Report from SCUBA-2 FTS-2 Preliminary Design Review

held at The University of Lethbridge
8 July 2005

Review Panel:	Don Jennings, chair	NASA/Goddard Space Flight Center
	Per Friberg	Joint Astronomy Centre
	Wayne Holland (remote)	UK Astronomy Technology Centre

In attendence: Gary Davis (JAC), Janos Molnar (UBC), Daphne Summers (UofW), Craig Walther (JAC, remote), David Naylor, Brad Gom, Andres Rebolledo, Dan Handford, Baoshe Zhang (all UofL).

Summary
The PDR was held to review the preliminary design of the SCUBA-2 Fourier Transform Spectrometer (FTS-2). The purpose of the review was to establish that a viable preliminary design exists and that the design can proceed to the final design stage. The review panel considered in particular the following points:

1. Does the FTS-2 preliminary design meet the scientific and technical requirements?
2. Are standards of good engineering practice being followed?
3. Are all risks and uncertainties in the preliminary design likely to be resolved in the final design?
4. Are interfaces clearly defined and accommodated in the design?
5. Is the development on track to deliver FTS-2 on time and within budget?

The PDR Review Panel found that the preliminary design of FTS-2 is well developed. Our general conclusion is that the team is ready to proceed to the final design phase. This report highlights important points discussed during the review and provides a list of specific recommendations to be addressed before the Critical Design Review.

Budget and Resourcing
The spending profile lags behind the funding profile, and unspent dollars have been moved forward to subsequent years. However, the period from PDR to delivery will probably use the entire remaining budget. The overall budget is fixed with no contingency from CFI, so careful planning will be necessary for the remainder of the project. The project management seemed to appreciate this situation. The synergism with SPIRE has permitted some manpower and technology sharing and has helped make cost estimates more mature. Time has been saved by capitalizing on the experience of personnel who started working on SPIRE and have transferred to FTS-2. Costs of some items such as mirrors that have been rising sharply are being closely watched. Co-op students have worked out well.

Schedule
The FTS-2 delivery date of Dec 2006 is approximate and will be dictated by the SCUBA-2 delivery date. The progress at JCMT is not critically dependant on the FTS-2 arrival. The panel and team agreed that the FTS-2 delivery would be set at six months after the

SCUBA-2 delivery. It was decided that the FTS-2 CDR should be held in the December 2005 to February 2006 timeframe.

Optical Design
A strawman optical design was presented. Because constraints on location, as well as the input and output beam configuration, only became available to the team in April 05, the optical design has lagged somewhat behind the mechanical design. The panel asked to see the detailed optical model when it is finished, including raytraced spot diagrams at the SCUBA-2 focal plane (to predict image quality). The team agreed to comply and estimated completion in approximately one month from PDR.

The PDR status of the optical design is sufficient to show that it is likely to meet the spectral imaging requirements while matching the optical and mechanical constraints of the JCMT and SCUBA-2. Modelling in Z-max has clearly been a major help in characterizing these interfaces. As recommended by the CoDR panel the team has adopted a design including two ports on the sky. This is a proven design with a number of benefits and will provide the best sky cancellation for sources of limited spatial extent. However, it leaves unresolved the issue of how to observe extended sources. A provision to insert a black body in either of the two input ports, as outlined the PDR documentation, is recommended for this purpose. Such a load would allow observing methods like DREAM to be explored. A related topic was whether nodding between source and blank sky would provide the needed reference for extended sources; it was suggested that this type of observing-specific planning should be left to the astronomer, with support documentation provided.

Mechanical Design
The panel was satisfied with the FTS-2 mechanical design. The layout of the mirrors and carriage within the housing framework was described. Particularly challenging to the design are the constraints imposed by the limited space available between the elevation bearing tube and mirror N1. This leads to a design that is highly folded in three dimensions, making the frame rigidity especially important. The possibility was discussed of moving the carriage laterally to gain some room for improving the beamsplitter mounting.

The primary vibration frequency of the rooftop mirror assembly is 474 Hz, well above the 200 Hz sampling frequency and away from the 60 Hz telescope frequency. However, not all structures have been analyzed. Some analyses of thermal effects on the telescope structure are available.

The procedure was presented for installing FTS-2 on the telescope. Using the overhead crane and a custom lifting fixture, the entire framework is to be lowered into place and positioned with micro-lock supports. No clamping will be needed. A fit-check of the FTS frame prior to installation of optics is advisable. After the first installation the position should be repeatable with minimum adjustment. Pickoff mirrors will be inserted into the telescope beam with a remotely operated mechanism. The mechanism will also be used to perform final optical alignment of the FTS-2 with the telescope and SCUBA-2. No laser

alignment is expected to be necessary. However, details of the mounting and alignment procedure, and identification of support equipment, has not been completely worked out. The custom lifting fixture should be certified to handle the weight (this is required by US law). The procedure for installing FTS-2 should be optimized to minimize the telescope down-time.

Control Systems Software
The panel generally approved of the FTS-2 control software design. Much of the discussion centered on simulation and testability of the control system before delivery and during commissioning. Craig Walther suggested that the RTS DRAMA client library be utilized in simulations to guarantee compatibility with the OCS; the team agreed. During commissioning, it will be possible to test the control system while FTS-2 is on the observatory floor before hoisting into place.

The need for spare instrumentation was discussed, as well as commonality with other instruments. It was suggested that a list of required spares be developed. Instrumentation should be identified that is already being used by the Polarimeter and the JCMT that might be implemented in FTS-2; an example is the PC being used by the Polarimeter. It was also noted that some computer equipment might need special ratings for operation at high altitude; hard drives were cited as an example. It was mentioned that a data header format needs to be established.

Data Reduction Software
The panel agreed that the pipeline software design was at an advanced stage. There was discussion concerning resampling interferograms to convert the time-sampled data to evenly-spaced OPD positions. Frame-sampling at near-constant carriage speed with 20 nanometer resolution appears to be adequate to minimize errors in interferogram resampling and phase correction. The situation is not so clear for spatial sampling, where two issues were identified: spectral change from pixel to pixel and image rotation during individual interferograms. The pixel-to-pixel characteristics of the array are not fully known and will need to be handled in calibration. Image rotation will be greatest near zenith where the telescope has the poorest tracking. Spatial over-sampling will aid in correcting for image smear. The instrument simulator under development will help characterize potential problems. High fidelity simulations of spectral-image data should be developed as input for these simulations. A complete calibration scenario should be developed for simulation purposes, beginning with observations of reference continuum and line sources and following through the data reduction process.

Requirements
During the discussion of the Functional and Performance Requirements, Section 3.0, the question was raised whether, in the rapid scan mode, the signal-to-noise is degraded by distortion near Nyquist sampling. This should be reviewed by the team. There is no requirement covering radiance sensitivity, but it was stated that FTS-2 would be limited by sky background flux noise, which is acceptable. Also, pertaining to requirement REQ-MEC-001, an alignment laser is stated to be required, but no laser is currently in the

design. Pertaining to REQ-ENV-004, temperature modeling has been performed for the telescope structure and some structures in the FTS, but a complete thermal analysis is yet to be done. Compliance with some optical requirements awaits the completion of the optical design.

Recommendations

The following is a list of recommendations that the PDR Panel asks the development team to address before the Critical Design Review.

1) Define the date of delivery to the telescope site as 6 months after SCUBA-2 delivery. Review whether budget limitations might require an earlier completion date.
2) Establish a strawman date for the CDR by end of July 2005. Goal: sometime in the December 2005 to February 2006 timeframe.
3) Start procurement of long-lead items before the CDR. Define these items by September 2005.
4) Complete details of the optical design by September 2005. In particular, model the spot patterns and image quality at the SCUBA-2 focal plane. Supply a description of the design to the PDR panel.
5) Design for the ability to operate the FTS in either of two modes, dual input or single input. It is not clear that the dual-input mode will work on extended sources. An ambient load that can be remotely inserted and removed in front of one of the input ports should be an integral part of the design.
6) Define all instrumentation spares that might be needed and should be included as part of the FTS delivery. Assess the availability and costs of these items.
7) Determine any equipment that could be common to both the FTS and the Polarimeter. Computers were suggested as an example.
8) Coordinate between JCMT and FTS personnel during August 2005 to set a date for implementation of the JCMT observation sequencer as a planning and testing tool.
9) Consider developing high fidelity simulations of expected data for use in testing and commissioning.
10) The portion of the FTS / SCUBA-2 Interface Control Document that specifies lifting apparatuses & procedures should be reviewed and approved by the JCMT operations staff.
11) Coordinate among groups to define a data header format. In particular, establish the format for splicing information into the data header.
12) Develop a financial summary chart (Spending Profile) with planned and actual yearly expenditures shown independent of carry-over. This will make it easier to compare with yearly allocations. It should be possible to also show carry-over funds and totals on this type of chart.
13) The built-in laser is deemed by the project to no longer be needed. The requirement to supply this laser should be reviewed and, if necessary, changed or eliminated.
14) Determine whether a shift in position of the mirror stage would create room to mount the beamsplitter more rigidly. The input mirrors might be adjusted slightly out-of-plane to accommodate this shift.

15) Consider the reduced S/N that results from integrating over a Nyquist interval in continuous scanning mode. Consider using a higher readout rate if feasible or a lower scanning speed.