SUBJECT: SPIRE Data Flowcharts for IA

PREPARED BY: Tanya Lim

DOCUMENT No: **SPIRE-RAL-DOC-002257**

ISSUE: Draft 0.1 **Date:** 13 January 2005

APPROVED BY: **Date:**

Distribution

Change Record

ISSUE	DATE	Changes
Draft 0.1		First Version

TABLE OF CONTENTS

FIGURES

TABLES

Glossary

1. INTRODUCTION

1.1 Scope

This document introduces the data flow envisaged for the standard processing of SPIRE data. For each observing mode a flowchart has been developed which is used as a top level definition for both the processing of each mode and the calibration tables required in order to do this.

1.2 Structure of Document

Section 2 introduces the SPIRE modes and approach to the standard processing of those modes. The following sections then give the flowchart and explanatory notes for each mode.

1.3 Documents

1.3.1 Applicable Documents

1.3.2 Reference Documents

2. SPIRE DATA PRODUCTS

2.1 Standard Processing

The SPIRE data processing will be Java-based to avoid reliance on commercial or platform-dependent systems which could restrict the ability of astronomers to have full access to and control over the data.
Standard Processing will be updated at appropriate (e.g. six monthly) intervals during mission operations. The Standard Processing results will be good, but not necessarily the best quality i.e. they will be out-of-date wrt the very latest algorithms that instrument experts have devised and they will not implement sophisticated interactive routines that can allow astronomers' skill and judgement to enhance data quality. However the Standard

Processing will provide the general user with a good enough product to do science. All assumptions made in calibration will be documented and thoroughly explained

The SPIRE ICC need not provide a high degree of interactive routines for the users. Limited resources on the part of the ICC and the HSC require that some of the burden of data reduction be borne by the users. The ICC will maintain trial versions of the Standard Processing prior to their public release, allowing scrutiny and parameter choice at all steps of the analysis. replacement of routines with different or updated versions, and analysis of data taken in special engineering modes The ICC will also have S/W for trend analysis, calibration analysis, instrument diagnostics, study of systematics, observation optimisation (e.g., more sophisticated time estimator, simulators, etc.)

2.2 Photometer Modes

Chopped point source photometry

- Calibrated signal with astrometric positions, statistical and pointing uncertainties
- This to be provided for all bolometers, in addition to the prime set corresponding to the source position
- Statistical errors based on mean and standard deviation of the set of de-glitched On-Off pairs

Seven-point photometry

- As for point source photometry for the individual map positions
- Results of a simple fit to signal and position with a quality caveat (TBC)

N-point Jiggle-map

- Calibrated signal, statistical uncertainties and astrometric positions for each bolometer for each of its map positions

Scan map

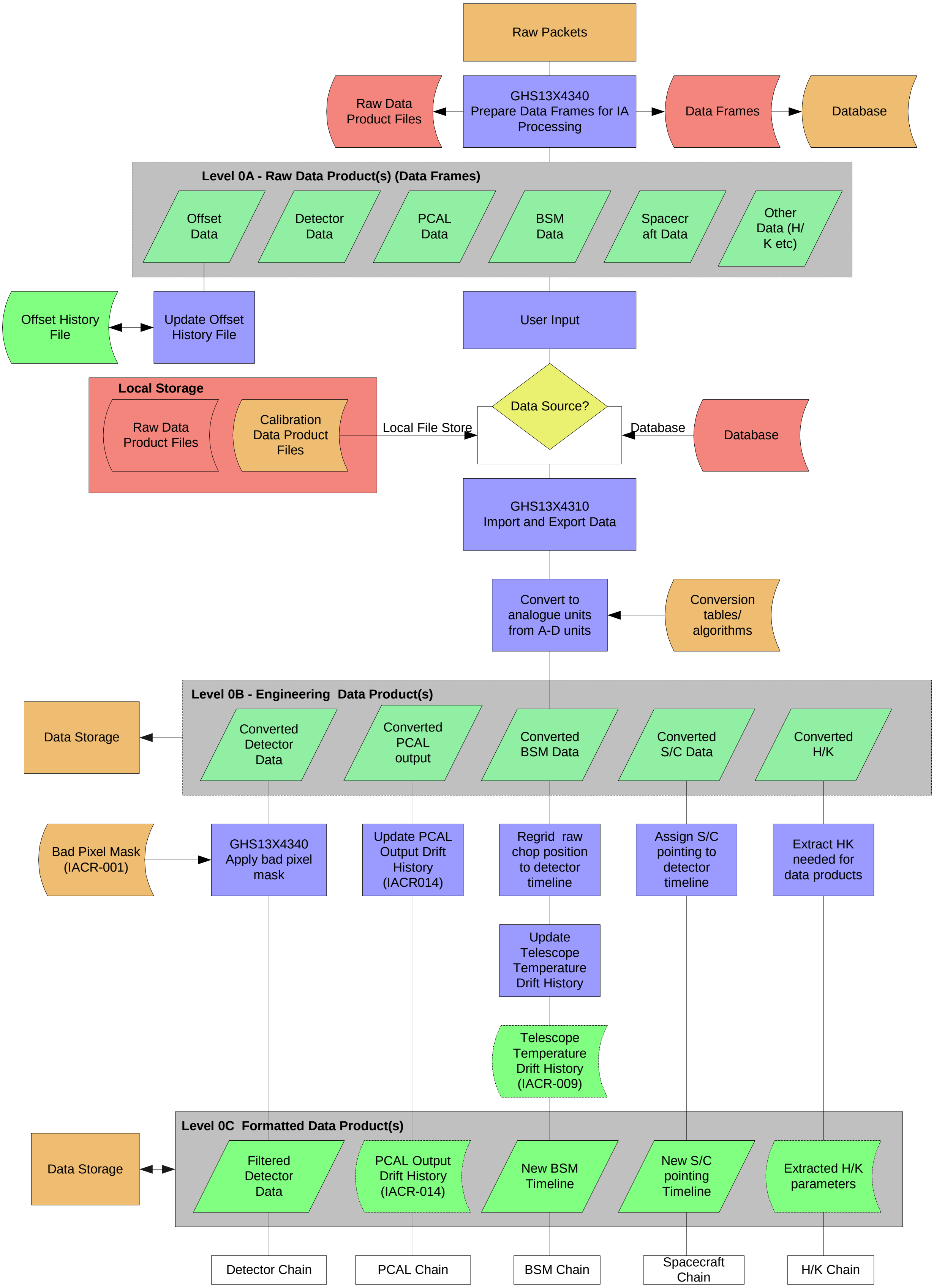
- Deglitched time-ordered data for each detector (signal vs. position)
- Telescope turn-around periods flagged as astrometrically uncalibrated data. Note: Full analysis of scan-map data to produce final maps, noise estimates and source extraction will be complex and specialised. This mode is expected to be used for large spatial survey programmes carried out by large consortia with relevant expertise, and bringing to the project additional data-processing capabilities over and above what the ICC will provide.

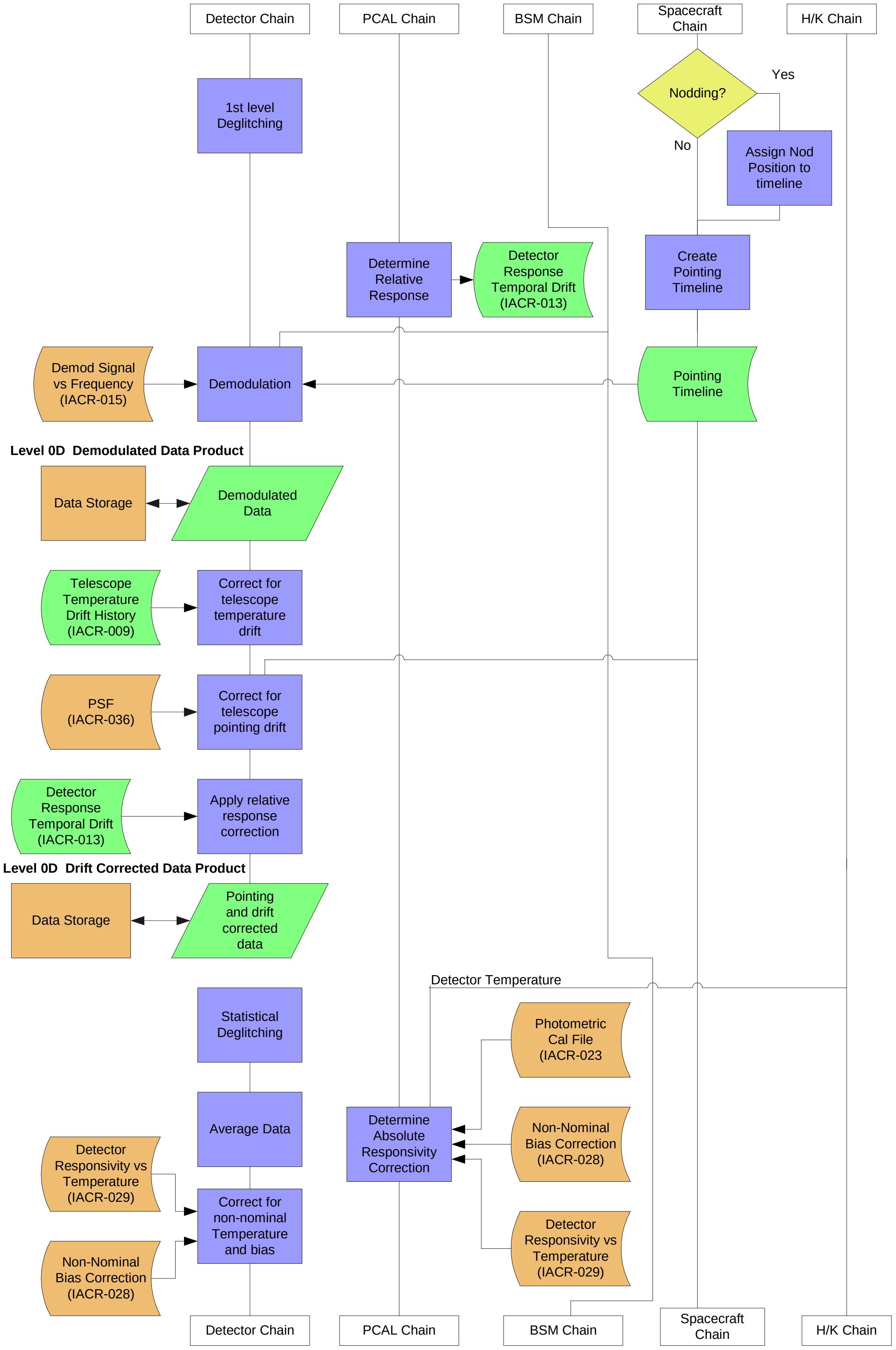
2.3 FTS Modes

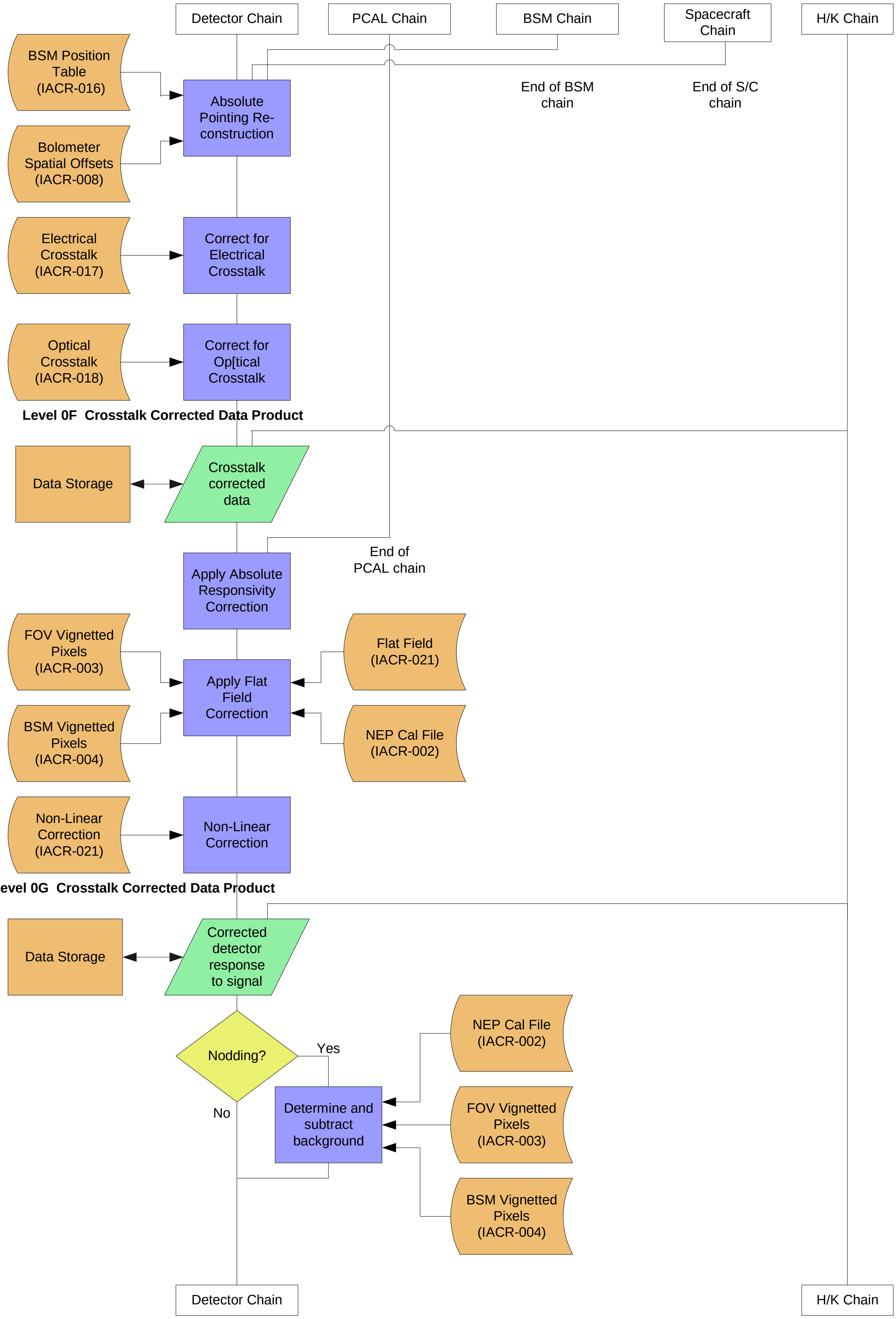
- Averaged (TBC) spectrum (signal in beam vs. frequency) for each detector at each relevant spatial position.
- All observations reduced and calibrated as point sources.
- Standard apodisation, resolution element shape, width and sampling. Basic deglitching already done at interferogram level.
- All pixels frequency calibrated.
- Filter transmission and flux calibration derived using standard astronomical source.
- All calibration data and steps to be fully explained. Note: Residual telescope emission will not be removed – this will be done by the astronomer using adjacent pixels or observation of adjacent patch of sky with the central pixel. Extended source observations to be encouraged only for expert observers

3. FLOWCHART FOR SINGLE POINTING PHOTOMETER AOT

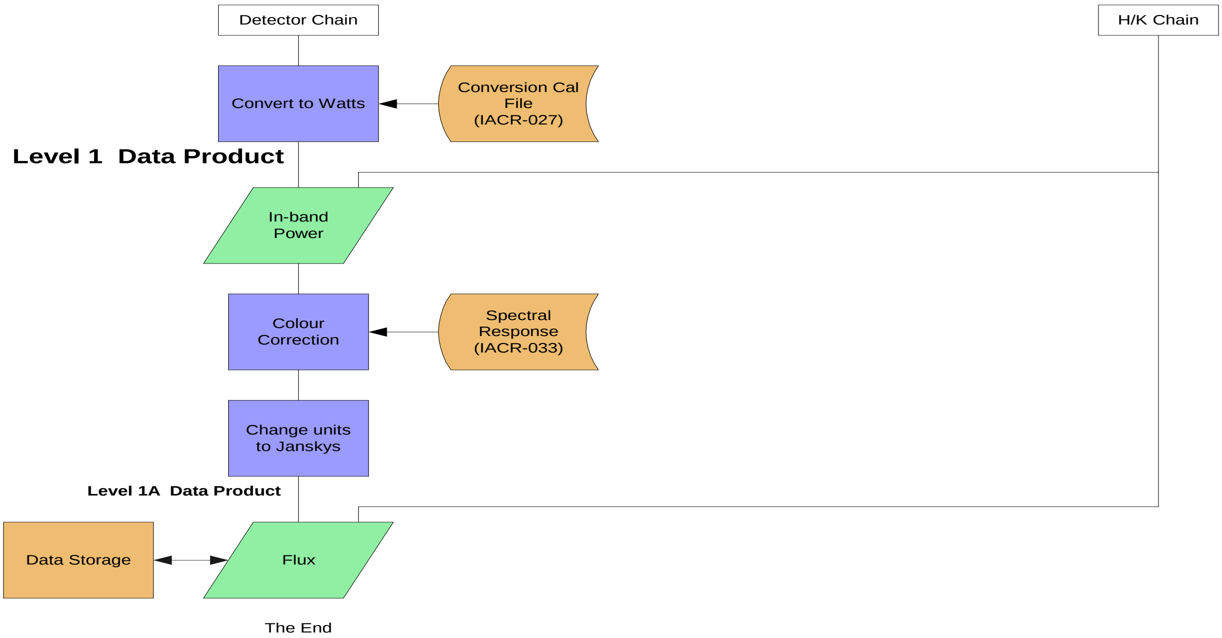
3.1 Flowchart For Single Pointing Photometer AOT (POF1)


Raw Packets
Raw Data Product Files
GHS13X4340 Prepare Data Frames for IA Processing
Data Frames
Database
Level 0A - Raw Data Product(s) (Data Frames)
Offset Data
Detector Data
PCAL Data
BSM Data
Spacecraft Data
Other Data (H/K etc)
Offset History File
Update Offset History File
User Input
Local Storage
Raw Data Product Files
Calibration Data Product Files
Local File Store
Data Source?
Database
Database
GHS13X4310 Import and Export Data
Convert to analogue units from A-D units
Conversion tables/ algorithms
Level 0B - Engineering Data Product(s)
Data Storage
Converted Detector Data
Converted PCAL output
Converted BSM Data
Converted S/C Data
Converted H/K
Bad Pixel Mask (IACR-001)
GHS13X4340 Apply bad pixel mask
Update PCAL Output Drift History (IACR014)
Regrid raw chop position to detector timeline
Assign S/C pointing to detector timeline
Extract HK needed for data products
Update Telescope Temperature Drift History
Telescope Temperature Drift History (IACR-009)
Level 0C Formatted Data Product(s)
Data Storage
Filtered Detector Data
PCAL Output Drift History (IACR-014)
New BSM Timeline
New S/C pointing Timeline
Extracted H/K parameters
Detector Chain
PCAL Chain
BSM Chain
Spacecraft Chain
H/K Chain


Detector Chain
PCAL Chain
BSM Chain
Spacecraft Chain
H/K Chain
Nodding?
Yes
No
Assign Nod Position to timeline
1st level Deglitching
Determine Relative Response
Detector Response Temporal Drift (IACR-013)
Create Pointing Timeline
Demod Signal vs Frequency (IACR-015)
Demodulation
Pointing Timeline
Level 0D Demodulated Data Product
Data Storage
Demodulated Data
Telescope Temperature Drift History (IACR-009)
Correct for telescope temperature drift
PSF (IACR-036)
Correct for telescope pointing drift
Detector Response Temporal Drift (IACR-013)
Apply relative response correction
Level 0D Drift Corrected Data Product
Data Storage
Pointing and drift corrected data
Detector Temperature
Statistical Deglitching
Photometric Cal File (IACR-023
Average Data
Determine Absolute Responsivity Correction
Non-Nominal Bias Correction (IACR-028)
Detector Responsivity vs Temperature (IACR-029)
Correct for non-nominal Temperature and bias
Detector Responsivity vs Temperature (IACR-029)
Non-Nominal Bias Correction (IACR-028)
Detector Chain
PCAL Chain
BSM Chain
Spacecraft Chain
H/K Chain



Detector Chain
PCAL Chain
BSM Chain
Spacecraft Chain
H/K Chain
BSM Position Table (IACR-016)
Bolometer Spatial Offsets (IACR-008)
Absolute Pointing Re-construction
End of BSM chain
End of S/C chain
Electrical Crosstalk (IACR-017)
Correct for Electrical Crosstalk
Optical Crosstalk (IACR-018)
Correct for Op[tical Crosstalk
Level 0F Crosstalk Corrected Data Product
Data Storage
Crosstalk corrected data
End of PCAL chain
Apply Absolute Responsivity Correction
FOV Vignetted Pixels (IACR-003)
Flat Field (IACR-021)
Apply Flat Field Correction
BSM Vignetted Pixels (IACR-004)
NEP Cal File (IACR-002)
Non-Linear Correction (IACR-021)
Non-Linear Correction
Level 0G Crosstalk Corrected Data Product
Data Storage
Corrected detector response to signal
NEP Cal File (IACR-002)
Nodding?
Yes
No
Determine and subtract background
FOV Vignetted Pixels (IACR-003)
BSM Vignetted Pixels (IACR-004)
Detector Chain
H/K Chain



3.2 Explanatory Notes For Single Pointing Photometer AOT (POF1)

3.2.1 Steps before Level 0A Raw Data Products (Data Frames)

It is assumed that following telemetry downlink a process will run which will unpack telemetry packets, construct data frames and automatically archive the data frames in the HCSS. It is assumed that spacecraft packets will be converted to spacecraft data frames via a parallel non- SPIRE specific process. These will contain two items of relevance to SPIRE, the spacecraft thermometry and the spacecraft pointing information, presumably in RA, Dec and roll angle.

3.2.2 Steps before Level 0B Engineering Data Products

The level B stage consists of user input being turned into formatted data ready for interactive analysis. The expectation is that data can be extracted from the archive and can either be fed straight into the pipeline or IA system or stored locally to be used later. At this point it will be data frames rather than packets which will be extracted.

Update Offset History File
Taking offsets is a separate process to normal detector operation. It is expected that the dominant emission coming from the telescope will only change very slowly therefore offsets will not need to be taken very often. When offsets are taken the information will be contained in offsets packets. For most observations the actual offsets used are not needed in the data processing but an offset history file is a useful file to generate as it can be used for diagnostic purposes.

Convert to Analogue Units

At this stage the conversion to analogue units will also take place. In the specific case of the detectors the conversion will also include accounting for instrument gains with the output of the stage being volts out the detectors rather than volts out the instrument. The conversion tables will be stored in the HCSS.

3.2.3 Steps Before Level 0C Formatted Data Products

The next stage essentially formats the data for the more advanced stages of the processing. Each of the steps described in this stage may happen simultaneously.

Apply a bad pixel mask
Note this step is currently defined as those pixels which can be considered dead as far as processing is concerned. It should be noted that this step can be applied at any time during the processing for this particular AOT and the reason it is applied first is that it may save effort in implementation by not processing the bad pixels from the first.

Update PCAL Output Drift History
Whenever PCAL is used a current is applied and a voltage read. Nominally the same applied current will always produce the same output voltage but it may be the case that this will change over the course of the mission. As well as the output voltage, any change of PCAL output will be diagnosed from observations of astronomical standards. PCAL output voltage will be tracked via the drift history file which will simply be a three column file with date, voltage output and a flag indicating whether this was measured in association with an astronomical standard or not.

Associate Raw Chop Position To Detector Timeline
As the BSM is nominally sampled at a higher rate than the detectors an actual BSM position needs to be attached to each detector readout. This might be an appropriate stage to also determine those times when the BSM is moving an attach flags to the detector data to indicate this. These times are likely to be during changes of jiggle position rather than during BSM chopping which may be synchronised with detector readout.
Therefore the output of this stage is a time line gridded on to the same timeline as the detector data with a column giving time, a column giving chop axis position, a column giving jiggle axis position and a column with a flag indicating whether this position occurs during BSM movement. It is assumed that there will be no information on position error within the data and that a standard figure for this will be adopted.

Assign S/C Pointing to Detector Timeline
In order to eventually determine the pointing and work out how to partition the detector data a pointing history will be needed for a the observation. It is likely that this information will be RA, Dec and roll angle encoded in S/C packets. This could then be attached to the detector data either directly by adding more columns to the detector file or by use of an intermediate file. The format of this intermediate file will depend on the requirements of the assign pointing step where both S/C pointing and BSM pointing need to be on a detector timeline basis.

Update Telescope Temperature Drift History
It may be necessary for SPIRE to maintain a history file on the telescope temperature. Although this is vital information for spectrometer observations it may still be useful to do this for photometer observations as any drifts within the observation timeline will need to be corrected.

Extract H/K needed for Data Products
Not all the H/K information will be needed for data products. It is a matter of implementation whether an intermediate file is generated and then attached to data products or whether the processes which generate the products do this step themselves.

3.2.4 Steps Before Level 0D Demodulated Data Product

1st Level Deglitching
This is the deglitching which takes place on a timeline before demodulation. In the case of this AOT where the input signal is not changing it is expected that the deglitching algorithm will detect large deviations in the signal and mask them.

Assign Nod Position To Detector Timeline

For nodding observations the times at each nod position need to be identified.

Create Pointing Timeline
There are various stages which take place in reducing pointing data and it is TBD at which stage each step takes place. For demodulation, the minimum that needs to have been done is to identify those times at each nod position allowing exclusion of slewing between nod positions. The next stage is to reconstruct the pointing of each pixel and this stage may happen later in the processing . The format of this is TBD but certainly a pair of positions per pixel will be generated at each nod position.

Demodulation
The algorithm used to demodulate the signal is TBD but the output of this step will be the signal from the source represented in volts out the detectors with various instrumental effects folded in. In order to perform the demodulation the pertinent regions in time will need to be identified. In this case this is likely to simply be the on- and off-source times at each nod position. This requires some processing of the pointing timeline to have been done before the demodulation step although this could be as basic as simply identifying the appropriate times.

3.2.5 Steps Before Level 0E Drift Corrected Data Product

The first set of actual corrections to the data is that which account for unwanted drifts during the observation. These corrections should be made following de-modulation as it is the source signal which should be corrected and not the signal + background on and off source.

Correct for Telescope Temperature Drift
This is essentially a placeholder as the telescope temperature is not expected to significantly drift during an observation.

Correct for Telescope Pointing Drift
It is not yet clear whether information will be available to make this correction. Even if it is it is not clear that this correction is necessary therefore this step will only be added if it is needed.

Determine Relative Response
Determine correction factors for any detector drifts using PCAL data.

Apply Relative Response
Apply factors to detector timeline.

3.2.6 Steps Before Level 0F Crosstalk Corrected Data Product

Statistical Deglitching
Median filtering of time series.

Average Data
Take the mean.

Correct for non-nominal Temperature and Bias
It is assumed all routine operations will be done at a single bias which will be well calibrated but the calibration scheme does allow for corrections to be made for non-nominal bias settings. The correction for temperature here refers to detector temperature. Assuming conditions are stable this correction will not be needed but issues such as responsivity vs temperature need to be characterised and this step acts as a placeholder in case it is found to be necessary.

Absolute Pointing Re-Construction
The pointing information from the telescope needs to be added to the metadata. This could be done as part of the pointing drift correction step.

Correct For Electrical Crosstalk

Providing SPIRE meets its electrical crosstalk requirement this step will not be necessary, however electrical cross talk should be easy to identify and hence correct if present.

Correct For Optical Crosstalk
Optical crosstalk may be less easy to separate out from the PSF therefore this may end up being a single correction.

3.2.7 Steps before Level 1

Determine Absolute Responsivity Correction
This is the relationship between the detector responsivity at the time the science observation is made compared with the responsivity at the time when the astronomical calibrator is observed. This ratio should only be determined once other effects such as temperature drifts and responsivity drifts internal to the observation have been removed. As with the removal of internal responsivity drifts, the internal calibrator will be used as the bridging source. A separate correction should be determined for each detector.

Apply Absolute Responsivity Correction
Apply to each detector, only stated as a separate step to account for cases where users wish to apply their own analysis.

Non-Linear Correction
Application of any additional calibration which may be source flux dependant.

Background Subtraction
This should be accounted for in the demodulation but if there are sky gradients which an IA user would like to factor into their data, a further background subtraction step is needed.

Convert to Watts
Use instrumental response to convert between detector units (volts) and in-band flux.

3.2.8 Last Steps

Colour Correction
To properly colour correct, knowledge of the source spectral profile is required, hence it is expected that most users will wish to perform this step themselves. SPIRE could provide a colour correction using an assumed spectral profile but this is not currently baselined.

Change Units To Janskys
Once the colour correction has been determined the flux density at the reference wavelength is known and this is established in $W/m^2/\mu m$ but can be converted to Janskys at the reference wavelength or frequency if desired.

3.3 Changes for 7 Point Jiggle Map and Raster Map AOTs

For a 7 point jiggle map the processing will be the same with each jiggle position having a set of chopped data on each of two pixels. Following the POF1 processing there will be two sets of 7 points one for each pixel used for chopping. For raster maps there will be a raster pattern of source pairs. In both cases the points need to be combined to form get the overall source flux or the map flux. This step will not be done by standard processing and it is expected that users will do this with external packages.

3.4 Changes for Scan Map AOT

Scan maps will be done without chopping so only timeseries will be produced. It is likely that these will comprise of a timeseries of in-band fluxes.

4. FLOWCHART FOR SPECTROMETER SCANNING A POINT SOURCE

Flowchart to be added

4.1 Explanatory Notes For Spectrometer Scanning A Point Source

TBW