Particle Physics and Astronomy Research Council

PPARC

Isaac Newton Group

INS-DAS-16

User Requirement Document for (Optical and Infra-red) UltraDAS

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1. INTRODUCTION

1.1 Purpose

This document defines the User Requirements for the UltraDAS data acquisition system. It supersedes [ING-DAS-16, v1.2] which mainly defined the requirements for the initial optical system in use at the INT and WHT. UltraDAS is expected to support both optical and IR observations, so requirements for both types of observing are specified. However, emphasis is placed on the requirements for IR, since these will drive enhancements to UltraDAS.

There are three classes of expected reader. Firstly those responsible for defining the requirements most be satisfied it is a correct description (Chris Packham, Nic Walton). Secondly representatives of other groups who will use UltraDAS (NAOMI, LIRIS) must be able to check that UltraDAS will meet their needs. Lastly, the developers (especially Guy Rixon), will want a clear description of what they have to implement.

1.2 Scope

ING requires a data acquisition system that will take data from both optical CCDs and IR detectors, operated through the SDSU II detector controller. This software system is called UltraDAS.

UltraDAS already works with CCDs, acquiring data though the SDSU II controller, but using the older s-bus interface for connection to the Sun host.

Now that the faster PCI interface is soon to be available, the IR implementation is expected to use this rather than the s-bus card. This faster interface will eventually be used for all CCD acquisitions as well.

1.3 Definitions, acronyms and abbreviations

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CCDC CCD Controller, here used to mean any SDSU detector controller whether used to drive CCD’s (Charge Coupled Devices) or other detectors.

DSP Digital Signal Processor

HAL Highest Acceptable Limit.

ING Isaac Newton Group of telescopes - La Palma

INT Isaac Newton Telescope

JKT Jacobus Kapteyn Telescope

LAL Lowest acceptable Limit.

SDSU San Diego State University

TBD To be determined.

TCS	Telescope Control System
WHT	William Herschel Telescope

1.4 References

DLP29NOV99 Private e-mail from Don Pollaco to Frank Gribbin, 29 Nov 1999

WHT1 ING document WHT-DAS-8 (issue 1.0)

INS-DAS-26 Observation files produced by UltraDAS, Guy Rixon, ING document INS-DAS-26 (issue 2.1), 26th Nov 1999.

CPOctT99 Meetings with Chris Packham (also NAW, SGR,FJG) in Oct 99 and subsequent discussions.

FITSREF1 NASA document NOST 100-1.1 Definition of the Flexible Image Transport System (FITS).

FOWLER Demonstration of an Algorithm for Read-Noise reduction in infrared arrays, A. M. Fowler and Ian Gatley, Astrophysical Journal, 353:L33-24, 10-Apr-1990.

HODAPP The HAWAII Infrared Detector Arrays : testing and astronomical characterization of prototype and science-grade devices, K. W. Hodapp et al, New Astronomy 1 (1996) 177-196

ID16 User requirement Document: The UltraDAS Data Acquisition System, Issue 1.2, 1999-06-17, D. B. Armstrong, ING document INS-DAS-16.

INT1 ING document INS-DAS-14 (issue 3.0)

INTWFC ING document INT Wide Field Camera.

IISR ING document INGRID Instrument Software Requirements (version 1). Note that [IISR] data acquisition requirements are now superseded by this document

JKTU ING document draft JKT URD

LONGMORE Notes on NAOMI-ICS requirements, Andy Longmore and Richard Myers, 24-Oct-1999.

NAOMIBDK ICD for NAOMI to Science Instrument (INGRID), B. D. Kelley, 16-Dec-1998, NAOMI/SOFT/BDK/1998.12/004

NOAOIDSD NOAO Image Data Structure Definitions.

WFC1 ING document INT-DAS-1 (issue 2.1)

WI1 IR Imager system: User Requirements, Keith Thompson, ING Doc WHT-INGRID-1, Issue 1.1; 1997-05-01

WHT2 ING document INS-DAS-14 (issue 3.0)

1.5 Overview

The rest of this document follows the ESA standard template for a User Requirements Document.

Under General Description, the is aim to describe what the UltraDAS should do and why, in a style that is easy to understand. Product Perspective describes some of the history and how the new IR+Optical UltraDAS relates to previous data acquisition systems. General Capabilities describes what UltraDAS and associated systems must do. Constraints notes where UltraDAS options are reduced by existing agreements and ING standards. In the User Characteristics an attempt to made to give a flavour of the different categories of people who will interact with the system. Within Operational Environment certain requirements on systems related to data acquisition are noted, since they must be met in any operational system, and although not part of the UltraDAS project, need to be checked during acceptance testing.

Specific Requirements lists the formal requirements for UltraDAS. It is against these requirements that the delivered system will be tested for acceptance. In the spirit of ESA standards, requirements are graded according to priority, however as suggested in [YOURDON] an easy to understand rating of MUST-DO (essential), SHOULD-DO (important) and COULD-DO (would be nice). Failure to meet MUST-DO requirements, in principal, means that UltraDAS cannot be deployed in full.

2. GENERAL DESCRIPTION

2.1 Product Perspective

At present most data acquisition on the WHT is still performed by the dated WHT VAX DAS, which controls the ‘Dutch’ CCD controller, reading data into the Detector Memory System. This system is at the end of it’s life since it cannot support readout speeds and volume of data produced by modern cameras. WHIRCAM, ING’s version of UKIRT’s Infra-red camera was retired this year. An early release of UltraDAS, using SDSU II CCD controllers and S-bus card in an Ultra 1 for data acquisition has been commissioned for use at prime focus, with twin EEV mosaic. INGRID an IR camera containing 1k*1k Hawaii array is due to be commissioned in 1Q2000 with an interim data acquisition and control system known as ‘Implementation B’, using an SDSU controller and S-bus interface.

In the INT the Wide Field Camera array is controlled by s-bus UltraDAS. CCDs used at Cassegrain focus with IDS are controlled by the ‘Dutch’ controller with data read into Sparc through an S-bus interface provided by Datacell. This arrangement suffers from the speed limitations of the Dutch controllers.

JKT uses the Datacell DAS.

UltraDAS as described in this document replaces the WHT VAX DAS, the Datacell DAS used in INT and JKT, the interim S-bus UltraDAS used in INT and WHT and the data acquisition aspects of INGRID ‘Implementation B’.

2.2 General Capabilities

2.2.1 Optical CCDs

TBD

2.2.2 Infrared Detectors

There is a general need for flexible readout modes. The table below lists the most common types of readout. However allowance needs to be made to extend the system to implement novel readout schemes. Keith Thompson [WI1(2g)] gave the example of sub-window resets on long integrations to prevent saturation from bright stars in the field.

Commonly used types of read-out for IR detectors

Type	Explanation	Advantages	Uses
MNDR	Reset, read n times, exposure, read n times	Reduces the read-noise by $n^{-1/2}$	Applications where read-noise>sky noise i.e. narrow band observations, spectroscopy
'Classical' read-out	Special case of MNDR where n=1	Simple and rapid read-out	Will satisfy most applications i.e. where sky noise>read noise
Read up the ramp	Gives best fit line to charge as accumulating on IR array i.e. reset, read, expose whilst reading n times	Gives best S/N for the array but at the expense of high processing power	Applications where read-noise>>sky noise i.e. narrow band observations, spectroscopy
Movie mode	Continuous stream of images sent directly to RTD tool	Necessary to acquire objects	Acquisition of objects
Co-averaging	*Any of the above but repeated and read to one file only*	*Reduces amount of disk space and processing on system computer*	*Almost all short exposure images/spectra*

Other IR requirements

?? Real-time display necessary. It should display the raw data once it has been read out, but does not have to display data as it is read out. Will also display appropriate interim reduced data frame.

?? Pixel non-linearity notification necessary ('magic' flagging required with co-averaging)

?? Scripting necessary

?? GUI interface is highly desirable

?? NAOMI requires that a custom interface so that data acquired from a small window may be returned to with low overheads. This feature is for use in alignment of NAOMI's Deformable Mirror.

2.3 General Constraints

2.3.1 Drama

Agreement with NAOMI project means that UltraDAS must have a DRAMA interface (for both commands and parameters), since NAOMI needs to be able to command UltraDAS via DRAMA.

2.3.2 Observation Preparation/Execution Tools

It's likely that ING will develop or adopt observation preparation and execution tools. These would be especially useful for IR observing and could be considered the successor to WHIRCAM execs. This means that control of UltraDAS from other (DRAMA) programs is required.

2.4 User Characteristics

2.4.1 Observer

The Observer is typically an Astronomer from a UK, Dutch or Spanish University. He may not have observed before, especially on JKT, and will have had a short introduction to observing by a local support astronomer or astronomy student, on his first night. At ING the trend is towards less support, so it's likely that he will be working without the assistance of local staff in INT and JKT.

2.4.2 Support Astronomer

The Support Astronomer is normally a member of ING staff or an astronomer assigned by the IAC. His task is normally to show the visiting observer how to use the instruments (and telescope in INT and JKT) and advise on astronomical performance. Typically they will be available in the first half of the first night of the observing run.

In JKT support Astronomers are being replaced by undergraduate students for reasons of cost.

Although one would hope that Support Astronomers would have significant experience, sometimes SA's with limited experience are required to provide support, either because of lack of training or for reasons of availability of more experienced staff.

During service nights, SA's perform the observations on behalf of observers who do not visit.

2.4.3 Telescope Operator

The Telescope Operator (TO) is responsible for the operating the Telescope. He may also be able to give advice about operation of the instrumentation, particularly in the case of faults. In WHT there is normally a TO every night, in INT during IDS runs and at start of WFC runs. The JKT does not have a TO.

2.4.4 Duty Engineer

There is a Duty Engineer (DE) on site every night. He is responsible for responding to faults that occur. He is officially on duty until 11pm and then on-call whilst asleep at the residencia (some 3 km away). Duty Engineers are drawn from various disciplines, and although expert in some aspect of telescope operations, are not necessarily experts in data acquisition systems.

2.4.5 Detector Engineer

Detector Engineers need access to detailed low level status of the detector and controller, hence the need for an engineering interface. Since they may be called up to resolve problems whilst at home, the interface must usable from PC connected by modem.

2.5 Assumptions and dependencies

2.5.1 INGRID shutter

At time of writing (Nov 1999) INGRID does not have a shutter, so UltraDAS cannot move the shutter. It is not expected that a shutter will be available before May 2000. UltraDAS should make provision for shutter control, but have this disabled for first installations. Likely shutter speed would be around 30 milliseconds [PCM24Nov99]

2.5.2 SDSU PCI Interface

It is expected that the PCI Interface will be now available in December 1999. However this must be considered a risk, because of SDSU's failure to meet earlier targets. In addition SDSU have indicated that the software for this board is likely to need revisions.

2.6 Operational environment

2.6.1 Archive (CD Tower)

Observation data files from all three telescopes are copied to CD during the night. FITS header data is used to build up a local catalogue of observations based on the Sybase RDMS. This catalogue is used as the basis for the observing log (see below). Writing of data to CD generally occurs during the night during observing.

Recent data is held on-line locally, but older CD's are shipped back to Cambridge where Cambridge Astronomical Survey Unit (CASU) maintain the ING archive.

Replacement of the CD system with DVD writing system is planned.

2.6.2 Pipe-line data reduction

Reduction of the INT Wide Field Survey (WFS) data occurs during the day. This is done using the powerful INT data reduction Sparc, during the day. So the reduced observations are available the following night.

In the future reduced WFS observations may be also be written to CD/DVD archive.

Extension of the pipe-line, by CASU, to cover data from INGRID is planned.

2.6.3 Observer's Log Display

Associated with the Archive is the log display utility, which is able to display a history of observations taken, in form of a scrollable table. The information to be displayed is taken from Sybase archive catalogue of observations and is updated every few seconds. Typically only observations taken since noon are displayed.

3. SPECIFIC REQUIREMENTS

3.1 Capability Requirements

3.1.1 General Requirements

Requirement 1 **UDAS1 UltraDAS support for both Optical and Infra-Red**

UltraDAS must support both Optical data and IR data acquisition. Optical data acquisition is required on all three ING telescopes, IR on WHT. In each case with a variety of instrumentation.

Priority: **MUST-DO** *Origin:* ID16 (UR01)

By supporting both Optical data acquisition from CCDs and Infra-Red data acquisition with the same software, ING will avoid the costs involved supporting two packages to perform similar functions.

Requirement 2 **UDAS16 Support for array of CCDs in one camera**

UltraDAS must support readout of multiple CCDs in a single camera.

Priority: **MUST-DO** *Origin:* ID16(Implied)

Current largest array (Nov 1999) is the INT WFC Mosaic, with 4 EEVs.

LAL: 4 Goal : 4? HAL : 32?

Requirement 3 **UDAS32 Run sequence number**

There will be one sequence of run numbers for each telescope. This sequence will cover both optical and IR observations.

Priority: **SHOULD-DO** *Origin:* FJG 01-Nov-1999

In case of WHT this run number sequence should be shared not only between optical and IR UltraDAS observations, but also with the old VAX DAS.

Requirement 4 **UDAS40 Multi controller data acquisition**

UltraDAS will support operation of detectors controlled by multiple CCDC's.

LAL: 3 Goal : 4 HAL: -

Priority: **COULD-DO** *Origin:* ID16(UR24)

This requires synchronisation of the controllers.

Requirement 5 **UDAS27 Timing (Exposure duration)**

Exposure duration shall be accurate to +/- values given in table below :

	LAL	**Goal**	**HAL**
Optical	**10 millisec**	**1 millisec**	**1 millisec**
IR	**1 millisec**	**1 millisec**	**1 millisec**

Priority: **MUST-DO(LAL)** *Origin:* ID16(UR16-1)

In case of IR observations, length of exposure is generally determined by delay between operations, whereas with optical CCDs, the exposure duration is generally defined as the time for which shutter is open.

Note : ING CCD shutters have a latency of around 30 millisec, so in practice a very short duration will lead to an uneven exposure in the (usual) optical case.

Note : SDSU controllers have timing interrupt with frequency of 0.8 millisec.

Requirement 6 **UDAS37 Reliability**

A failure rate can be defined which is the percentage of the total observing runs for which the data was not saved correctly.

Failure rate	**LAL**	**Goal**	**HAL**
Failed observations in a night	**1 %**	**0.5%**	**-**
Failed observations : 6 month average	**1:1500**	**1:5000**	**1:10000**

Priority: **MUST-DO (LAL)** *Origin:* ID16(UR23)

This requirement is generally more stringent for IR work since multiple reads are required for a typical IR observation (e.g. MNDR), whilst only a single read needed for a typical optical observation (although generally with a larger detector).

3.1.2 Common Operations

It is required that up to n (independent, non overlapping) windows can be defined.

Priority: **MUST-DO (LAL)** *Origin:* ID16(UR08-1)

Requirement 7 **UDAS10A Windowing**

LAL: 4 windows Goal: 5 windows HAL: 10 windows

For devices having more than one output, any window may overlap the boundaries of readout areas, e.g. in the case of INGRID a window defined near centre of detector may cover regions of distinct sizes from all four readout quadrants.

Note that for IR observations, LAL is 2 [CPOct99]

Note that windowing on the INT WFC is not currently possible, and would probably be of little use, since the same window would be set on each of the 4 chips.

Requirement 8 **UDAS10C Enable/Disable individual windows**

Would be nice to enable and disable individual windows.

Priority: **COULD-DO** *Origin:* ID16(UR08-30)

Allows user to define a number of windows and select which are used for an exposure. In the absence of such a facility, it should be possible to enable or disable all defined windows.

Requirement 9 **UDAS16 Selection of CCDs in array of multiple CCDs**

Support is required for readout of a CCD or group of CCDs from an larger array.

Priority: **SHOULD-DO** *Origin:* ID16(UR11-2)

Where a camera has multiple CCDs, it can be useful to select a subset to be read out. This could be because the application needs only a smaller area (e.g. at WHT prime focus, some observations may not require the use of both chips in WHT Mosaic), or because a failed chip produces worthless data.

Requirement 10 **UDAS26 Timing (start)**

Exposure start time should be accurate to +/- values given below:

	LAL	**Goal**	**HAL**
Optical	**100 millisec**	**30 millisec**	**30 millisec**
IR	**50 millisec**	**30 millisec**	**30 millisec**

*Note that GTR suggested that with dedicated local nntp server clock accuracy of +/- 20 millisec should be achievable***.**

Priority: **MUST-DO (LAL)** *Origin: ID16(*UR16-1)

Start time must be within accuracy specified above. This would be of special relevance to fast photometry. However, for many observations the accuracy of start time is not critical.

3.1.3 Optical Operations

Requirement 11 **UDAS2 Cycle time for optical observation**

Requirement body

Priority: **MUST-DO** *Origin:* ID16 (UR02)

Cycle time is defined by the pixel readout rate for the CCD plus a fixed overhead dependent on the software (memory access / disk acquisition / file transfer / network transfer rates). Cycle times are measured during a repetitive sequence such as MULTBIAS. For a 4k x 2k EEV42 CCD, the full frame times are

LAL: **30** *sec* *Goal:* **12** *sec* *HAL:* **5** *sec*

Requirement 12 **UDAS3 Fast photometric mode (Optical)**

UltraDAS should support fast photometric mode with suitable CCD.

Priority: **COULD-DO** *Origin:* ID16 (UR03),DLP29Nov99

Needs up to three windows of up to 128*128 pixels, one to be used for object, second for comparison and third for check star (to make sure comparison isn't varying). Ideal is that the cycle time is no more than time to read pixels in the window(s). Cycle time requirements for EEV42 for three 128x128 windows:

LAL: **1** *sec* *Goal:* **0.5** *sec* *HAL:* **96?** *millisec*

Collection of FITS headers should be done at start and end of whole sequence. However the start of each cycle should be recorded accurate to +/- 50 millisec. Each sequence should be able to continue for a considerable length of time:

LAL: **15** *min* *Goal:* **30** *min* *HAL:* **indefinitely**

Requirement 13 **UDAS5 Readout Speed (Optical observations)**

Support required for two and only two readout speeds for optical CCDs, FAST and SLOW. Fast is high speed and low gain with SLOW being low speed with high gain.

Priority: **SHOULD-DO** *Origin:* ID16 (UR05:1)

Readout speed should be silicon limited.

HIGH speed is for a series of short exposures with each exposure <=1 sec. See [WHT2-r1]. Series must be maintainable for >15 minutes for 1024 chip with 10 pixel wide strips.

Requirement 14 **UDAS6 Readout Speed (IR observations)**

Only one readout speed, NORMAL, is required for IR detectors.

Priority: **MUST-DO** *Origin:* CP21OCT99

As above.

Requirement 15 **UDAS9 Switchable gains (Optical)**

Support is required for gain values of x1, x2 and x4

Priority: **SHOULD-DO** *Origin:* ID16

Can be used to maximise dynamic range for a given noise.

Requirement 16 **UDAS7 Clear Speed (Optical)**

Only one clear speed, NORMAL, is required.

Priority: **COULD-DO** *Origin:* ID16(UR05)

As above

Requirement 17 **UDAS11 Binning (Optical)**

Binning factors of from 1 to 10 in both x and y are required.

Priority: **SHOULD-DO** *Origin:* ID16(UR09)

Binning factors of 1 to 10 must be settable in both x and y dimensions, where binning factors may be different in x and y.

Requirement 18 **UDAS13 Exposure types (Optical)**

Required exposure types are :

1. Run

Close shutter (if necessary), Clear CCD, open shutter, expose for specified duration, close shutter, read out and save data. Telemetry is gathered at start of exposure for most items and at end for remaining items. This telemetry is stored in the FITS file header.

2. Continuous run

Used for fast photometry. Sequence is clear CCD; open shutter; then repeat : wait (expose) , read; close shutter, save data. Headers are collected as shutter opens and updated when closes. Start times of each expose/read cycle are also recorded.

3. Bias

Close Shutter (if necessary), Clear CCD, read out and saved data. Telemetry is gathered at start of readout.

4. Flat

Used for DOME flat fields. Like RUN but exposure type set to FLAT in headers.

5. Arc

Used for comparison frames taken of arc lamps. Like RUN by exposure type set to ARC in headers.

6. Dark

Used for measuring DARK current, like RUN but shutter does not open.

7. Glance

Like RUN except that data is stored in a temporary file, which is overwritten by next GLANCE

8. Sky

Used for sky flat fields. Like RUN but exposure type set to SKY in headers.

9. Flash

Like DARK except that LEDs in CCD camera are switched on for short time to 'pre-flash' the CCD. Pre-flash is not generally needed for current CCDs, but is useful for test purposes.

10. Multrun

Used to perform a sequence of identical exposures. As well as MULTRUN to perform multiple RUNs there are equivalents for other exposure types.

11. multi continuous run

See MULTRUN.

12. multi bias

See MULTRUN.

13. multi flat

See MULTRUN.

14. multi glance

See MULTRUN.

15. multi scratch

See MULTRUN.

16. multi sky

See MULTRUN.

17. multi flash

See MULTRUN.

18. Data Cubes

All of the above exposure types (apart from CONTINUOUS run) should be operable in a mode where data is read out and saved in successive 'planes'.

In the case of TAURUS the requirement is to save successive CCD readouts as 'planes' in one data file. Each plane corresponds to a setting of the etalon. Planes may be written in any order. General FITS headers are saved at the start and updated at the end of the whole sequence. It is required to be able to save partial cubes after ABORT or FINISH (see below).

19. Abort

Abort exposure, discarding data. *Note that it is not possible to send command to the SDSU whilst it is reading out, ABORT is really only useful whilst CCD is being exposed/integrating.*

In case of a data cube, abort current exposure, but save the incomplete data cube.

20. Finish

Finish integrating immediately. Read out and save data. In case of a data cube, save the incomplete cube.

21. Newtime

Set integration time to new value longer than currently exposed time. Attempts to set value to less than currently exposed value should be rejected (perhaps with message suggesting use of FINISH).

22. focus_run

Used for focussing the telescope. FOCUSRUN is not strictly part of UltraDAS, but implemented as a higher level script. However it is noted here because UltraDAS must provide the fine grain control necessary, such as : clear, expose (opening shutter for predetermined number of seconds, then closing), wait (while telescope position and focus are offset), read out and save data.

23. dither_run

Again not strictly part of UltraDAS but implemented as a higher level script. Telescope is offset between exposures so that a Mosaic is built up where light from objects is integrated on different regions of the detector.

Priority: **MUST-DO** *Origin:* ID16(UR10)

Requirement descriptions as above.

Requirement 19 **UDAS23 Abort during exposure (Optical)**

Aborting while CCD is exposing, results in immediate termination of exposure. Data is not read out.

Priority: **MUST-DO** *Origin:* ID15(UR15-1)

Data is not saved, device returns to idle (continuous clearing) state.

Requirement 20 **UDAS24 Abort during readout(Optical)**

Abort during readout causes the readout to terminate. Any data read out is discarded.

Priority: **COULD-DO** *Origin:* ID15(UR15-2)

Data is not saved, device returns to idle (continuous clearing) state.

Requirement 21 **UDAS64 Data orientation for multiple-output device**

UltraDAS must write all the images from a multiple output device the same way around so that they fit together easily.

Priority: **COULD-DO** *Origin:* GTR,MJI

INGRID has 4 outputs, one for each quadrant. Data should be stored in the same orientation (perhaps that of quadrant 1). This allows a simple display of the data into an tiled imaging tool such as Ximtool. It also corresponds to NOAO's approach [NOAOIDSD].

Requirement 22 **UDAS25 Data Orientation for multiple devices in a Camera**

UltraDAS will save data from separate detectors in the same camera in the order they were read out.

Priority: **MUST-DO** *Origin:* MJI

Thus for separate devices data is saved in the "amplifier" orientation. This maintains current situation for INT WFC, as requested by MJI for CASU. It would be helpful to have some indication in headers of which output was in use (might change to alternative output if there were a failure).

Any need to orient the frame (e.g. with respect to sky) could be met y writing World Co-ordinate System headers allow a logical transformation.

For spectroscopic observations there is also a need for data reduction software to know which is the spectroscopic direction. Again this is best met by writing suitable headers (TBD by Robert Greimel), rather than transforming the raw data.

3.1.4 IR Operations

Requirement 23 **UDAS46 Correlated Double Sampling (Classical IR readout)**

UltraDAS must support Correlated Double Sampling (CDS)

Priority: **MUST-DO** *Origin:* CP22Oct99

This is the 'classical' IR read-out. Can be considered as a special case of MNDR where n=1, for longer integrations. For short integrations, duration is determined by shutter (see below).

Requirement 24 **UDAS47 Short CDS exposures using shutter**

UltraDAS should be able to shutter for timing CDS exposures where duration is 1 second or less.

Priority: **COULD-DO** *Origin:* WI1(B2d)

Since a read of the full Hawaii array will take around 0.85 sec, this sets the minimum achievable exposure time assuming shutter is left open. With a shutter having a lag of 30 milliseconds shorter exposures could performed in Z, J and H but bands. Use of the shutter in K band is less likely because thermal radiation from the shutter prevents the use of this approach.

Sequence is shutter closed, reset, read, shutter open, integrate, shutter closed, read. Both the first and last image must be stored.

Low priority, since INGRID does NOT currently have a shutter and is not likely to by May 2000. Until shutter is available all CDS exposures will be timed as for longer exposures.

Requirement 25 **UDAS47 Multiple Non-destructive Readout (IR)**

UltraDAS must support multiple non-destructive readout (MNDR) for IR devices.

Priority: **MUST-DO** *Origin:* CP22Oct99

Shutter open, reset, read n times, exposure, read n times, shutter closed.

Requirement 26 **UDAS48 Coaveraging**

UltraDAS must support coaveraging.

Priority: **MUST-DO** *Origin:* CP22Oct99

Simple arithmetic is acceptable with Hodapp's algorithm.

Coaverage = [sum (1^{st} half reads) – sum(2^{nd} half reads)] / Nreads

Integration time is then defined as the interval between number 1 read and NREADS+1 read. It will be necessary to store both sums from above in the final data file (i.e. two frames per file). For coaveraging RTD will need to display difference between current sum (1^{st} half reads) and sum(2^{nd} half reads), as well as displaying latest raw data.

Requirement 27 **UDAS49 Read up the Ramp (IR)**

UltraDAS must implement Read up the ramp acquisition for IR devices.

Priority: **MUST-DO** *Origin:* CP22OCT99

Reset, read, expose whilst reading n times. Gives best fit line to charge as accumulating on IR array.

Read up the ramp is expected to be used with LIRIS and INGRID narrow band imaging. It need not be implemented in the initial release of IR capable UltraDAS, but system must be designed with this capability in mind, since it demands high processing power.

Chris Packham suggests that 25% of INGRID observing will be narrow band.

Requirement 28 **UDAS50 Movie Mode**

UltraDAS must implement Movie Mode acquisition for IR, in which a continuous stream of images is sent to the RTD tool.

Priority: **MUST-DO** *Origin:* CP22Oct99,WI1

This mode is used to acquire objects, using single correlated sampling or possibly shutter controlled timing (when available). Used for instrument setup and target acquisition. Data is not saved.

Requirement 29 **UDAS51 Idle Mode (IR)**

When array is not otherwise operating it shall be reset at least every 2 seconds.

Priority: **MUST-DO** *Origin:* WI1(2)

Needed because Hawaii array suffers from image persistence. This is already implemented in the SDSU controller [KLT comment 7].

Requirement 30 **UDAS52 Very fast (photometry) mode (IR)**

Very fast mode required for supporting windows around 2 point sources. Effectively a repeated CDS, with all readouts stored. For two 40x40 pixel windows, performance should be 40 ms integrations, tagged to a time resolution of 100 ms.

Priority: **COULD-DO** *Origin:* WI1(2(j))

System should be able to continue indefinitely at this rate.

Requirement 31 **UDAS53 Shutter open continuously**

UltraDAS must provide an option to keep the shutter open continuously.

Priority: **COULD-DO** *Origin:* WI1(B2d(iii))

Would be used in conjunction with fast photometry. However see 2.5.1

Requirement 32 **UDAS54 On Chip Fast Guiding Mode**

Simultaneous long full array integrations and fast sub-array reads (preferably up to 20 Hz).

Priority: **COULD-DO** *Origin:* WI1(2(e))

This is low priority. Has been done by Max-Planck group with NICMOS-3 devices.

Requirement 33 **UDAS2A Cycle time for IR observations**

Overheads for IR observations must be kept low.

Priority: **MUST-DO** *Origin: CP22Oct99*

Cycle time is defined by the pixel readout rate for the detector plus a fixed overhead dependent on the software (memory access / disk acquisition / file transfer / network transfer rates). In the case of IR observations the minimum time is that for a reset followed by two successive non-destructive reads with no delay (CDS with no delay, similar to optical CCD Bias). Measurement is for a cycle within sequence of such operations (c.f. optical MULTRUN).

For the INGRID 1024x1024 Hawaii array, the cycle time should be :

LAL: **6** *sec* *Goal:* **6** *sec* *HAL:* **1.7** *sec*

Note that on 24Nov99, PCM gave current INGRID (Hawaii array) readout times as 4.6 usec per pixel, although goal is to reduce to 2 usec per pixel.

Requirement 34 **UDAS8 Reset Speed (IR)**

Two reset speeds are required for IR use, FAST and SLOW.

Priority: **COULD-DO** *Origin:* ID16(UR05)

Note that reset in the IR case is equivalent to clear in the optical case. PCM

Requirement 35 **UDAS10 Switchable gains (IR)**

Switchable gain is required for IR. Selectable gains should be HIGH??? and LOW???

Priority: **N/A** *Origin:* PCM24NOV99

Note that the high gain use deep wells, whilst low gain uses shallow wells???

Requirement 36 **UDAS10D Fast windowed acquisition for Naomi (GRAB)**

UltraDAS shall permit NAOMI to initiate a windowed exposure, confirm completion of exposure and obtain the data. Entire sequence should complete in no longer than 0.1 seconds for a 128x128 pixel window.

Priority: **MUST-DO** *Origin:* NAOMIBDK

Agreed command interface [NAOMIBDK] requires a Drama command of the form

Obeyw ultradas grab integration_time xmin xmax ymin ymax

On completion of the GRAB the UltraDAS returns a 2-D array in the DRAMA completion message.

Note that the question of whether image needs to be flat fielded, and if so, which software subsystem is responsible for doing this has yet to be determined.

Requirement 37 **UDAS12 Binning (IR)**

Binning is not required for IR

Priority: **N/A** *Origin:* CP22Oct99

Not required.

Requirement 38 **UDAS15 Multiple Outputs**

Support is required for 4 outputs per device

Priority: **MUST-DO** *Origin:* ID16(UR11-1)

IR Hawaii array in INGRID has 4 outputs. Data is read out from the 4 quadrants. This implies that there is a need to reconstruct the image.

Requirement 39 **UDAS22 Reserved (Alarms and status)**

Requirement body

Priority: **COULD-DO** *Origin:* ID16(UR14)

Requirement description

Requirement 40 **UDAS25 Abort of IR observations**

Ability to abort IR data acquisition is required, but where data has already been acquired it should be saved. After an abort, system shall be returned to the idle state in which the array is continuously reset.

Priority: **COULD-DO** *Origin:* ISRV1(SWReq_6).

SDSU does not allow abort of data acquisition during readout, since there is no provision for sending commands to the controller during readout.

ABORT is also used to stop 'Movie Mode'

3.1.5 Data Format

Requirement 41 **UDAS10B Storage of windowed data**

Ability to condense windows into one image file is required, such that storage of blank areas is minimised.

Priority: **SHOULD-DO** *Origin:* ID16(UR08-2,4)

One important application is to provide a windowed science area with associated bias strip or over scan region. See [INS-DAS-26] for description of data storage.

Requirement 42 **UDAS14 FITS data format**

FITS data format is 16 bit for optical data, and 32 bit real for IR.

Priority: **MUST-DO** *Origin:* ID16(UR10)

See [INS-DAS-26]

Requirement 43 **UDAS28 Data to be saved in FITS format on disk**

Acquired data is to be stored in FITS files, on network accessible disks

Priority: **MUST-DO** *Origin:* ID16(UR17-1,2)

Use of FITS format is data reduction package neutral. Most packages allow import of FITS files from disk. Iraf can work directly with FITS disk files. Furthermore use of this format makes writing FITS tapes simple and is convenient for the CD tower archive.

Storage to disks accessible by general network to is essential for operation of CD Tower archive scavenger, as well as being convenient for data assessment.

FITS headers for INT and JKT are defined in [INS-DAS-26]. Current FITS headers for WHT are defined in [WHT-PDF-1], including headers VAX DAS and for INGRID. *It is planned that INS-DAS-26 will be updated to include all headers to be written for WHT by UltraDAS.*

Requirement 44 **UDAS64 Storage of INGRID Hawaii array data**

Data from each quadrant of Hawaii array will be stored in a separate FITS image extension.

Priority: **COULD-DO** *Origin:* NAW,MJI

CASU data reduction Pipe-line is facilitated by having data from 4 quadrants saved separately. Since each amplifier has it's own behaviour. Each image extension has it's own header items and can thus store information specific to the quadrant.

A simple CDS exposure FITS file will then contain 8 images, 4 for pre-read and 4 for post-read.

Requirement 45 **UDAS32 Run sequence number**

There will be one sequence of run numbers for each telescope. This sequence will cover both optical and IR observations.

Priority: **SHOULD-DO** *Origin:* FJG 01-Nov-1999

In case of WHT this run number sequence should be shared not only between optical and IR UltraDAS observations, but also with the old VAX DAS.

Requirement 46 **UDAS35 Observer/Programme identification**

An IDENTIFY command is required to set the observer/programme id in FITS headers.

Priority: **SHOULD-DO** *Origin:* ID16(UR20-1)

Observer must be able to set initial and PATT/CATT programme name to be stored in headers.

Requirement 47 **UDAS29A FITS Headers for IR observations**

Header Item Description	**INGRID Implementation B**	**Optical (s-bus) UltraDAS**
Detector Name	**DETECTOR**	**CCDNAME**
Detector Controller Software Identifier	**INGSWID**	**None**
Array Read Time	**INGRDTIM**	**None**
Array Set Temperature	**INGSTMP**	**None**
Array Actual Temperature	**INGATMP**	**None**
Detector readout noise	**READNOIS**	**RDNOISE**
Gain	**GAIN**	**GAIN**
Detector Array Bias Voltage Setting	**INGBIASV**	**None**
Array read mode	**INGRDMOD**	**None**
Number of reads in MNDR	**INGNR**	**None**
Number of co-averages	**INGNM**	**None**
Total number of images in MULTRUN sequence	**INGNM**	**None**
Index within multi-run sequence	**INGIM**	**None**
Shutter Mode [OPEN, CLOSED, FAST, LONGINT]	**INGSMODE**	**None**

CLOSED, FAST, LONGINT]		
Integration time (sec)	**INGITIM**	**???**
On-sky Exposure Time (sec)	**EXPOSED**	**EXPOSED**
On-sky Exposure Time (sec)	**EXPTIM**	**EXPOSED**
Temperature monitoring point 1 (K)	**INGTEMP1**	**None**
Temperature monitoring point 2(K)	**INGTEMP2**	**None**
Temperature monitoring point 1 (K)	**INGTEMP3**	**None**

Priority: **MUST-DO** *Origin:* CP,SGR, [WHT-PDF-1]

The Table above lists required header items. It is **not** required that the names of items are the same as in INGRID Implementation B.

Although headers relating to window co-ordinates were specified for INGRID Implementation B, following WHT DAS style, they are of no practical use, since windowing is not supported. UltraDAS should follow a common convention for Optical and IR windowing.

INGRDTIM is the time it takes for the driver electronics to scan the detector array. This time is dependent on the number of pixels to be read out as determined by the window setup. INGRDTIM provides a measure of the time slew between reading the first pixel in the array and reading the last; it also determines the minimum integration period for a particular window setup.

INGITIM reflect the period over which pixels in the detector array are integrated as determined by the diver electronics. Where timing of exposure is done by the shutter this would be different from the period over which they are exposed to sky. However since INGRID will initially operate without a shutter, INGITIM will be same as EXPOSED.

Current INGRID Implementation B headers are described in [WHT-PDF-1].

There will be a need to store details of dithered exposures in the headers, and identify appropriate dark frames, so that the data reduction pipeline can operate.

Requirement 48 **UDAS29B FITS Headers for INGRID observations**

INGRID instrument headers as per INSTINGR packet.

Priority: **MUST-DO** *Origin:* CP

INGRID INSTINGR Implementation B headers are described in [WHT-PDF-1]. Would expect this to be added to [WHT-DAS-26] description for UltraDAS.

3.1.6 Real-time Display

For optical observations a real-time display (RTD) is not required. For IR work it is essential. There is already an implementation of the RTD for INGRID ‘implementation B’ by Simon Rees and IAC.

Requirement 49 **UDAS55 RTD display windows**

RTD should show both raw data and processed data. One window shows the raw data whilst other shows the processed results.

Priority: **COULD-DO** *Origin:* CP

This is like the WHIRCAM Alice display, where left hand window shows the raw data and right hand window show the resulting processed data (e.g. results of co-averaged sequence). In the case where there is no processed data to display, the processed data window need not be displayed.

Requirement 50 **UDAS56 RTD automatic display and ‘Freeze’**

RTD shall normally be updated automatically as a new image is taken. However it should be possible to disable or ‘Freeze’ the display.

Priority: **MUST-DO(LAL)** *Origin:* CP,FJG

RTD will update the raw display as each image is taken and update the processed image display as data becomes available. Automatic display is the default mode and is used in conjunction with ‘Movie Mode’ during target acquisition.

Display update is complete within n seconds of receipt of last pixel in readout of full array:

LAL: 5 seconds Goal: 2 second. HAL: 1 second.

Display update is complete within n seconds of receipt of last pixel in readout of 128*128 window

LAL: 0.5 second Goal: 0.1 HAL: 0.1 second.

‘Freeze’ enables observer to examine an image in detail.

Requirement 51 **UDAS57 Display Arithmetic**

RTD must allow user to select display of following images :

1. **Post-integration minus Pre-integration image (called ‘S’ below)**
2. **Sky subtracted : (Object S) - (Sky S)**
3. **Sky subtracted and flat fielded : (object S) / (flat field) – (sky S)/(flat field)**

Priority: **SHOULD-DO** *Origin:* CP

User should be able to select the sky and flat field frames.

Requirement 52 **UDAS58 RTD Automatic detection of saturated pixels**

RTD shall automatically detect saturated pixels and identify them on display.

Priority: **SHOULD-DO** *Origin:* CP

Saturated pixels should be clearly displayed as such (using for example a special colour). If a frame is the result of image arithmetic, then a saturated pixel in an input frame will be flagged as saturated in the output.

Requirement 53 **UDAS59 RTD display location**

It should be possible to put the display on any suitable X-term screen, although display will normally be on the same screen as data acquisition control.

Priority: **SHOULD-DO** *Origin:* CP

RTD should be easy to see and control from the observer's console. It may be helpful to be able to move the display for use with NAOMI, especially for engineering tests.

Requirement 54 **UDAS36 RTD processing priorities (Refresh Rate)**

Although RTD should display every image, neither RTD processing nor absence of RTD must hold up data acquisition.

Priority: **SHOULD-DO** *Origin:* ID16(UR20-1),CP25NOV99

It would be preferable for RTD to skip display of (intermediate) frames rather than delay data acquisition or instrument control.

Requirement 55 **UDAS61 Image examination utilities**

Calculation of image statistics (max, min, mean, standard deviation) for a moveable box, automatically updated as new image is displayed.

Priority: **SHOULD-DO** *Origin:* CP

User should be able to move box and have statistics calculated. Once he has positioned box, statistics are calculated whenever new image is displayed.

Requirement 56 **UDAS62 Seeing Monitor**

Calculate seeing on each frame, by finding brightest 1-5 brightest objects and calculate FWHM. Display as a graph of seeing against time.

Priority: **SHOULD-DO** *Origin:* CP

Behaviour need to be selectable, since would not be appropriate for spectroscopic observations.

Need to avoid selecting hot pixels and cosmic rays.

Requirement 57 **UDAS63 Sky Background Monitor**

Automatically find blank piece of sky and form the median. Display as a graph of sky brightness against time.

Priority: **SHOULD-DO** *Origin:* CP

As each new frame is displayed, identify a region of blank sky (where there are no near-IR sources) and find the median. Plot this value as the sky brightness against time. Since brightness will change as filters are changed, change of filter should be indicated (perhaps as colours on graph).

3.1.7 User Interfaces

Requirement 58 **UDAS20 Observer's Mimic**

A mimic display is required for observer, which should allow control of the detector and well as showing observation and detector status.

Priority: **MUST-DO** *Origin:* ID16(UR13-1)

Requirement description TBD, since it will often be sensible to integrate into an instrument specific Mimic display.

Requirement 59 **UDAS21 Engineering Mimic**

Engineering mimic will show the full status of device and CCDC

Priority: **COULD-DO** *Origin:* ID16(UR13-2)

Requirement description TBD. Await input from PCM.

Requirement 60 **UDAS60 Engineering DSP Interface**

DSP command window as provided by CCD Tool

Priority: **COULD-DO** *Origin:* GUYW

Low level access as provided by CCD Tool DSP window.

Requirement 61 **UDAS55 Error Reporting – Talker Log**

Errors, progress messages and debug status messages should be reported via ING's Talker Log.

Priority: **MUST-DO** *Origin:* FJG

Talker Log based on Unix syslogd permits programs on multiple machines to make entries which are then displayed as a single log, facilitating fault finding.

Requirement 62 **UDAS30 Observer's Log (Optical)**

System must automatically create an observing log, and display the log to observer.

Priority: **MUST-DO** *Origin:* ID16(UR18)

There is already a log created as optical observations, via CD Tower Archive.

Standard items should include : run number, object name, RA, Dec, Co-ordinate system, air mass, sky p.a., UT of start of observation, exposure time (seconds).

Requirement 63 **UDAS31 Observer's Log (IR)**

System must automatically create an observing log and display log to observer.

Priority: **MUST-DO** *Origin:* CP

This should be the same log as produced for optical observations, via CD Tower Archive.

Standard items should include : run number, object name, RA, Dec, Co-ordinate system, air mass, sky p.a., UT of start of observation, exposure time (seconds).

Items specific to INGRID :

1. Waveband of filter in use.
2. Photometric system.
3. Filter ID.

Items for general IR log are :

1. Number of frames co-averaged.
2. Number of multiple non-destructive readout pairs (N as in MNDR).
3. Array read mode, i.e. MNDR, Read up the ramp.

3.2 Constraint Requirements

Requirement 64 **UDASC1 Commonality**

UltraDAS will be the same on each telescope (subject to actual differences in telescopes and instruments/detectors.)

Priority: **SHOULD-DO** *Origin:* ID16

An Optical CCD can in principle be moved between three ING telescopes. A user operating the detector at the command line should expect to use the same commands at each telescope, although at the WHT an additional parameter may be needed to specify which camera should be used. A data file produced at one telescope will have the same format as that produced at another, although the header items relating to the telescope and instrumentation will differ since they refer to different hardware. Where a GUI is provided as part of UltraDAS then operation of data acquisition appear the same.

Since UltraDAS is not expected to control IR detectors on INT and JKT, there is no special requirement for IR compatibility.

Requirement 65 **UDASC2 Unix shell scripting**

It is required that basic commands are accessible via the standard unix shells (e.g. tcsh, csh) to facilitate scripting.

Priority: **MUST-DO** *Origin:* ID16

This requirement need not apply to sequences defined in a observation preparation/execution tool.

Requirement 66 **UDASC3 Ease of Use**

A novice user should be able to use the DAS after 1 hour of training

LAL : 2 hours *Goal :* 1 hour *HAL :* without training

Priority: **MUST-DO(LAL)** *Origin:* ID16(UR22)