SPIRE

SUBJECT: **Operating the SPIRE Instrument**

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Acronyms

BSM   Beam Steering Mirror
DCU   Detector Control Unit
DPU   Digital Processing Unit
DRCU   Detector Readout and Control Unit
FTS   Fourier Transform Spectrometer
HK   Housekeeping
MCU   Mechanism Control Unit
OBS   On-Board Software
POF   Photometer Observatory Function
S/C   Spacecraft
SCU   Sub-system Control Unit
SMEC   Spectrometer Mechanism
SOF   Spectrometer Observatory Function
SPIRE   Spectral and Photometric Imaging Receiver

References

Applicable Documents

AD-1   Operating Modes for the SPIRE Instrument (SPIRE-RAL-DOC-000320)
AD-2   FIRST/Planck Packet Structure Interface Control Document (SCI-PT-IF-07527)
AD-3   FIRST/Planck Instrument Interface Document - IID Part A (SCI-PT-IIDA-04624 - Issue 1/0, 01/9/2000)

Reference Documents

RD-1   DPU Interface Control Document (SPIRE-IFS-PRJ-000650 - Issue 1.0, 2/4/2001)
RD-2   MCU Design Description (LAM/ELE/SPI/000619)
RD-3   SPIRE Design Description (SPIRE-RAL-PRJ-000620, Issue 0.1, 12/4/2001)
RD-4   SPIRE Data ICD (SPIRE-RAL-DOC-????)

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1. INTRODUCTION

The document "Operating Modes for the SPIRE Instrument" [AD-1] describes the instrument operating modes required to implement the types of observations for realising the science objectives of SPIRE.

The purpose of this document is to provide a description of the set of instrument commands that shall be executed by the On-board Software (OBS) in order to carry out science observations with SPIRE. A typical science observation with SPIRE will consist of a number of Observatory Functions executed sequentially. An Observatory Function itself consists of Instrument Functions, Data Configurations and S/C functions. The components of an Observatory Function will finally be expanded into individual instrument level commands which the OBS interprets and which may lead to commands being sent to the DRCU sub-units (viz. DCU, MCU and SCU).

This document also describes the types of science telemetry that needs to be generated in various operating modes. The actual structure and contents of the SPIRE telemetry packets are covered in [RD-4].

1.1 Scope

The current document only discusses those instrument commands required for implementation of the Observatory Functions as described in [AD-1]. Future versions will describe the complete set of instrument commands. It has been found that the implementation of these commands may place requirements on the DRCU-DPU interface and so this preliminary version of the document is issued in order to ensure that these requirements are considered.

In this document the elaboration of Observatory Functions [AD-1] is confined to just the Instrument Functions and Data Configurations. The Spacecraft Functions necessary for the definition and execution of these Observatory Functions are not discussed here and it is assumed that they will be implemented as described in the Annexe "FIRST Pointing Modes" of [AD-3].

1.2 Assumptions

For photometry observations all chop-throws will be performed in the Y direction. We assume that it will not be possible to change the orientation of the S/C arbitrarily to allow observers to specify their own chop positions on the sky (e.g. in terms of RA and Dec).

At present there are no anomaly actions defined for the failure of an Observatory Function.

It is further assumed that the execution of OBS commands will be independent of spacecraft triggers.

2. OBSERVATORY FUNCTIONS

2.1 Nomenclature

- An astronomical observation with SPIRE will consist of a sequence of Observatory Functions.

- An Observatory Function is expected to consist of a number of tasks involving putting the instrument into a specific operating mode, setting the sub-system hardware and data configurations and then finally carrying out the Instrument Functions to make a measurement and take data.

- The structure of an Observatory Function is illustrated schematically in Figure 1, with the sequence of steps running from top to bottom. Each rectangular block in the diagram represents a specific task that has to be performed in the execution.

- Each indicated Observatory Function task includes sending commands to the DRCU. These commands are prefixed by the name of the DRCU sub-unit to indicate their destination as shown in these two examples:

  1. DCU_photo_heater_pwr is a command for the DCU.
  2. MCU_Start_SMEC is a command for the MCU.
  3. DRCU_Sync_Time is a command for the DRCU.

  The sub-unit commands listed here have been take from [RD-1] where possible. It is important to note that not all commands have been documented in [RD-1]. They are however needed ASAP to complete this document.

- Parameters which the DPU needs to set are prefixed with the letters 'DPU'. DPU_SAMPLE_COUNT, for example, would be used by the OBS to tag sample numbers to detector data as received from the DCU.

2.2 Structure of an Observatory Function

A brief explanation of all the constituent steps of an Observatory Function, as shown in Figure 1, is now given.

2.2.1 INST_STBY

This is the assumed state of the sub-instrument at the start of an Observatory Function. For observations with the photometer SPIRE will start and end in the PHOT_STBY state whilst for FTS observations it will start and end in the SPEC_STBY state. There will also be the generic STBY state from which the instrument will switch to either PHOT_STBY or SPEC_STBY *before* the start of an Observatory Function. In order to maximise observation efficiency and to minimise unnecessary switching of instrument states it is desirable to group together observations according to sub-instrument in use, i.e. photometer or FTS.

2.2.2 Sub-system Data Configuration (SDC1)

This task is designed to select the housekeeping parameters and their sampling for the next step in the sequence of the Observatory Function. It should enable us to sample, for example, a particular parameter at a high rate such that we can effectively monitor the progress of the next step.

2.2.3 Sub-system Hardware Configuration (SHC1)

This task essentially involves the switching-on of power to mechanisms and configuring the instrument for the observing mode. Steps 2 and 3 may be repeated as required but each time a different SDC and SHC will be set. During the execution of an Observatory Function the instrument remains in this selected configuration until explicitly changed.

2.2.4 Measurement Data Configuration (MDC)

Sets up the data configuration of the instrument for the measurement part of the Observatory Function, e.g. photometer chopping, FTS scanning, calibrating etc. The sampling of the detectors, BSM and FTS mirror positions are all expected to be set here.

2.2.5 Instrument Operation Actions (IOA)

This task covers the instrument actions that have to be performed to carry out the measurement part of the Observatory Function, e.g. photometer chopping, FTS scanning, calibrating etc. Steps 4 and 5 may be repeated a number of times.

2.2.6 Sub-system Data Configuration (SDC2)

Sets up the configuration of the instrument prior to the switching off of mechanisms. The sampling rates of the detectors and the position of a mechanism can be selected here. It should enable us to sample, for example, a particular parameter at a high rate such that we can effectively monitor the progress of the next step.

2.2.7 Sub-system Hardware Configuration (SHC2)

This task involves configuring the instrument for the end of an Observatory Function. The switching-off of power to the mechanisms also happens here. Steps 6 and 7 may be repeated as required but each time a different SDC and SHC will be set.

2.2.8 Instrument Data Configuration (IDC)

Puts the instrument in a data configuration appropriate for the STBY mode of the sub-instrument.

2.2.9 INST_STBY

The instrument is in the sub-instrument STBY state of the Observatory Function.

2.2.10 Other Tasks

During the execution of an observatory function there will be a number of other tasks which will be active throughout. These are also shown in Figure 1 and include:

- Active cooler control
- Periodic HK generation
- Monitoring of parameters
- Memory checking
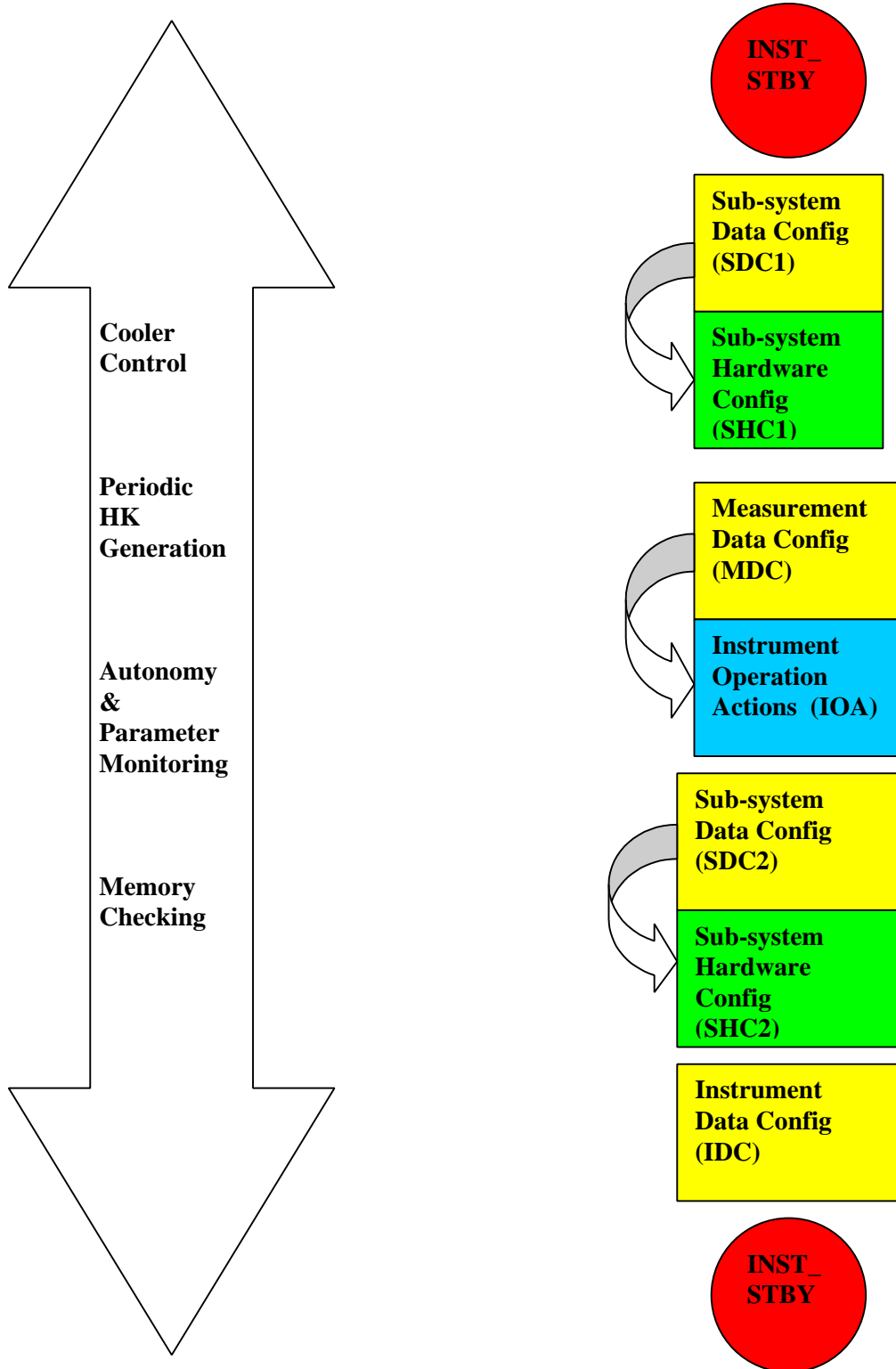
Figure 1: Structure of a SPIRE Observatory Function. The execution flow is from top to bottom.

3. PHOTOMETER OPERATIONS

3.1 PHOT_STBY

As already described in section 2, for all photometer operations the instrument is expected to be in the PHOT_STBY state. A possible scenario for switching from the generic STBY state to PHOT_STBY state is as follows. The order in which these commands appear may have to rearranged depending on how the various sub-units in DRCU and the hardware operate:

1. Switch on the photometer detector arrays

   - It is not clear to me whether there is an explicit DCU command to do this - or are the detector arrays switched on by a subset of the commands listed below?
   - Is it possible to switch on just one array or do they all have to be switched on at the same time?

1. Switch on the photometer heater power
   DCU_Set_photo_heater_pwr (On)

2. Set the bias amplitudes and bias frequencies for the detectors

   For i=0, 3 DCU_Set_photo_bias_ampl(i, PTable_bampl(i))
   where i is the Channel ID and PTable_bampl(i) is the bias amplitude (0 to 255).

   - Where are values for PTable_bampl to be stored? Presumably somewhere in the DPU. How are they to be overridden?
   - Why does i go from 0 to 3? Should it be from 0 to 2 for the three arrays?

   DCU_Set_photo_bias_freq(frequency divider)
   where frequency divider is in the range 64 to 511.

   - Is it the same frequency for all detectors?

3. Set the offsets on the detectors

   For i=0, 287 DCU_Set_photo_offset(i,PTable_offset(i))

   - Where are values for PTable_offset to be stored? How can they overridden?
   - Why does the loop counter not go to 269? There are 270 detectors in all.

4. Wait for detector temperatures to stabilise

   DPU_Wait(N_Phot_Det)
   where N_Phot_Det is the number of seconds the DPU waits before issuing further commands to the DCU.

   - How is N_Phot_Det to be determined and how is it stored?
   - Is there a table of such wait times depending on the detector settings?

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5. Set the JFET power levels and voltages

    DCU_Set_photo_JFET_pwr(On)

    - What are the exact arguments for setting the power to the JFETs?

    For i=0,11 DCU_photo_JFET_Vss(i,PTable_VJFET(i))
    where PTable_VJFET can take any value between 0 to 255.

    - Where are values for PTable_VJFET to be stored? Presumably in the DPU. How can they be overridden?

6. Wait for some TBS time to allow the JFETs to stabilise

    DPU_Wait(N_Phot_JFET)
    where N_Phot_JFET is the number of seconds the DPU waits before issuing commands to the DCU.

    - How is N_Phot_JFET to be determined and how is it stored?
    - Will there be table/s of such wait times depending on the JFET settings?

3.2 POF1: Chop Without Jiggling

This Observatory Function, which is the simplest one for the photometer, is expected to become a key component of other Photometer Observatory Functions to be discussed later in this document. The high level tasks for POF1 are as follows:

SDC1_POF1: Set the sub-system data configuration of the instrument before switching on any mechanisms.

1. Set sampling rates for HK and science parameters to be sampled

    What else needs to go here?

SHC1_POF1: Switch on and configure the mechanisms.

1. Switch on the BSM
    What are the MCU commands to do this?

2. Wait for TBS time to allow the BSM to stabilise
    DPU_Wait?

3. Move the BSM to its "rest" position (Y_0,Z_0) using both chop (Y) and jiggle (Z) axes, as necessary.

- Can the MCU accept commands like these?
  $MCU\_Set(Chop,Posn,Y_0)$
  $MCU\_Set(Jiggle,Posn,Z_0)$

MDC_POF1: Set data configuration of the instrument prior to carrying out the scientific part of POF1.

1. Select readout mode for photometer arrays (Frame structure type T1/T2 for subset/full array)

   Are these commands feasible?
   - DCU_Set_frame_type(T1) - for subset
   - DCU_Set_frame_type(T2) - for full array

2. Set the readout rate for photometer arrays

   $DCU\_Set\_multiple\_frames(N,N_d)$ - where N is the number of frames and N_d is the frame rate divider.
   > N = 0 for continuous or 1-255
   > N_d = 1-255

3. Set the data mode

   DCU_Set_data_mode(Mode)
   > Mode = 0-9.
   > For the photometer:

Mode	Data
1	Photometer offset - What is this for?
3	Photometer Bolo - All arrays for the photometer?
5	Photometer array (PLW)
6	Photometer array (PMW)
7	Photometer array (PSW)

4. Set sampling rates for HK and science parameters to be sampled

5. Reset counters for the detector sample number and the chop number

   - DPU_Det_Sample_Count = 0
   - DPU_Chop_Count = 0

IOA_POF1: Start chopping between current position (Y_1,Z_1) and desired position (Y_2,Z_2) at frequency f for N chop cycles taking detector and BSM data.

1. Synchronise time between subsystems

   DRCU_Sync_Time(   )

   - What are the arguments of this command?

2. Move BSM to commanded central position (Y_1,Z_1) - such that the source falls on the three co-aligned detectors.
   Presumably there will be position tables on-board which the OBS will use in determining the path the BMS takes in reaching the requested position?

3. Ask the DCU for m detector samples for the first-half (on source) of a chop cycle.
   How is this done?

4. Ask the MCU for n BSM position samples for the first-half (on source) of a chop cycle.
   How is this done? It is assumed that the detector sampling and the chop position sampling will be done asynchronously.

5. Move the BSM to commanded offset position (Y_2,Z_2).
   Presumably there will be position tables on-board which the OBS will use in determining the path the BMS takes in reaching the requested position?

6. Ask the DCU for m detector samples for the second-half (on source) of a chop cycle.

7. Ask the MCU for n BSM position samples for the second-half (on source) of a chop cycle.

8. Increment chop count: DPU_Chop_Count = DPU_Chop_Count + 1

9. Zero the detector sample counter: DPU_Det_Sample_Count = 0

10. Repeat steps 2-10 for N chop cycles

11. Move the BSM to its rest position

NOTES:
- This task includes sending commands to the DCU and to the MCU to start taking detector data and recording BSM position sensor data respectively.
- The OBS has to keep track of the chop position samples and the detector samples and associate them with the chop count within POF1.
- The data and hardware configuration of the instrument must not change during the execution of this POF. Any internal photometric calibration will be performed using POF8 as described later in this document.

SDC2_POF1: Set data configuration of the instrument before switching off any mechanisms.

1. Set the data mode as appropriate using the command DCU_Set_data_mode
2. Set sampling rates for HK and science parameters to be sampled

SHC2_POF1: Switch off and configure the mechanisms.

1. Move the BSM back to its "rest" position (Y_0,Z_0) using both chop (Y) and jiggle (Z) axes, as necessary.

Can the MCU accept commands like these?

- MCU_Set(Chop,Posn,Y_0)
- MCU_Set(Jiggle,Posn,Z_0)

2. Switch off the BSM
   How is this done?

3. Wait for TBS time to allow the BSM to stabilise.
   DPU_Wait?

IDC_POF1: Set data configuration of the instrument prior to putting the instrument in PHOT_STBY mode.

1. Set the data mode as appropriate using command DCU_Set_data_mode
2. Set sampling rates for HK and science parameters to be sampled
6. Reset counters for the detector sample number and the chop number

- DPU_Det_Sample_Count = 0
- DPU_Chop_Count = 0

3.3 POF2: Seven-Point Jiggle Map

In principle this POF should simply consist of POF1 being executed at each of the seven jiggle positions. The general sequence of steps, which is still to be elaborated, is as follows:

1. Synchronise time between subsystems
2. Execute POF8 (photometer internal calibrator) as necessary
3. Execute POF1
4. Execute POF8 (photometer internal calibrator) as necessary
5. Increment jiggle position number
6. Repeat steps 2-5 for all seven jiggle positions
7. Execute POF 8 (photometer internal calibrator) as necessary

- Will the number of chop cycles be the same at each jiggle position? If so, will it always be the case?
- The OBS has to keep track of the seven jiggle positions.
- Is it necessary for the photometer internal calibrator to be flashed for each jiggle position? [AD-1] states that POF8 will be executed at an interval of an hour or more.

3.4 POF3: n-Point Jiggle Map

In principle this POF is also very similar to POF1 being executed at each of the n jiggle positions. The general sequence of steps, which is still to be elaborated, is as follows:

1. Synchronise time between subsystems
2. Execute POF8 (photometer internal calibrator) as necessary
3. Execute POF1
4. Execute POF8 (photometer internal calibrator) as necessary
5. Increment jiggle position number

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6. Repeat steps 2-5 for all n jiggle positions
7. Execute POF 8 (photometer internal calibrator) as necessary

- Will the number of chop cycles be the same at each jiggle position? If so, will it always be the case?
- The OBS has to keep track of all n jiggle positions.
- Is it necessary for the photometer internal calibrator to be flashed for each jiggle position? [AD-1] states that POF8 will be executed at an interval of an hour or more.

3.5 POF4: Raster Map

A raster map is simply a rectangular grid of several n-Point Jiggle Maps (POF3) interleaved with photometer internal calibrator flashes.

1. Synchronise time between subsystems
2. Execute POF8 (photometer internal calibrator) as necessary
3. Execute POF3
4. Execute POF8 (photometer internal calibrator) as necessary
5. Increment raster position sample
6. Repeat steps 2-5 for all raster positions
7. Execute POF 8 (photometer internal calibrator) as necessary

- The OBS has to keep track of all raster positions.
- Is it necessary for the photometer internal calibrator to be flashed for each raster point? [AD-1] states that POF8 will be executed at an interval of an hour or more.

3.6 POF5: Scan Map Without Chopping

A scan map without chopping is a continuous map of a region of the sky over a number of lines on the sky interleaved with photometer internal calibrator flashes.

1. Synchronise time between subsystems
2. Move the BSM to its "rest" position using both chop (Y) and jiggle (Z) axes, as necessary
3. Execute POF8 (photometer internal calibrator) as necessary
4. Ask the DCU for m detector samples
5. Increment line scan number
6. Repeat steps 3-5 for lines in the scan map
7. Execute POF8 (photometer internal calibrator) as necessary

- The OBS has to keep track of the line scan count.
- The BSM needs to be commanded to the nominal "rest" position even for this POF because there needs to be active control over its position in case it starts to drift.
- It is assumed that the photometer internal calibrator will be flashed for each line scan. [AD-1] states that POF8 will be executed at an interval of an hour or more.

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3.7 POF6: Scan Map With Chopping

A scan map with chopping is a continuous map of a region of the sky over a number of lines on the sky interleaved with photometer internal calibrator flashes. This POF is similar to POF1. The BSM is used to chop in the Y direction, which may not necessarily be in the direction perpendicular to the scan.

1. Synchronise time between subsystems
2. Execute POF8 (photometer internal calibrator) as necessary
3. Execute POF1
4. Increment line scan number
5. Repeat steps 2-4 for all lines in the scan map
6. Execute POF8 (photometer internal calibrator) as necessary

- The OBS has to keep track of the line scan count.
- It is assumed that the photometer internal calibrator will be flashed for each line scan. [AD-1] states that POF8 will be executed at an interval of an hour or more.

3.8 POF7: Photometer Peak-Up

TBW

3.9 POF8: Photometer Calibrate

A photometer calibration takes place with the BSM switched off so that the only modulation of the detectors is as a consequence of the Photometer Calibrator (PCAL).

SDC1_POF8: Set measurement configuration of the instrument to prepare it for POF8. It is assumed that the instrument will already be in PHOT_STBY mode with the photometer detector arrays switched on.

1. Set sampling rates for HK and science parameters to be sampled.
2. Reset counters for the detector sample number and PCAL parameters.

SHC1_POF8: Put the instrument in a H/W configuration for PCAL operations.

1. Switch on PCAL subsystem
2. Select excitation sequence for PCAL (e.g. waveform, duration etc)

MDC_POF1:

1. Select power level for PCAL
2. Select sampling of current through PCAL
3. Select sampling of PCAL temperatures
4. Reset counter for PCAL data sample number
5. Select readout modes for photometer arrays (Frame structure type T1/T2 for subset/full array)
6. Set the readout rates for photometer arrays
7. Set the readout rates for the PCAL parameters

IOA_POF8: Start PCAL sequence and collect data.

1. Activate PCAL excitation sequence
2. Ask for m detector samples
3. Ask for n samples of each PCAL parameter (e.g. current, temperature, etc)
4. Wait some TBS time
5. Repeat steps 1-4 as necessary

SDC2_POF8: Set data configuration of the instrument for exiting POF8.

1. Set sampling rates for HK and science parameters to be sampled.
2. Reset counters for the detector sample number and PCAL parameters.

SHC2_POF8: Put the instrument in H/W configuration to stop PCAL operations.

1. Switch off PCAL subsystem.
2. Wait TBS time before resuming operations.

IDC_POF8: Set data configuration to put the instrument back into PHOT_STBY state.

1. Set sampling rates for HK and science parameters to be sampled.

4. SPECTROMETER OPERATIONS

4.1 SPEC_STBY:

2. Switch on the FTS detector arrays

   - It is not clear to me whether there is an explicit DCU command to do this - or are the detector arrays switched on by a subset of the commands listed below?
   - Is it possible to switch on just one array or do they all have to be switched on at the same time?

7. Switch on the FTS heater power
   DCU_Set_spectro_heater_pwr (On)

8. Set the bias amplitudes and bias frequencies for the FTS detectors

   For $i=0$, 1 DCU_Set_spectro_bias_ampl(i, STable_bampl(i))
   where i is the Channel ID and STable_bampl(i) is the bias amplitude (0 to 255).

   - Where are values for STable_bampl to be stored? Presumably somewhere in the DPU. How are they to be overridden?
   - Why does i go from 0 to 3? Should it be from 0 to 2 for the three arrays?

   DCU_Set_spectro_bias_freq(frequency divider)
   where frequency divider is in the range 64 to 511.

   - Is it the same frequency for all detectors?

9. Set the offsets on the detectors

For i=0, 71 DCU_Set_spectro_offset(i,STable_offset(i))

- Where are values for STable_offset to be stored? How can they overridden?
- Why does the loop counter not go to 55? There are 56 detectors in all.

10. Wait for detector temperatures to stabilise

DPU_Wait(N_Spec_Det)
where N_Spec_Det is the number of seconds the DPU waits before issuing further commands to the DCU.

- How is N_Spec_Det to be determined and how is it stored?
- Is there a table of such wait times depending on the detector settings?

11. Set the JFET power levels and voltages

DCU_Set_spectro_JFET_pwr(On)

- What are the exact arguments for setting the power to the JFETs?

For i=0,2 DCU_spectro_JFET_Vss(i,STable_VJFET(i))
where STable_VJFET can take any value between 0 to 255.

- Where are values for STable_VJFET to be stored? Presumably in the DPU. How can they be overridden?

12. Wait for some TBS time to allow the JFETs to stabilise

DPU_Wait(N_Spectro_JFET)
where N_Spectro_JFET is the number of seconds the DPU waits before issuing commands to the DCU.

- How is N_Spectro_JFET to be determined and how is it stored?
- Will there be table/s of such wait times depending on the JFET settings?

13. Switch on the second element of spectrometer calibrator (SCAL), i.e. Large area heated plate.

4.2 SOF1: Spectrum of Point Source

SDC1_SOF1: Set the sub-system data configuration of the instrument before any mechanisms are switched on. It is assumed that the instrument will already be in SPEC_STBY mode with the spectrometer detector arrays switched on.

1. Set sampling rates for HK and science parameters to be sampled

What else needs to go here?

Set the data mode (DCU command Set_data_mode)
1. Set sampling rates for other parameters to be sampled ???

2. Reset counters for the detector sample number

SHC1_SOF1:

1. Switch on the FTS Mechanism (SMEC).
2. Wait for some TBS time to allow the SMEC to stabilise. DPU_Wait?

MDC_SOF1: Set the data configuration for the measurement.

1. Select readout modes for FTS arrays (Frame structure type T1/T2 for subset/full array)
2. Set the readout rates for FTS arrays (DCU_Set_multiple_frames)
3. Set input power level for the second element of the SCAL source (heated plate)
4. Set sampling rate for the SCAL temperature (or does it go in HK?)
5. Set the scan length for the FTS (MCU_Set_scan_length)
6. Set the scan speed of the FTS mirror (MCU_Set_scan_speed)
7. Select the FTS mode of operation (e.g. closed loop; MCU_Set_SMEC_mode)
8. Set sampling rate for the optical path difference (related to the mirror scan speed)
9. Reset counters for FTS scan and detector sample number

IOA_SOF1: Start scanning between positions SX_1 and SX_2 at frequency f for N scans.

1. Synchronise time between subsystems
2. Start the FTS scanning mechanism (SMEC)
3. Start scanning between positions SX1 and SX2
4. Ask the DCU for m detector samples in scan
5. Ask the MCU for n time samples corresponding to the pulses at each sampled position of the mirror
   - Increment counter for each time sample number
   - Increment other counters?
6. Increment scan number
7. Repeat steps 3-6 for all scans

   - The BSM is under active control during the execution of the function.
   - The data configuration of the instrument must not change during the execution of this function.

SDC2_SOF1: Set sub-system data configuration to exit SOF1.

TBW

SHC2_SOF1: Set H/W configuration to exit SOF1.

TBW

IDC_SOF1: Set instrument data configuration for SPEC_STBY.

TBW

NOTE: At present there is no calibration Observatory Function for the FTS in [AD-1].

4.3 SOF2: Fully Sampled Spectral Map

TBW