SCUBA-2
Spectrometer Project

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Summary of Review Panel Comments Prior to CoDR

This document summarizes the comments from the CoDR review panel that were raised after the initial release of the CoDR documentation set. Questions were raised by the panel, Mark Halpern (MH), Don Jennings (DJ), William Duncan (WDD), and Per Friberg (PF). A summary is given at the end of the document.

1. Performance / Requirements

Q.1.1) (panel) In general the FTS specifications are not derived explicitly from the science case. It would be helpful to see the specifications and requirements generated from the science case.
A) The FTS is unfortunately very much an ad-hoc project. The project was initiated with the goal of making the best possible spectrometer with the available funds and engineering constraints. Most of the specifications and requirements that could be derived from the science case, such as sensitivity or angular resolution, are already fixed by the SCUBA-2 design. The only variables for the FTS are resolution (table length), number of pixels (optics size) and observing modes.

Q.1.2) (WDD) It would be nice to see some simulations of the data taking and analysis modes to see which is the best method of obtaining data and what we need to do with the heater signal and dark shutter. Also how do we take spectrally and photometrically calibrated data with the FTS in beam. This will affect the software provided a great deal.
A) We agree that this needs to be done, however simulations at this level are beyond the scope of the CoDR.

Q.1.3) (MH) Detector Linearity
If you do not null both interferograms, or perhaps even if you do, How linear is the detector response through ZPD? The usefulness of a Fourier Transform of the data depends on this.
A) Linearity of the detector response over the ZPD is something that we will need to get from the ATC. From the loading analysis, the FTS only increases the loading by 40 to 50%, and doesn't exceed the pixel power loading budget. We don't have enough information about the SCUBA-2 detectors to evaluated the linearity at this time.

Q.1.4) (MH) Do you have "realistic" loading models?
A) The loading values listed were derived from the SCUBA-2 850um MathCAD loading model, modified to calculate the full radiative transfer through the FTS, which is the most realistic model we have. See http://research.uleth.ca/scuba2/documents/analysis/SCUBA-2_noise_analysis_FTS_80K.pdf

2. Optical / Mechanical Design

Q.2.1) (panel) Optical performance and observing modes
The CoDR documents do not give many details about the optical modeling and observing modes. An issue was if the CoDR should be delayed to give the team more time to do modeling or present existing results.
(MH) Can you return to SCUBA-2 a beam identical to the beam which would have been there without the FTS? Does this ability depend on path difference? Off-axis distance? We think an affirmative answer here requires a beam pupil at the dihedrals. Is this true? Do you do this? The curved mirrors look to us to be in the wrong places for this.
A) Optical modeling is not sufficiently advanced to give details of such things as image quality as a function of OPD, etc. The beam will not be identical to the non-FTS case, and as with any FTS will be affected by path difference, but we should be able to minimize these effects. We do not have a pupil at the dihedrals, and do not think it is necessary. We have taken the curved mirror concept from the SPIRE design, which faces similar design problems.

Q.2.2) (panel) Dual port system
Using both output ports to reduce effects of transmission variation (see email by Ed). Each port of the array would then use a sub array.
A) A full dual input dual output MZ system would have advantages, but the main reason this is not planned is that there is not really enough space, particularly for the pickoff optics. If this was a main driver at the beginning, we would have made a tradeoff by sending 2 beams back to SCUBA-2 with fewer pixels in each, rather than trying to fit as many pixels as possible through the spectrometer. Another problem with this approach is that it requires two arrays with identical characteristics for the two ports. This is more easily accomplished with optical/IR CCDs than in the submm. The effects of cirrus in the submm is also far less that at near-IR wavelengths.

Q.2.3) (DJ) Suggestion about the moving mirrors in the FTS.
The back-to-back arrangement of the moving mirrors in the Mach-Zehnder design can be used to produce passive tilt and shear compensation. The concept is this: If two cube corner retroreflectors are placed back-to-back with coincident apices, then any lateral motion or tilt of the moving assembly will produce matching offsets in the two FTS arms. The cube-corners eliminate tilt, and any shear introduced by the carriage will be the same in both arms and will leave no effect in the recombined beams. During the development of the SPIRE FTS I suggested that the roof mirrors be replaced by cube-corners for this purpose. This design was seriously considered for SPIRE, but was found to be incompatible with the rotation of the image in that instrument. Since the SCUBA-2 design is in its early stages it might be worth considering the idea here.
A) We can minimize tilt and shear with good mechanical design. Corner cubes would have advantages, but the disadvantages would be the increased size, mass, and cost, which make them unattractive. The added height of a corner cube arrangement would also interfere with the beams coming down from the beamsplitters in our folded design.

Q.2.4) (WDD) I presume that the optics for the FTS picks off the light intended for one of the 40 by 32 pixel arrays and not 1/4 of the field near the centre. If so, which array is it?
A) We have not yet chosen the quadrant to use, as it only impacts the design of the pickoff mirrors. The mirror design and alignment would surely be simpler if we used the center of the beam. If we use a subarray, we will plan on using the one that will be delivered first.

Q.2.5) (MH) Beam Splitter
What is the PHASE of the beam through the BS? Is it uniform across the aperture? Should I care? Can the efficiency of the BS be improved at 850 um?
A) The phase should be uniform, and you probably don't need to care. The efficiency of the BS can be optimized for particular wavelengths, but Peter Ade should be able to make beam splitters that are optimal for both the 850 and 450. The beam splitters are basically very wide filters with 50% efficiency, rather than the very narrow filters with high efficiency that Cardiff group normally makes.

3. Operating Modes

Q.3.1) (panel) For the DREAM mode to work it is important that no curvature is introduced in the background due to phase differences across the array.
(WDD) Will their be significant phase differences across the field of view which might affect DREAM mode when the FTS is set close to the central maximum? DREAM mode will come up with the background and an estimate of the non-background flux on each pixel. If there is strong curvature of the background due to the FTS, then we may have some problems unscrambling this from the time varying tilt and curvature in the atmospheric background. Thus, when using DREAM at each setting of the interferometer is the sequence of DREAM astronomical fluxes a good representation of the interferogram for that pixel? The data and noise for each pixel will not be independent after DREAM processing.
A) This will have to be investigated in more detail. Back of the envelope calculations make us confident that there will be negligible phase differences between pixels at ZPD, which is the most problematic point for the DREAM mode. Detailed analysis of noise performance with the DREAM mode has not yet been done.

Q.3.2) (PF) Why is "stare" mode as used by the current FTS not considered? Doing a fast FTS scan on source then move off the source with the antenna and take another scan followed by an subtraction (after the FFT). True it is not the most effective observing mode but it does currently work. Further, jittering or jiggling to fill in for dead pixels, gaps between arrays and 450 array under sampling would cause complications. However, if DREAM mode not works this would be a possible backup. Since you actually are obtaining an reference observation there is not a flat fielding problem - you must still flat field but not to that accuracy.
A) The stare mode with off-source subtraction is indeed a backup, but sky correction is a major issue that we are hoping to solve with the DREAM mode.

Q.3.3) (PF) From what I understand has step and integrate not work well with the current FTS due to changes in the atmosphere due to the long scan time (hours). DREAM mode by removing the background should help in that respect (you don't need to be concerned about overall spectral changes in the observed window). Together with using a WVM to correct for opacity changes it might work much better than now in that respect.
A) In the past we have successfully used a step and integrate mode with the FTS (scan time of ~20 minutes), but there was no means for atmospheric correction, and there were difficulties at the time of chopping the secondary for modulation, which was the limiting factor.

Q.3.4) (PF) Do you not need to flat field in the spectral dimension too? If you need to do it I don't think it is a big issue but it needs to be taken care of.
A) Yes, spectral calibration needs to be done, but the instrument characteristics should not vary rapidly with time, if at all.

Q.3.5) (WDD) If we have low 1/f in the system we may not need to use DREAM mode at all and instead modulate with some movement of the telescopes (Lissajou figues) as used with great success with SHARC II. What then for the FTS?
A) If we were forced to use such a mode, then we would have to use the output of each cycle as frames in a step and integrate interferogram, in the same manner as we would use DREAM frames. Failing this, we would have to use a staring, rapid scan mode for the FTS.

Q.3.6) (MH) The array is at the Nasmyth focus, so the image rotates. How can you transform a data set which is acquired during one hour? Do you intend to construct a single pixel interferogram from data measured with many different bolometers? We estimate that at 2 arc minutes from image center and looking at Polaris a spot on the sky moves 30"/hour, or one 850 um pixel in 12 minutes!!! Is this the longest useful interferogram?
A) SCUBA-2 must correct the sky rotation anyhow. We assume that the input to our FTS processing pipeline will be atmosphere and rotation corrected frames. With long scans, interferograms for one pixel may contain data from more than one bolometer, but we are not anticipating huge variations in spectral response between bolometers.

Q.3.7) (MH) Nulling the ZPD signal
In the documents you say you will be able to null the interferogram with a separate dewar. Can you? Do you intend to? Does this satisfy the "no cryogens" rule?
A) We are still investigating the options for the nulling blackbody. We are planning on a cryocooled design (even though it is a waste of money compared to lN2). Can we build one? We think so. Do we intend to? We hope not to have to. We still don't know conclusively whether nulling will be necessary. It will depend critically on how we scan the FTS (ie step-and-integrate or continuous scan, and at what speed). If a nulling BB can not be made, then the option is simply to scan slowly through the ZPD. We still plan to deliver a cryogen-free ~77K blackbody to reduce the overall loading.

Q.3.8) (MH) If you slow down the scan, as suggested in risk mitigation, will this work? Will the intfs be at all linear?
A) Slowing down near the ZPD in a continuous scan mode will require throwing away some frames, or a non-uniform Fourier transform, which is much more computationally intensive, but not prohibitively so. Slowing down in a step and integrate or aliased mode will only affect overall observing efficiency.

Q.3.9) (MH) Why is there no mention of re-biasing at ZPD? I thought this was the plan to cope with loading. How well would that work?
A) Re-biasing the detectors during a scan would be problematic, although might not be too bad in a step and integrate mode. The loading shouldn't be a problem- the rapid change in loading at ZPD is the problem. This is more easily solved by slowing the scan down than by trying to re-bias fast enough.

Q.3.10) (MH) How hard, complicated or stable is phase correction likely to be? Will this be a drain on computing or operating resources?

A) Phase correction is complicated, but something that our group has a lot of experience with and something which we have already coded for single pixel systems. The overhead will be no more than 15% of the total FTS processing time, but we are just starting to write multi-pixel phase correction code for SPIRE and are not sure of the final processing overhead (At worst it will scale directly with the number of pixels, and will be stable with time).

Q.3.11) (panel) Large maps:
The operational concept states that the FTS will primarily be a galactic spectrometer (Operational Concepts section 2.3 first paragraph). SCUBA-2 will map extended objects by rapidly scan the antenna (scan-mapping). No corresponding FTS observing mode exists or is proposed. The DREAM mode separates the background from the signal through small scale jiggling and hence will be less sensitive to very extended emission.
A) Large FTS maps will likely need to be done at lower resolution. We could in principle use a step and integrate mode with the scan map mode in the same way as we plan to use the DREAM mode.

4. Project Management

Q.4.1) (panel) Project schedule
The current FTS project plan has delivery scheduled for December 2005 However, SCUBA-2 is scheduled to arrive to the telescope late December 2005 and installation, commissioning and initial observing is expected to take 6 months. If the FTS were delivered on time it would stay in a crate at the JAC for about six months before being commissioned. Further, SCUBA-2 will be delivered with only one sub array per wavelength band. The remaining sub arrays are delivered in fall of 2006. This raises the issue if there is any point in commissioning the FTS before all sub arrays have arrived. Particular if the FTS uses more than one sub array. I.e. if both output ports of the FTS are used or if the FTS looks at the center of the SCUBA-2 field which only is 25% populated until October 2006. The appropriate time frame for the commissioning has implications for the project plan, budget and staffing.
A) To facilitate testing of the SCUBA-2 detectors and filters during commissioning, we were planning on delivering the instrument as soon as possible after the SCUBA-2 system is installed. The FTS does not need to be fully commissioned to be useful for these tests. If the FTS uses the center of the full array, then it may not make sense to commission the FTS until the full arrays are operational. We have adjusted the project milestones such that the delivery of the FTS occurs in March 2006, and commissioning is planned for 2 to 3 months after SCUBA-2 commissioning.

Q.4.2) (panel) Project Management
The FTS project is currently on the back burner to reserve resources for SCUBA-2 if required. The PDR is scheduled to occur just after the full resources should be available again. The CDR is scheduled just two months later. Is this a realistic schedule? The dilemma is that the chosen observing modes have implications for the SCUBA-2 data acquisition and reduction systems. These systems are in the design phase now and input mid next year might be too late. Are the resources enough after the CoDR to do the anticipated follow up work on observing modes in a timely manner? To access if the project plan is realistic (point 5 in the term of reference) more information about budget, staffing and project plan is required
A) We have adjusted the review dates in the project plan. We do not plan to drive the design of the SCUBA-2 data acquisition or reduction systems. So long as provisions are made to record the FTS

information in the frame headers, we should be able to make any observing mode work, with the stare mode as contingency if we can't. We can provide specific budget, staffing, and planning details on request.

Q.4.3) (panel) It would be useful to have an interface matrix and a separate ICD for each interface defined in the matrix.
A) Agreed.

Question	More Work Required?	Significance	Comments
1. Scientific Performance / Requirements			
1.1 Requirements not from science case	-	-	
1.2 Analysis simulations needed	Yes	Medium	
1.3 Detector linearity	Yes	High	Linearity specs required from ATC
1.4 Loading model	Done	Medium	
2. Optics / Design Details			
2.1 Optical modeling	Yes	Medium	This is the next step in the development
2.2 Dual port system	Not planned	-	Not deemed practical
2.3 Corner cube mirrors	Not planned	-	Not deemed practical
2.4 Choice of quadrant	TBD at a later date	Low	Choice of quadrant doesn't change FTS design significantly.
2.5 Beam splitter issues	No	Low	
3. Operating Modes			
3.1 DREAM phase curvature	Yes	Low	More DREAM modeling required
3.2 Stare mode	Contingency	Low	
3.3 Step and Integrate history	-	-	We have used step and integrate successfully
3.4 Spectral calibration	No	Low	This is part of the planned software
3.5 Dish modulation mode	Potentially	Low	Same as DREAM for FTS
3.6 Image rotation	No	Low	SCUBA-2 must correct this anyhow
3.7 ZPD signal nulling	Potentially	Medium	There are options to mitigate this problem
3.8 Variable scan speed	No	Low	
3.9 Detector re-biasing	Potentially	Medium	We don't anticipate needing this
3.10 Phase correction	No	Low	This is part of the planned software
3.11 Large maps / Scanmap	Potentially	Low	More scanmap modeling required
4. Management			
4.1 Delivery Schedule	Done	Low	
4.2 Project milestone dates	-	-	Dates have been adjusted
4.3 ICD matrix required	Yes	Low	