SPIRE ICC

User Requirements Documents
Photometer Processing

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1 Introduction

1.1 Purpose & Scope

Requirements put on the ICC by the Photometer observing modes. It will describe the form the data is expected to take and the information required to fully characterise it. It also puts requirements on the ICC by the need to produce a data reduction process for the photometer observation modes of SPIRE. These observation modes might have either a purely scientific goal or an engineering purpose. The potential users of the data reduction process might be either members of the SPIRE Consortium, or astronomers having access to the FIRST observations (via the FSC). (This description was taken from RD-1). This document does not cover the requirements from the need to calibrate the modes, nor the need to command the instrument which are covered in RD-3 & RD-4

1.2 Definitions of Terms and Acronyms

Listing of acronyms that are “unusual” to this URD

FIRST	Far InfraRed and Submillimetre Telescope
SPIRE	The Spectral and Photometric Imaging REceiver for FIRST
ICC	Instrument Control Centre
URD	User Requirement Document
ILT	Instrument Level Test
AVM	Avionics Model
CQM	Cryo Qualification Model
PFM	Proto-Flight Model

PV	Performance Verification
GST	Ground Segment Testing

In addition two web pages are available describing terms applicable to SPIRE
http://www.ssd.rl.ac.uk/spire/consortium/information/FIRSTacronyms.shtm
http://www.ssd.rl.ac.uk/spire/consortium/information/FIRSTdefinitions.asp
These are to be updated.

1.3 Related Documents

RD-1	SPIRE ICC URD Scope Document
RD-2	FIRST Common Science System Development Work Report (Neal Todd, Edinburgh 20th October 2000)
RD-3	SPIRE ICC URD Calibration
RD-4	SPIRE ICC URD Common Uplink System
SIRD	Science Implementation Requirement Document esp. ICCF-055 ICCF-130 ICCO-060 ICCO-065

1.4 Overview

2 User Characteristics

2.1 The Calibration Scientists

The calibration scientist has a strong astronomical background and an in-depth knowledge of the properties and operations of the instrument. He/She plans the necessary calibration observations to characterize the instrument, determines and verifies the calibration parameters of the instrument and specifies how these parameters have to be applied in the standard product generation. [ICC actor v0.4]

2.1.1 Photometer Calibration Scientist

A calibration scientist with special responsibilities for the Photometer

2.2 Interactive Analysis Developer

The IA developer will need to be able to modify IA routines in response to proposed changes in calibration procedures.

2.3 Instrument Engineer

The instrument engineer will provide information about the instrument necessary for the processing. S/he will also be making requirements on what processing steps and outputs are required.

2.4 Consortium Astronomers

The photometer processing is can only be properly assessed when applied to real scientific measurements. Special scientific observations may require special processing. It is the astronomers who will eventually be able to decide whether the processing is achieving the desired results. Those involved with the processing activity need to be closely corresponding with Astronomers, in particular Consortium Astronomers.

2.5 Non-Consortium Astronomers

The photometer processing is can only be properly assessed when applied to real scientific measurements. Special scientific observations may require special processing. Those involved with the processing activity need to be closely corresponding with Astronomers, to a lesser extent non-Consortium Astronomers via the FSC.

2.6 FSC

3 Requirements

3.1 UR-PHT-100: Instrument Modes

UR-PHT-110: Definition of various Instrument Modes

The ICC are required to define the various operating modes of the instrument

- **Source** SIRD-ICCF-055
- **Importance** Essential
- **Frequency** yearly
- **Phase** AVM

UR-PHT-120: Process specific modes

Process as applicable "specific" instrument modes (e.g. parallel and serendipity data) generated by the photometer. Deliver to the HSC.

- **Source** SIRD-ICCA-040
- **Importance** Desired
- **Frequency** yearly
- **Phase** Archive

3.2 UR-PHT-200: Development

The processing of instrument data is expected to be a continually evolving skill

UR-PHT-210: Design

The ICC is required to design the processing software

- **Source** SIRD-ICCF-130
- **Importance** Essential
- **Frequency** yearly?
- **Phase** AVM

UR-PHT-220: Implementation

The ICC is required to implement the processing software (TBD what this means), but see next section.

- **Source** SIRD-ICCF-130
- **Importance** Essential
- **Frequency** yearly
- **Phase** AVM

UR-PHT-230: Test

The ICC is required to test the processing software (TBD what this means)

- **Source** SIRD-ICCF-130
- **Importance** Essential
- **Frequency** yearly
- **Phase** AVM

UR-PHT-240: Validation

The ICC is required to validate the processing software (TBD what this means).
"support the validation of the scientific processing S/W prior to release for use by the community. Note: the scientific data processing software will evolve considerably during the mission from the basic, imperfect set available at launch. The ICC teams shall process "selected" observations in order to validate the various processing algorithms. Upon validation the S/W is released for use by the HSC and the community. The Observations to be checked shall be selected in such a way that all instrument modes (AOTs) are covered as well as possible"
"Support validation of the data products generated with improved algorithms/calibration data"

- **Source** SIRD-ICCF-130
  SIRD-ICCF-065
  SIRD-ICCA-035
- **Importance** Essential
- **Frequency** yearly
- **Phase** AVM

UR-PHT-240: Improvement

Improve processing algorithms. Deliver updates to HSC

- **Source** SIRD-ICCA-030
- **Importance** Essential
- **Frequency** yearly
- **Phase** AVM

3.3 UR-PHT-300: Interactive Analysis: General

This section indicates some general requirements of the Interactive Analysis (IA).

UR-PHT-310: Platforms

IA should be multiplatform with goal of platform independence. The platforms that are currently required are Solaris, Linux, DecUltra with a goal of one Windows platform (NT/95/98 or 2000). The list of supported platforms will be subject to change at time scale of one tear (TBC).

- **Source** RD2
- **Importance** Essential/Desirable
- **Frequency** yearly
- **Phase** AVM

UR-PHT-320: Modularity

The IA should be designed such that new algorithms can be developed and interchanged with ease.

- **Source** SJO (here)
  SIRD-ICCF-130
- **Importance** Essential
- **Frequency** continuous
- **Phase** AVM

UR-PHT-330: IA consists of different generic types of modules

(a) <u>interactively processing data</u>
(b) <u>visualizing data; - at all stages of processing, not just final images</u>
(c) <u>input/ output of data</u>

- **Source** RD2
  SIRD-ICCF-130
- **Importance** Essential
- **Frequency** once
- **Phase** AVM

UR-PHT-340: Interfaces

Interactive analysis will consist of both GUIs and Command Line interfaces
A scripting language can be run within IA

- **Source** RD2
  SIRD-ICCF-130
- **Importance** Essential
- **Frequency** continuous
- **Phase** AVM

UR-PHT-350: Data formats

IA will be able to export/ import data in formats than can be imported/exported to/ from other software – which?

- **Source** RD2
  SIRD-ICCF-130
- **Importance** Essential
- **Frequency** once
- **Phase** AVM

UR-PHT-360: Interfaces to other software

The possibility that the IA will allow the calling of other data reduction packages
and/ or libraries (possibly in other languages) whilst in IA is an open issue. This is expected to be difficult and so is very much a goal rather than a requirement.

- **Source** RD2
- **Importance** Desirable
- **Frequency** once
- **Phase** AVM

UR-PHT-370: User Help

IA will have a help system including reference guides and recipes

- **Source** RD2
  SIRD-ICCF-130
- **Importance** Essential
- **Frequency** continuous
- **Phase** AVM

UR-PHT-380: Source code

Modules will be open source so that the Astronomer can see the algorithms applied and have the facility to locally modify and run code. – dangerous ?

- **Source** RD2
- **Importance** Essential
- **Frequency** once
- **Phase** AVM

UR-PHT-390: History

The product generation history will be a component part of the products

- **Source** RD2
- **Importance** Essential
- **Frequency** once
- **Phase** AVM

UR-PHT-400: Data Products

The data products should be processed to the extent that is required by the quality of the data and by the nature of the observations being carried out. Under each observing mode we specify what the end results of the data processing are expected to be. We do this because the specific processing steps expanded below may not be the only ways of reaching these end-points. N.B. these are all science end points, it may be that there are other engineering/calibration end points which will be of interest.

- **Source** Here
- **Importance** Essential
- **Frequency** once
- **Phase** AVM

UR-PHT-410: POF1 : Chop Without Jiggling

Flux (or upper-limit) of a point source with known position (which is expected to be in centre of central bolometer, but might later be found to be at a known position off centre?)
Error in Flux
Measure of Goodness of Fit

Average intensity recorded in each bolometer-sky position
Error in intensity

UR-PHT-420: POF2 : Seven-Point Jiggle Map

Detection of previously unknown point sources?
Positions of previously unknown point sources?
Fluxes for previously unknown point sources?
Significance levels of detections?
Errors in positions?
Errors in fluxes?

Flux (or upper-limit) of a point source with known position (which could be anywhere within the boundaries of the map)
Error in Flux
Measure of Goodness of Fit

Map of Intensity
Error in Intensity

Average intensity recorded in each bolometer-sky position
Error in intensity

UR-PHT-430: POF3 : N-Point Jiggle Map

Detection of previously unknown point sources
Positions of previously unknown point sources
Fluxes for previously unknown point sources
Significance levels of detections
Errors in positions
Errors in fluxes

Flux (or upper-limit) of a point source with known position (which could be anywhere within the boundaries of the map)
Error in Flux
Measure of Goodness of Fit

Map of Intensity
Error in Intensity

Average intensity recorded in each bolometer-sky position
Error in intensity

UR-PHT-440: POF4 : Raster Map

Detection of previously unknown point sources
Positions of previously unknown point sources
Fluxes for previously unknown point sources
Significance levels of detections
Errors in positions
Errors in fluxes

Flux (or upper-limit) of a point source with known position (which could be anywhere within the boundaries of the map)
Error in Flux
Measure of Goodness of Fit

Map of Intensity
Error in Intensity

Average intensity recorded in each bolometer-sky position
Error in intensity

UR-PHT-450: POF5 : Scan Map Without Chopping

Detection of previously unknown point sources
Positions of previously unknown point sources
Fluxes for previously unknown point sources
Significance levels of detections
Errors in positions
Errors in fluxes

Flux (or upper-limit) of a point source with known position (which could be anywhere within the boundaries of the map)
Error in Flux
Measure of Goodness of Fit

Map of Intensity
Error in Intensity

UR-PHT-460: POF6 : Scan Map With Chopping

Detection of previously unknown point sources
Positions of previously unknown point sources
Fluxes for previously unknown point sources
Significance levels of detections
Errors in positions
Errors in fluxes

Flux (or upper-limit) of a point source with known position (which could be anywhere within the boundaries of the map)
Error in Flux
Measure of Goodness of Fit

Map of Intensity
Error in Intensity

UR-PHT-470: POF7 : Photometer Peak-Up (TBD)
Position of point source with approximately known position
Flux (or upper-limit?) of a point source with determined position
Error in Flux
Measure of Goodness of Fit

UR-PHT-480: POF8 : Operate photometer internal calibrator
Average intensity recorded in each bolometer-sky position
Error in intensity

UR-PHT-490: POF9 : Special engineering modes (TBD)
TBD,

UR-PHT-500: Interactive Analysis: Processing of Observing Modes
The Interactive analysis must be capable of processing all observing modes. This section indicates what we currently expect to be the procedures required for each mode. The procedures described here are currently indicated in a flow chart in the Appendix.

UR-PHT-510: General
The following processes will be required on all data regardless of observing mode (except where explicitly excluded in the observing mode specific sections below)

3.3.1.1 Data from FINDAS
Includes all SPIRE relevant data

3.3.1.2 Injection into SPIRE pipeline
1., 3.,4. are obvious, 5., may not be required, 2 may include real astrometric information as a function of UT but may require a software module which can interpret or reinterpret satellite pointing data as the reconstruction models are improved (these modules could be implemented at any stage in the pipe-line)

3.3.1.3 Construct Inst. Mode/Status history from H/K
Self explanatory. May be checked against requested mode?

3.3.1.4 Flagging missing and Bad data
Self explanatory

3.3.1.5 Converting mechanical data to Physical Units
Physical units would be Volts, x,y, positions in mm, angles in degrees, etc.

3.3.1.6 Validation of mechanical data
Checking e.g. that the position of the chopper mirror is appropriate (dependent on mode?). This includes checks which would not have been trapped by the usual out of limits (hard or soft).

3.3.1.7 Calibration Tables
Required as input to the two conversion processes. Presumably these are likely to be look-up tables or parameters for simple algorithms

3.3.1.8 Reports
Reports are required to indicate where the mode is non-standard in some way, or if there is an anomalously high rate of bad pixels

3.3.1.9 Stored data
There are two points at which data is stored. In general data should be stored at a point in the pipe-line that one may wish to return to (to run new procedures) without having to go further back. So it is likely that data should be stored after time-consuming or stable processes.

The two points indicated here for storage are not cast in stone, but appear after what are presumed to be reasonable stable processes

3.3.1.10 Visualisation

Two points are indicated where QLA visualisation routines would be required. I.e. we would like to be able to examine the most raw of data products, before any real processing has occurred, and we would like to be able to visualise the data in physical units.

UR-PHT-520: POF1: Chop Without Jiggling

3.3.1.11 0^{th} Order Deglitching

Filtering out very high significance, short time-scale spikes in the time-line

3.3.1.12 Demodulation

Differencing on-off chop position

3.3.1.13 Gain Drift correction

Probably requires sensitivity measurements as a function of time and interpolates between. No reason to expect significant drift but I guess useful to have the capability. This is what the internal calibrator is for. The calibrator signal will be demodulated either at the same time as the astronomical signal or periodically, then for each detector the relative gain can be compared to the standard value and if necessary either adjusted or simply flagged.

3.3.1.14 Deglitch 2

Filtering out outliers from “average” of chopped signals at a single jiggle pointing

3.3.1.15 Flat-fielding

Taking out the differing responsivity of the different detectors. This should be a trivial step just multiplying by a lookup table.

3.3.1.16 Cross-talk

Self explanatory if hard. If necessary can in principle be removed by matrix inversion, where the matirix contains the crosstalk of each pixel to every other, messy though.

3.3.1.17 Glitch removal

Deviations between signals from sequential returns to the same jiggle position can be filtered out, iterative with previous step

3.3.1.18 Look at pointing data

Assign astrometric positions to co-added detector images. This doesn’t really belong in here with the basic number-crunching algorithmns, it’s more of a astronomical processing step.

3.3.1.19 Combine pairs of nod positions

Combine images which are taken at genuinely different telescope pointings, i.e. not different because of the jiggle and chop movements of the mirror

3.3.1.20 Calibration

Self-explanatory

***UR-PHT-530:* POF2: Seven-Point Jiggle Map**

POF2 is a special case of POF3. No special, additional processing steps required.

UR-PHT-540: POF3: N-Point Jiggle Map

Same as for POF1, except for the following:

3.3.1.21 Coadd Jiggle Images

As we return a number of times to each jiggle position within a single nod pointing we need to average the signals within the nod pointing

3.3.1.22 Glitch removal

Deviations between signals from sequential returns to the same jiggle position can be filtered out, iterative with previous step

3.3.1.23 Calibration

Self-explanatory

UR-PHT-550: POF4: Raster Map

This is just an extension of POF3, whereby the telescope makes jiggle maps at a sequence of positions.
Additional requirements:

3.3.1.24 Combining raster positions

UR-PHT-560: **POF5: Scan Map Without Chopping**

Radically different from jiggle-mapping or photometry. The signal is now spread over a wide-range of frequency bandwidth, rather than in a narrow-band about the chop frequency, so the signal processing is completely different. If the detectors are DC-coupled then it is much simpler but it is not clear to me that they will be. This and POF5 need a proper system analysis by someone who undertsands signal processing.

UR-PHT-570: **POF6: Scan Map With Chopping**

Again radically different from EITHER the scan-map without chopping OR the jiggle-mapping modes. This time the signal still spread out in bandwidth but contained in sidebands about the chopping frequency. Consecutive samples contain the DIFFERENCE signal between points separated by the chop distance and once the whole scan has been completed these have to be inverted to recover the true signal (known as the "Emerson, Klein" and Haslam, "NOD2" or "EKH" method). In order to avoid Zero-crossings in the window function in spatial frequency space the true sky map can only be recovered by combining scans taken with different chop throws and ideally in difference directions as well, which is the way SCUBA does it for example (the "Emerson2" method). This means an "image" can only be properly made from several "observations".

Despiking is very much more difficult as well

UR-PHT-580: POF7: Photometer Peak-Up (TBD)

Basically just several photometry points done sequentially and then some fitting routine used to find the peak signal position.

UR-PHT-590: POF8: Operate photometer internal calibrator

3.3.1.25 **Demodulate internal calibrator signal, and then compare to standard values for each pixel**.

UR-PHT-600: POF9: Special engineering modes (TBD)