.html`). The hierarchical keywords convention has been submitted to the Registry in September 2007.

4.4.1 The domain name structure

A hierarchical keyword starts by convention with HIERARCH and is followed by words describing each a domain except the last one before the = sign which describes the parameter being reported.

The general scheme of hierarchical keyword used by ESO is

```
HIERARCH ESO category [subsystem(s)] parameter = value / comment
```

Examples of this scheme are

```
HIERARCH ESO DET WIN1 STRX  =            3 / Lower left pixel in X
HIERARCH ESO INS FILT1 NAME = 'OIII/3000' / Filter name
HIERARCH ESO OBS NAME       = 'NGC1275  ' / Observation block name
```

[1] Another example of a domain name management is the very well known structure of Internet network addresses (e.g. host.domain.country), except that here the hierarchy is reversed: from general (broad) to specific (narrow).

where DET, INS, OBS are categories, WIN1 and FILT1 are subsystems and STRX, NAME are parameters (see next sections).

Categories

The parameters are classified in a small number of broad *categories*. Seventeen such categories are presently defined, and designated by a 2- or 3-letter abbreviation:

- DPR (originally DATA PRODUCT) describes the category and purpose of the data file. It is defined for raw files only[2] (see page 39).
- OBS (OBSERVATION) provides parameters that relate to the parent observation block to which this frame belongs (see page 40).
- TPL (TEMPLATE) gives information on parameters for templates (see page 43).
- GEN (GENERAL) provides parameters that relate to the observatory (see page 43).
- TEL (TELESCOPE) describes the telescope setup, e.g. position and tracking (see page 43).
- ADA (ADAPTER) includes all descriptive parameters, when an adapter and/or a rotator is located between the telescope and the instrument (see page 44).
- INS (INSTRUMENT) describes any element along the optical path between the telescope (or the adapter) and the detector (see page 44).
- DET (DETECTOR) describes the detector setting parameters (see page 47).
- OCS (OBSERVATION CONTROL SOFTWARE) describes parameters used by the Observation Software (OS), (see page 50).
- DEL (DELAY LINE) describes the VLTI delay lines (1 through 8), (see page 50).
- COU (COUDE) describes the VLTI coude optics (see page 50)
- ISS (INTERFEROMETRIC SUPERVISOR SOFTWARE) describes the VLTI supervisor software (see page 50).
- AOS (ADAPTIVE OPTICS SYSTEM) describes Adaptive Optics Systems (see page 50).
- PAF (PARAMETER FILE) describes VLT Parameter File header information (see Chapter 6, p. 60).
- SIM (SIMULATOR) describes simulator information like assumptions taken for the simulation process, e.g. sky emissivity or source brightness (see page 50).
- PRO (PROCESS) describe data processing parameters, it is defined in products files only (see page 50).

[2] The name of this category – DPR – is kept for historical reasons; ESO definition of *data products* specifically excludes raw frames.

- QC (QUALITY CONTROL) contains results of the quality control process performed by the pipeline (see page 51).

For each category there is one or more dedicated dictionary that contains the definitions of all keywords belonging to this category.

A category designation can be appended with an integer index. This should be done only in cases where there are more than one logical blocks of keywords belonging to the relevant category. An example of this situation is a frame obtained with FLAMES+UVES, where both components require separate INS categories. It is permitted to use indexed and non-indexed categories in the same file (i.e. INS together with INS1).

A detailed description of each category is given in subsequent sections.

Subsystems

A *subsystem* keyword identifies a component in a category and can consist of zero or more words, which as a rule should not consist more than four characters. Subsystems commonly used by ESO are listed in Table 4.7.

An integer suffix i can be added to the last word of the subsystem when several identical components are available in order to differentiate them. As an example, FILT1 and FILT2 could be used to describe two filter elements along the light path. For historical reasons, it is allowed to use a number as the last character of the subsystem name in individual cases, e.g. RETA2 and RETA4 for half- and quarter-wave retarders, respectively.

Subsystems may be concatenated for a particular context, e.g. AMBI WIND to describe ambient (instead of dome) wind measurements. However, only a maximum of two subsystems should be used.

Parameters

The last word in the hierarchy designates which parameter of the (sub)system is reported, and implies the *format* (Boolean, integer, real, character string) as well as the *unit* used for the parameter. In order to keep to a minimum the size required by the complete hierarchy, it is recommended to use names not exceeding 8 characters. Characters allowed are (as for primary FITS keywords) all uppercase letters, numbers, the dash and underscore characters.

The basic *parameter* keywords used in the following sections are described in Table 4.8, examples are given in Table 4.12 and Table 4.13, standard units are given when applicable.

A numeric suffix may be appended to the parameter name in the case of multidimensional parameters (e.g. a complex slit made of several slitlets), as it is done in standard FITS. As an example, X1 refers to the x-position of the first component of the parameter.

Numeric suffixes must not contain leading zeroes, i.e. the second component of the X parameter must be spelled X2, and not X002.

The dictionary definition of suffixed parameters contains the letter i as a placeholder for any integer number (see Chapter 7). An indexed dictionary definition also includes non-indexed use of the parameter, e.g. Xi describes both X and X1.

The following two parameters deserve special attention because of their usage:

Table 4.7: List of commonly used subsystem keywords

Subsystem	Meaning
ACTO	Active Optics
ADAO	Adaptive Optics
ADC	Atmospheric Dispersion Corrector
AIRM	Airmass parameters
AMBI	Observatory ambient conditions
CAT	Target catalog
CHIP	Detector chip
COMP	Control computer
DLMT	Delay line metrology
DOME	Anything related to the telescope enclosure
DROT	Derotator
DPOL	Depolarizer assembly
DPOR	Depolarizer rotator
DPOS	Depolarizer slide
EXP	Exposure
FILT	Filter
FOCU	Focus
FRAM	Frame type
GRAT	Grating
GRIS	Grism
GRP	Group of some kind
GUID	Guiding system
LAMP	Any kind of lamp
MIRR	Instrument mirror
MOS	Multiple Object Spectrum details
OPTI	Optical element inserted in the light path
OUT	Detector readout Output
PRIS	Prism
PROG	Observing Programme (accepted proposal)
REDU	Data reduction
ROT	Rotating device
RETA2	Half-wave retarder plate
RETA4	Quarter-wave retarder plate
SEIS	Seismic monitor
SENSOR	Digital sensor
SHUT	Shutter
SLIT	Any kind of slit
SOFW	Identifies control software for a subsystem
TARG	Target (astronomical object observed)
TILT	Tilt
TRAK	Tracking system
WIN	Detector Window
WIND	Anything related to wind measurements
VLTI	Anything related to coherent modes

- ID provides a unique, ESO-wide identification for a component, part or element. It is built using the following guidelines:
  - hardware serial numbers for passive parts (e.g. prisms);

Table 4.8: Basic parameter keywords

	Parameter	Meaning
(R)	ALT	Altitude angle in the ALT-AZ system (°)
(R)	POSANG	Position angle (°, North=0, East=90)
(R)	AZ	Azimuth angle (° left handed)
(S)	DAYTIM	Civil date and time as 'YYYY-MM-DDThh:mm:ss.sss' (restricted ISO 8601)
(S)	DATE	UTC date and time as 'YYYY-MM-DDThh:mm:ss.sss' (restricted ISO 8601)
(R)	DEC	Declination d (°)
(S)	DID	Data Interface Dictionary to which a subsystem complies
(R)	DIST	Distance in m
(R)	DIMX	Size along x-axis (m)
(R)	DIMY	Size along y-axis (m)
(R)	ENC	Encoder value
(R)	ENCREL	Encoder relative displacement (in encoder units)
(R)	FWHM	Seeing measurements (arcsec)
(S)	ID	Identification which is *unique* for any component
(R)	LEN	Any angular length (arcsec)
(R)	LLEN	Any linear length (m)
(R)	LWIDTH	Any linear width (m)
	MAX	A maximum value
	MIN	A minimum value
(S)	MODE	Optional mode description
(S)	NAME	a clear designation of the item
(I)	NO	Integer number or identifier (e.g. a position on a wheel)
	POS	Position
(S)	PARM	Parameter in free format, e.g. Par=value
(R)	PRES	Pressure (Pa)
(R)	RA	Right ascension α (°)
(R)	RATEA	Tracking rate in RA (°/s)
(R)	RATED	Tracking rate in DEC (°/s)
(R)	RHUM	Relative humidity (%)
(R)	ROT	Rotation angle (°)
(R)	SCALE	Scale factor
(R)	SCALX	Scale factor along x-axis
(R)	SCALY	Scale factor along y-axis
(R)	SPEED	Speed of any system (m/s)
(L)	ST	a status binary flag, as True when the (sub)system is on, False when off
(S)	STATUS	a status of the system
(R)	TEMP	Temperature of any system (K)
(R)	TILTA	Tilt angle around the East-West axis (°). See Figure 1.1.
(R)	TILTB	Tilt angle around the North-South axis (°). See Figure 1.1
(R)	TIME	Elapsed Time (seconds)
(S)	TYPE	Type or class of component
(S)	UNIT	Unit (see Chapter 8)
(R)	UTC	Universal Time Coordinated (seconds since midnight)
(R)	WIDTH	Any angular width (arcsec)
(R)	WLEN	Wavelength in nm
(R)	X	Position along x-axis (m)
(R)	Y	Position along y-axis (m)
(R)	ZENITH	Zenithal distance (°)

  - name/version.revision for software programmes;
  - a combination of both for combined elements (e.g. a detector consists of both chip and controller) and
  - the uniform identification scheme for all optical elements (filters, grisms, gratings, etc.) given in Chapter 9.

- NAME provides a verbose name for the element that complements the ID. Names must follow the convention specified in Chapter 9.

As a rule, a component change/replacement or a subsystem upgrade should be reflected in the ID parameter, but not in the NAME parameter.

4.4.2 Hierarchical keyword categories

Category *Data Product* (DPR)

The DPR category includes parameters related to the raw data files and their contents. As mentioned earlier, the name of this category is kept for historical reasons.
DPR keywords are set by instrument template software (sequencer scripts).

- DPR CATG, DPR TYPE and DPR TECH provide unique high level description of the observation in terms of its purpose and technique.

  Note that only certain combinations of these keyword values are meaningful. It is the task of the template designer to characterise the observation making use of a suitable combination of values.

- DPR CATG gives the observation category. It must take one of the values given in Table 4.9.

Table 4.9: List of DPR CATG values

Value	Explanation
SCIENCE	Any scientific object
CALIB	Any calibration source
ACQUISITION	Any exposure taken to verify telescope pointing
TECHNICAL	Any exposure taken to verify instrument performance/setup (see text)
TEST	Any exposure taken to test instrument performance/setup/software/conditions (see text)
OTHER	Any other exposure

DPR CATG = 'TEST' is to be used to identify frames taken during instrument or software tests. The TEST frames are allowed to use relaxed header rules: except for valid entries in FITS mandatory keywords and in MJD-OBS and INS ID (and DPR CATG, naturally), those frames are not under obligation to follow any header/data rules specified in this document. However, the responsibility for proper description of those frames for any future use lies entirely with the individual/group taking the data.

DPR CATG = 'TECHNICAL' is to be used for frames taken to verify instrument setup and/or performance, which are obtained in operational setup, and are under obligation to conform to the standards set forth in this document. Examples of such frames are: focus tests, shutter errors, ccd linearity, charge transfer efficiency, etc. In contrast to calibration frames (DPR CATG = 'CALIB'), these frames are not used to calibrate scientific data or to routinely measure the state and health of the instrument. 'TECHNICAL' data are typically acquired rarely, during technical nights.

- DPR TYPE gives the type of observation/exposure.
- DPR TECH gives the technique used during the observation.

  DPR TYPE and DPR TECH can each take more than one value; it is recommended to limit the number of entries to at most three. The values should be separated with commas, with no blank spaces. This provides the means to describe a wide range of observations. If more than one value is present, the entries should as a rule follow the "general-to-specific" order, i.e. the first entry should be a general term describing the type or technique, followed by qualifiers describing more specific details (e.g. 'FLAT,LAMP' and 'FLAT,SKY' should be used instead of 'LAMP,FLAT' or 'SKY,FLAT').

  Tables 4.10 and 4.11 list commonly used values for DPR TYPE and DPR TECH keywords.

  Note: Tables 4.10 and 4.11 do *not* show complete lists of allowed values, since development of new instruments and new observation techniques will quickly render obsolete any list claiming to be complete.

  The tables are intended as guidelines showing what type of information is included in the keywords. In both tables, the first groups of values show the commonly used principal observation types or techniques, and those values will usually be the first entries in the DPR TYPE or DPR TECH value strings. Second groups of values show examples of qualifiers to the types or techniques. Third groups show few examples of instrument-specific qualifiers.

  New values for the DPR keywords must be submitted for approval to the DIC Board.

As examples, a twilight sky flat is described with:

```
DPR CATG = 'CALIB'
DPR TYPE = 'FLAT,SKY'
DPR TECH = 'IMAGE'
```

and a jittered NACO polarimetry observation of a scientific target with the Wollaston prism is described with:

```
DPR CATG = 'SCIENCE'
DPR TYPE = 'OBJECT'
DPR TECH = 'POLARIMETRY,WOLLASTON,JITTER'
```

Category *Observation* (OBS)

This category refers to ObservationBlock and frame identification and timing, and may apply to any kind of observation.

Table 4.10: DPR TYPE: examples of principal values (first group), qualifiers (second group) and instrument-specific qualifiers (third group).

Value	Explanation
OBJECT	any observation of an unspecified object
STD	any observation of a standard calibration source
ASTROMETRY	astrometric standard field
BIAS	readout frame
DARK	dark exposure (shutter closed)
FLAT	any flat field exposure
SKY	any observation of an empty field in the sky
LAMP	any lamp exposure
DOME	any exposure using the dome
SCREEN	any exposure using an illuminated screen
FLUX	flux standard (spectroscopy and photometry)
PSF-CALIBRATOR	reference star for PSF calibration
WAVE	any (instrument-internal) wavelength calibration
FOCUS	any focus exposure
SLIT	any non-spectroscopic exposure using a slit
FIBER	any exposure using fibers
FMTCHK	any arc-lamp exposure to obtain first-order guesses for dispersion sol. (UVES)
ORDERDEF	any flat-field exposure to derive order and background positions (UVES)
OzPoz	exposures taken using the Fibre Positioner (FLAMES)

OBS keywords are set by the Observation Handling Subsystem through its Phase 2 Proposal Preparation tool (P2PP). OBS keywords are added untouched to the header by the instrument OS software.

Subsystems in this category are:

- PI-COI contains information about the programme PI/CoI:
  - OBS PI-COI NAME contains the name of the programme PI/CoI,
  - OBS PI-COI ID a numeric ID which was assigned to the PI/CoI by ESO.
- PROG provides details about the observing programme.

  The following keywords have a special meaning and usage convention:
- OBS PROG ID is the identification code assigned to each observing run[3] by the Observing Programme Committee (OPC) in the format ppp.c-nnnn(r), where
  - programme type:

    0pp Normal Science Programme
    1pp Large Programme
    2pp Director's Discretionary Time Programme
    3pp Short Programme (obsolete as of this writing)
    4pp Calibration Programme

[3]Note: keyword OBS PROG ID stores run identifier, not programme ID. This convention is kept for historical reasons.

Table 4.11: DPR TECH: examples of principal values (first group), qualifiers (second group) and instrument-specific qualifiers (third group).

Value	Explanation
IMAGE	any picture
SPECTRUM	single-order spectrum
ECHELLE	cross-dispersed spectrum
MOS	frame with spectra of several objects
MXU	frame with spectra of several objects using a pre-manufactured mask
IFU	Integral Field Unit observation
POLARIMETRY	polarimetric exposure
CORONOGRAPHY	coronography exposure
INTERFEROMETRY	coherent exposure with more than one telescope beam
TEL-THROUGH	telescope through-focus sequence
INS-THROUGH	instrument through-focus sequence
WEDGE	focus wedge frame
HARTMANN	Hartmann focus test
ABSORPTION-CELL	absorption lines included (e.g. Iodine cell)
DRIFTSCAN	drift scanning exposure
FABRY-PEROT	exposure using Fabry-Pérot technique
WOLLASTON	Wollaston polarimetry
WIRE_GRID	Wire grid polarimetry
DIRECT	qualifier indicating direct imaging/spectroscopy
CHOPPING	exposure utilising M2 chopping
NODDING	exposure utilising telescope nodding
CHOPNOD	exposure utilising both chopping and nodding
JITTER	exposure utilising source jittering technique
SLIC#<i>	observation using image slicer #i (UVES)
HIT	high time resolution mode (FORS)
FILTERCURVE	spectroscopic flatfield with a narrowband filter included (FORS)
SPIDER	exposure using SkySpider (SINFONI)

– pp is the period number pp set to 60 indicates a technical programme, used for calibration),
– c is the programme scientific category as defined by the ESO OPC (currently A to D),
– nnnn is the running number,
– r is the observing run identifier, an uppercase letter.

This keyword allows the archive facility to assign ownership to the data and consequently to enforce proprietary rights of observations. This keyword must be present in all science, calibration and acquisition data files.

- TARG contains information about the target that was observed:

  OBS TARG NAME gives the name of the target package which was used for the preparation of the OB with P2PP.

Other keywords in this category are:

- OBS ID contains a unique numeric id which was assigned to the observation block by the Observation Handling Subsystem.
- OBS NAME contains the name of the observation block itself.
- OBS OBSERVER contains the name of the observer.
- OBS START gives the exact start time of the OB in the restricted ISO 8601 format.
- OBS TPLNO gives the template sequence number within the observation block. The first template in the observation block shall have the OBS TPLNO value of 1.

Category *Template* (TPL)

TPL keywords are set by the instrument template software (sequencer scripts).

This category describes parameters needed by VLT observing templates. It includes the following header keywords:

- TPL ID and TPL NAME to identify the observing template to which this frame belongs;
- TPL NEXP which gives the total number of exposures expected for this template;
- TPL EXPNO which gives the current exposure number within this template; the first exposure in a template shall have the TPL EXPNO value of 1;
- TPL START which gives the exact start time of the template in the restricted ISO 8601 format;
- other template specific information such as loop parameters or parameters computed during the template execution.

Category *General* (GEN)

This category describes observatory information. GEN keywords are added to the header by the Data Pipeline Software and are found principally in the processed frames.

Subsystems in this category are:

- AMBI describes observatory ambient conditions such as temperature (TEMP), relative humidity (RHUM), wind speed and direction (WIND), seeing (FWHM, full width at half maximum at 0.5μm), airmass parameters (AIRM), seismic events (SEIS) and atmospheric coherent time (COTI).

Category *Telescope* (TEL)

TEL keywords are set by the Telescope Control Software (TCS).

Subsystems in this category are:

- ACTO details Active Optics characteristics.

- ADC details Atmospheric Dispersion Corrector characteristics. This subsystem may be embedded in the INS category if the corrector is part of the instrument.
- AIRM gives airmass values at start and end of the observation.
- AMBI gives ambient parameters as received from the ambient server.
- CHOP gives parameters related to telescope chopping.
- DOME details dome conditions such as temperature (TEMP), wind speed and direction (WIND).
- FOCU gives details of the focal length, scale and focal station.
- M1/M2 give details about M1 and M2 status and general active optics information.
- PARANG gives parallactic angles at start and end of the observation.
- TARG gives details about the observation target.
- TRAK describes tracking parameters.

TEL DATE shall give the installation date of the telescope control software system.
TEL ID shall give the revision number of the telescope control software.

Category *Adapter* (ADA)

ADA keywords are set by the Telescope Control Software (TCS).
Subsystems used in this category are:

- GUID which gives guiding system information such as guide probe location and status;
- ABSROT which describes absolute adapter rotation angles. The reference frame is defined in the dictionary for the adapter.

Category *Instrument* (INS)

INS keywords are set by the Instrument Control Software (ICS) or by the Observation Support Software (OS). For each instrument exists at least one dictionary. For some instruments there's a separate ICS and OS dictionary.

A template for ICS dictionaries (ESO-VLT-DIC.XXX_ICS) is available from the Data Interface Control Board.

Many subsystem keywords are used in this category. In some cases, a possible integer i suffix will be required when several similar subsystems can be mounted.

A suffix shall be appended to a given subsystem name, if more than one instance of this subsystem are available for the instrument, even if the second instance is not mounted. For example, if a given instrument has two filter wheels, but a filter is selected in only one of them (and the other is set to an open position) then the subsystem describing this filter should be FILT1.

The dictionary definition of parameters with suffixed subsystem names contains the letter `i` as a place holder for any integer number (see Chapter 7). An indexed dictionary definition also includes non-indexed use of the parameter, e.g. `KWDi` describes both `KWD` and `KWD1`.

An example of the typical keywords required to describe an instrument setting is given in Table 4.12. It includes a general description of the instrument itself (the `ID` parameter, a possible `MODE`), followed by an accurate description of each element used.

While optical elements are described in the FITS headers by the corresponding keywords (`FILT`, `GRIS`, etc.), the generic `OPTI` subsystem gives the means to describe elements for engineering purposes. The `OPTI` subsystem may refer to any selectable optical element: filter, a grism, a polarimeter, a diaphragm, etc. Such elements are generally mounted on a wheel.

An example for `OPTIi` keywords is given when an instrument operates several wheels to implement a logical function (e.g. `FILT1`), i.e. the user selects one filter to be inserted into the light path and the instrument internal logic selects which wheel has the filter mounted. For such cases, `FILTi` keywords are used for instrument setup while the `OPTIi` set of keywords describe uniquely the internal instrument configuration.

Another example for the usage of `OPTIi` keywords is the case of 'multi-purpose' wheels. In this case a single wheel is used to mount different element types, e.g. grisms and a focus-wedge. Again here it is advisable to separate the user function (setup selection) from the actual instrument configuration recording. `OPTIi` keywords provide the mechanism to accurately describe the actual setup independently of user intention.

It is assumed that n wheels are available; for each of these wheels, the following parameters must be known:

- `OPTIn NO` specifies the actual slot number n in the wheel.
- `OPTIn ID` specifies the identification of the filter, grism, etc. The identification scheme is given in Chapter 9, p. 69.
- `OPTIn TYPE` and `OPTIn NAME` provide an explanation of what is inserted along the optical path. These two parameters can normally be derived from the contents of the `OPTIn ID` keyword. `OPTIn TYPE` provides a generic name for the optical element, `OPTIn NAME` provides a verbose name for the optical element. The naming convention is given in Chapter 9, p. 69.

  Angles that describe the orientation of a grism or polarimeter include:

  1. `OPTIn POSANG` specifies the position angle of the optical element on the sky, East of North.
  2. `OPTIn ROT` specifies the rotation angle in regard to the optical axis.
  3. `OPTIn TILTA` specifies the tilt angle in regard to the plane perpendicular to the optical axis along the East-West direction.
  4. `OPTIn TILTB` specifies the tilt angle in regard to the plane perpendicular to the optical axis along the North-South direction.

  All angles are expressed in degrees, and measured according to the conventions given in Section 1.6 on page 15.

  For example:

Table 4.12: Example of the INS category

	Keyword	Example	Explanation
(S)	INS ID	'UVES '	Instrument ID
(S)	INS DID	'ESO-VLT-DIC.UVES_ICS-1.73'	Data dictionary for INS
(S)	INS SOFW ID	'$Revision: 1.73 $'	Instrument SW
(S)	INS SOFW MODE	'NORMAL '	Simulation mode
(S)	INS PATH	'RED '	Optical path used
(S)	INS MODE	'RED '	Instrument mode used
(S)	INS MIRR1 ID	'FREE '	Mirror unique ID
(S)	INS MIRR1 NAME	'FREE '	Mirror common name
(I)	INS MIRR1 NO	1	Mirror slide position
(S)	INS MECH1 ID	'lpin1 '	General mechanical device unique ID
(S)	INS MECH1 NAME	'Filt. Locking Pin'	General mechanical device common name
(S)	INS OPTI1 ID	'PS3 '	General optical device unique ID
(S)	INS OPTI1 NAME	'M5BM10B '	General optical device common name
(I)	INS OPTI1 NO	3	Slot number
(S)	INS SLIT1 NAME	'FREE '	Slit common name
(I)	INS SLIT1 NO	1	Slide position
(S)	INS DROT MODE	'ELEV '	Instrument derotator mode
(R)	INS DROT RA	84442.230003	RA (J2000.0) pointing (deg)
(R)	INS DROT DEC	-544231.759900	DEC (J2000.0) pointing (deg)
(R)	INS DROT POSANG	0.0000	Position angle (deg)
(R)	INS DROT BEGIN	155.7380	Physical position at start (deg)
(S)	INS DPOL MODE	'OFF '	Instrument depolarizer mode
(S)	INS DPOS NAME	'OUT '	Instrument depolarizer slide posit
(I)	INS DPOS NO	1	Depolarizer slide position
(S)	INS FILT1 ID	'FREE '	Filter unique id
(S)	INS FILT1 NAME	'FREE '	Filter common name
(I)	INS FILT1 NO	13	Filter wheel position index
(S)	INS OPTI2 ID	'DIAPHR.27MM'	General Optical device unique ID
(S)	INS OPTI2 NAME	'OVRSIZ '	General Optical device common name
(I)	INS OPTI2 NO	3	Slot number
(S)	INS MIRR2 ID	'RED\#1 '	Mirror unique ID
(S)	INS MIRR2 NAME	'RED '	Mirror common name
(I)	INS MIRR2 NO	1	Mirror slide position
(S)	INS SHUT1 NAME	'Telescope shutter'	Shutter name
(L)	INS SHUT1 ST	T	Shutter open
(R)	INS SLIT3 WID	0.30	Slit width (arcsec)
(R)	INS SLIT3 LEN	8.90	Slit length (arcsec)
(S)	INS FILT3 ID	'BS4 '	Filter unique id
(S)	INS FILT3 NAME	'SHP700 '	Filter common name
(I)	INS FILT3 NO	4	Filter wheel position index
(S)	INS DET6 NAME	'Red exp. meter PMT'	detector name
(R)	INS DET6 CTTOT	3.	Total counts during exposure
(R)	INS DET6 UIT	1.000	User defined Integration time
(S)	INS GRAT2 ID	'CD\#3 '	Grating unique ID
(S)	INS GRAT2 NAME	'CD\#3 '	Grating common name
(R)	INS PIXSCALE	0.182	Pixel scale
(R)	INS GRAT2 X	2048.0	X pixel for central wavelength
(R)	INS GRAT2 Y	2048.0	Y pixel for central wavelength
(I)	INS GRAT2 NO	1	Grating wheel position index
(R)	INS GRAT2 WLEN	520.0	Grating central wavelength
(I)	INS GRAT2 ENC	1363503	Grating absolute encoder position
(R)	INS TILT2 POS	0.0	Science camera tilt (pixels)
(R)	INS TILT2 POSMIN	-222.0	Minimum camera tilt (pixels)
(R)	INS TILT2 POSMAX	222.0	Maximum camera tilt (pixels)
(S)	INS TILT2 ENC	15927	Camera tilt absolute encoder position
(R)	INS DROT END	155.7550	Physical position at end (deg)

```
HIERARCH ESO INS OPTI3 TYPE = 'FILTER'    / Optical element used
HIERARCH ESO INS OPTI3 NO   =           7 / Position of wheel used
HIERARCH ESO INS OPTI3 ID   = '#590'      / ID of the element
HIERARCH ESO INS OPTI3 NAME = 'OIII/3000' / Name of the element
```

would describe filter `'#590'` (OIII/3000) being mounted on wheel 3 in position 7.

- `SOFW` identifies the detector control software and gives related parameters (see the log example in Section 5.1 on page 55).

A `MECH` subsystem provides a generic way of storing information about the state of mechanical devices (e.g. clamp/lock/brake mechanisms).

- `MECHn ID` specifies the identification of the device.
- `MECHn TYPE` and `MECHn NAME` can normally be derived from the contents of the `MECHn ID` keyword. `MECHn TYPE` provides the generic name, while `MECHn NAME` provides the verbose name of the device.
- `MECHn ST` and `MECHn STAT` provide - if applicable - a Boolean and string descriptions of the status of the device.
- `MECHn SWSIM` provides a Boolean indicator showing if the status of the device is software-simulated.

For example:

```
HIERARCH ESO INS MECH1 ID    = 'lpin1   '   / Mechanical device ID
HIERARCH ESO INS MECH1 NAME  = 'Filt. Locking PiOut' / Mechanical device name
HIERARCH ESO INS MECH1 ST    =            T / Device Status
HIERARCH ESO INS MECH1 STAT  = 'In      '   / Device Status
HIERARCH ESO INS MECH1 SWSIM =            F / Simulated if T
```

would describe the status of a locking pin.

`INS DATE` shall give the installation date of the instrument control software system.

`INS ID` shall include the revision number of the instrument control software (see Chapter. 10 on p. 73).

Category *Detector* (`DET`)

`DET` keywords are set by the Detector Control Software (DCS) for optical instruments and by the Instrument Control Software for infrared instruments.

Subsystems used in this category are:

- `CHIP` describes each CCD chip when an array of CCDs is exposed.
- `EXP` describes exposure parameters.
- `FRAM` describes the frame type.

- OUT describes the outputs used for read-out. This subsystem includes the description of detector orientation.
- PARM gives unspecified detector parameters.
- READ gives readout parameters.
- SHUT gives shutter parameters.
- SOFW identifies the detector control software and gives related parameters (see the log example in Section 5.1 on page 55).
- WIN describes read-out window(s) parameters.

Keywords from the DET CHIP hierarchy (NX, NY, etc.) refer to the physical chip.

The subsystem OUTi should carry an index, even if only one output is used. DET OUTPUTS shall provide the number of outputs used. Note that the pixel area which is covered by each output is not a setup parameter but instead a static configuration of the detector chip. It is the task of the detector controller to assemble the selected window(s) properly.

Keywords from the DET OUTi hierarchy relate to the image pixels produced by the relevant output.

The outputs shall be counted per chip, not over the entire instrument, i.e. there shall be subsystems DET OUT1, DET OUT2, ... for each chip.

DET OUTi NX and DET OUTi NY, respectively, should contain the number of *image* pixels that are read out through port i, *including* any prescan and overscan pixels.

The subsystem WINi should carry an index, even if only one window is used.

WINi includes parameters that define the readout region used on the CCD: the location of the window on the chip (offset position), its size, and the binning factors used. The horizontal axis is named X, and the vertical axis Y.

Let us assume that the window is defined with its lower left corner at position (i_0, j_0), a size $\Delta i \times \Delta j$, and binning factors (f_i, f_j); the largest window has the values $(1, 1)$ for the start position, and binning factors $(1, 1)$. The window is described by:

- NX and NY give the number of pixels, i.e.: $\Delta i = \mathtt{NX} \times f_i$ and $\Delta j = \mathtt{NY} \times f_j$.

  The pixels in the pre- and overscan areas are included. The values are obviously identical to those given in NAXIS1 and NAXIS2;
- BINX and BINY give the binning factors f_i and f_j, respectively;
- STRX and STRY represent the start position of the window, i.e. i_0 and j_0, respectively.

In the cases in which several outputs are used to read-out the chip *and* disjoint windows are read, the subsystem combination DET OUTn WINm must be used.

DET FRAM subsystem shall provide the description of the frame type.

DET ID shall provide the name and revision number of the detector control software.

Table 4.13: Example DET category keywords

	Keyword	Example	Explanation
(S)	DET ID	'CCD FIERA - Rev 2.69'	Detector system Id
(S)	DET NAME	'ccdF - fors'	Name of detector system
(S)	DET DID	'ESO-VLT-DIC.CCDDCS-1.3'	Dictionary
(I)	DET BITS	16	Bits per pixel readout
(R)	DET RA	53.19183333	Apparent 03:32:46.0 RA
(R)	DET DEC	-27.69388611	Apparent –27:41:37.9 DEC
(S)	DET SOFW MODE	'Normal '	CCD sw operational mode
(I)	DET CHIPS	1	# of chips in detector array
(S)	DET CHIP ID	'CCID20-14-5-6'	Detector chip identification
(S)	DET CHIP NAME	''MIT/LL mosaic'	Detector chip name
(S)	DET CHIP DATE	'2000-04-01T12:34:56.789'	Date of installation
(I)	DET CHIP X	1	X location in array
(I)	DET CHIP Y	1	Y location in array
(I)	DET CHIP NX	2048	# of pixels along X
(I)	DET CHIP NY	2049	# of pixels along Y
(R)	DET CHIP PSZX	24.0	Size of pixel in X
(R)	DET CHIP PSZY	24.0	Size of pixel in Y
(I)	DET EXP NO	911	Unique exposure ID number
(S)	DET EXP TYPE	'Dark '	Exposure type
(I)	DET EXP DUMDIT	0	# of dummy readouts
(R)	DET EXP RDTTIME	33.026	image readout time (s)
(R)	DET EXP XFERTIM	33.094	image transfer time (s)
(S)	DET READ MODE	'normal '	Readout method
(S)	DET READ SPEED	'normal '	Readout speed
(S)	DET READ CLOCK	'ABCD,1x1,high'	Readout clock pattern used
(I)	DET OUTPUTS	1	# of outputs
(I)	DET OUTREF	0	reference output
(S)	DET OUT1 ID	'A '	Output ID as from manuf
(S)	DET OUT1 NAME	'A '	Description of output
(I)	DET OUT1 CHIP	1	Chip to which the output belongs
(I)	DET OUT1 X	1	X location of output
(I)	DET OUT1 Y	1	Y location of output
(I)	DET OUT1 NX	2048	valid pixels along X
(I)	DET OUT1 NY	500	valid pixels along Y
(I)	DET OUT1 PRSCX	0	Prescan region in X
(I)	DET OUT1 OVSCX	0	Overscan region in X
(R)	DET OUT1 CONAD	1.46	Conversion from ADUs to e- (e-/ADU)
(R)	DET OUT1 RON	5.16	Readout noise per output (e-)
(R)	DET OUT1 GAIN	0.68	Gain setting [ADU/e-]
(I)	DET FRAM ID	1	Image sequencial number
(S)	DET FRAM TYPE	'Dark '	Type of frame
(I)	DET WIN1 STRX	1	Lower left pixel in X
(I)	DET WIN1 STRY	500	Lower left pixel in Y
(I)	DET WIN1 NX	2048	# of pixels along X
(I)	DET WIN1 NY	500	# of pixels along Y
(I)	DET WIN1 BINX	1	Binning factor along X
(I)	DET WIN1 BINY	1	Binning factor along Y
(I)	DET WIN1 NDIT	1	# of subintegrations
(R)	DET WIN1 UIT1	0.000000	user defined subint. time (s)
(R)	DET WIN1 DIT1	0.019151	actual subint. time (s)
(R)	DET WIN1 DKTM	0.0192	Dark current time (s)
(S)	DET SHUT TYPE	'Iris '	type of shutter
(S)	DET SHUT ID	'fors shutter'	Shutter unique identifier
(R)	DET SHUT TMOPEN	0.000	Time taken to open shutter (s)
(R)	DET SHUT TMCLOS	0.000	Time taken to close shutter (s)

Category *Observation Control Software* (`OCS`)

`OCS` keywords are set by the instrument's Observation Software. They are accordingly defined in the `OS` dictionaries of the different instruments.

This category includes parameters that are created by the OS upon creation of a frame.

Category *Delay Lines* (`DEL`)

`DEL` keywords are set by the VLTI Control Software.

This category includes parameters that relate to the VLTI delay lines.

Category *Coude Optics* (`COU`)

`COU` keywords are set by the VLTI Control Software.

This category includes parameters that relate to the VLTI coude optics.

Category *Interferometric Supervisor Software* (`ISS`)

`ISS` keywords are set by the VLTI Interferometric Supervisor Software.

This category includes parameters that relate to the VLTI telescope setup.

Category *Adaptive Optics System* (`AOS`)

`AOS` keywords are set by the Control Software, Observation Software or Real time Control Software of Adaptive Optics Systems (e.g. NAOS).

Category *Simulator* (`SIM`)

`SIM` keywords are set by the Quality Control subsystem. Currently this category is only used by NAOS.

This category includes parameters that relate to the simulation process, in particular those for which the simulator needs assumptions. Examples are sky emissivity in the infrared, object brightness or assumptions regarding the PSF.

Category *Process* (`PRO`)

`PRO` keywords are set by the Data Pipeline Software.

This category includes parameters used during a standard reduction process. This keyword category is found principally in the processed frames.

Category *Quality Control* (`QC`)

`QC` keywords are also set by the Data Pipeline Software.

This category includes parameters describing results of the Quality Control process performed by the pipeline.

Category *Laser Guide Star* (`LGS`)

This category includes parameters describing the settings of the Laser Guide Star Facility.

4.5 Keywords containing date/time information

All string-valued keywords storing date/time information shall use the restricted ISO 8601 format: `'YYYY-MM-DDThh:mm:ss.sss'` (e.g. `'2007-12-31T12:34:56.789'`), or `'YYYY-MM-DD'` when only date is shown (e.g. `'2007-12-31'`). See [AD7] and Section 4.4.2.1 of [AD4].

4.6 Errors and statistics parameters

In some cases it is important to provide, in addition to the parameter value being reported, also an error, range or some other statistical property. The convention for such cases is to provide auxiliary parameters whose names share the first 5 characters with their root parameter name and end with one of the strings given below:

- `ERR` error bars (e.g. `FWHMERR`), i.e. the uncertainty of the root parameter value in both directions ($+$ and $-$);
- `MIN/MAX` minimum and maximum values (e.g. `RHUMMIN`, `TEMPMAX`) during a given period of time (e.g. during the exposure);
- `RMS` root mean square of the parameter values during a given period of time;
- `AVG` average of the parameter values during a given period of time;
- `PTV` peak to valley variation of the root parameter values during a given period of time.

The unit of the `ERR`, `MIN`, `MAX`, `AVG` and `PTV` parameter is always the same as the root parameter.

In case of enumerated parameters, (e.g. `TEMP1`) the index suffix shall be added at the end (`TEMPMAX1` in this example).

4.7 Pipeline processed frames

The keyword specifications described in the preceding sections shall also apply to the pipeline processed frames (referred to in this document as Internal Data Products, or IDPs), with the following exceptions:

- The IDPs shall contain the Boolean keyword `PRO SCIENCE` which will be set to `T` for science files and `F` for all other files.[4]
- The IDPs shall not contain keywords from the `DPR` category, i.e. keywords described in Section 4.4.2 on page 39.
- The IDPs shall contain the `PRO TECH` keyword, which shall contain the value from the `DPR TECH` keyword in the original file.
- The following keywords from the PRO dictionary:

  ```
  PIPEFILE
  PRO DID
  PRO REC1 ID
  PRO REC1 DRS ID
  PRO REC1 PIPE ID
  PRO DATANCOM
  PRO CATG
  DATAMD5
  ```

  are mandatory in processed science and calibration frames.
- At least one of the two following keywords: `PRO REC1 RAW1 NAME` or `PRO REC1 CAL1 NAME`, shall be present in, respectively, processed science and calibration frames. They must be accompanied by the corresponding `PRO REC1 RAW1 CATG` or `PRO REC1 CAL1 CATG` keyword.

Non-FITS pipeline products (logs or plots) may be encapsulated in "ancillary" files using the scheme described in [AD6]. Each extension HDU of those files shall contain keywords required by [AD6]: `FG_GROUP`, `FG_FNAME`, `FG_FTYPE`, `FG_LEVEL`, `FG_FSIZE`, `FG_FMODE`, `FG_FUOWN`, `FG_FUGRP`, `FG_CTIME` and `FG_MTIME`. Additionally, the primary HDUs must contain:

```
HIERARCH ESO PRO ANC =  T                       / File is an ancillary product
HIERARCH ESO PRO CATG = 'ANCILLARY_FILE'        / Product category
HIERARCH ESO PRO CONTENT = '<dataset content>' / LOGS or PLTS (plots)
HIERARCH ESO PRO DPCATG = '<dataset mode>'      / Dataset mode (CALIB, SCIENCE)
HIERARCH ESO PRO DATASET = '<dataset ID>'       / Unique dataset identifier
```

[4]Archived files generated prior to the introduction of this requirement shall assume the value of this keyword of `F`.

4.8 External data products

The External Data Product (EDP) category consists of broadly understood high-level data products, provided by the astronomical community, typically consisting of fully reduced and calibrated scientific data.

Principal Investigators of ESO Large Programmes are required to deliver their final data products to ESO at the time of publication of their results. This category also includes high-level products from Public Surveys with ESO survey telescopes.

This section describes the general interface requirements for data belonging to this category. Because it is not possible to account for all possible types of EDPs, this document describes only requirements for the generic metadata describing the products. Detailed requirements are described in [RD9]. This document is available from the "ESO External Data Products standard" web site, `http://www.eso.org/sci/observing/phase3.html`; the users should always consult this page before submitting EDPs. In case the products are not covered in the web site the users should contact the ESO External Data Products team via email at `usd-help@eso.org`, with the subject of `Phase 3`.

All external data products must contain all applicable FITS generic keywords from those described in Section 4.1 and shown in Table 4.1.

All external data products must contain appropriate WCS keywords (see Section 4.2 on p. 29). It is strongly recommended that the `CDn_m` matrix is used to describe pixel scale and rotation, but it is allowed to use other supported WCS conventions (`CDELTn+PCn_m` or `CDELTn+CROTAn`). Only one WCS convention shall be used in each file.

If possible, EDPs should contain provenance information, i.e. information allowing for identification of observations or files from which the EDP has been derived. If relevant, EDPs must contain association information, i.e. identifiers of products associated to the EDP.

The following convention shall be used in EDPs to store the relevant information (if it is available):

`RA_TARG` (float) – Right ascension of the target position, in degrees.

`DEC_TARG` (float) – Declination of the target position, in degrees.

`ERR_TARG` (float) – Uncertainty of the target position, in degrees.

`EXPTIME` (float) – The sum of the individual integration times (in seconds) of all exposures combined in this data product. In certain products (e.g. in mosaic images) this quantity may vary across the image; in those cases the keyword shows the effective integration time as appropriate for the product (see [RD9] for detailed description).

`TEXPTIME` (float) – The arithmetic sum of the integration times (in seconds) of all exposures combined in this data product.

`OBSTECH` (string) – observation technique (`'IMAGE'`, `'SPECTRUM`, etc.).

`PRODCATG` (string) – The data product category for this product. One of a list of EDP-defined categories, as available from [RD9].

`MJD-END` (float) – point in time of the end of data acquisition. If the data product is a result of the combination of multiple observations, the end of the latest observation must be specified here.

Note that this is in addition to the corresponding time at the beginning of data acquisition, stored in MJD-OBS.

FILTER (string) – Filter name; in spectroscopy EDPs it shows the order-blocking filter name. If more than one, the value shall be 'MULTI', and the individual filter names shall be stored in keywords FILTERn, where n is an integer index between 1 and 99, with no leading zeros.

GRATING (string) – The name of the main dispersive element (e.g. 'GR300', 'GRISM', 'PRISM', etc.).

SPECSYS (string) – Frame of reference for spectral coordinates (e.g. 'BARYCENT', 'HELIOCEN', etc.). See [RD8] for the list of recognised values.

FLUXCAL (string) – Can be 'UNCALIBRATED' or 'ABSOLUTE'; see [RD9] for detailed description.

PROG_ID (string) – ESO programme ID of the observations upon which this data product is based. If more than one, the value shall be 'MULTI', and the individual programme IDs shall be stored in keywords PROGIDn, where n is an integer index between 1 and 99, with no leading zeros.

ASSONi (string) – The list of files associated to this data product. Index i is a sequential number starting from 1. If n files are associated to the product, the indexed keywords ASSONi and ASSOCi should appear n times.

ASSOCi (string) – Specifies the category of the associated file given by ASSONi. One of a list of EDP-defined categories.

PROVi (string) – Processing provenance, i.e. the list of science files originating this data product. Index i is a sequential number starting from 1, with no leading zeros. Keywords PROVi should appear as many times as needed to identify the complete set of science data files this product has been generated from.

OBIDi (integer) – Set of Observation Block IDs to identify the original observations this product results from. If the product includes data from n observations, OBIDi with index i running from 1 to n, with no leading zeros, should be provided.

Chapter 5

Logging

The log database defines all information that characterises the environment in which a specific observation was obtained. It represents the logbook of telescope operation. It uniquely associates a scheduled observing programme to a set of acquired exposures.

The log database includes night reports and the log files defined in Section 3.2 on page 22.

The log files will record a number of actions and parameters which are defined in the corresponding dictionaries. In addition, log files may temporarily include any number of parameter records to be used e.g. for trouble shooting purposes.

The log file format is designed to allow an accurate trace of VLT operations. Every log record is uniquely identified by the logging source (given through the source mask, see below) and its date/time stamp. This design allows to merge all log records in the log database independently of how many log files where created. The unique source mask also permits to trace the parallel operation of two instruments, e.g. one doing science exposures while the other is used to acquire calibration frames.

5.1 Log File format

A log file consists of maximum 250 byte long records terminated with a newline character (\n), however, keywords and values (see below) must be written within the first 72 characters. The restriction to 72 characters is due to the need to be able to include relevant log records in the FITS headers of observations.

Log records have the general format:

```
hh:mm:ss> keyword / comments [<srcmask>]
```

or:

```
hh:mm:ss>/ comments [<srcmask>]
```

where:

- `hh:mm:ss>` is the time stamp, consisting of the time (UTC). `hh:mm:ss.sss>` may be used if a higher time resolution is required;

- `keyword` is a hierarchical keyword (or set of words) which explains what happened (verb|action| keyword) or identifies the reported parameter (followed by `= value`). Note that the words `HIERARCH ESO` are omitted here.
- comments explain the keyword reported, and
- `<srcmask>` is the event source identification mask ("source mask"; see Section 5.2, p. 59).

A log file always starts at noon (UTC). The first record of a log is a *date stamp* record in the following format:

```
12:00:00> DATE = 'YYYY-MM-DD'     / Weekday Month Day, Year [source]
```

A *date stamp* record must also be the first record written on the log after midnight (UTC).

The following *classes* of records can be found in a log:

Action records reporting an action initiated by the observer/operator; typical examples are opening and closing operations, or moving the telescope. An action record starts with an *action* keyword (a verb starting with a dash); it cannot have any associated value, but may be followed by parameter record(s) like the telescope slew at the end of the log example on page 56. Subsystem names are taken from Table 4.7. See Section 5.1.1 for the record syntax.

Parameter records These can be meteorological parameters (wind speed, dome temperature), seeing conditions, or the status of some instrument. The parameter name is normally followed by a value. Such parameters are either acquired periodically (e.g. the dome temperature), or recorded as a result of a given action. See Section 5.1.2 for the record syntax.

Unforeseen event records, reporting unexpected events, like the failure of a lamp or the loss of synchronisation between modules. See Section 5.1.4 for the record syntax.

Alarm event records, reporting alarm conditions. See Section 5.1.5 for the record syntax.

Comments inserted by the PI/Co-I or science operations staff. See Section 5.1.6 for the record syntax.

Typical examples of what can be found in the log file are given below.

```
12:00:00> DATE = '1995-03-31'         / Fri Mar 31, 1995              [wemmi]
12:46:19>-START COMP                  / Computer restarted            [wemmi]
12:46:19> COMP ID = 'HP RTE-A V5'     / Operating system identifier   [wemmi]
12:46:19> COMP NAME = 'NTI'           / Network node identifier       [wemmi]
12:46:19> TEL ID = 'ESONTT'           / Control NTT telescope         [wemmi]
12:47:35>-START OBS SOFW EMMI         / EMMI observ. prog. started    [wemmi]
12:47:35> OBS SOFW ID = 'OBST-V4.2'   / Programme name-version        [wemmi]
12:47:35> OBS SOFW MODE = 'NORMAL'    / Hw enabled for OBST           [wemmi]
12:47:48>-START INS SOFW EMMI         / EMMI control prog. started    [wemmi]
12:47:48> INS SOFW ID = 'EMMI-V4.1'   / Programme name-version        [wemmi]
12:47:48> INS SOFW MODE = 'NORMAL'    / Hw enabled for EMMI           [wemmi]
12:47:48>-START DET SOFW EMMI RED     / CCD control prog. started     [wemmiR]
12:47:48> DET SOFW ID = 'CCDR-V4.2'   / Programme name-version        [wemmiR]
12:47:48> DET SOFW MODE = 'NORMAL'    / Hw enabled for CCDR           [wemmiR]
12:47:49>-START DET SOFW EMMI BLUE    / CCD control prog. started     [wemmiB]
```

```
12:47:49> DET SOFW ID = 'CCDB-V4.2'    / Programme name-version         [wemmiB]
12:47:49> DET SOFW MODE = 'NORMAL'     / Hw enabled for CCDB            [wemmiB]
12:47:54>/UNFORESEEN: Error while initialising EMMI Red CCD             [wemmi]
12:47:57>/UNFORESEEN: Error while initialising EMMI Blue CCD            [wemmi]
12:47:57>-STOP ADA B LAMP-0            / Calibration lamp switched off. [wemmiB]
12:48:50>-STOP ADA B LAMP-0            / Calibration lamp switched off. [wemmiB]
12:50:17>-START DET EMMI RED           / Start wiping CCD EMMI RED      [wemmiR]
12:50:17>-START EMMI CALIBRATION       / Start cal. procedure           [wemmi]
12:50:17>-START ADA B OPTI             / Calibration unit moved in      [wemmiB]
12:50:17>-CLOSE EMMI CAL SHUT-ALL      / Close all cal. shutters        [wemmi]
12:50:18>-CLOSE ADA B SHUT-0           / Calibration shutter closed.    [wemmiB]
12:50:18>-STOP EMMI CAL LAMP-ALL       / Switch off all cal. lamps      [wemmi]
12:50:18>-STOP ADA B LAMP-0            / Calibration lamp switched off. [wemmiB]
12:50:19>-START EMMI CAL LAMP14        / Switch on cal. lamp            [wemmi]
12:50:19>-START ADA B LAMP14           / Calibration lamp switched on.  [wemmiB]
12:50:19>-OPEN EMMI CAL SHUT14         / Open cal. shutter              [wemmi]
12:50:20>-OPEN ADA B SHUT14            / Calibration shutter open.      [wemmiB]
12:51:16>-START EXPO EMMI RED          / Start exp. on CCD EMMI RED     [wemmiR]
12:51:16> EXPO EMMI RED NO = 3107      / Exp. num. on CCD EMMI RED      [wemmiR]
12:53:17>-STOP EXPO EMMI RED           / Stop exp. on CCD EMMI RED      [wemmiR]
12:53:17>-READ DET EMMI RED            / Reading CCD EMMI RED           [wemmiR]
12:55:01>/UNFORESEEN: Failed image transfer to host                     [wemmiR]
12:55:08>/RECOVERY: Image transfer to host recovered                    [wemmiR]
12:55:08>-STOP TRANS DET EMMI RED      / Transf. OK from CCD EMMI RED   [wemmiR]
12:55:08> DET PARM(1) = -8.05, 3.00, 23.52 / DET: VLO1, VHI1, VDD1      [wemmiR]
12:55:08> DET PARM(4) = -4.06, 5.99, 13.77 / DET: HLO1, HHI1, VDR1      [wemmiR]
12:55:08> DET PARM(7) = -0.36, 12.00, 0.31 / DET: RLO1, RHI1, VGS1      [wemmiR]
12:55:08> DET PARM(10)=-14.73, 14.80, 27.34 / DET: -15V, +15V, +30V     [wemmiR]
12:55:15>-CLOSE EMMI CAL SHUT14        / Close cal. shutter             [wemmi]
12:55:15>-CLOSE ADA B SHUT14           / Calibration shutter closed.    [wemmiB]
12:55:15>-STOP EMMI CAL LAMP14         / Switch off cal. lamp           [wemmi]
12:55:18>-STOP ADA B LAMP14            / Calibration lamp switched off. [wemmiB]
22:56:12>-MOVE TEL PRESET NTT          / Initiate new tel position      [wt5tcs]
22:57:37> TEL RA = 67.265296           / RA (deg) after move            [wt5tcs]
22:57:38> TEL DEC = -36.328608         / DEC (deg) after move           [wt5tcs]
```

5.1.1 Action records

The general structure of an action record is:

```
hh:mm:ss>- action_verb category [subsystem(s)] / comments [<srcmask>]
```

The first keyword in an `action` record is one of the verbs listed in Table 5.1; such keywords start with a dash, and can therefore easily be located, even visually, in the log. If any parameter is required (e.g. move the telescope to some (α, δ) position), an action record is normally followed by one or several *parameter records*.

Subsystem names are taken from Table 4.7.

5.1.2 Parameter records

A parameter record will have the general structure:

```
hh:mm:ss> category [subsystem(s)] parameter [(start_index)] value(s) /comments [<srcmask>]
```

where subsystem and parameter names follow the guidelines given in Section 4.4 (p. 34).

Table 5.1: Logging action verbs

Keyword	Meaning
-ABORT	Abort an executing action (e.g. an exposure)
-PAUSE	Pause an executing action (e.g. an exposure)
-RESUME	Resume a paused action (e.g. an exposure)
-OPEN	Open any system (e.g. a shutter)
-CLOSE	Close any system
-MOVE	Move some piece (e.g. the telescope)
-CHANGE	Change some piece (e.g. a filter in a wheel)
-START	Start or switch on a system (e.g. the exposure)
-STOP	Stop or switch off (e.g. a lamp)
-READ	Start a reading procedure (typically detector readout)
-WRITE	Start a writing procedure

5.1.3 Parameter arrays

When necessary, *arrays* of numbers may be logged as several numbers separated by commas. Arrays are recognised by the parenthesised `start_index` preceding the '=' sign; cf. the `DET PARM` values shown in the log example on page 56.

The `start_index` begins from 1; if all values of the array cannot be recorded in a single line, similar lines with adequate values for `start_index` shall be written.

Each value of the array is written in a free-format form, but the values must be separated by commas. Null (non-existent) values are allowed; they are given as a double hyphen '--'.

5.1.4 Unforeseen event records

The log files also include the record of events that are considered unforeseen by the control software. Such events are typically the failure of a calibration lamp or loss of time synchronisation.

The record format is:

```
hh:mm:ss>/UNFORESEEN: succinct description of the event [<srcmask>]
```

Recovery records are used to signal the success of an action in response to an *unforeseen* event, they have the format:

```
hh:mm:ss>/RECOVERY: description of the recovery measure [<srcmask>]
```

In some cases it may be desirable to be able to match a recovery log entry to its corresponding unforeseen event. This can be done by filtering log records with the source mask, under the assumption that one single subsystem is issuing only few of such events at a given time.

5.1.5 Alarm records

Alarm events are recorded in the log with the following format:

```
hh:mm:ss>/ALARM: succinct description of the alarm event [<srcmask>]
```

5.1.6 Comment records

Two different comment record formats are provided. They have the following structure:

```
hh:mm:ss>/ free-format comment up to 50 characters
```

or

```
hh:mm:ss>/COMMENT NN free-format comment, possibly spanning several lines
```

where NN is a two letter code meaning OB, SA or NA for the observer, staff/service astronomer or night assistant, respectively.

5.2 Event source mask

The format for the source mask is:

```
[<host-name><attribute-1><attribute-2><attribute-3>]
```

where

- <host-name> is the node name of the workstation or LCU on which the event originates (instrument workstation, telescope workstation, detector LCU, etc.). In test environment, where the node name may be different from the target node name, the target node name should be used. The list of VLT host names is given in [RD10].
- <Attribute-i> are three characters available to generate unique source masks within the same host-used by OS, ICS and DCS to identify multiple instrument arms.

The source mask is mandatory for all reporting systems.

5.3 Log file names

The names of operations log files shall follow the following scheme:

```
<host-name>.YYYY-MM-DD.ops.log
```

where <host-name> is the node name of the computer generating the log file and YYYY-MM-DD stands for the date of the beginning of the night (for example: wvisir.2007-04-01.ops.log).

The names of the log files containing Quality Control Level 1 parameters generated on-site shall follow the following scheme:

```
QC1_<instrument>.YYYY-MM-DD.ops.log
```

where <instrument> identifies the relevant instrument and YYYY-MM-DD stands for the date of the beginning of the night (for example: QC1_VISIR.2007-04-01.ops.log).

Chapter 6

VLT parameter files

Observation preparation tools provide the means to create and edit *Observation Blocks* as the basic unit of an executable sequence of *Templates*. Each template, in turn, requires a given input configuration or parameter list, described by a so-called *template signature*. These parameters are stored in a format called *Parameter File Format*. Any template corresponds with a certain predefined mode of observation, and has consequently a *Reference Setup File* attached to it. Reference setup-files list the default configuration of all elements in the light path, and are also written in the parameter file format.

Observation blocks can be represented in *Parameter File Format*. They include information on the programme that owns the block, scheduling requirements and links to other blocks. They also include or refer via the templates to *Setup Files* for setting target positions, instrument and detector configurations, all of which can be re-used in a number of observations, e.g. when a list of target pointings are to be observed with the same instrumental configuration.

From the observation block information, the VLT Control Software (VCS) will eventually generate setup-commands for its own operations. Doing so it will complement the information contained in the reference setup-file corresponding with the running template.

6.1 Parameter File format

Many VLT files containing control information are written in the Parameter File Format. This is the case for, e.g., setup-files, instrument configuration files and template parameter files. These files consist of a mandatory header and parameter records. Their syntax is optimised for fast parsing by the VLT Control Software and therefore it differs from other formats described in this document (see [RD11]).

A parameter record is written with the following syntax:

```
<short FITS keyword> value; [# comment]
```

where:

- `<short FITS keyword>` is an ESO keyword following the same naming convention as defined in Section 4.4 except that for technical reasons the subsystems, categories and parameters of hierarchical keywords are connected by dots `'.'` rather than spaces (e.g. `INS.FILT1.NAME` instead of `INS FILT1 NAME`); also, the prefix `HIERARCH ESO` is not used. This syntax is called *short FITS keyword*.

- `value` can be one of the values defined in Section 4.1, however, strings must be enclosed in double rather than single quotes, i.e. `"string"`. The value part must be finished with a semicolon `';'` and must be given on the same line.

  Optional comments can be included at the end of a line by prefixing them with the hash sign (`"#"`).

6.1.1 Parameter File header

The header consists of a number of records identifying the purpose and type of the parameter file. Header records are mandatory. Parameter header records are grouped in the `PAF` category.

Table 6.1 gives an example of a parameter file header.

Table 6.1: Parameter file header keywords

```
PAF.HDR.START;                                  # Marks start of header
PAF.TYPE            "Template Signature";       # Type of parameter file
PAF.ID              "@(#) $Id: VIMOS_img_obs_Jitter.tsf,v 1.5 2001/08/06$";
PAF.NAME            "VIMOS_img_obs_Jitter";     # Name of PAF
PAF.DESC            "Jitter image";             # Short description of PAF
PAF.CRTE.NAME       "mvmgr";                    # Name of creator
PAF.CRTE.DAYTIM     "2001-08-06T14:17:49";      # Civil Time for creation
PAF.LCHG.NAME       "vmmgr";                    # Author of par. file
PAF.LCHG.DAYTIM     "2001-08-06T14:17:49";      # Timestamp of last change
PAF.CHCK.NAME       "vmmgr";                    # Name of appl. checking
PAF.CHCK.DAYTIM     "2001-08-06T14:17:49";      # Time for checking
PAF.CHCK.CHECKSUM   "hcHjjc9ghcEghc9g";         # Checksum for the PAF
PAF.HDR.END;                                    # End of PAF Header
#-----------------------------------------------------------------------
TPL.INSTRUM         "VIMOS";                    # Instrument
TPL.MODE            "imaging";                  # Mode of observation
TPL.VERSION         "@(#) $Revisions: 1.5 $";# Version of the template
TPL.ID              "VIMOS_img_obs_Jitter";     # Template signature ID
TPL.REFSUP          "VIMOS_img_Generic.ref"; # Reference Setup File
TPL.PRESEQ          "VIMOS_img_obs_Jitter";     # Sequencer script
TPL.GUI             "";                         # Template GUI panel
TPL.TYPE            "science";                  # Keyword type
TPL.EXECTIME        "computed";                 # Expected execution time
TPL.RESOURCES       "";                         # Required resources
#-----------------------------------------------------------------------
TPL.PARAM           "DET.WIN1.UIT1";            # Next template parameter
DET.WIN1.UIT1.TYPE  "number";                   # Keyword type
DET.WIN1.UIT1.RANGE "0.001..100000";            # Valid range
DET.WIN1.UIT1.DEFAULT"Nodefault";               # Default value
DET.WIN1.UIT1.LABEL "Exposure time";            # Label used in P2PP
DET.WIN1.UIT1.MINIHELP"Exposure time for each subframe";# Short help
```

The keyword PAF.TYPE identifies the kind of parameter file. It must take one of following the values:

```
"Reference Setup"
"Instrument Setup"
"Detector Setup"
"Telescope Setup"
"Reference Configuration"
"Configuration"
"Ambient Data"
"Template Signature"
"OB Description"
"Pipeline Result".
```

It is also possible to write a verbose description of the parameter file within the header. This description must be written as a number of description lines:

```
PAF.DESC <description heading>;
PAF.DESC <description line 2>;
PAF.DESC . . .
PAF.DESC . . .
```

The keyword PAF.CHCK.CHECKSUM provides a way by which the parameter files are protected against changes. The checksum is computed and written by the checking application according to the algorithm given in Section 4.4.

The header always starts with a PAF.HDR.START keyword and finishes with PAF.HDR.END.

After the header the reference setup files can contain a so-called *protected region*, which is a list of setup parameters which should not be overridden in this particular mode of observation. This region starts with a PAF.PROT.START keyword and finishes with PAF.PROT.END.

Chapter 7

Data Interface Dictionaries

The ESO Data Interface Dictionaries (DID) include the specification of all parameters used in a particular context. A specific dictionary is defined by its scope, e.g. a given instrument, observatory site, etc.

In the course of the history of a given system, e.g. an instrument, the data interface for that system may change as new keywords become necessary or modifications to old ones are made. In order to keep an archive of keywords, Data Interface Dictionaries are maintained under configuration control.

Data Interface Dictionaries are submitted for approval to the ESO Data Interface Control Board. The Board maintains all dictionaries and amendments to them.

7.1 Format specification

The Data Interface Dictionary contains a DID Identification Record as the first record of the document and as many parameter description records as needed. A record is a set of lines each containing a field name and its value formatted in the following way (lines are restricted to 80 characters maximum):

```
<field name>: <field value>
```

Records are separated by one or more empty lines. Comment lines can be included if starting with a hash sign ('#').

When the dictionary is stored as a file on a computer system, the file name should be equal to the dictionary name (see below).

7.2 DID Identification Record

The DID identification record includes the following fields:

```
Dictionary Name:   ESO-VLT-DIC.<scope>
Scope:             <scope identifier>
Source:            <source identifier>
Version Control:   <configuration control version number>
```

```
Revision:          <version number>
Date:              <YYYY-MM-DD>
Status:            <release status>
Description:       <free text revision history, possibly spanning more
                   than one line>
```

The fields `Revision`, `Date`, `Status` and `Description` must be repeated for each revision of the dictionary.

The following rules apply to the fields:

- the dictionary name is built as:

  `ESO-VLT-DIC.<scope>-<version>`

  e.g. `ESO-VLT-DIC.FORS-1.34`, `ESO-VLT-DIC.TEL-2.5`, etc.;
- the `<scope>` identifier designates for which part of the overall data system the dictionary applies;
- the `<source>` must be the name of the person, organisation or consortium submitting the dictionary;
- the `<version>` control number should be automatically assigned by the configuration control software. This is accomplished by inserting the RCS tag `"@(#) $Id$"`;
- the revision number and date is assigned by the source;
- the date in which the DID is effective is assigned by the Data Interface Control Board;
- the status is either `draft`, `submitted` or `released`;
- the description text may span over more than one line but it cannot include empty ones. It is suggested that it contains the revision history.

Example DID identification record:

```
Dictionary Name:   ESO-VLT-DIC.PRO
Scope:             PRO
Source:            ESO DFS/DMD
Version Control:   "@(#) $Id: ESO-VLT-DIC.PRO,v 1.12 2001/06/21 13:55:08 vltsccm Exp $"
Revision:          1.10
Date:              2001-03-07
Status:            submitted
Description:       Date field made ISO 8601 conform
Revision:          1.11
Date:              2001-03-12
Status:            submitted
Description:       Index j renamed to i
                   DATAMIN, DATAMAX removed
Revision:          1.12
Date:              2001-03-23
Status:            submitted
Description:       keywords PRO DATAMEAN, PRO DATAMEDI and
                   PRO DATASIG renamed for DICD compliance
```

7.3 DID Parameter Records

Parameter records include the following fields:

```
Parameter Name:   [<category> [<subsystem>] ]<parameter>
Class:            <class identifier>[|<class identifier>]
Context:          <context identifier>[|<context identifier>]
Type:             <the type of the parameter>
Value Format:     <format (ANSI C standard printf convention)>
Unit:             <SI or derived SI units as a text string>
Comment Format:   <standard comment>
Description:      <free text description of this parameter, possibly
                  spanning several lines>
```

The following rules apply to the fields:

- The subsystem and parameter elements of the parameter name may contain a suffix `i`, which is a placeholder for an integer describing multi-dimensional subsystems or parameters.
- The class can be any combination of the following separated with '|':

`setup`	keyword appears in a setup operation
`header`	keyword appears in science headers
`prim-header`	keyword appears in a primary header unit
`ext-header`	keyword appears in an extension header unit
`maint-header`	keyword appears in maintenance headers
`template`	keyword appears in a template script or signature file
`conf-log`	keyword appears in the configuration log
`cond-log`	keyword appears in the conditions log
`ops-log`	keyword appears in the operations log
`reduc-log`	keyword appears in the reduction log
`qc-log`	keyword appears in the quality control log
`config`	keyword appears in a configuration description
`private`	keyword is used only internally by the subsystem

- The context is the overall category to which the keyword belongs, for examples `instrument` or `telescope`.
- The type can be either `string`, `logical` (Booleans), `integer` or `double`.
- The value format defines the precision and representation of the value. For a string the precision defines the maximum length. The definition used for the ANSI-C function call `printf()` is applied for the format, with the exception that the `"G"`/`"g"` option is forbidden. For Boolean keywords the value must be either `T` or `F` and the format will be `%c`.

  It is strongly recommended that precision be explicitly specified for all floating point keywords (e.g. `%.3f` for values with three significant digits instead of generic `%f`).

- The unit can take one of the values described in Chapter 8 on p. 68.
- The comment field gives a brief description of the keyword's meaning. It can include one of the replacement tags listed in the table below

	Unit					
Tag	s	mjd	deg	rad	arc min	K
%TIME	●					
%DAYTIM	●	●				
%DEGREE			●	●	●	
%HOURANG			●	●	●	
%CELSIUS						●

The tag gets replaced by the edited value of the keyword when the keyword is written to the header or log file.

To increase human readability, the comment field may contain unit abbreviation enclosed in square brackets. The abbreviation should follow convention described in Chapter 8 on p. 68. The unit stored in the comment should not be used by software; if it is necessary to specify the unit of any given quantity, then a separate keyword with parameter `UNIT` must be used.

- The field `Comment Format:` may also be named `Comment Field:`.
- The description field includes the semantic meaning associated to this parameter.

  All dictionaries must contain a parameter record describing the dictionary itself. It should look as follows:

```
Parameter Name:   <category> DID
Class:            <whatever is applicable>
Context:          <context identifier>
Type:             string
Value Format:     %30s
Unit:
Comment Format:   Data dictionary of <category>
Description:      Name-version of ESO DID to which <category>
                  keywords comply
```

The class should comprise the classes of all keywords defined in the dictionary. Accordingly, the keyword itself should be written to all subsystems described by the classes.

For example, the `DID` keyword describing the `PRO` dictionary release 1.14 is called `PRO DID` and a FITS header record for this keyword should look as follows:

```
HIERARCH ESO PRO DID ='ESO-VLT-DIC-PRO-1.14' / Data dictionary for PRO
```

It is written to the FITS header of all pipeline products (`Class = header`).

If applicable, the comment part of the FITS/LOG/etc. record should contain the name of the physical unit in parentheses (see example below).

An example of a parameter record is:

```
Parameter Name:   INS SLIT1 WIDTH
Class:            setup|header
Context:          Instrument
Type:             double
Value Format:     %.2f
Unit:             arcsec
Comment Format:   Width of slit 1 [arcsec]
Description:      Width of the slit in seconds of arc.
```

A FITS header record for this keyword would be:

```
HIERARCH ESO INS SLIT1 WIDTH = 2.51 / Width of slit 1 [arcsec]
```

Chapter 8

Physical Units

Per IAU recommendation, physical units used in a DID must comply with basic or derived (i.e. using accepted prefixes) SI units. Exceptions are allowed for special units which are more convenient for astronomy. It is also allowed to utilise commonly used units for engineering parameters (e.g. liters per minute for flow, etc.).

Table 8.1: Physical units allowed for ESO DIDs

Quantity	**Unit String**	**Meaning or use**
	SI base & supplementary units	
length	`m`	meter
mass	`kg`	kilogram
time	`s`	second of time
plane angle	`rad`	radian
solid angle	`sr`	steradian
temperature	`K`	kelvin
electric current	`A`	ampere
	IAU-recognised derived units	
frequency	`Hz`	hertz
energy	`J`	joule
electric potential	`V`	volt
force	`N`	newton
pressure, stress	`Pa`	pascal
	Additional units allowed	
position or plane angles	`deg`	degrees of arc
dimension on the sky	`arcmin`	minutes of arc
offsets on the sky	`arcsec`	seconds of arc
magnitude	`mag`	magnitude (at given wavelength)
flux	`Jy`	jansky (10$^{-26} W m^{-2}$Hz^{-1})
wavenumber	`cm^-1`	wavenumber (used in interferometry)
angular spatial frequency	`arcsec^-1`	UV plane parameter (used in interferometry)
temperature	`C`	centigrade (degrees celsius)
pixel	`pixel` or `pix`	pixel
unit of A/D converter	`adu`	unit of A/D converter
encoder unit	`Enc`	Encoder unit

For units not covered in Table 8.1 abbreviations specified in [AD10] must be used.

Chapter 9

Naming convention for optical components

This section describes how optical components in use at the VLT telescopes are named and identified.

Such identifiers are used:

- by astronomers when selecting a particular observing configuration;
- by operations staff when setting up the requested optical elements for the upcoming night;
- by operations staff when operating instruments and performing service observations;
- by VCS when writing FITS keywords into the data headers;
- by pipeline software when performing standard data reduction;
- by astronomers when reducing data off-line;
- by archive users who prepare archive research programmes.

Astronomers are likely to use names while observatory staff will mostly use identifiers. The convention described in this section was developed with the aim of facilitating all of the tasks mentioned above while at the same time maintaining the discipline needed in order to handle the few hundred elements that will be used at the VLT.

This naming convention will be applied to all VLT instruments.

9.1 Identification scheme

Each optical element, i.e. filters, grisms, etc., in use at any VLT, NTT or other VLT compliant instruments shall have a unique identifier and a verbose name.

Verbose names are recorded in the keyword `NAME` (e.g. `FILT NAME`, `GRIS NAME` or `OPTIi NAME`) and follow the scheme described in Section 9.3.

Identifiers are typically sequential numbers which are given to each element when acquired. These identifiers are recorded in the keyword `ID`, e.g. `FILT ID`, `GRIS ID` or `OPTIi ID` (see Section 4.4.2 on page 44 for more details). The `ID` serves as the reference to the full characterisation file (e.g. transmission and efficiency curves of filters and grisms etc.) which is the authoritative source of information for each component.

The identifier serves as unique label for each individual piece of hardware. For example, the observatory utilises several K filters; all observations with any of these filters will have `FILT NAME` set to `'K'` with `FILT ID` identifying the specific physical filter used.

Identifiers of elements that cease to exist (e.g. a broken filter) shall be retained in order to ensure the historical validity of the Science Archive.

Instrument Consortia preparing Data Interface Dictionaries must foresee at least 10 characters space for the `ID` keywords and 30 characters for the `NAME` keywords.

9.2 Usage of the `OPTIi` keywords

`OPTIi` keywords are used to setup the internal functions of the instrument and to record instrument engineering parameters usually on the operations and configurations logs (see description in Section 4.4.2 on page 44).

The allowed `OPTIn TYPE` values are:

MIRROR	FABRYPEROT
FILTER	SLIT
GRISM	MASK
GRATING	FOCUSWEDGE
ECHELLE	HARTMANN
WOLLASTON	RETARDER
BEAMSPLITTER	DICHROIC
FIBER	LENS
PRISM	FREE (nothing mounted in the slot)

Additions to the above list need to be submitted for approval to the DIC Board.

9.3 Naming scheme

This section describes the scheme applied when assigning a name to optical elements.

Optical elements shall have a *technical* name that describes its major physical characteristics and may have a short, commonly used conventional name.

Technical names describe the element independently of its context (camera or instrument). The basic rule for technical names is to prefix the name with a four letter mnemonic of the element in question followed by some of its optical characteristics.

Conventional names are typically used in user interfaces and recorded in the relevant `NAME` keyword in the frame header.

Except for slit widths, the values for wavelengths and other characteristics should be rounded to the nearest integer (see below).

9.3.1 Filters

Filters will be characterised by

- technical names:
  - `FILT_<central wawelength in nm>_<FWHM in nm>` for general filters (at arbitrary wavelengths);
  - `FILT_VARi` for variable filters; `i` is the serial number;
  - `FILT_<50% wavelength in nm>_<cuton/-off>` for long-/shortpass filters; `<cuton/-off>` is `L` for longpass filters or `S` for shortpass filters;
  - `FILT_ND_<optical density>` for neutral density filters, where “optical density” is equal to the negative logarithm of fractional transmittance (i.e. for a free filter this quantity would be equal to 0.0).
  - `FILT_BANDSTOP_<central wawelength in nm>_<FWHM in nm>` for band-stop (incl. notch) filters.

- conventional names, used as values in all “filter name” keywords:
  - the commonly known name, e.g. `K`, `OG590`, `OIII/3000`, when applicable;
  - the system and the name within that system, e.g. `U_BESS`, `U_STRM`;

9.3.2 Grisms

Grisms will be characterised by

- `GRIS_<#grooves/mm><characteristic letter>`, where `<characteristic letter>` indicates the approximate central wavelength (e.g. `R`, `B`).

9.3.3 Gratings

Gratings will be characterised by

- `GRAT_<#grooves/mm><characteristic letter>`, where `<characteristic letter>` indicates the approximate blaze wavelength (e.g. `R`, `B`) or none if the grating is unblazed.

- `ECHE_<#grooves/mm><characteristic letter>`, where `<characteristic letter>` indicates the approximate wavelength of use (e.g. `R`, `B`).

9.3.4 Wollaston prisms

Wollaston prisms will be characterised by:

- `WOLL_<separation angle in arcmin>`

9.3.5 Retarder plates

Retarder plates will be characterised by:

- `RETA2` for lambda/2 plates,
- `RETA4` for lambda/4 plates.

9.3.6 Fabry-Pérot etalons

Fabry-Pérot etalons will be characterised by:

- `FPET_<finesse>`, where `<finesse>` is the dimensionless number characterising the resolving power of the Fabry-Pérot interferometer.

9.3.7 Slits

Fixed width slits (e.g. in a punched plate) will be characterised by:

- `SLIT_<width in arcsec>`

where `<width in arcsec>` is given with one decimal digit (e.g. `1.5` or `0.5`).

Variable width slits, such as those on a decker or with a motorised function, will be named `SLIT_DECKER` or `SLIT_FUNCTION`.

Chapter 10

Instrument Identifiers and File Names

This chapter describes conventions to be utilised in ESO Data Flow in recording names of instruments installed on ESO telescopes.

ESO recognises the following instrument identifiers:

Common instrument name The name given to the instrument by the Instrument Consortium (examples: “OmegaCAM”, “HAWK-I”).

While no specific requirements are put on those names, a recommended good practice is that these names follow the ESO Instrument Identifier convention listed below.

ESO Instrument Identifier This identifier shall be between 4 and 8 characters long and contain only uppercase letters A-Z and digits 0-9. It shall be generated from the common instrument name (examples: “OMEGACAM”, “HAWKI”).

ESO Instrument Identifier shall be stored in the configuration keyword `INS.CON.ID`. This keyword shall be the sole source for names used further in the system. In particular, it shall be used in template names, operation log names and filenames on the instrument workstations.

This identifier shall be stored in keyword `INSTRUME` (see Sec. 4.1).

The ESO Instrument Identifier as it appears in `INS.CON.ID` and its uniqueness shall be finalised as part of the Preliminary Design Review for new instruments.

ESO Instrument Identifier/Revision This identifier shall consist of the ESO Instrument Identifier (see above), forward slash sign (‘/’) and the revision number of the instrument control software (example: “XSHOOTER/1.57”).

This identifier shall be stored in keyword `INS.ID` (see Sec. 4.4.2).

OLAS_ID The environment variable `OLAS_ID` shall be set to the value of `INS.CON.ID` or to first five characters of this value, whichever is shorter.

Instruments which entered operations prior to the introduction of the above requirements and which do not follow them (e.g. VIRCAM and NAOS+CONICA) are allowed to maintain their current naming schemes.

10.1 File names for frames

The names of frames are used by a variety of persons at different times, e.g.:

- the astronomer/operator to manage the data obtained during the run;
- the Data Flow Operations team to track programme completion and quality control the exposure levels;
- the Science Archive Operations team to check safe storage of the data, to maintain the data holdings and to service requests for archive data;
- the User Support team to answer queries from users after observations.

The requirements for file names from various users are vastly different, therefore ESO adopts several schemes for naming the data frames.

10.1.1 FITS files used internally within the Data Flow System

The requirements for file names for Data Flow Operations can be summarised as follows. File names:

- shall be unique through the history of the VLT,
- should be easy to check against logs,
- should be easy to recreate in the case of directory/disk/media corruption (e.g. after being moved to "lost+found" directory)
- should allow being grouped into "nights" without additional information.

The scheme chosen for FITS file names is based on the time of start of exposure (given through the `MJD-OBS` keyword). This scheme has the following advantages:

- the names are easy to create and recreate using the `MJD-OBS` value;
- the "night" directory can be automatically generated together with the filename (i.e. with one system call);
- it does not require extra processes or procedures;
- it is easily expandable to both VLT Common Software and DFS;
- the names are easy to check in the operations log (`START EXP` event);
- the data re-play (in Garching) is straightforward.

In this scheme the file names take the form (using the restricted ISO 8601 format for the time tag):

```
<INS-PREFIX>.YYYY-MM-DDThh:mm:ss.sss.fits
```

A TEL/INS prefix warranties the uniqueness of the name. The prefix shall be constructed from the first letters of the ESO Instrument Identifier (see Chapter 10 on page 73). For consistency with common practice it is recommended to limit the length of the prefix to five characters.

Examples:

- `FORS2.2000-12-19T09:57:51.333.fits` (corresponds to `MJD-OBS=51897.41517746`)
- `UVES.2000-03-14T09:14:24.988.fits` (corresponds to `MJD-OBS=51617.38501143`)

FITS files generated by the pipeline should follow a similar scheme:

```
r.<INS-PREFIX>.YYYY-MM-DDThh:mm:ss.sss_<iiii>.[t]fits
```

or

```
r.<INS-PREFIX>.YYYY-MM-DDThh:mm:ss.sss_tpl_<iiii>.[t]fits
```

The first case refers to a FITS file which was created by a pipeline recipe as a result of a single input frame, the second case describes a file which results from the reduction of a set of frames created by an observation template. `<iiii>` is a four-digit integer which is automatically created by the pipeline.

10.1.2 Archive file names

ESO Archive configuration requires that frames are stored under unique names, independently from other considerations. In practical terms it means that a new version of any file must have a name different from the old version. This requirement is incompatible with the general scheme described in Section 10.1.1 above, and therefore it is necessary to maintain a separate filename scheme for archive storage.

In all cases, the original file name must be preserved in the Archive database. All FITS frames which are renamed for the purpose of archiving must preserve the original name as a value of a header keyword appropriate for the file type.

The following describes the archive filename convention:

- Raw FITS frames shall use the scheme as described in Section 10.1.1, i.e.

  ```
  <INS-PREFIX>.<TIME-TAG>.fits
  ```

  where:

  - `<INS-PREFIX>` is equal to the value of the environemnt variable `OLAS_ID`;
  - `<TIME-TAG>` describes the value of the `MJD-OBS` keyword expressed in the restricted ISO 8601 format.

- Internal Data Products, i.e. FITS files generated by pipeline processing within the ESO Data Flow, shall use the scheme

  `<PIPELINE-PREFIX>.<INS-PREFIX>.<ARC-TIME-TAG>.fits`

  where:

  - `<PIPELINE-PREFIX>` can be 'S' for science files, 'M' for calibration files ('M' stands for 'Master Calibration', which is how these files were historically called) and 'A' for ancillary files (pipeline-related files encapsulated in FITS files using scheme described in Section 3.4.2);
  - `<INS-PREFIX>` describes the instrument;
  - `<ARC-TIME-TAG>` denotes the archive ingestion date, in restricted ISO 8601 format.

- Other processed frames, originating from both internal and external sources, shall use the scheme

  `ADP.<ARC-TIME-TAG>[.<EXT>]`[1]

  where:

  - `<ARC-TIME-TAG>` denotes the archive ingestion date, in restricted ISO 8601 format;
  - `<EXT>` is the file extension, in lowercase (`fits`, `tar`, `jpg`, etc.).

  There is no instrument designation in Processed Data Products because, unlike the first two types of frames, it is possible for such products to be derived from data from more than one instrument.

- Operation logs shall use file names as described in Section 5.3 on page 59.

All other file types must have their naming conventions approved by the DIC Board.

10.2 File names for files used internally within the VLT Control Software (VCS)

The scheme is described in [RD12].

10.3 File names for template scripts and signature files

The scheme is described in [RD12].

[1]Prefix 'ADP' is used historical reasons; it is not intended to contain any information about frame's quality or provenance.

Appendix A

Mandatory header keywords

This appendix lists mandatory header keywords. These keywords are mandatory in the sense that they must be present in the header when applicable, i.e. when the parameter in question plays a role in the acquisition of the frame. Parameters not used for the exposure should not appear in the header even though they are listed below (e.g. the TEL keywords should not be included in bias frames).

Keywords directly describing the data part of an HDU – such as WCS keywords, keywords describing pre- and overscan regions, kewyord defining windows, etc. – should be stored in the header of the relevant HDU. Other keywords should be stored in the header of the primary HDU.

Values of the mandatory FITS header keywords: SIMPLE, BITPIX and NAXIS, and, if applicable, NAXISn, XTENSION, PCOUNT, GCOUNT and EXTEND must be written in FITS fixed format.

A.1 Basic keywords

A.1.1 Primary header

```
SIMPLE  =                    T / Standard FITS format
BITPIX  =                   %d / # of bits storing pix values
NAXIS   =                   %d / # of axes in frame
NAXISn  =                   %d / # of pixels along n-th axis
EXTEND  =                    T / Extensions may be present
BZERO   =                   %f / real=fits-value*BSCALE+BZERO
BSCALE  =                   %f / real=fits-value*BSCALE+BZERO
BLANK   =                   %d / Value used for NULL pixels
INSTRUME=                   %s / Instrument used
TELESCOP=                   %s / ESO Telescope designation
OBJECT  =                   %s / Target description
OBSERVER=                   %s / Name of observer
ORIGIN  =                   %s / ESO
PI-COI  =                   %s / Name(s) of proposer(s)
EXPTIME =                   %f / Exposure time (sec)
RA      =                 %.6f / %HOURANG RA (J2000.0) pointing (deg)
DEC     =                 %.5f / %DEGREE DEC (J2000.0) pointing (deg)
```

```
EQUINOX =                 %.0f / Standard FK5 (years)
RADECSYS=                   %s / FK5
DATE    =                   %s / Date this file was written
MJD-OBS =                 %.8f / Obs start %DAYTIM (days)
DATE-OBS=                   %s / Date the exposure was started
TIMESYS =                   %s / Time system used
LST     =                 %.3f / %TIME LST at start (sec)
UTC     =                 %.3f / %TIME UTC at start (sec)
CTYPEn  =                   %s / pixel coordinate system
CRVALn  =                   %f / Coordinate value of ref pixel
CRPIXn  =                   %f / Ref pixel in n-th axis
CDn_m   =                   %f / Transformation matrix element
CUNITn  =                   %s / Unit of coordinate
CHECKSUM=                   %s / HDU checksum
DATASUM =                   %s / data unit checksum
```

A.1.2 Extension header

```
BITPIX  =                   %d / # of bits storing pix values
NAXIS   =                   %d / # of axes in frame
NAXISn  =                   %d / # of pixels along n-th axis
PCOUNT  =                   %d / # of parameters per group
GCOUNT  =                   %d / # of groups
TFIELDS =                   %d / # of table columns
TTYPEn  =                   %s / column name
TFORMn  =                   %s / column data format
TUNITn  =                   %s / column units
CTYPEn  =                   %s / pixel coordinate system
CRVALn  =                   %f / Coordinate value of ref pixel
CRPIXn  =                   %f / Ref pixel
CDn_m   =                   %f / Transformation matrix element
CUNITn  =                   %s / Unit of coordinate
CHECKSUM=                   %s / HDU checksum
DATASUM =                   %s / data unit checksum
INHERIT =                   %c / T if primary header keywords are inherited
```

A.2 Telescope

```
HIERARCH ESO TEL ID          =        %30s / Telescope Control SW ID
HIERARCH ESO TEL DID         =        %30s / Data dictionary for TEL
HIERARCH ESO TEL DATE        =        %10s / TCS installation date
HIERARCH ESO TEL ALT         =        %.3f / Tel ALT angle at start (deg)
HIERARCH ESO TEL AZ          =        %.3f / Tel Azimuth at start (deg)
HIERARCH ESO TEL GEOELEV     =        %.0f / Elevation above sea level (m)
HIERARCH ESO TEL GEOLAT      =        %.4f / Tel geographic lat (+=North) (deg)
HIERARCH ESO TEL GEOLON      =        %.4f / Tel geographic lon (+=East) (deg)
HIERARCH ESO TEL OPER        =        %30s / Telescope Operator
HIERARCH ESO TEL CHOP POSANG =        %.3f / Posang of chopping (N=0 E=90) (deg)
HIERARCH ESO TEL CHOP ST     =          %c / TRUE when chopping active
HIERARCH ESO TEL CHOP THROW  =        %.3f / Chopping throw (arcsec)
HIERARCH ESO TEL CHOP FREQ   =        %.0f / Chopping frequency (Hz)
HIERARCH ESO TEL CHOP CYCL   =          %d / # chopping cycles
```

```
HIERARCH ESO TEL FOCU ID     =        %10s / Telescope focus station ID
HIERARCH ESO TEL FOCU LEN    =        %.3f / Focal length (m)
HIERARCH ESO TEL FOCU SCALE  =        %.3f / Focus scale (arcsec/mm)
HIERARCH ESO TEL FOCU VALUE  =        %.3f / M2 setting (mm)
HIERARCH ESO TEL PARANG END  =        %.3f / Parallactic angle at end (deg)
HIERARCH ESO TEL PARANG START=        %.3f / Parallactic angle at start (deg)
HIERARCH ESO TEL TRAK RATEA  =        %.3f / Tracking rate in RA (mas/sec)
HIERARCH ESO TEL TRAK RATED  =        %.3f / Tracking rate in DEC (mas/sec)
HIERARCH ESO TEL TRAK STATUS =        %10s / Tracking status
HIERARCH ESO TEL AIRM START  =        %.3f / Airmass at start of exposure
HIERARCH ESO TEL AIRM END    =        %.3f / Airmass at end of exposure
```

A.3 Instrument

```
HIERARCH ESO INS ID          =        %30s / Instrument Control SW ID
HIERARCH ESO INS DID         =        %30s / Data dictionary for INS
HIERARCH ESO INS DATE        =        %10s / ICS installation date
HIERARCH ESO INS ADC STATUS  =        %10s / ADC status
HIERARCH ESO INS ADC POS     =        %10s / ADC position
HIERARCH ESO INS OPER        =        %30s / Instrument Operator
HIERARCH ESO INS FILTi ID    =        %10s / Filter i unique id
HIERARCH ESO INS FILTi NAME  =        %10s / Filter i name
HIERARCH ESO INS GRATi POSANG=        %.3f / Grating posang (N=0 E=90) (deg)
HIERARCH ESO INS GRATi ID    =        %10s / Grating unique ID
HIERARCH ESO INS GRATi NAME  =        %30s / Grating common name
HIERARCH ESO INS GRATi DISP  =        %.1f / Grating dispersion (nm/mm)
HIERARCH ESO INS GRATi WLEN  =        %.1f / Grating central wavelength (nm)
HIERARCH ESO INS GRISi POSANG=        %.3f / Grism posang (N=0 E=90) (deg)
HIERARCH ESO INS GRISi ID    =        %10s / Grism unique ID
HIERARCH ESO INS GRISi NAME  =        %30s / Grism common name
HIERARCH ESO INS GRISi DISP  =        %.1f / Grism dispersion (nm/mm)
HIERARCH ESO INS GRISi WLEN  =        %.1f / Grism central wavelength (nm)
HIERARCH ESO INS LAMPi NAME  =        %10s / Lamp name
HIERARCH ESO INS LAMPi EXPTIM=        %.3f / Lamp exp time (sec)
HIERARCH ESO INS MODE        =        %10s / Instrument mode used
HIERARCH ESO INS TEMP        =        %.1f / Instrument temperature (C)
HIERARCH ESO INS PATH        =        %10s / Optical path used
HIERARCH ESO INS OPTIi POSANG=        %.3f / Position angle (N=0 E=90) (deg)
HIERARCH ESO INS OPTIi ID    =        %10s / OPTIi unique ID
HIERARCH ESO INS OPTIi NAME  =        %10s / OPTIi name
HIERARCH ESO INS OPTIi NO    =          %d / OPTIi slot number
HIERARCH ESO INS OPTIi TYPE  =        %10s / OPTIi element
HIERARCH ESO INS MECHi ID    =        %10s / MECHi unique ID
HIERARCH ESO INS MECHi NAME  =        %10s / MECHi name
HIERARCH ESO INS MECHi NO    =          %d / MECHi slot number
HIERARCH ESO INS MECHi TYPE  =        %10s / MECHi element
HIERARCH ESO INS MOS SETUP   =        %30s / MOS setup
HIERARCH ESO INS MOSi POSANG =        %.5f / MOSi posang (N=0 E=90) (deg)
HIERARCH ESO INS MOSi WID    =        %.2f / MOSi slit width (arcsec)
HIERARCH ESO INS MOSi LEN    =        %.2f / MOSi slit length (arcsec)
HIERARCH ESO INS MOSi RA     =        %.8f / RA of slit (deg)
HIERARCH ESO INS MOSi DEC    =        %.8f / DEC of slit (deg)
HIERARCH ESO INS SLIT WID    =        %.2f / SLIT width (arcsec)
```

```
HIERARCH ESO INS SLIT LEN    =        %.2f / SLIT length (arcsec)
HIERARCH ESO INS SLIT POSANG =        %.3f / SLIT posang (N=0 E=90) (deg)
HIERARCH ESO INS SLIT RA     =        %.8f / RA of slit (deg)
HIERARCH ESO INS SLIT DEC    =        %.8f / DEC of slit (deg)
HIERARCH ESO INS PIXSCALE    =        %.3f / Pixel scale (arcsec)
```

A.4 Detector

```
HIERARCH ESO DET DID         =        %30s / Data dictionary for DET
HIERARCH ESO DET ID          =        %30s / Detector Contro SW ID
HIERARCH ESO DET NAME        =        %10s / Name of detector system
HIERARCH ESO DET CCDS        =          %d / # of CCDs in detector array
HIERARCH ESO DET OUTPUTS     =          %d / # of outputs
HIERARCH ESO DET OUTREF      =          %d / reference output
HIERARCH ESO DET OUTi CHIP   =          %s / Chip to which output belongs
HIERARCH ESO DET OUTi CONAD  =        %.2f / Conversion from ADUs to e- (e-/ADU)
HIERARCH ESO DET OUTi GAIN   =        %.2f / Gain (ADU/e-)
HIERARCH ESO DET OUTi ID     =        %30s / Detector identification
HIERARCH ESO DET OUTi PRSCX  =          %d / Prescan region in X
HIERARCH ESO DET OUTi PRSCY  =          %d / Prescan region in Y
HIERARCH ESO DET OUTi OVSCX  =          %d / Overscan region in X
HIERARCH ESO DET OUTi OVSCY  =          %d / Overscan region in Y
HIERARCH ESO DET OUTi RON    =        %.2f / Readout noise
HIERARCH ESO DET OUTi X      =          %d / X location of output
HIERARCH ESO DET OUTi Y      =          %d / Y location of output
HIERARCH ESO DET CHIPi OUTPUTS=         %d / # of outputs
HIERARCH ESO DET CHIPi OUTREF=          %d / reference output
HIERARCH ESO DET CHIP DATE   =        %30s / Date of installation
HIERARCH ESO DET CHIP ID     =        %30s / Detector chip identification
HIERARCH ESO DET CHIP INDEX  =          %d / Chip index
HIERARCH ESO DET CHIP NAME   =        %16s / Detector chip name
HIERARCH ESO DET CHIP NX     =          %d / # of pixels along X
HIERARCH ESO DET CHIP NY     =          %d / # of pixels along Y
HIERARCH ESO DET CHIP PSZX   =        %.1f / Size of pixel in X (mu)
HIERARCH ESO DET CHIP PSZY   =        %.1f / Size of pixel in Y (mu)
HIERARCH ESO DET CHIP X      =          %d / X location in array
HIERARCH ESO DET CHIP XGAP   =        %.6f / Gap between chips along X
HIERARCH ESO DET CHIP Y      =          %d / Y location in array
HIERARCH ESO DET CHIP YGAP   =        %.6f / Gap between chips along Y
HIERARCH ESO DET EXP TYPE    =          %s / Type of exp as known to the CCD sw
HIERARCH ESO DET EXP ID      =          %d / Unique exposure ID number
HIERARCH ESO DET EXP DUMDIT  =          %d / # of dummy readouts
HIERARCH ESO DET READ NO     =          %d / # of times the same pixel is read
HIERARCH ESO DET READ MODE   =        %10s / Readout method
HIERARCH ESO DET READ SPEED  =        %10s / Readout speed
HIERARCH ESO DET READ SHIFT  =          %d / # of lines shifted between exp
HIERARCH ESO DET READ CLOCK  =        %10s / Readout clock pattern used
HIERARCH ESO DET FRAM ID     =          %d / Image sequential number
HIERARCH ESO DET FRAM TYPE   =        %16s / Type of frame
HIERARCH ESO DET FRAM NAVER  =          %d / Number of images averaged
HIERARCH ESO DET FRAM BIAS   =           T / bias frame subtraction performed
HIERARCH ESO DET FRAM FLATF  =           T / flat field division performed
HIERARCH ESO DET WINi ST     =           T / Windowing enabled
```

```
HIERARCH ESO DET WINi STRX   =         %d / Lower left pixel in X
HIERARCH ESO DET WINi STRY   =         %d / Lower left pixel in Y
HIERARCH ESO DET WINi NX     =         %d / # of pixels along X
HIERARCH ESO DET WINi NY     =         %d / # of pixels along Y
HIERARCH ESO DET BINX        =         %d / Binning factor in X
HIERARCH ESO DET BINY        =         %d / Binning factor along Y
HIERARCH ESO DET DKTM        =       %.3f / Dark current time (sec)
HIERARCH ESO DET REQTIM      =       %.3f / Requested exposure time (sec)
HIERARCH ESO DET NDIT        =         %d / # of subintegrations
HIERARCH ESO DET UITi        =       %.3f / requested subintegration time (sec)
HIERARCH ESO DET DITi        =       %.3f / actual subintegration time (sec)
HIERARCH ESO DET SHUT TYPE   =       %16s / type of shutter
```

A.5 Adapter

```
HIERARCH ESO ADA POSANG      =       %.5f / Position angle at start (deg)
HIERARCH ESO ADA ABSROT START=       %.5f / Abs rot angle at exp start (deg)
HIERARCH ESO ADA ABSROT END  =       %.5f / Abs rot angle at exposure end (deg)
HIERARCH ESO ADA GUID STATUS =       %10s / Status of autoguider
HIERARCH ESO ADA GUID RA     =       %.5f / %HOURANG Guide star RA J2000.0 (deg)
HIERARCH ESO ADA GUID DEC    =       %.5f / %DEGREE Guide star DEC J2000.0 (deg)
HIERARCH ESO ADA GUID ROT    =       %.5f / Rot of guide probe arm (deg)
```

A.6 ObsBlock

```
HIERARCH ESO OBS DID         =       %30s / Data dictionary for OBS
HIERARCH ESO OBS ID          =         %d / Observation block id
HIERARCH ESO OBS NAME        =       %30s / Observation block name
HIERARCH ESO OBS GRP         =       %30s / linked blocks
HIERARCH ESO OBS PROG ID     =       %20s / ESO programme identification
HIERARCH ESO OBS TPLNO       =         %d / Template seq # in OB
```

A.7 Template

```
HIERARCH ESO TPL DID         =       %30s / Data dictionary for TPL
HIERARCH ESO TPL ID          =       %30s / Template ID
HIERARCH ESO TPL NAME        =       %30s / Template name
HIERARCH ESO TPL SEQNO       =         %d / Template seq # within OBS
HIERARCH ESO TPL NEXP        =         %d / Number of exposures within template
HIERARCH ESO TPL EXPNO       =         %d / Exposure number within template
```

A.8 Raw file categories (originally ‘Data Product’)

```
HIERARCH ESO DPR CATG        =       %30s / Observation category
HIERARCH ESO DPR TYPE        =       %30s / Observation type
HIERARCH ESO DPR TECH        =       %30s / Observation technique
```

A.9 Keywords related to tile compression

```
ZIMAGE  =                    T / extension contains compressed image
ZTENSION=                   %s / original extension type
ZBITPIX =                   %d / data type of original image
ZNAXIS  =                   %d / dimension of original image
ZNAXIS1 =                   %d / length of original image axis
ZNAXIS2 =                   %d / length of original image axis
ZPCOUNT =                    0 / original PCOUNT keyword
ZGCOUNT =                    1 / original GCOUNT keyword
ZTILE1  =                   %d / size of compressed tiles
ZTILE2  =                   %d / size of compressed tiles
ZCMPTYPE=                   %s / compression algorithm
ZNAME1  =                   %s / compression block size
ZVAL1   =                   %d / pixels per block
ZHECKSUM=                   %s / orignal HDU checksum
ZDATASUM=                   %s / original data unit checksum
```

A.10 Keywords in Internal Data Products

```
PIPEFILE                     = %s / Pipeline output file name
DATAMD5                      = %s / MD5 checksum
HIERARCH ESO PRO DID         = %s / Data dictionary for PRO
HIERARCH ESO PRO RECn ID     = %s / Pipeline recipe (unique) identifier
HIERARCH ESO PRO RECn DRS ID = %s / Data Reduction System identifier
HIERARCH ESO PRO RECn PIPE ID = %s / Pipeline (unique) identifier
HIERARCH ESO PRO DATANCOM    = %d / Number of combined frames
HIERARCH ESO PRO CATG        = %s / Category of pipeline product
HIERARCH ESO PRO SCIENCE     = %c / Scientific product if T
```

A.11 Keywords in FITS files encapsulating non-FITS pipeline products

A.11.1 Primary header

```
HIERARCH ESO PRO ANC         = %c / File is an ancillary product
HIERARCH ESO PRO CATG        = %s / Product category
HIERARCH ESO PRO DATASET     = %s / Unique dataset identifier
HIERARCH ESO PRO CONTENT     = %s / LOGS or PLTS (plots)
HIERARCH ESO PRO DPCATG      = %s / Dataset mode (CALIB, SCIENCE)
```

A.11.2 Extension header

```
FG_GROUP                     = %s / Group name
FG_FNAME                     = %s / Filename
FG_FTYPE                     = %s / File type
FG_LEVEL                     = %d / Directory level
```

```
FG_FSIZE                      = %d / Data size (bytes)
FG_FMODE                      = %s / File mode
FG_FUOWN                      = %s / File mode
FG_FUGRP                      = %s / File mode
FG_CTIME                      = %s / File mode
FG_MTIME                      = %s / File mode
```

___oOo___