SUBJECT: **FTS Pipeline Scientific Validation, Phase 1: Documentation Review Report**

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Change Record

ISSUE	DATE	Changes
1.0	September 11th, 2008	Issue 1.0 from Phase 1 Document Review

1. INTRODUCTION

1.1 The SPIRE FTS Validation Group

1.1.1 Group Membership

Coordinators:

Ed Polehampton (RAL)
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Cross-members (coordinating across all 4 groups):

Sarah Leeks (RAL)
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1.1.2 Objectives

The Objectives of the validation group are:

1. To ensure the pipeline conforms to the top-level documentation in terms of their overall architecture and detailed implementation.
2. To ensure that the developer documentation for individual modules conforms to the top-level documentation in terms of requirements and algorithms.
3. To verify that testing carried out at the developer module level is adequate and documented
4. To test the pipeline to validate the correct operation of individual modules and end-to-end systems.
5. To identify and initiate correction of errors or omissions in the pipeline documentation.
6. To identify and report errors in the module implementation and operation.
7. To document all results from the test phases.

The review of the pipeline module documentation aims to check:

- Consistency with top-level documents and module requirements
- Consistency with calibration file definitions (as described in the Pipeline Description Document)
- Correctness and clarity of implementation (i.e. algorithms used are correct and method clear)
- Commonality in use of symbols and terminology (i.e. inputs/outputs to each module use consistent terminology, algorithms use consistent symbols)
- Status of module-level testing (i.e. testing that has been carried out so far)

1.2 Structure of this Document

This document summarises the recommendations of the FTS Scientific Validation group on both, pipeline documentation, and functionality concerning the SPIRE FTS Pipeline.

1.3 Documents

1.3.1 Applicable Documents

Scientific Requirements	*SPIRE Scientific Requirements* (SPIRE-UCF-PRJ-000064), Walter Gear and Matt Griffin, Version 3.0 21 November 2000
Chris' Document	SPIRE Pipeline Description (SPIRE-RAL-DOC-002437) Issue 1.0, 2 August 2008
Trevor's Document	SPIRE Spectrometer Pipeline Description (SPIRE-BSS-DOC-002966) Issue 1.1, 4 August 2008
Module Requirements	SPIRE Data Processing Pipeline Module Requirements (SPIRE-ICS-DOC-002998) Draft 1.4, 27 August 2008

1.3.2 Reference Documents

SVR1	SMEC and Spectrometer Performance (SPIRE-RAL-REP-002566), Issue 1.0, 16 January 2006

2. LIST OF MODULES

The following is a list of data processing tasks included in the FTS pipeline starting at Level-0.5 products and the relevant sections of the two top level review documents and the module requirements.

Processing task name	Trevor's	Chris'	Module Requirements
Compute BSM Angles	-	5.1.1	5.11
First Level Deglitching	3.1.1 + A.1	5.1.2	5.4
Removal of Electrical Crosstalk	3.1.2	5.1.3	5.8
Clipping Correction	3.1.3	5.1.4	7.1
Time-Domain Phase Correction	3.1.4	5.1.5	7.2
Non-Linearity Correction	3.1.5	5.1.6	5.19
Temperature fluctuation correction	3.1.6	5.1.7	5.15
Interferogram Creation	3.2.1	5.1.8	7.3
SCAL and telescope correction	3.3.1	5.1.9	7.4
Interferogram Baseline Correction	3.3.2	5.1.10	7.5
Level 2 Deglitching	3.3.3	5.1.11	7.6
Channel Fringe Correction	3.3.4	n/a	11.6
Phase Correction	3.3.5	5.1.12	7.8
Apodisation	3.3.6	5.1.13	7.7
Fourier Transform of Interferogram	3.4.1	5.1.14	7.9
Spectral Response Correction	3.5.1	5.1.15	7.10
Flux Conversion	3.5.2	5.1.16	7.11
Optical Crosstalk Removal	3.5.3	5.1.17	7.12
Spectral Averaging	3.5.4	5.1.18	7.13
Spatial Regridding	4.1	5.2.1	7.14

3. REVIEW OF SPIRE SCIENTIFIC REQUIREMENTS DOCUMENT

The scientific requirements relevant to the FTS are all consistent with the current implementation of the pipeline:

SRD-R 8: Limits on crosstalk
The pipeline is consistent with this requirement, and includes modules to remove both electrical and optical crosstalk should this be necessary.

SRD-R 16: Spectrometer design optimised for point sources, but with imaging capability
The pipeline currently processes data assuming a point source, but allows to project mapping data onto a uniformly sampled spatial grid. Therefore the pipeline is consistent with this requirement.

SRD-R 17: Sensitivity of the FTS should be limited by photon noise from the telescope
Not directly relevant to the pipeline software.

SRD-R 18: Dynamic range shall be 12 bits or higher
Not directly relevant to the FTS specific pipeline as the data are converted from ADU to volts in the common part of the pipeline.

SRD-R 19: Photometric accuracy shall be 15% (goal 10%)
The pipeline is consistent with this requirement (assuming calibration files are made with sufficient accuracy). Uncertainties should be tracked through every pipeline step allowing the final accuracy to be determined.

SRD-R 20: Spectrophotometric resolution of 2 cm^{-1}
The pipeline is consistent with this requirement as both low resolution and high resolution interferograms can be processed. The resolution requirements for the low resolution operating mode of the SPIRE spectrometer was changed during the SPIRE Science Verification Review 1 to a spectral resolution of ~1 cm^{-1} instead of the originally quoted ~2 cm^{-1}, see reference document SVR1, section 3.1.3.

SRD-R 21: Uniformity of the width of FTS instrument response across field of view
Not directly relevant to the pipeline software.

SRD-R 22: Maximum spectral resolution at least 0.4 cm^{-1} (goal 0.04 cm^{-1})
The pipeline is consistent with this requirement as both low resolution and high resolution interferograms can be processed. Data from the high resolution operating mode of the SPIRE spectrometer will have spectral resolution elements at a spacing of ~0.04 cm^{-1}., i.e. a spectral resolution of ~0.05 cm^{-1}, see reference document SVR1, section 3.1.2.

4. REVIEW OF TOP LEVEL DOCUMENTATION

4.1 General Comments

The following aspects of the pipeline documentation were **out of scope** during Phase 1 of Scientific Validation:

- Quality Control infrastructure will be reviewed during Phase 2. The details will be decided later by the Science Validation coordinating group.
- Developer documentation within the build (javadoc, Design Document, Test Plan, User Guide) was not available in a reviewable state and is to be released in time for Phase 1 software testing.
- Requirements for Interactive Analysis (IA, as opposed to Standard Product Generation, SPG) for the modules are not defined at present. The groups should recommend what key parameters for each module should be available for modification interactively. Chris' pipeline description document will document these IA requirements. These requirements should be consolidated during software testing.
- The reviewers made numerous comments on the sequence of processing tasks. However, a comprehensive and detailed review of the processing sequence, possibly in conjunction with software tests, should be performed in a later phase of scientific validation.

4.2 SPIRE Spectrometer Pipeline Description (Trevor's) Document

[FTS-1] Section 2.1, Table 2.1: In first column of the table, "intermediate" in columns 4 and 7 should be replaced by "full".

[FTS-2] Section 2.1, Table 2.1: There should be a reference to the mapping modes note (SPIRE-RAL-NOT-002801) which describes the offsets in the jiggle. Maybe a figure could be taken from that and adapted to show exactly how the beam spacing is calculated. The SLW beam spacing should be updated to be 28.1" for intermediate sampling and 14.1" for full sampling.

[FTS-3] Table 2.2: Spectral resolution for High mode should be 0.04 cm^{-1}.

[FTS-4] Section 2.3: There is a blank space in the first sentence – presumably for a reference to figure 2.1?

[FTS-5] For Section 2.3, figure 2.1, define what V(t), z(t), n(t), P(t), V(x), B(σ) and I(σ) in Fig. 2.1 stand for.

[FTS-6] Section 3.1 Detector Timeline Modifications: Fig. 3.2 is not consistent with the same figure in Chris' document (Fig. 11).

[FTS-7] In order to make it easier to verify the consistency between Trevor's Fig. 2.1 and Chris's Fig. 11, add the calibration tables to Trevor's document.

[FTS-8] Second paragraph of Section 3: "The data processing pipeline of the SPIRE spectrometer in two sections" should be "The data processing pipeline of the SPIRE spectrometer IS SPLIT inTO two sections"

[FTS-9] Sec 3.1: Part 2 of the pipeline (modify timelines) should have the same title as section 3.1 (Detector Timeline Modifications).

4.3 Pipeline Description (Chris') Document

[FTS-10] part 5.1 Spectrometer Scan Processing: In Fig. 11 there is some ambiguity with the five fundamental operations (outlined as dotted boxes). "Create Interferograms" and "Fourier Transform", as fundamental operations by themselves, should be separated from "Modify Timelines" and "Modify Interferograms" respectively (in the figure these dotted boxes overlap).

[FTS-11] Sec 3.1 of Trevor's Document lists the 6 major processing groups on the spectrometer pipeline. Chris' doc lists 5 as it doesn't include the common part. It would be good to have

consistency between the two and decide if the common part is considered part of the spec pipeline.

[FTS-12] In general, the output product from each module has an error column. However, neither Trevor's document or Chris' define precisely how the systematic errors from each module are propagated. We recommend that a separate document be produced detailed the error propagation through the pipeline. This should ensure that the final error on the level-1 spectrum contains all the relevant systematic and statistical errors accumulated during the pipeline flow. The results of this document for each module should be inserted with the description of the output product.

4.4 Module Requirements Document

[FTS-13] Some modules specifically name calibration products and some do not. A convention should be found and if this involves naming calibration products specifically, all of the spectrometer modules should be updated accordingly.

[FTS-14] Correct propagation of errors through each task should be listed as a requirement.

[FTS-15] Section 2: Spectral Response Correction (Spectrometer) should be changed to Flux Conversion (Spectrometer).

[FTS-16] Section 2: In the list of modules, it should be clarified what S in brackets means in the Inst. Column

[FTS-17] Section 2: In the list of modules, the non-linearity correction should either be listed as applicable to both the spectrometer and photometer, or should be added separately for the spectrometer.

[FTS-18] Section 2: In the list of modules, the Temperature Fluctuations Correction should be listed as applicable to the Spectrometer.

[FTS-19] Section 3: TBD and TBC's should be filled in.

[FTS-20] Section 3: SPIRE-PERF-010: "normal observation" should be defined more precisely.

[FTS-21] Section 3.2: We need some mechanism to document the specific quality control metrics each task uses. It could either be a stand-alone document or a mandatory sub-section "Quality Control Metrics" could be introduced for each task.

[FTS-22] Section 3.4 Documentation Requirements:

- SPIRE-DOC-010 should mention that this is the "software" design of the module. It should also contain the implementation details (which should not be in the Programmer's Guide).
- SPIRE-DOC-060 should come before SPIRE-DOC-020
- SPIRE-DOC-020 should not include implementation details and should mention that the Programmer's Guide is in fact Javadoc (it is normally referred to as the Developer's Reference Manual rather than Programmer's Guide).
- SPIRE-DOC-030 should be updated to be consistent with the plans for combining individual module User Guides into the final Astronomer User Guide.
- SPIRE-DOC-040: the test plan should detail the module test harnesses, plus other tests as applicable.
- SPIRE-DOC-050 should be clear about the difference between Validation and Verification (e.g. from Wikipedia: "*verification is ensuring that the product has been built according to the requirements and design specifications, while validation ensures that the product actually meets the user's needs, and that the specifications were correct in the first place. Verification ensures that 'you built it right'. Validation confirms that the product, as provided, will fulfil its intended use"*). The test report should contain verification, and the validation is done as part of the current review.

[FTS-23] In many of the spectrometer modules, the fact that the input is derived from an observation using an AOT. Should this be removed from individual modules and included as an overall requirement? Maybe it doesn't apply to all photometer modules though.

[FTS-24] The document should be re-organised to follow the data flow more closely (where some modules apply to both photometer and spectrometer, there should still be a section heading in the relevant pipeline chapter that points to section number containing the requirement, rather than repeating the whole section several times – this would make it consistent with the organisation in Chris' document).

4.5 Compute BSM Angles

4.5.1 Trevor's Document (Not Applicable)

Trevor's document does not need to cover this processing step as sufficient description is included in Chris' Document.

4.5.2 Chris' Document Section 5.1.1

4.5.2.1 *Consensus Recommendations*

[FTS-25] Add an explanation about the meaning of the Y and Z angle errors and how they are computed or estimated.

4.5.2.2 Minor Comments

[FTS-26] Fig. 12 is redundant with Fig. 3 in the same document. Is it necessary to reproduce this figure twice, or can the text refer to a single figure?

4.5.3 Module Requirements Document Section 5.11

4.5.3.1 *Consensus Recommendations*

4.5.3.2 Minor Comments

[FTS-27] The name of this module should be changed from "BSM Angles Conversion" to "Compute BSM Angles" to be consistent with Chris' document.

[FTS-28] The first sentence should be deleted and replaced with: "This module will compute the angle on sky of the Beam Steering Mirror by applying the calibration from ADU to angle".

[FTS-29] Section 5.11.3: First sentence should be replaced with: "The purpose of this module is to convert the measured positions of the Beam Steering Mirror in Sensor Signal units to angles on the sky (in spacecraft Y-Z plane)."

[FTS-30] Sections 5.11.4.1 and 5.11.4.2 and 5.11.4.3: Beam Steering Mirror Chopping Sensor should be replaced with Beam Steering Mirror Chop Sensor Signal.

[FTS-31] It should be made clear that for the photometer jiggle observations a BSMT is the input, but for scan map and spectrometer observations it is NHK (see Chris' Document).

[FTS-32] Section 5.11.4.2: The calibration product does not currently contain "authorised ranges of angles", but it does contain the rest position of the BSM in sensor signal units.

[FTS-33] Section 5.11.4.3: Should be "decimal degrees" and "the SPIRE Data Products Specification" (but could this document be referenced as an Applicable Document rather than being written each time specifically).

[FTS-34] BSMConverter-FUN-010 should mention BSMT or NHK

[FTS-35] BSMConverter-FUN-020 should specifically mention that the conversion is from ADU to angle.

[FTS-36] BSMConverter-FUN-040 does not make sense unless the calibration product is extended from its current definition. Either it should be explained more clearly and the calibration product updated, or removed.

4.6 First Level Deglitching

Deglitching requires two steps: glitch identification and glitch removal (data reconstruction). The identification and removal of glitches with the methods available has not yet been optimised. We recommend a detailed study be performed by Blue Sky Spectroscopy with support from LAM and/or IPAC to identify deglitching strategies. At least four methods have been proposed to reconstruct "glitched" samples:

- wavelet analysis
- similar to clipping correction (polynomial interpolation)
- new suggestion from Bernhard (from SAG1 work)
- simple averaging of scans as for 2nd level deglitching

Blue Sky and LAM aim to analyse the performance of 1st and 2nd level deglitching (glitch identification and removal) with PFM and synthetic data and optimise the algorithms in the process, in particular for small sample sizes (down to 2). The resulting performance report should be made available before Phase 2 of the Scientific Validation and will provide a solid foundation for a more thorough review of these tasks then. The documentation should be updated following this report.

4.6.1 Trevor's Document Section 3.1.1

4.6.1.1 *Consensus Recommendations*

[FTS-37] Blue Sky and LAM will analyse the performance of 1st and 2nd level deglitching (glitch identification and removal) with PFM and synthetic data and optimise the algorithms in the process, in particular for a small number of scan repetitions (down to 2). This will result in a report whose results should be incorporated into the document.

[FTS-38] The document should include a mention of all the possible choices (i.e. the four choices outlined above) even if detailed descriptions are placed in technical notes. We will test the wavelet method in Phase 1 of the validation. We then request to test this module again in Phase 2, when the other reconstruction methods will have been coded and so we can compare them and select the best method for the standard pipeline.

4.6.1.2 Minor Comments

[FTS-39] "Section A.1" in the first paragraph should be made clearer by calling it "Appendix A.1"

[FTS-40] Should make clear that glitched samples are flagged (reference masks document if this is where the flagging is described).

4.6.2 Chris' Document Section 5.1.2

4.6.2.1 *Consensus Recommendations*

[FTS-41] Identify the calibration requirements for this processing step and add updated information to the calibration files table.

4.6.2.2 Minor Comments

[FTS-42] The calibration file containing the glitch identification method parameters does not need to include bias dependence because the task adapts dynamically to the level of noise present in the data and cosmic ray glitches should be much stronger than any change in noise due to the bias setting. Therefore one set of parameters will be sufficient.

[FTS-43] Outputs section: the outputs should be the RECONSTRUCTED deglitched SDT

[FTS-44] Delete the reference to "Section A.1" here. Appendix A.1 is in Trevor's document.

4.6.3 Module Requirements Document Section 5.4

4.6.3.1 *Consensus Recommendations*

4.6.3.2 Minor Comments

[FTS-45] The module owner should be updated to Dominique Benielli.

[FTS-46] Subsection numbering not correct.

[FTS-47] The reference in the introduction is not needed. The algorithm is described in Trevor's document.

[FTS-48] It should be specified whether the input control parameters are contained within a calibration product or whether they are keyword inputs to the task.

[FTS-49] DEG-FUN-050 should mention that flagging follows the policy set out in the Masks Document.

[FTS-50] Requirements on the reconstructed timeline should be included – for example a requirement on the noise properties of the reconstructed data compared to the input data.

[FTS-51] The first sentence in section 5.7.1.1 and DEG-FUN-010 should read "… in the form of a spectrometer or photometer detector timeline." This task does not operate on interferograms.

[FTS-52] Clarify how the task treats samples which have been masked by earlier processing tasks. Are these samples ignored, used as is, or replaced with dummy values?

[FTS-53] Specify all mask bits which are set by this task and state their respective meanings (and add reference to the Mask Policy document).

4.7 Remove Electrical Crosstalk

George Bendo is currently conducting a study on identifying electrical cross-talk in the SPIRE photometer arrays. He reports, as an interim result, that he has “found no electronic crosstalk at any measurable level” (email, Sep 4, 2008).

4.7.1 Trevor’s Document Section 3.1.2

4.7.1.1 Consensus Recommendations

4.7.1.2 Minor Comments

4.7.2 Chris’ Document Section 5.1.3

4.7.2.1 *Consensus Recommendations*

[FTS-54] In the photometer pipeline, they have been discussing whether to swap the order of first level deglitching and electrical crosstalk removal. This is because some crosstalk may be caused by glitches and so would not be removed correctly if the strongest glitches have already been removed. This also makes sense for the FTS pipeline, although should be tested.

[FTS-55] Verify how the calibration framework traces not only where the calibration data were derived but also what the related error is and how it will impact the science data.

4.7.2.2 Minor Comments

4.7.3 Module Requirements Document Section 5.8

[FTS-56] Module requirements should be written.

4.8 Clipping Correction

4.8.1 Trevor's Document Section 3.1.3

4.8.1.1 *Consensus Recommendations*

[FTS-57] This task should be careful about producing specific Quality Control metrics, such reporting if there are a large number of consecutive clipped samples, or if there are a large proportion of clipped samples over the whole observation.

4.8.1.2 Minor Comments

[FTS-58] There is frequent mention of "missed" samples. Instead, the document should refer to "clipped" samples.

[FTS-59] The stress on the Nyquist criterion is a hold over from the previous clipping method (even though the number of clipped points compared to the sampling is still important to some degree). This should be explained more clearly in the context of the polynomial reconstruction method.

[FTS-59] It should be noted that this task will be included in the pipeline but may be most important in the interactive pipeline rather than the standard automatic one.

[FTS-60] First paragraph: imput should be input

[FTS-61] Second paragraph: fo should be of

[FTS-62] The presence of clipped samples depends on the source strength and the detector offset setting (which is determined by the total power level rather than the amplitude of ZPD in the interferogram).

[FTS-63] Equ. 3.3. is not clear: what is the meaning of V''? Is it referring to the "corrected" samples? This should be explained clearly.

4.8.2 Chris' Document Section 5.1.4

4.8.2.1 Consensus Recommendations

4.8.2.2 Minor Comments

[FTS-64] Better to call these samples "clipped" rather than "erroneous"

[FTS-65] The output should have the clipped samples "reconstructed", rather than "corrected"

4.8.3 Module Requirements Document Section 7.1

4.8.3.1 Consensus Recommendations

4.8.3.2 Minor Comments

[FTS-66] The module description states that a sinc interpolation is used but the other documents say that an 8th order polynomial is used. Confirm that an 8^{th} order polynomial is used and update the document accordingly.

[FTS-67] CLIPPING-FUN-030 should also be made consistent with the other documents.

[FTS-68] If there will be a mask bit that keeps track of which clipped samples have been corrected, a Functional Requirement should be added to state the name and function of this mask bit (with reference to the Mask Policy document).

4.9 Time-Domain Phase Correction

Even though this module is supposed to correct the difference between forward and reverse scans, it is important to keep the two separate in the rest of the pipeline in case there are uncorrected effects that slip through (e.g. from the beamsplitter).

4.9.1 Trevor's Document Section 3.1.4

4.9.1.1 *Consensus Recommendations*

[FTS-69] The thermal response of the SPIRE bolometers should change with bias voltage. Even though this has not been observed in PFM data it will be important to monitor (via a dedicated IDL analysis or trend analysis) whether this will also be true after launch.

4.9.1.2 Minor Comments

[FTS-70] Eq. 3.4: Define ω_s (signal modulation frequency) and clarify its value (=0?) used in the pipeline.

[FTS-71] Eq. 3.5.: Define $\omega_{Thermal}$.

[FTS-72] Eqs. 3.4. – 3.6.: Review the use of subscripts for the Omega's.

[FTS-73] Cite Section 4 (in addition to Section 3.5) of AD01 as reference on modelling the thermal relaxation of the bolometer crystal as an RC filter. It should also be pointed out that the spectrometer model does not take a slow, secondary bolometer time constant into account, which is introduced in that section 4. The importance and impact of this long term time constant should be investigated with real data.

4.9.2 Chris' Document Section 5.1.5

4.9.2.1 Consensus Recommendations

[FTS-74] There is no description of the calibration table for the detector thermal response coefficient.

[FTS-75] Explain in more detail the difference between "single array offset" vs. "full array offset" in the calibration file description.

4.9.2.2 Minor Comments

[FTS-76] It seems that part of a sentence is missing at the end of the paragraph between equations (22) and (23).

[FTS-77] Clarify the value of ω_s used by the pipeline.

[FTS-78] The Channel Time Offset calibration file is not needed for this module.

4.9.3 Module Requirements Document Section 7.2

4.9.3.1 *Consensus Recommendations*

4.9.3.2 Minor Comments

[FTS-79] TDPHASECORR-CAL-020 and 030 should say "A calibration product that contains.."

4.10 Non-Linearity Correction

4.10.1 Trevor's Document Section 3.1.5

4.10.1.1 *Consensus Recommendations*

[FTS-80] This task should be placed before Clipping and Time-Domain Phase Correction. The reason is that clipping occurs on the most non-linear part of the interferogram and temperature fluctuations in the timeline could affect the time-domain phase correction. We will check the effect of this swap in Phase 2 when we test this part of the pipeline.

4.10.1.2 Minor Comments

[FTS-81] The reference voltage point V_r is arbitrary, and is not given in the calibration table. Currently, it is simply set it to V_0. So the correct statement near the end of this section is: "we will have a calibration table (of K's and V_0) per bias voltage."

4.10.2 Chris' Document Section 5.1.6

4.10.2.1 *Consensus Recommendations*

[FTS-82] On the web page of product definitions, ScalSpecNonLinCorr has two separate table data sets, one for SSW and one for SLW. The table in this document appears to have just one table data set for both arrays. Verify how the calibration tables are arranged.

4.10.2.2 Minor Comments

[FTS-83] The calibration file name has a typo: alSpecNonLinCorr --> ScalSpecNonLinCorr.

[FTS-84] Column 3: units: s should be changed to volts.

4.10.3 Module Requirements Document Section 5.19

4.10.3.1 *Consensus Recommendations*

4.10.3.2 Minor Comments

[FTS-85] There is a long description of the task. This could be transferred to Trevor's document so that the detailed description does not need to be maintained in all three documents.

[FTS-86] Applicable and Reference documents should be removed from this section and incorporated into the general document list.

[FTS-87] There should be two separate sections for the photometer and spectrometer (as the spectrometer module does not include flux conversion).

[FTS-88] Ms, Mp, Ls and Lp should be defined.

4.11 Bath Temperature fluctuation correction

4.11.1 Trevor's Document Section 3.1.6

4.11.1.1 *Consensus Recommendations*

[FTS-89] The possible connection between this module and the interferogram baseline removal module should be looked into by Blue Sky and IPAC.

4.11.1.2 Minor Comments

4.11.2 Chris' Document Section 5.1.7

4.11.2.1 Consensus Recommendations

[FTS-90] Some parameters in the calibration product for the spectrometer bath temperature drift correction module may have different units than their photometer counterparts. We are dealing with everything in Volts here, while the photometer side already is in Jy at this point.

4.11.2.2 Minor Comments

4.11.3 Module Requirements Document Section 5.15

4.11.3.1 *Consensus Recommendations*

4.11.3.2 Minor Comments

[FTS-91] The description mentions empirical and model based pipeline. The empirical pipeline should be the baseline assumption. A convention should be determined for whether both empirical and model based requirements are included in the document, or whether only the one in current use is included.

[FTS-92] Applicable and Reference documents should be removed from this section and incorporated into the general document list.

[FTS-93] There should be two sections, one for the photometer and one for the spectrometer if the requirements are different for each.

[FTS-94] There is extra information in the description section that is not included in the other documents. This should be removed and placed in Trevor's document.

[FTS-95] The nomenclature in equations should be the same as used in Chris' document.

4.12 Interferogram Creation

4.12.1 Trevor's Document Section 3.2.1

4.12.1.1 *Consensus Recommendations*

[FTS-96] The pointing should be calculated per scan rather than per building block. This will give astronomers and calibration scientists the option to examine any jitter in pointing for themselves and take this into account in their data reduction.

[FTS-97] More explanation is required for the scaling factor "f". The obliquity effect should be mentioned.

4.12.1.2 Minor Comments

[FTS-98] The last sentence of the 1st paragraph is not clear.

[FTS-99] In step 2, the text refers to signal timelines with different indices (5, 6, ...). These indices should be defined. Furthermore, for better reading, these indices should be introduced into the corresponding figures 3.3, 3.4 and so on.

4.12.2 Chris' Document Section 5.1.8

4.12.2.1 *Consensus Recommendations*

[FTS-100] The ZPD information table for each detector is missing in the calibration files section.

[FTS-101] In the SDI product there are OPD error & Signal error. It is not clear where these errors are defined/computed/estimated.

4.12.2.2 Minor Comments

4.12.3 Module Requirements Document Section 7.3

4.12.3.1 *Consensus Recommendations*

4.12.3.2 Minor Comments

[FTS-102] CREATEIFGM-INP-051: The SPP does not contain a timeline of pointing, but rather a method to determine the pointing at a particular time.

4.13 SCAL and Telescope correction

[FTS-103] This module should be called SCAL, telescope and beamsplitter correction. The beamsplitter emits a signal out of phase with the port and this correction removes that too. This change should be applied in all three documents.

[FTS-104] The two scan directions should be treated differently, i.e. the calibration products should contain two sets of reference data per detector.

[FTS-105] State explicitly that the baseline assumption for SCAL is that it will be kept at one unique operating point throughout the whole mission.

4.13.1 Trevor's Document Section 3.3.1

4.13.1.1 *Consensus Recommendations*

4.13.1.2 Minor Comments

[FTS-106] It should be made clearer that the SCAL settings are determined, then the calibration observation is made, and finally the astronomical observation (i.e. the astronomical observation uses settings matched to the calibration observation and not the other way around).

4.13.2 Chris' Document Section 5.1.9

4.13.2.1 *Consensus Recommendations*

4.13.2.2 Minor Comments

[FTS-107] The last two sentences of the first paragraph should be joined together (a spurious full stop divides them).

[FTS-108] In the description of the calibration file, there should be one interferogram per scan direction (currently says that there "may" be one per scan direction, but there should "definitely" be one per scan direction in order to not introduce unwanted noise/error).

[FTS-109] In the description of the calibration file, it should be clarified that although a family of interferograms are required, there will actually be very few different SCAL settings used (a few in PV phase, but only a single setting will be used in routine operations). The calibration will be re-observed if the telescope temperature changes.

4.13.3 Module Requirements Document Section 7.4

4.13.3.1 *Consensus Recommendations*

4.13.3.2 Minor Comments

[FTS-110] References are made to the model based approach as well as the empirical one. A convention should be determined for whether both empirical and model based requirements are included in the document, or whether only the one in current use is included. If both are to be included, a separate section should be added to describe the requirements for the model-based SCAL and telescope removal task.

[FTS-111] The input calibration product section should be put into same format as other modules.

[FTS-112] SCAL-FUN-020: It should be noted that the input is in Volts for the empirical approach and not picoWatts.

4.14 Interferogram Baseline Correction

4.14.1 Trevor's Document Section 3.3.2

4.14.1.1 *Consensus Recommendations*

[FTS-113] Both methods (Fourier or polynomial fitting) should be described.

[FTS-114] Both methods can be tested and compared when we test this module – we should include this in the test plan.

4.14.1.2 Minor Comments

[FTS-115] Section A.2 should be Appendix A.2.

[FTS-116] Clarify that the fit of the 4th-order polynomial is to the whole interferogram and the DC level is set to the fitted coefficient a_i.

[FTS-117] The wording should be reviewed to address the following concerns:

"a component that is constant as a function of OPD" is not exactly correct, since the baseline is in fact varying with OPD (likely due to detector vignetting).

"As the offset term does not contain any spectral information": The baseline variation provides information about the vignetting which is changing with OPD along the SMEC scan. So the "modulated" part of the interferogram is also affected by this vignetting which acts like an apodisation function and the final spectral resolution will be consequently degraded a bit (compared to the expected one without vignetting).

4.14.2 Chris' Document Section 5.1.10

4.14.2.1 *Consensus Recommendations*

4.14.2.2 Minor Comments

[FTS-118] Equation (35) is wrong "+" should be replaced by "-"

4.14.3 Module Requirements Document Section 7.5

4.14.3.1 *Consensus Recommendations*

4.14.3.2 Minor Comments

[FTS-119] Section 7.5.2: It should be added that the baseline needs to be removed in order to avoid spectral artefacts after the Fourier transform of an interferogram that does not go towards zero at its maximum OPD.

[FTS-120] The functional requirements should also contain the alternate way of deriving the baseline by using the low frequency components of the interferogram.

[FTS-121] A functional requirement should be added to select the order of the polynomial and the cut-off frequency for the Fourier fitting.

4.15 Level 2 Deglitching

4.15.1 Trevor's Document Section 3.3.3

4.15.1.1 *Consensus Recommendations*

[FTS-122] The identification of these outliers is done by comparing one sample in one scan to those from all other scans in the same observation at the same OPD. As we know that the forward and reverse scans are not giving the same information (there are still some differences in the spectra from the two directions), samples should be compared only with those obtained in the same direction: otherwise we would be obliged to raise the threshold around ZPD to take account of this measured difference signal. The case of observations with only two repetitions will cause a real problem: in that case, we may have to mix the two scan directions together with a consequently higher threshold level.

4.15.1.2 Minor Comments

[FTS-123] A minimum number of 6 interferograms is mentioned which is not correct since a minimum of 2 repetitions has been required for the submission of observing proposals.

4.15.2 Chris' Document Section 5.1.11

4.15.2.1 *Consensus Recommendations*

[FTS-124] Clarify the calibration file.

[FTS-125] Describe the way the signal error is modified from the Input to the Output.

4.15.2.2 Minor Comments

4.15.3 Module Requirements Document Section 7.6

4.15.3.1 *Consensus Recommendations*

4.15.3.2 Minor Comments

4.16 Channel Fringe Correction

4.16.1 Trevor's Document Section 3.3.4

4.16.1.1 *Consensus Recommendations*

[FTS-126] State specifically that no such task is currently available for SPIRE data processing and apodisation has been proposed to reduce the impact from channel fringes.

4.16.1.2 Minor Comments

[FTS-127] There is a redundant sentence prior to the numbered list which should be removed:
"Two other methods of fringe correction are under consideration. These methods are:"

4.16.2 Chris' Document

Not applicable.

4.16.3 Module Requirements Document Section 11.6

[FTS-128] This section should be removed, since no such task is under development.

4.17 Phase Correction

4.17.1 Trevor's Document Section 3.3.5

4.17.1.1 *Consensus Recommendations*

[FTS-129] It should be made clear which steps will be used in the mission: in PV phase we should have the fitting function available, but in routine operations we can probably use a fixed phase from a calibration product.

[FTS-130] We need to monitor the actual phase (using a fit to the data) in case it is not stable over different observations. We can do this by using the calibration file to provide initial correction and then compute the remaining phase with a fit and report it as a quality control measure.

[FTS-131] The signal to noise ratio will be low in the majority of faint sources and so a good fit may not be possible in those observations. The default for the task within the pipeline should therefore be to retrieve the phase from a calibration file.

4.17.1.2 Minor Comments

4.17.2 Chris' Document Section 5.1.12

4.17.2.1 *Consensus Recommendations*

[FTS-132] The "Non-linear (Optical) Phase Correction Table" contents should be clarified – i.e. the difference between the phases and phase errors. In addition, in this step the interferogram is from the source only (after removal of telescope & SCAL emission), therefore we need only one optical phase, i.e. that for the input beam from the sky.

4.17.2.2 Minor Comments

4.17.3 Module Requirements Document Section 7.8

4.17.3.1 *Consensus Recommendations*

4.17.3.2 Minor Comments

[FTS-133] The calibration file mentioned in PHASECORR-CAL-030 is not mentioned in any functional requirement. It is not clear what a "position-dependent phase" is.

4.18 Apodisation

4.18.1 Trevor's Document Section 3.3.6

4.18.1.1 *Consensus Recommendations*

[FTS-134] State explicitly which apodising functions are available through this task and which one will be used in the SPG pipeline.

4.18.1.2 Minor Comments

[FTS-135] State that the baseline approach for the SPG pipeline is to deliver two spectral products to SPIRE users: one un-apodised and one apodised with a standard apodisation function.

[FTS-136] Reference the technical note on apodising SPIRE spectra.

4.18.2 Chris' Document Section 5.1.13

4.18.2.1 *Consensus Recommendations*

[FTS-137] Do we need a calibration file containing the apodisation functions?

[FTS-138] State which apodising function will be used in the SPG pipeline.

4.18.2.2 Minor Comments

[FTS-139] State clearly that the user can select from a range of apodisation functions in Interactive Analysis.

[FTS-140] State that the baseline approach for the SPG pipeline is to deliver two spectral products to SPIRE users: one un-apodised and one apodised with a standard apodisation function. The method of achieving this should be determined based on memory constraints (i.e. running the whole pipeline twice, or each individual module twice).

4.18.3 Module Requirements Document Section 7.7

4.18.3.1 *Consensus Recommendations*

4.18.3.2 Minor Comments

4.19 Fourier Transform of Interferogram

4.19.1 Trevor's Document Section 3.4.1

4.19.1.1 *Consensus Recommendations*

4.19.1.2 Minor Comments

[FTS-141] Clarify which spectral resolution modes (H, M, L and H+L) should be processed in which way (single or double-sided)? At the moment only single and double sided interferograms are mentioned, but which corresponds to which mode?

4.19.2 Chris' Document Section 5.1.14

4.19.2.1 *Consensus Recommendations*

4.19.2.2 Minor Comments

[FTS-142] Between eq. (46) & (47; not labelled) there is something missing Delta sigma = 1/2 ? as it is also in the text three lines above.

[FTS-143] What is the difference between the interferogram number and the Scan number in the meta data of the output product?

[FTS-144] Explain how the spectral error is derived.

4.19.3 Module Requirements Document Section 7.9

4.19.3.1 *Consensus Recommendations*

4.19.3.2 Minor Comments

[FTS-145] Output data requirements FXFORM-OUT-041 and 042 make reference to a "flux" column, but at this stage, the data are in units of Volts and not flux.

4.20 Flux Conversion

General Points:

[FTS-146] The following calibration measurements are planned for these two modules:
- Extended RSRF: measurements of SCAL and the telescope during cooldown (observations to allow for differential measurements are specifically requested)
- Point-source RSRF: (very time-consuming) measurements of Uranus/Neptune with every detector (differential measurements are not as well controlled – we can't just change the temperature of the planets)
- Point-source RSRF: scan the telescope across Uranus/Neptune while the SMEC is at a fixed position with every detector.

Check the feasibility to add to the latter set of measurements low-resolution scanning of the SMEC in order to measure the wavelength-dependent beam-size.

[FTS-147] Q: How is the RSRF derived? How are the flux conversion tables derived? As a ratio of a measured spectrum over the known/modelled spectrum of a calibration source? How is the RSRF taken into account?
A: There are currently two approaches to computing a Relative Spectral Response Function. One approach is based on one measurement of a well-modelled source where the RSRF is defined as the ratio of the model and the measurement. The other approach is based on a differential measurement of two well-modelled sources where the RSRF is defined as the ratio of the differences of the models and measurements. The former is the baseline for the in-flight measurement of the point-source RSRF. The latter removes any unknown incidental stray-radiation and has been used by JPB and TF to analyse PFM data.

JPB, TF, and SL are to make explicit these two different approaches and agree on terms and the advantages and disadvantages of the two approaches. Email exchange should start this process and should be followed up at the consortium meeting.

4.20.1 Trevor's Document Sections 3.5.1/2

4.20.1.1 *Consensus Recommendations*

[FTS-148] State clearly that point-source calibration is the baseline calibration for the SPIRE FTS and will be applied in the SPG pipeline. Most scientific observations will lie between the two extreme cases of point and extended homogeneous sources. Observers will be advised to apply a correction for extended sources on top of the point-source calibration.

[FTS-149] Spectral Response Correction and Flux Conversion should be merged into a single module called Flux Conversion, whilst still keeping the possibility of separating RSRF from flux conversion by using two input calibration files. Calibration product names refer to their content and should, as much as possible, kept unchanged. A robust selection of the product name and its contents should be identified.

[FTS-150] Does the flux calibration depend on the apodisation?
A: Not for the continuum (apodising functions are normalised to unity at ZPD) and only slightly (<4% for the adjusted Norton-Beer apodising functions) for the lines if Gaussian fits are used to extract line information (see chapter 5 in the note Apodising SPIRE interferograms http://www.rssd.esa.int/llink/livelink/open/2847961/).

[FTS-151] Take account of the fact that flux calibration may depend on BSM position (if vignetting depends on BSM position for example). This (potential ?) issue should at least be mentioned.

4.20.1.2 Minor Comments

[FTS-152] In the first line of the Flux Conversion section, the measured spectra should be B(sigma) in the input SDS rather than I_n (i.e. following the nomenclature in the previous section).

[FTS-153] Only official documents should be referenced. If results from SDAG minutes are needed, they should be copied into the description.

4.20.2 Chris' Document Sections 5.1.15/16

4.20.2.1 *Consensus Recommendations*

[FTS-154] The description should be updated to reflect the changes proposed to Trevor's document.

4.20.2.2 Minor Comments

4.20.3 Module Requirements Document Section 7.10/11

4.20.3.1 *Consensus Recommendations*

4.20.3.2 Minor Comments

[FTS-155] The Spectral Response Correction and Flux Conversion modules should be merged into a single module called Flux Conversion.

[FTS-156] This single module should maintain the two calibration products from the original tasks as input. Robust names should be identified for these products.

4.21 Optical Crosstalk Removal

4.21.1 Trevor's Document Section 3.5.3

4.21.1.1 *Consensus Recommendations*

[FTS-157] State that the initial assumption is that the optical crosstalk is negligible.

[FTS-158] Verify that the PV phase includes measurements to characterise optical crosstalk, e.g. scanning across point sources (while scanning the SMEC to get this information as a function of wavelength).

4.21.1.2 Minor Comments

4.21.2 Chris' Document Section 5.1.17

4.21.2.1 *Consensus Recommendations*

4.21.2.2 Minor Comments

4.21.3 Module Requirements Document Section 7.12

4.21.3.1 *Consensus Recommendations*

4.21.3.2 Minor Comments

[FTS-159] Requirements should be written.

4.22 Spectral Averaging

4.22.1 Trevor's Document Section 3.5.4

4.22.1.1 Consensus Recommendations

[FTS-160] The recommendation is to average forward and reverse scans separately while employing an outlier identification (probably median/MAD) on a spectral bin basis and present one average spectrum per detector to the user (note that the standard deviation will also be presented to the user as spectral error). The outliers identified earlier will be disregarded when computing the average and standard deviation. NB: Outlier identification is problematic for very small sample sizes.

[FTS-161] Create quality control information, such as number of identified outliers, or the difference between the forward and reverse average.

[FTS-162] This task should operate on data from multiple building blocks within one observation that may be separated by PCAL flashes, rather than only within a single building block. The position should be checked in this case so that in jiggled observations, only spectra from the same position are averaged.

4.22.1.2 Minor Comments

4.22.2 Chris' Document Section 5.1.18

4.22.2.1 *Consensus Recommendations*

4.22.2.2 Minor Comments

4.22.3 Module Requirements Document Section 7.13

4.22.3.1 *Consensus Recommendations*

4.22.3.2 Minor Comments

[FTS-163] In the module description, the end of the sentence should read: "...for a given observation (which may contain several building blocks)."

[FTS-164] The input data requirements should be expanded to allow several SDS products to be entered (these may be from several building blocks within one observation).

[FTS-165] In SPECAVG-FUN-021, the clipping cutoff for outliers (currently stated to be 3 median absolute deviations) should not be hardcoded, but should be selectable by the user.

[FTS-166] The outlier cutoff in SPECAVG-FUN-021 should adjust itself dynamically to the number of scans to be averaged according by default. We have to check the maths so we understand how to do this. The good old 'three sigma' criterion translates roughly into a 5 mad criterion.

4.23 Spatial Regridding

4.23.1 Trevor's Document Section 4.1

4.23.1.1 Consensus Recommendations

[FTS-167] Verify that suitable calibration measurements are planned for the PV phase to derive the information where the detectors point to with respect to the line of sight of the spacecraft.

[FTS-168] Take account of the possibility that this module replaces the Spectral Averaging module for mapping data – i.e. averaging could be done by the gridding task rather than beforehand by the averaging task.

4.23.1.2 Minor Comments

[FTS-169] A comment should be added to state that both fixed coordinates (RA and Dec) and moving coordinates (e.g. Solar System objects) should be dealt with.

4.23.2 Chris' Document Section 5.2.1

4.23.2.1 Consensus Recommendations

[FTS-170] A calibration product containing beam profiles is required.

4.23.2.2 Minor Comments

[FTS-171] A comment should be added to state that both fixed coordinates (RA and Dec) and moving coordinates (e.g. Solar System objects) should be dealt with.

4.23.3 Module Requirements Document Section 7.14

4.23.3.1 Consensus Recommendations

[FTS-172] SPECCUB-INP-020 specifies that the input SDS should have been averaged. The possibility of carrying out the averaging in the process of creating the cube should be investigated and this requirement updated as necessary.

[FTS-173] SPECCUB-OUT-021 means that Solar System data cannot be processed by this module. This should be replaced with a requirement that both fixed (RA and Dec) and moving (e.g. Solar System object) coordinates are possible.

4.23.3.2 Minor Comments

[FTS-174] SPECCUB-INP-022 should specify that all input spectra should have the same value of the commandedResolution metadata.