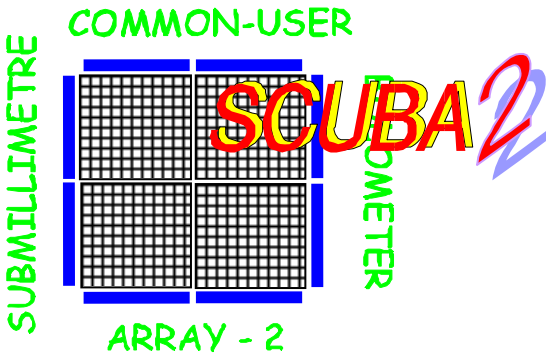

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Change Record

Issue	Date	Section(s) Affected	Description of Change / Change Request Reference / Remarks
1.0	17/06/02	All	First release version (SC2/FTS/SYS/001)
1.1	23/06/02	Timeline	Adjusted milestone dates
1.2	28/07/03	Timeline	Adjusted milestone dates
2.0	26/04/05	All	PDR draft version. New document number.
3.0	17/10/06	All	CDR version. No major changes.
3.1	7/11/06	10.4	Updated signal interfaces. Typo corrections
3.2	9/11/06		Minor corrections, typos

Contents

1. Summary

This document presents the functional and performance requirements placed on the FTS-2 systems by the external interfaces. The requirements on the external interfaces by the FTS-2 system are described in the relevant Interface Control Documents.

1.1. Architecture of the FTS

The FTS-2 instrument design is based on the Mach-Zehnder design which has been adopted for the SPIRE instrument (of ESA's Herschel mission) and the U of L spectrometer operating at the JCMT. A schematic of a Mach-Zehnder FTS is shown in Figure 1. Radiation from the input ports passes through an equal intensity beam splitter, is reflected by stationary mirrors to a moving rooftop mirror, and then reflected to a second beam splitter. In the FTS-2, one input will be used for the astronomical source, the other input for an adjacent background location, and the interferometer will cancel the majority of the common mode atmospheric noise. The two output ports will be imaged onto two diagonal subarrays.

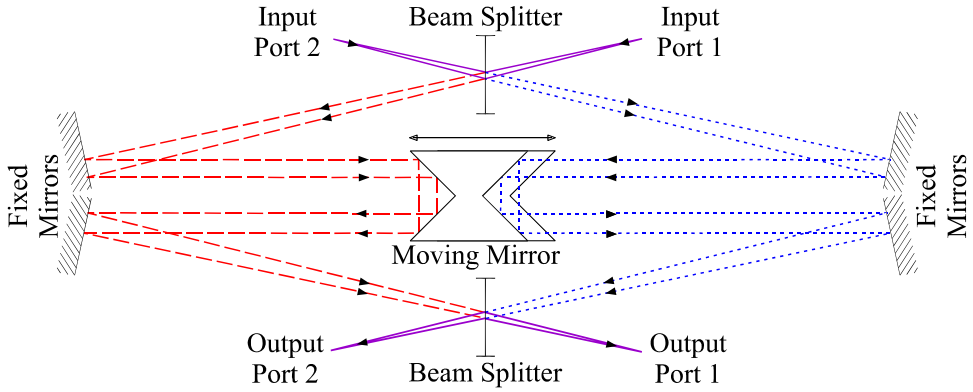

Figure 1. Schematic of a Mach-Zehnder FTS.

The design of the FTS-2 instrument is complicated by the fact that we do not have access to a small diameter collimated beam in the SCUBA-2 feed optics. In order to construct an imaging FTS for the SCUBA-2 system that uses ~ 1/4 of the full array in each band, the following key components are required:

1) **Beam splitters**: Two intensity beam splitters are required that have equal transmission and reflection in both the 450 and 850 bands. The target is to image one quarter of the full SCUBA-2 beam through the FTS, therefore the beam splitters will need to be large enough to accommodate one quarter of the full SCUBA-2 beam at the outside of the elevation bearing after it has been suitably collimated. Size constraints at the mounting location limits the diameter of the beams within the FTS to ~180 mm, and the beamsplitters must therefore have clear apertures of ~ 200 mm.
2) **Pickoff mirrors**: Since the beam is not collimated between mirrors C3 and N1, and there is not enough space to place an FTS directly in the beam, pickoff and return mirrors will be required to divert the desired portion of the beam and, after passing through the

spectrometer, return it to mirror N1 in its original state. These mirrors will need to be on a motorized stage so that they can be removed from the beam when the FTS is not in use. Due to the inaccessibility of the FTS-2 mounting location, the pickoff mirrors will require remotely controlled adjusters to allow alignment of the input and output ports.

3) **Linear Stage**: The moving rooftop mirrors will need to be large enough to accommodate the desired beam diameter, and will be quite massive. (If they are made from aluminum and not lightweighted, then the mass will be < 70 kg.) The linear stage must have a suitable load capacity, be powerful enough to accelerate the mirrors (~1 m/sec^2), and have a positional accuracy of 1 um or better.

1.2. Interfaces with SCUBA-2 and JCMT

The mechanical interfaces between FTS-2 and the JCMT are described in detail in the *FTS-2 to JCMT Interface Control Document* (SC2/FTS/SYS/007). The software and electrical interfaces are described in the FTS-2 to OCS ICD (SC2/FTS/SOF/02) and FTS-2 to RTS ICD (SC2/FTS/SYS/005) documents. The following sections give a brief overview of the main interfaces.

Mechanical Interface: The FTS will sit within the mounting framework for mirror N1, and will likely encroach on the receiver cabin access walkway. There should be adequate protection provided for the two fixed mirrors that will be nearest to the walkway so that they are not disturbed by passing traffic. Alternatively, the walkway may need to be extended. The entire FTS will be protected by a cover to prevent the accumulation of dust. The mass of the FTS is roughly estimated to be 400 kg, and the volume will be approximately 2.2 m x 0.8 m x 1.4 m (w x d x h). The JAC should prescribe limits for the inertial forces in all three axes that the FTS can exert on the mount during operation in order to prevent misalignment of mirror N1.

Operation of the FTS will consist of moving the pickoff mirrors into the SCUBA-2 beam, scanning the moving mirror assembly to acquire interferogram data, and then retracting the pickoff mirrors once FTS observations are complete.

Electronics Interface. Construction of the FTS will require very little custom electronics; the major electronic component is the microcontroller based motion controller for the moving mirror linear stage and for the pickoff mirrors. The motion controller and electronics will be interfaced to a control PC. This PC will be interfaced with the SCUBA-2 network so that the 32 bit stage position is recorded in the header of each frame when an FTS observation is in progress.

Software Interface. The FTS control PC will take commands from the RTS Client to initiate a scan, and will send commands to the motion controller to move the mirror at the required speed and distance, and return the mirror position to the software pipeline. The control PC will also monitor the various limit switches and FTS housekeeping parameters.

The display provided to the observer by the FTS instrument control software should include the following information:

- Status of the instrument; i.e. position of the pickoff mirrors, position and velocity of the moving mirror, time remaining, etc.
- A real-time image of the array; i.e. from the standard SCUBA-2 quicklook display.
- A means to display the last interferogram from a given pixel, as well as the corresponding spectrum, for data quality assessment.

The rest of the information (source name, position in the sky, sidereal time, etc.) should all be given on the main SCUBA-2 display(s).

The FTS data processing will be performed within the SCUBA-2 data analysis pipeline. This FTS-specific code will be written by the U of L team, in close communication with the data analysis software group. An FTS software requirements document will describe these software issues.

2. Basic Requirements

2.1. Atmospheric Correction

REQ-BAS-001: The FTS-2 instrument shall provide access to both input ports and both output ports, so that basic atmospheric correction can be performed by the interferometer.

Provided that a suitable background target can be assigned to the second input port, the interferometer will remove any common-mode atmospheric noise by differencing the two input ports. If a background target is not available, then the second input port will need to be blocked and another technique such as DREAM must be employed to provide atmospheric correction of the interferogram frames.

2.2. Interference

REQ-BAS-002: The FTS-2 shall not interfere with the SCUBA-2 optical beam when the FTS is not in use.

2.3. Alignment

REQ-BAS-003: The FTS-2 pickoff and return mirrors shall be adjustable while the instrument is mounted on the telescope to enable alignment of the input ports to the telescope and the output ports to the SCUBA-2 arrays.

2.4. Calibration

REQ-BAS-004: It shall be possible to calibrate the FTS-2 instrumental lineshape and frequency scale in an automated fashion.

The off-axis pixels will experience apodization, vignetting and frequency shifts as a result of the optical design. It should be possible to correct for these artefacts in the pipeline if calibration data is kept current. Spectral scans of a flat-field source and of a known spectral line source should provide the necessary data.

2.5. Availability

REQ-BAS-005: The FTS-2 instrument shall be available for use whenever the SCUBA-2 system is operational.

The FTS-2 system is placed into operation by moving the pickoff mirror assembly into the optical beam. This process is automated and should only take < 1 minute.

3. Performance Requirements

3.1. Resolution

REQ-PER-001: The FTS-2 instrument shall provide a maximum spectral resolution of 0.006 cm^{-1} and a minimum resolution of 0.1 cm^{-1}.

The FTS resolution is arbitrarily adjustable in software within the limits defined by the travel range of the moving mirror assembly. The baseline plan is to provide a single low resolution mode and a single high resolution mode which will cover the vast majority of observations.

3.2. Field of View

REQ-PER-002: Each port of the FTS shall accommodate a ~100 mm diameter beam, and encompass as much of a full subarray as possible, limited by the maximum beamsplitter diameter and optical layout.

3.3. Speed

REQ-PER-003: The FTS-2 scan speed shall be matched to, and limited by, the SCUBA-2 detector time constant. In the step-and-integrate mode, the step speed shall be limited by the SQUID flux-locked-loop frequency response.

The scanning speed of the FTS (in units of OPD) is determined from the desired Nyquist frequency (σ_{max}) and the frequency response of the detectors (f) by the following equation:

$$v_{OPD} = \frac{f}{\sigma_{max}}$$

3.4. Accuracy

REQ-PER-004: The FTS-2 mirror position shall be recorded synchronously with the RTS data valid strobe to an accuracy of 1 μm.

3.5. Data acquisition rate

REQ-PER-005: The FTS-2 motion controller shall record the position of the moving mirror assembly at the 200 Hz rate of the SCUBA-2 DA system. The collected data points shall be transferred to the DR pipeline before the next scan begins.

4. Operational Requirements

4.1. Instrument control

REQ-OPE-001: Software shall be provided to control all operations of the FTS-2 instrument and mechanisms.

4.2. Instrument status

REQ-OPE-002: Software shall be provided to monitor the status of the FTS-2 instrument, and to display all information required for conducting observations with the instrument.

Parameters to be monitored include: stage position, stage velocity, stage limit switch status, pickoff mirror position. The quick look display will also monitor software and observing mode parameters, see section 12.1.1.

4.3. Instrument testability

a) In preparation for a normal shift:
Once the FTS pickoff mirrors have been moved into the beam, and the image quality verified, the FTS operation can be tested by performing a scan of an arbitrary source. If the moving mirror operates properly, then the resulting interferograms and spectra can be inspected to determine if the FTS performance is acceptable. The various housekeeping parameters monitored by the FTS-2 control PC will indicate if there are problems with the instrument.

b) As part of routine maintenance:
The FTS-2 linear stage contains precision rails and bearings that will need to be lubricated periodically, and inspected for wear. On a yearly basis, or after any maintenance, the linear stage and optical alignment should be checked using alignment tools.

c) During development:
The FTS will be fully assembled and tested in the lab prior to commissioning, but there will be extra alignment tests required during installation at the JCMT. Image quality tests will have to be done on the overall SCUBA-2 optical alignment with the FTS in the beam.

REQ-OPE-003: Software shall be provided to test the basic functionality of the FTS-2 mechanisms before the instrument is used for observations.

Communication with the motion controller(s) must be established, the moving mechanisms must be exercised, and the limit switches must be checked to verify the instrument operability.

4.4. Observation monitoring

REQ-OPE-004: A quick look display shall be provided which displays data reduced to a level sufficient to judge the data quality and observation progress. The display shall be updated at a rate that is fast enough to keep up with the FTS scan rate, so that the display is refreshed before the next scan completes.

Two modes will be considered for the quick look display: a low-resolution mode for SED observations, and a high-resolution mode for spectral line observations. Low resolution spectra are acquired at a faster rate (~ seconds) than high resolution spectra (~ minutes), and can also be processed at a much faster rate since the array sizes are smaller and some computational steps such as phase correction can be skipped. As a result, for the SED mode it will be possible, for example, to display a map for the full FTS-2 field of view showing either the integrated flux or the slope of the continuum for each pixel. For the high-resolution mode, it may not be possible to display entire data cubes at a fast enough rate, so the quick look display might instead present the spectra for a few pre-defined pixels, and statistics (such as the variation in integrated flux) for the rest of the pixels.

5. Mechanical Requirements

5.1. System Functional Requirements

5.1.1. Instrument Alignment Provision

REQ-MEC-001: The FTS-2 instrument shall include alignment tools / laser to allow alignment of the internal optics to an accuracy satisfying REQ-MEC-003, REQ-OPT-004 and REQ-OPT-005.

REQ-MEC-002: The FTS-2 instrument shall include adjustable supports to provide vertical alignment and levelling.

REQ-MEC-003: The FTS-2 pickoff mirror assembly shall provide alignment of the input/output beams to within 1/2 pixel on the image plane.

5.1.2. Mechanical Tolerances

REQ-MEC-004: Where adequate mounting precision cannot be provided by dead reckoning, means shall be provided to measure the misalignment of optical components and then adjust the alignment with a precision that allows the optical performance specifications to be met (REQ-MEC-003, REQ-OPT-004 and REQ-OPT-005).

5.1.3. Instrument Physical Envelope

REQ-MEC-005: FTS-2 shall be designed as a self-contained instrument which can be supported by the N1 mirror framework, does not interfere with the telescope dish backing structure, and does not block the SCUBA-2 optical beam when not in use.

The instrument dimensions and mass are specified in the FTS-2 to JCMT ICD (SC2/FTS/SYS/007).

5.1.4. Access

REQ-MEC-006: All electrical connections shall be accessible from the side of the instrument towards the rear of the telescope, and shall be accessible without removing the instrument.

REQ-MEC-007: All optics requiring alignment during normal operation shall be operated remotely.

5.1.5. Mechanism Safety

REQ-MEC-008: No mechanism shall move in the event of power loss.

5.1.6. Environmental Cover

REQ-MEC-009: The FTS-2 instrument shall have environmental covers to protect internal optics and mechanisms from dust and debris.

5.1.7. Instrument Handling

REQ-MEC-010: The FTS-2 mechanical framework shall incorporate adjustable mounting feet for support, and suitable hoist points for the JCMT instrument handling facilities.

5.1.8. Units of Measure

REQ-MEC-011: All FTS-2 components and drawings shall use metric units.

REQ-MEC-012: All FTS-2 fasteners shall be standard metric sizes, and called out as such on the as-built drawings.

5.2. System Performance Requirements

5.2.1. Instrument Alignment Maintenance

REQ-MEC-013: The alignment of FTS-2 with the SCUBA-2 optical beam shall be maintained to the accuracy specified in **REQ-MEC-003**.

5.2.2. Mechanism Operation

REQ-MEC-014: Individual FTS-2 mechanisms shall be set within 30 seconds.

REQ-MEC-015: The FTS-2 system configuration shall be achieved in < 5 minutes.

Configuring the FTS-2 mechanisms involves checking the limit switches, zeroing the stage encoder, and positioning the pickoff mirrors.

REQ-MEC-016: The total error at the SCUBA-2 detector resulting from reconfiguration of all mechanisms shall be less than 0.5 pixels.

6. Optical Requirements

6.1. Optical Components

REQ-OPT-001: The FTS-2 optics shall accommodate input ports of ~100mm diameter.

REQ-OPT-002: The FTS-2 optics shall have a surface finish suitable for laser alignment.

6.2. Optical Alignment

REQ-OPT-003: All optical mounts shall provide alignment satisfying **REC-MEC-003**.

REQ-OPT-004: The orientation of the rooftop mirror units shall be adjustable to 1 arcsec precision.

REQ-OPT-005: The orientation of the beamsplitter units shall be adjustable to 1 arcsec precision.

7. Control System Requirements

7.1. Functional Requirements

REQ-CON-001: All mechanisms in FTS-2 shall be controllable by a 1U Intel-based rackmount PC running Linux kernel 2.6 with at least one PCI port, one parallel port, and one RS-232 serial port.

REQ-CON-002: The FTS-2 control system shall be based on DRAMA.

REQ-CON-003: The FTS-2 control PC shall control the following mechanisms:

Mechanism	Type	Positions
Moving Mirror Assembly	Translation Stage	arbitrary
Pickoff Mirror Assembly	Translation Stage	2
Pickoff Mirror Units	Micrometer Adjusters	arbitrary
Port Shutter	Solenoid	2

7.2. Performance Requirements

7.2.1. Configuration Time

REQ-CON-004: The control system overhead shall not cause the total system configuration time to be longer than that specified in **REQ-MEC-015.**

7.2.2. Impact on Mechanism Accuracy

REQ-CON-005: The control accuracy of the FTS-2 mechanisms shall not be limited by the performance of the control system.

7.2.3. Impact on Scientific Performance

REQ-CON-006: The control system shall not degrade the scientific performance of FTS-2.

8. Electrical Requirements

8.1. Power Supply

REQ-ELE-001: The FTS electronics shall provide filtered IEC power inlets, with transient voltage protection. The inlets must accept the JCMT 110V AC, 60Hz mains supply.

8.2. Grounding and Shielding

REQ-ELE-002: Separate ground returns shall be provided for low-level signals, noisy components such as relays and motors, and hardware components such as mechanical enclosures, chassis, and racks.

8.3. Electrostatic Discharge

REQ-ELE-003: All static sensitive components shall be protected from electrostatic discharge.

8.4. Ventilation

REQ-ELE-004: All components that are not passively cooled shall include filtered ventilation systems.

9. Environmental Requirements

9.1. Altitude Ranges

REQ-ENV-001: FTS-2 shall be capable of being transported by any transportation mode at altitudes between 0 and 4200 metres. FTS-2 components shall be capable of being transported by commercial jet with pressurized cargo compartments at altitudes between 0 and 15 kilometres.

REQ-ENV-002: FTS-2 shall be capable of being stored in or out of its shipping container(s) at altitudes between 0 and 4200 metres.

REQ-ENV-003: FTS-2 shall be capable of being operated at altitudes between 0 and 4200 metres.

9.2. Temperature Ranges

REQ-ENV-004: FTS-2 shall be operable at temperatures of -15°C to +25°C.

REQ-ENV-005: FTS-2 shall survive storage and transportation at temperatures of -20°C to +50°C without damage.

9.3. Humidity Ranges

REQ-ENV-006: FTS-2 shall be survive storage and transportation at humidity levels of 0 to 100% RH, with condensing moisture.

10. External Interface Requirements

10.1. JCMT Support Structure Interface

REQ-EXT-001: FTS-2 interfaces mechanically with the N1 mirror support framework. The JAC shall provide suitable mounting pads on the N1 framework.

10.2. Optical Feed

REQ-EXT-002: FTS-2 shall accept and use the SCUBA-2 optical beam at the mounting location immediately outside the telescope elevation bearing tube.

10.3. Power Interface

REQ-EXT-003: FTS-2 shall have separate power connections for motors and for electronics/computers. The computer and electronics shall use UPS power, while the motors shall use normal mains supply.

REQ-EXT-004: Power connectors shall be specified by the JAC.

10.4. Signal, Control and Data Interfaces

REQ-EXT-005: FTS-2 shall use JAC-specified network connectors for the control PC and motion controller if standard RJ-45 is not suitable.

REQ-EXT-006: The FTS-2 control PC shall interface with the RTS system via a PMC-Parallel-485 converter board which accepts the differential RTS signals via a PCI interface.

REQ-EXT-007: JAC shall provide cabling and connectors to the RTS interface card.

REQ-EXT-008: The FTS-2 motion controller requires a copy of the DV signal at the instrument location. JAC shall provide cabling and connectors for the DV signal line.

11. Data Reduction Requirements

The FTS-2 data reduction requires the processing of spectral data cubes, which are stacks of SCUBA-2 images registered with the position of the FTS-2 moving mirror assembly.

11.1. Speed

REQ-DR-001: The FTS-2 data reduction algorithms shall be able to process the data from one night's observations before the next night's observations begin.

11.2. Calibration, spectral corrections

REQ-DR-002: Instrumental artefacts such as beamsplitter phase, off-axis frequency shifts, vignetting, etc. shall be corrected in the reduced spectral using data from periodic calibrations.

11.3. Features

REQ-DR-003: The FTS-2 data reduction code shall be able to read/write SCUBA-2 data files.

REQ-DR-004: The FTS-2 processing modules shall provide the following features:

- Interferogram interpolation – to correct for non-uniform OPD sampling
- Phase correction – to remove instrumental phase from the data
- Apodization – to minimize unwanted ringing due to finite interferogram length
- FFT – for Fourier transformation of both single-sided and double-sided interferograms

12. Software Requirements

Details of the FTS-2 software architecture can be found in the FTS-2 to OCS ICD document (SC2/FTS/SOF/002) and the FTS-2 DR Engine document (SC2/FTS/SOF/001).

The data reduction software for FTS-2 will take the form of a processing 'engine' which is called from the main SCUBA-2 pipeline.

12.1. Software Functional Requirements

12.1.1. Observer Interface

REQ-SW-101: As far as possible, FTS-2 shall use existing SCUBA-2 display packages. Where existing packages are not suitable, the FTS-2 project shall provide display system code with the guidance of the JAC.

REQ-SW-102: The FTS-2 software shall provide a display of hardware status and any instrumental parameters useful for conducting observations.

REQ-SW-103: A Quick-Look (QL) system shall be implemented which displays minimally processed data which is sufficient for judging the observation progress.

REQ-SW-104: The SCUBA-2 stripchart utility shall be used to display time series of instrumental parameters and statistics on reduced data.

REQ-SW-105: The QL display shall have a refresh rate less than 10 seconds.

REQ-SW-106: The QL display for the SED observing mode shall display an image corresponding to the ratio of the integrated intensity between the two bands, or the slope of the continuum within a single band.

REQ-SW-007: The QL display for the Spectral Line observing mode shall display spectra from a single pixel or an average of a group of pixels, along with statistics of the spectral S/N.

12.1.2. Compatibility

REQ-SW-001: FTS-2 shall be a "conforming" instrument; it shall use DRAMA and conform to JCMT software and control system standards.

REQ-SW-002: FTS-2 shall use the standard JCMT operator workstation interface, connected to a DRAMA-based system for instrument control and communication.

REQ-SW-003: The interface between the FTS-2 instrument and the JCMT system shall conform to the JCMT software standards. (eg JAC System Note 44.0)

REQ-SW-004: The FTS-2 shall communicate with the Observatory Control System (OCS) according to the FTS-2 to OCS ICD document (SC2/FTS/SOF/002).

12.1.3. Engineering Interface

REQ-SW-005: The FTS-2 system shall include a means to command and control all mechanisms without having JCMT control systems (OCS, RTS) present and connected.

REQ-SW-006: The FTS-2 Engineering Interface shall be capable of commanding and controlling all FTS-2 mechanisms and reading the status of all FTS-2 sensors and encoders

12.1.4. Mechanism Control

REQ-SW-007: All FTS-2 mechanisms and controlled features shall be controlled through the standard DRAMA control path from the instrument Control System (see section 7).

12.2. Software Performance Requirements

12.2.1. Configuration Time

REQ-SW-008: The software system overhead shall not cause the total system configuration time to be longer than that specified in **REQ-MEC-015.**

12.2.2. Impact on Mechanism Accuracy

REQ-SW-009: The control accuracy of the FTS-2 mechanisms shall not be limited by the performance of the software system.

12.3. Testability

REQ-SW-010: The FTS-2 control software shall provide a small set of commands to test the basic functionality of the system (REQ-OPE-003). Performance of the DR software shall be testable using data acquired using the control software.

13. Other Requirements

13.1. Documentation

REQ-DOC-001: FTS-2 shall be delivered with adequate documentation to facilitate the operation, maintenance and repair of the instrument.

13.1.1. Users Manual

REQ-DOC-002: The Users Manual shall be written to enable a new user of FTS-2 to easily understand the operation of the instrument.

The User's Manual shall contain all information necessary to enable a user who is familiar with the JCMT telescope, but not necessarily familiar with the instrument, to understand the operation of the instrument. The User's Manual will include, but not be limited to, the following areas:

(1) the instrument performance characteristics;
(2) the instrument design and configuration;
(3) modes of operation; and
(4) calibration procedures.

13.1.2. Service and Calibration Manual

REQ-DOC-003: A manual shall be written to enable JCMT technical support personnel to maintain FTS-2. This manual shall include documentation to describe the observations required to allow calibration of FTS-2 data.

The Service and Calibration Manual shall include assembly and disassembly procedures, wiring diagrams, inspection procedures, performance curves, and similar applicable information as necessary to guide service and maintenance of the instrument. Mechanisms requiring calibration or lookup tables will have standard calibration procedures included in the Service and Calibration Manual. Previous histories or results will be included in the Service and Calibration Manual as an indicator of normal operating parameters and as a diagnostic tool. The Service and Calibration Manual shall include all test data pertaining to the system's optical components.

13.1.3. Software Maintenance Manual

REQ-DOC-004: A Software Maintenance manual shall be provided to enable JCMT software maintenance staff to maintain the FTS-2 software.

The Software Maintenance Manual shall describe the software at a level of detail that a programmer familiar with the JCMT software environment, but not initially familiar with the software, can maintain it properly. The manual shall include detailed written descriptions of all software systems and subsystems at a high level, describing purpose, organization, and interaction with other software systems and subsystems. The manual

shall include any systems analyses, data flow diagrams, data dictionaries, structure charts, and specifications developed during the software design process, updated to reflect as-built condition. The manual shall also include listings of all software delivered as part of the system, including firmware, etc. All software source code modules shall include a standard header documenting the module contents, and each module shall contain a sufficient number and quality of comments explaining the purpose and function of each few lines of code so that a programmer unfamiliar with the software can understand it. Any systems engineering analyses that led to the allocation of functions between hardware and software or the software design used shall be included.

13.1.4. As-Built Drawings

REQ-DOC-005: The as-built drawings shall show all dimensions in millimetres, down to 0.01 mm. All fasteners specified in these drawings will be standard metric sizes. All drawings shall otherwise be to RSAA standards used in instruments of similar size, function, and complexity.

13.1.5. Drawing Standards

REQ-DOC-006: All drawings shall comply with Canadian Standard AS1100 (TBD) or a JCMT approved standard.

13.1.6. Drawing Numbering System

REQ-DOC-007: All drawings shall be numbered (TBD) in accordance with JCMT instructions.

13.1.7. Drawing Filing System

REQ-DOC-008: Drawings shall be maintained in electronic format. Final drawings shall be provided in AutoCAD format and converted to PDF format on CDROM. Paper based printouts will be produced when necessary. A database of drawings shall be maintained in Microsoft Access format.

- Final released drawings will be maintained by JCMT.
- The software applications needed to access or read the electronic versions includes:
  - AutoCAD R2000i
  - Mechanical Desktop V5
  - Protel 99SE

13.2. Training

REQ-DOC-009: The FTS-2 development team shall provide training documentation and a training course to JCMT operations personnel on the operation, maintenance, and repair of FTS-2.

13.3. Reliability

13.3.1. Downtime

REQ-FPR-001: FTS-2 shall have a downtime of < 2% scheduled time on the telescope and where possible, component failure shall result in gradual performance degradation.

13.3.2. Spares

REQ-FPR-002: Single point failures that may result in significant downtime shall be determined and, where necessary, critical spares shall be identified.

A list of recommended spares with sources and prices shall be provided.

13.3.3. Continuous Duty

REQ-FPR-003: FTS-2 shall be designed and built for continuous operation. Modules containing moving parts shall be designed or selected to meet requirement **REQ-FPR-001** assuming continuous operation.

13.4. Maintenance and Serviceability

13.4.1. Standard Components

REQ-FPR-004: Wherever possible, FTS-2 will use unmodified commercially available standard components.

13.4.2. Modularity

REQ-FPR-005: To the extent possible, FTS-2 shall be designed to be modular.

13.4.3. Access

REQ-FPR-006: Access to components and subassemblies shall be considered in the FTS-2 design, particularly for those elements that are accessed frequently. Tool and hand clearances shall be considered, as well as space required to remove modules, visual access to components (or a means to feel their correct position and alignment, e.g., for electronic connectors).

13.4.4. Alignment

REQ-FPR-007: Alignment of optical components shall be achieved to the greatest extent possible by accurate machining of locating fixtures.

This can be achieved by machining captive thick shims to achieve the assembled tolerances, but the intention is to avoid an involved re-alignment procedure on assembly or re-assembly.

13.4.5. Relative Equipment Arrangements

REQ-FPR-008: Equipment shall be located with due consideration of the sequence of operations involved in maintenance procedures. To the greatest extent possible, the most accessible locations shall be reserved for the items requiring most frequent access.

13.4.6. Subassemblies

REQ-FPR-009: Subassemblies of the equipment that require more frequent service (inspection, adjustment, repair, or replacement) shall be configured as plug-in modules or, if in racks, as drawers that can be withdrawn easily.

13.4.7. Handling

REQ-FPR-010: Modules greater than 5 kg in mass shall have suitable handles for use in removing, replacing, and carrying them. Handles shall be located such that the vector sum of resultant handling forces shall pass close to the centre of gravity of the unit.

13.4.8. Ease of Inspection for Electronics

REQ-FPR-011: Multilayer electronic boards shall not be used unless they are replaceable as a module. Backplane interconnections between custom boards are discouraged.

13.5. Lifetime

REQ-FPR-012: FTS-2 shall be designed for an operational lifetime of 3 years without a major overhaul. Components likely to affect the lifetime requirement shall be identified.

13.6. Materials

13.6.1. Toxic Products and Formulations

REQ-FPR-013: No toxic products and formulations shall be used for the development, construction, and maintenance of FTS-2.

13.7. Magnetic Field

13.7.1. Magnetic Field Generation

REQ-FPR-014: The magnetic field due to FTS-2 shall not be greater than ambient levels at the outside of the SCUBA-2 cryostat.

13.8. Electromagnetic Radiation

13.8.1. Electromagnetic Radiation Generation

REQ-FPR-015: EMR generated by FTS-2 shall not negatively affect the performance of other SCUBA-2 or JCMT systems when they are in operation.

13.8.2. Susceptibility to Electromagnetic Radiation

REQ-FPR-016: FTS-2 performance shall not be compromised by the existing electromagnetic radiation of its operating environment.

13.9. Workmanship

REQ-FPR-017: Standard workshop practices shall apply to workmanship in development and construction.

13.10. Safety

REQ-FPR-018: Normal considerations, including compliance with applicable regulations, shall apply in the areas of mechanical, electrical, and electrostatic safety.

13.11. Human Engineering

REQ-FPR-019: Human engineering considerations shall apply especially with respect to handling of system items required in readying FTS-2 for use on the telescope and its removal after use, and in the design of the user interfaces.