6 Flight operations

6.1 Operating Modes

6.1.1 Basic operating modes

SPIRE will have 7 (TBC) basic operating modes, as described below.

Observe: The spacecraft will be pointing in a specific direction or, for scan mapping, will be moving slowly over a given region of the sky. The instrument will take scientifically meaningful data and use the full telemetry bandwidth. It is assumed that any calibrations required will also be done in the observe mode (TBC). There will be 6 (TBC) sub-modes of the basic observe (see below). Raster maps will be carried out by concatenating identical observations at a grid of spacecraft pointing positions.

1. **Standby:** The spacecraft may be pointed in an arbitrary direction (observing with another instrument for instance). The instrument will transmit only housekeeping information, and perhaps some limited science data (see below), at a rate very much lower than the full telemetry bandwidth.

2. **Real time commanding:** During ground contact it may be necessary to command the instrument in real time and analyse the resultant data on the ground in near real time for instrument testing and debugging purposes. In this case the full telemetry bandwidth will be required for the duration of the instrument test in question. It is not anticipated that this will occur frequently.

3. **Commissioning/calibration mode:** During the commissioning and performance verification phases of mission operations, many housekeeping and other health check parameters will be unknown or subject to revision. This mode allows the limits on selected health check parameters to be ignored by whatever real time monitoring systems are in place on the spacecraft/instrument.

4. **Cooler recycle:** The baseline ^{3}He cooler will require recycling 46 hours after the previous re-cycle. During re-cycling, the instrument will be switched off except for vital housekeeping information (e.g., on cooler parameters). The recycling takes 2 hours to complete with some additional settling time before instrument operations can recommence. During cooler recycling the heat load onto the helium bath is estimated as 20 mW.

5. **On:** In this mode, the DPU shall be switched on and be able receive and interpret instrument commands; by default, all other subsystems shall be switched off but for engineering purposes it will be possible to command the instrument to switch them on from this mode. Full housekeeping data and some science data will be telemetered.

6. **Off:** All instrument sub-systems will be switched off, including the DPU and there will be no instrument telemetry.

The *Observe* mode will have the following sub-modes.

Obs. 1. Photometer chop: The focal plane chopper is used to switch between two separate positions on the sky with the spacecraft pointed at a fixed position, thus modulating the signal on the detectors. The full telemetry bandwidth will be required. To maintain the absolute calibration of the instrument, periodic calibrations will be done during observations of this type by switching on the photometer’s on-board calibration source. It is assumed that these calibrations will have no impact on spacecraft operations (TBC).

Obs. 2. Photometer scan: This is an alternative method of mapping an area of sky larger than the instantaneous field of view of the instrument. The spacecraft will slew across a given area.

In this way sky signals will be modulated by movement across the beam patterns of the array pixels. The focal plane chopper may also be used to switch to another portion of the sky in a direction orthogonal to the direction of slew. The speed of slew will be no more than 50 arcsec./second and may be in an arbitrary direction with respect to the spacecraft axes. The full telemetry bandwidth will be required.

Obs. 3. Photometer partner mode: This mode allows for the possibility that the PHOC and SPIRE instruments may sometimes be used to make simultaneous observations of the same portion of the sky. In this case a reduced telemetry rate will be available to each instrument. In the case of SPIRE this will mean that either the data will have a reduced angular resolution or that additional on-board data processing will be required. The feasibility and scientific utility of this mode depend on the detailed design, on-board data processing and telemetry requirements of the two instruments and require further study.

Obs. 4. Photometer serendipity mode: During spacecraft slews, scientifically useful information can be obtained without the necessity of using the focal plane chopper - essentially these will be rapid scan maps. It is assumed that at least half the bandwidth will be available to SPIRE (PHOC may have a similar mode) and that this will be filled with science data from the photometer arrays only. The chopper and spectrometer mechanisms will be switched off in this mode. Accurate pointing information will be required from the AOCS to reconstruct the slew path in the data analysis on the ground.

Obs. 5. Photometer parallel mode: When observations are being made with another instrument, that are not partner observations, then scientifically useful data may be obtainable from the photometer, albeit with degraded scientific performance. In this mode a science data packet will be telemetered alongside the standard housekeeping data. The chopper and spectrometer mechanisms will be switched off in this mode.

It is assumed that this will be the default standby mode for SPIRE.

Obs. 6. FTS operation: In this mode the spectrometer mirrors will be scanned back and forth over the appropriate distance (which will depend on the required spectral resolution). The spacecraft will be pointed at a fixed position and the focal plane chopper will not be switched on. The spectral calibrator will be on during all spectrometer operations. The full telemetry bandwidth will be required.

6.2 Backup option observing modes

If SPIRE uses the backup detector option of individual spider web bolometers and feed-horns which under-sample the image in the focal plane, different observing modes will be necessary for the spectrometer and photometer. These are:

Photometer peak up: For observations of known sources, if the absolute pointing error of the spacecraft does not allow instantaneous acquisition of a given target to within 2-3 arcsec., or if the co-ordinates of the source are not known to this accuracy, then a peak up procedure will be available. This will use the *photometer chop* mode (see above) to identify the position of a source by executing a small cross raster across the pointing given by the spacecraft. If this mode is required it will involve on-board signal processing by SPIRE to determine the required corrections to the pointing and the ability to communicate the calculated offset to the AOCS independently of ground communication.

Jiggle-photometry: In this case, as well as chopping in a fixed direction, the internal chopper unit will move the field-of-view in small steps (nominally 9”) in two directions in order to allow the field-of-view to be fully-sampled. To obtain a fully sampled image in all three bands at the same time, a 64-point jiggle map would be required for $2F\lambda$ pixels and a 16-point map would be required for $1F\lambda$ pixels.

Jiggle-spectral-imaging: In order to make a fully-sampled spectral map, spectral scans would be made at multiple fixed positions of the chopping mirror. This mode of operation is more complex than would be the case with a focal plane array that fully samples the field of view.

6.3 Instrument commanding

6.3.1 High-level commands

The only high-level commanding required from the spacecraft to the instrument is to switch on or off the DC power line to the DPU. All other instrument power lines will be derived from the DC/DC converters within the instrument DPU. All instrument sub-system functions will be controlled via commands sent to the instrument DPU.

6.3.2 Instrument on-board software

A general description on the instrument on-board software is given in section 2.

6.3.3 Instrument command scripts

For in-flight operations a script language consisting of mnemonics plus parameters will be developed to allow the instrument controllers to command the instrument in a straight forward manner. This language will allow simple programme control (do loops, if statements, etc.), Boolean algebra and floating point and integer arithmetic. The scripts will then be passed through a translation stage that will check for anomalous instrument operations and convert the mnemonics, parameters etc. into command sequences for subsequent uplink to the instrument.

It is anticipated that the same script language will be employed for ground testing, commissioning phase, performance verification and AOTs. For AOT generation, software will be written that allows the observer to input astronomically meaningful data into an ASCII file or database table that is then converted into an instrument command language script.

6.4 General requirements from the spacecraft

In addition to the requirements listed in section 2, the following general requirements are requested for SPIRE from the FIRST spacecraft:

1. Some of the operating modes require on-board data-processing and integration using the instrument's own on-board processing capabilities and mass memory. It is required that, although the average data rate from the instrument to the spacecraft on-board data storage does not rise above that permitted by the downlink bandwidth, data can be transferred between the instrument and spacecraft mass memories at a higher rate than permitted by the downlink bandwidth over a short period of time. This will allow the instrument to make full use of the downlink bandwidth whilst reducing the total amount of data to be telemetered to the ground.

2. The instrument health check parameters must be monitored in near real time by the spacecraft on-board control system. If any critical health check parameter goes out of limits the spacecraft must have the ability to react and take the appropriate action - including switching the instrument off.

3. There will be other health check parameters (e.g., the supply current to the instrument) that can only be monitored by the spacecraft systems. It is assumed that these will be monitored by the spacecraft systems and appropriate action will be taken in the event of any anomaly occurring.

4. Any instrument on-board software ram patches are required to be held in the spacecraft mass memory. This will greatly speed up the activation of the instrument following a switch off.

5. A special instrument data packet is required for passing data to the spacecraft systems. More specifically, the peak up mode will need to pass data to the AOCS for pointing correction - a specialised data packet that can be requested by the spacecraft on-board software must be defined.

6. The heterodyne instrument local oscillators will be switched off during all periods when the bolometer instrument is in any *observe* sub-mode (including during slews).

6.5 Data packet types

Three (TBC) basic data packet types have been identified for the bolometer instrument downlink telemetry.

1. **Science packet:** This contains all types of science data from the observe and commissioning and verification modes. This packet will be always be produced when the instrument is in any *observe* sub-mode (this includes *Standby* as parallel and serendipity data will still be taken whenever the instrument is not actually making a pointed observation).

2. **Housekeeping packet:** This contains all types of housekeeping and health check data. This packet is always produced when the instrument is on (this includes *On* mode as some housekeeping and health check parameters may be valid for this mode).

3. **Event packet:** This contains a history of instrument command events and anomalies. It will be used on the ground as a quick check of the instrument behaviour before further data analysis proceeds.

It is anticipated that there will be sub-types of these packets to handle photometer data, spectrometer data, full housekeeping, essential housekeeping, and so on. The detailed definition of the telemetry packets will proceed alongside the instrument development.