SUBJECT: SPIRE Calibration Plan

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Glossary

FOV	Field of View
FTS	Fourier Transform Spectrometer
IA	Interactive Analysis
ILT	Instrument Level Testing
PV	Performance Verification
TE	Time Estimator

1. INTRODUCTION

1.1 Scope

The calibration plan outlines all SPIRE calibration tables and it is intended that this document is the only place where the complete list of tables resides. It combines requirements from the time estimator and IA into a single set of requirements tabulated in section 2. Each requirement is then expanded into a description of the tables required, the tests which will give the data to meet this requirement, the observations which are required in flight and how often the file will be generated.

The detailed generation of the tables will be described in either the ground calibration plan, the PV phase plan and/or the routine phase plan as applicable.

1.2 Structure of Document

Section 2 combines the requirements from the time estimator and IA (uplink to be added). Section 3 details each calibration table and section 4 gives the cross-reference between the calibration tables and tests.

1.3 Documents

1.3.1 Applicable Documents

AD1 Calibration Requirements
AD2 IA Calibration Requirements
AD3 Time Estimator Calibration Requirements

1.3.2 Reference Documents

2. Combined Requirements

Identifier	Ref.	Needed	Description
Detector Information			
CALT-D01	IACR-001	Yes	Bad pixel mask for each array, each mask just contains a flag indicating which detector(s) should not be used.
CALT-D02	IACR-002, TECR-004	Yes	NEP for each detector, divided into arrays, may be needed for several bias values and will be needed as a function of both bias and chop frequency
CALT-D03	TECR-005	Yes	Pseudo noise sources
CALT-D04	IACR-023	Yes*	File containing identifier of reference pixel and response (flux) to reference source (probably PCAL) at the reference time. One reference pixel per array. *Will not be needed if we adopt an absolute flat field.
CALT-D05	IACR-028, IACR-029, TECR-006	Yes	Detector responsivity as a function of operating temperature, bias frequency and amplitude
CALT-D06	IACR-015	Yes	A table giving factors to reference the demodulated signal at various frequencies to the signal at the calibrated frequency
CALT-D07	TECR-007, TECR-008, IACR-013	Yes	Detector response temporal drift
CALT-D08	uplink?	Yes	Characterisation of detector response to different PCAL currents
CALT-D09	IACR-014	Possibly	PCAL temporal drift correction
CALT-D10	IACR-009	Possibly	Telescope temperature drift history file
CALT-D11	IACR-027	Yes*	Astronomical conversion factors, one per array *Will not be needed if we fold this is with absolute response correction
CALT-D12	TECR-006, TECR-010, IACR-024	Yes	Detector linearity
Photometer Specific			
CALT-P01	IACR-033	Yes	Photometer spectral response curves
Spectrometer Specific			
CALT-S01	IACR-019	Yes	A lookup table relating detector identifier to the optical encoder and LVDT ZPD position for that detector
CALT-S02	IACR-005	Yes	Lookup table to convert mirror position counter to mechanical position
CALT-S03	IACR-006	Yes	Lookup table to convert LVDT position to mechanical position
CALT-S04	IACR-007, IACR-012	Yes	Lookup table giving mechanical position against OPD, may need this for every detector
CALT-S05	IACR-011, IACR-025	Yes	Apodisation maps for each spectrometer resolution setting.

CALT-S06	TECR-011, uplink?	Yes	Spectral resolution vs scan range
CALT-S07	TECR-011	Possibly	Spectral resolution vs wavelength
CALT-S08	IACR-030	Yes	Spectrometer spectral response, one value in spectral domain per resolution element per resolution mode.
CALT-S09	IACR-032, TE??	Possibly	Spectral response vs SMEC speed
CALT-S10	IACR-031	Possibly	Correction factors for changes in the spectrometer spectral response with time.
CALT-S11	uplink??	Yes	SCAL commanded current vs SCAL temperature
CALT-S12	uplink?	Possibly	Characterisation of detector response to different SCAL combinations
CALT-S13	IACR-020	Yes	SCAL power output spectrum lookup table or model
CALT-S14	IACR-010	Possibly	SCAL temperature drift history file
Spatial Information			
CALT-A01	IACR-036, TECR-003	Yes	PSF associated with each pixel in each array
CALT-A02	IACR-026, IACR-036, TECR-003	Yes	Spectrometer off-axis vignetting and PSF
CALT-A02	TECR-001	Yes	Photometer instrument throughput
CALT-A03	TECR-002	Yes	Spectrometer instrument throughput
CALT-A04	IACR-017	Possibly	Electrical crosstalk table
CALT-A05	IACR-018	Possibly	Optical crosstalk given per pixel pair or as one factor (considering all pairs) per pixel
CALT-A06	IACR-021	Yes	Photometer flat fields, response of each detector referred to one detector in the same array
CALT-A07	IACR-022	Yes	Spectrometer flat field, response of each detector referred to one detector in the same array at a given SMEC position
CALT-A08	TECR-009	Yes	Stability of the flat field
CALT-A09	IACR-008	Yes	Detector spatial offset positions. One set of offsets will be needed for each detector and these will relate that detector's pointing to the spacecraft boresight.
CALT-A10	IACR-003	Possibly	Identifiers for the vignetted pixels
BSM Related Information			
CALT-B01	uplink??	Yes	Commanded ADU vs BSM position, closed loop
CALT-B02	uplink??	Yes	Commanded ADU vs BSM position, open loop
CALT-B03	uplink??	Yes	BSM commanded position vs readout position, closed loop
CALT-B04	uplink??	Yes	BSM commanded position vs readout position, open loop
CALT-B05	IACR-016	Yes	Table relating BSM chop and jiggle positions to position on the detector or position in detector coordinates
CALT-B06	IACR-004	Possibly	BSM vignetted pixel mask
External			
CALT-G01	IACR-034	Possibly	Reference spectra or default colour corrections for a

			given spectral type
CALT-G02	IACR-035	Possibly	Response curves for another photometric system?
CALT-G03	IACR-037	Possibly	Line database, nabbed from elsewhere then converted to IA format.

2.1 Other Instrument Factors Which May Affect Calibration

No specific requirements have been fed into the calibration plan regarding microphonics and out of band radiation rejection. Both of these are defined in the instrument test plans.

3. CALIBRATION TABLES

3.1 Detector Tables

3.1.1 Dead Pixel Mask

ID: CALT-D01
Req Source: IA-BPM
Table Description: 1-D table for each array, the column indicating identifiers of dead pixels. Possible further tables indicating pixels are bad for other reasons.
Measurement description: No dedicated measurement.
Analysis: Lack of signal on any pixel will indicate that it is dead, other indicators such as excessive noise or low responsivity may be used to generate further tables.
Astronomical Source Req: None
Phase:

ILT: No dedicated test
Commissioning Phase: No dedicated observation
PV Phase: No dedicated observation
Routine Phase: No dedicated observation

Definitely needed?: Yes

3.1.2 NEP Tables

ID: CALT-D02
Req Source: IA-NEP, TECR-004
Table Description: Several dimensions of parameter space, i.e. detector ID, bias freq, bias amplitude, and detector temperature will be covered by ILT testing. It is TBD how this will be formatted for IA and the TE.
Measurement description: Time series data will be taken for various detector and instrument configurations.
Analysis: The noise level will be obtained from the power spectra derived from each configuration tested.
Astronomical Source Req: A dark patch of sky with good visibility throughout the mission.
Phase:

ILT: ILT-PERF-DNA, ILT-PERF-DNC
Commissioning Phase: Possibly, may use a subset of configurations
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission with full check, weekly with a subset of configurations.

Definitely needed?: Yes

3.1.3 Pseudo Noise Tables

ID: CALT-D03
Req Source: TECR-005
Table Description: A pseudo noise source is anything that induces an uncontrollable variation of the input flux level. Such sources in SPIRE could be the Beam Steering Mirror and the FTS mirror. These are moving parts and when their motions depart from the nominal ones, they may induce uncontrollable flux variations that add to the noise. This also includes

the impact that uncertainties in the FTS mirror position has on the spectrum reconstruction. Actual tables produced are TBD depending on the source of the extra noise.
Measurement description: To the extent possible the instrument will be blanked off and the noise measured. The BSM and SMEC will then be moved in turn and the noise during movement will be measured. If an excess is found further tests may be derived to characterise it.
Analysis: The noise is measured directly.
Astronomical Source Req: A dark patch of sky with high visibility throughout the mission
Phase:

> *ILT:* ILT-PERF-DMA
> *Commissioning Phase:* Yes, via ILT-PERF-DMA on dark sky background
> *PV Phase:* Possibly, yes if not done in commissioning
> *Routine Phase:* Yes, 3-4 times during the mission on same patch of sky to check for temporal variation.

Definitely needed?: Possibly, depending on results from tests/observations

3.1.4 Detector Response Reference Table

ID: CALT-D04
Req Source: IA-ABR
Table Description: File containing identifier of reference pixel and response (volts) to a reference source (probably PCAL) at the reference time. For the spectrometer this may be referenced to the ZPD position. One reference pixel per array. *Note: This will not be needed if we adopt an absolute flat field. Also, this is may be folded in with the conversion to astronomical units (volts per watt), depending on implementation of removing various temporal and operating dependencies (see following sections).*
Measurement description: Observation of PCAL then known flux source then PCAL again.
Analysis: This file contains the response of the reference pixel to PCAL at the time the absolute flux standard was observed.
Astronomical Source Req: The prime calibrator.
Phase:

> *ILT:* ILT-PERF-CPT
> *Commissioning Phase:* No
> *PV Phase:* Yes, once
> *Routine Phase:* Yes, weekly check on a single pixel plus 3-4 times during the mission over more pixels.

Definitely needed?: Possibly, depending on IA methology adopted

3.1.5 Detector Responsivity Variation with Detector Operation

ID: CALT-D05
Req Source: IA-BTC, IA-RBC, TECR-006
Table Description: Tables will need to be generated of the detector responsivity (V/W) in order to convert to astronomical units. The detector responsivity is dependent on bias, operating temperature, and may be dependent on bias frequency. The exact format of the tables showing these dependencies is still TBD.
Measurement description: Load curves i.e. measurements of a set of known input fluxes on the detectors at various detector settings, in particular various detector bias voltages.
Analysis: ILT-PERF-DAL will establish the responsivity to a uniform illumination of known flux. In test the point source version of this will be done via ILT-PERF-DRB although it is not yet clear whether it will be possible to obtain a high level of accuracy due to atmospheric

conditions in the lab. In flight, the observations of the standard source should be used as the definitive source of this information.
Astronomical Source Req: The prime calibrator
Phase:
ILT: ILT-PERF-DAL, ILT-PERF-DRB
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission
Definitely needed?: Yes

3.1.6 Signal vs Chop Frequency

ID: CALT-D06
Req Source: IA-MFC
Table Description: A table giving factors to reference the demodulated signal for each detector at various frequencies to the signal at the calibrated frequency, note this is unlikely to impact IA as the maximum BSM frequency is unlikely to impact detector signal and may only exist for information purposes.
Measurement description: The signal from a chopped non-varying point source is measured at various chop frequencies on each detector. For the spectrometer the SMEC is set to ZPD
Analysis: The signal vs modulation frequency curve will be fitted, the detector time constant will also be derived from this.
Astronomical Source Req: Bright non-varying point continuum source (continuum source needed for the spectrometer).
Phase:
ILT: ILT-PERF-DRB
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission
Definitely needed?: Possibly

3.1.7 Detector Response to different PCAL Settings

ID: CALT-D07
Req Source: uplink? IA?
Table Description: TBD, the detector response to different PCAL currents and operating frequencies will be characterised. In principle a 2-D table per detector is produced assuming nominal detector operating conditions. It is not yet clear how these tables will be structured for either uplink or IA use i.e. we may decide on only using a single reference detector.
Measurement description: PCAL will be set to different levels and static measurements will be made. This may be accompanied by a measurement of a known external source. The static measurements are then used to set levels for the PCAL frequency measurements.
Analysis: Signal per setting per detector.
Astronomical Source Req: If done in conjunction with an astronomical source a primary standard or well known secondary is required.
Phase:
ILT: ILT-PERF-CPC, ILT-PERF-CPT
Commissioning Phase: Yes, a small subset will be used
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission
Definitely needed?: Yes

3.1.8 Detector Response Temporal Drift Correction

ID: CALT-D08
Req Source: TECR-007, TECR-008, IA?
Table Description: TBD, this is dependent on the strategy used to removed the detector response drift i.e. correct for the change in response from the time a standard is observed to the time of the observation. If the LWS method of PCAL flashes (needing a constant background) surrounding every observation is employed then this table will not be necessary as the ratio can be obtained directly. Otherwise a drift correction table will be produced using PCAL flashes from each 48 hour period (or possibly longer)
Measurement description: The nominal PCAL sequence is executed and the detector response measured.
Analysis: The correction should come from the ratio of an individual detector's response to a PCAL flash at the time of the observation to that when the calibration standard was observed. If no PCAL flash is available, the correction table will either consist of fitted drift coefficients relevant to a particular time period, or all relevant responses for a particular time period.
Astronomical Source Req: Primary standard or well known secondary
Phase:

ILT: ILT-PERF-CPC, ILT-PERF-CPT
Commissioning Phase: Yes, a small subset will be used
PV Phase: Yes, once
Routine Phase: Yes, the drift will be measured with each PCAL flash, the comparison with the prime standard or a known secondary will be made at least weekly.

Definitely needed?: Yes

3.1.9 PCAL Temporal Drift Correction

ID: CALT-D09
Req Source: IA??
Table Description: The PCAL output at its nominal settings may vary with time. A correction will need to be made for this variation and this may take the form of a set of coefficients or a look up table.
Measurement description: PCAL will be flashed then an observation will be made of a non-varying source. This is repeated at regular intervals e.g. weekly and only needs to be done with the photometer.
Analysis: The ratio of the source to PCAL is taken and the variation of the ratio with time is used as the basis of the calibration file.
Astronomical Source Req: Non-varying point source with good visibility
Phase:

ILT: TBD
Commissioning Phase: Yes, the initial measurement will be established
PV Phase: Yes, at TBD regular intervals
Routine Phase: Yes, weekly

Definitely needed?: Possibly, depending on results from observations

3.1.10 Telescope Temperature Drift

ID: CALT-D10
Req Source: IA-TDR
Table Description: TBD, any telescope temperature drift will lead to loss of nulling in the spectrometer and will affect backgrounds in the photometer. In the photometer, the change in background may necessitate an operational change e.g. a reset of the detector offsets,

therefore it is not clear that the solution to this calibration issue is necessarily a table. Like any SCAL variation, different spectral templates can be used in the spectral domain to cancel out nulling, therefore we may envisage a set of spectral templates being used for this purpose.
Measurement description: No dedicated measurement?
Analysis: TBD, There might be a spacecraft parameter (or set of spacecraft parameters) which can be used as a direct measure of telescope temperature drift.
Astronomical Source Req: None
Phase:

ILT: No
Commissioning Phase: Not via dedicated observation
PV Phase: Not via dedicated observation
Routine Phase: Not via dedicated observation

Definitely needed?: Possibly

3.1.11 Astronomical Flux Conversion Table

ID: CALT-D11
Req Source: IA-CAU
Table Description: Astronomical conversion factors, one per array, assuming rest is dealt with via a flat field. Will not be needed if we fold this is with absolute response correction.
Measurement description: We will need to establish the detector response of a given reference detector to a known source, (Volts per Watt) for a given operating condition of the detector i.e. at nominal temperature, bias and chop frequency. Deltas on this will be dealt with in other tables (see previous sections). To do this a chopped measurement of a known source is needed.
Analysis: The responsivity is obtained directly.
Astronomical Source Req: The prime calibrator.
Phase:

ILT: Yes, ILT-PERF-DNC, ILT-PERF-DAL, ILT-PERF-DRB, ILT-PERF-OPI, ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM, It is important that this measurement is taken with the source centred, hence, OPI, OSB, OSL, BSM. DNC for the ambient noise and DAL for the actual responsivity.
Commissioning Phase: Possibly
PV Phase: Yes, via dedicated load curve observations plus regular observations at a single nominal bias.
Routine Phase: Yes, weekly during mission via regular observations at a single nominal bias, load curve measurements repeated at 3 month intervals through the mission.

Definitely needed?: The information will be definitely needed but as a separate file is TBD.

3.1.12 Detector Non-Linearity Correction

ID: CALT-D12
Req. Source: TECR-006, TECR-010, IA??
Table Description: TBD, initially this could just give the useful operating range for each detector or each array which would meet the TE requirement. Understanding of the data may lead to a more sophisticated treatment of non-linearity later.
Measurement description: Observation of a range of known flux point sources, ideally done for each detector.
Analysis: The ratio of SPIRE output to model expectation is compared to model flux.

Astronomical Source Req.: A set of 10-20 point like, of known flux, sources that cover the SPIRE operating range, may require different sources for the different photometer bands, a subset of the photometer sources will be used for the spectrometer.
Phase:
ILT: Yes, ILT-PERF-DRB, ILT-PERF-DRL
Commissioning Phase: No
PV Phase: Yes, once, may only use a subset of the sources
Routine Phase: Yes, 3-4 times during mission
Definitely needed?: Yes

3.2 Photometer Specific Tables

3.2.1 Photometer Spectral Response

ID: CALT-P01
Req Source: IA-PSR
Table Description: Wavelength and/or wave number plus response of each detector (N columns depending on array size). One table per array, resolution dependant on resolution adopted for test.
Measurement description: Continuum point source (black body) passed through laboratory FTS and the FTS is scanned, interferogram recorded by the detector. The scans need to be performed at two different black body temperatures to remove the FTS background
Analysis: The spectrum is obtained then the comparison with the known input gives the spectral response.
Astronomical Source Req: None
Phase:
ILT: Yes, ILT-PERF-DSR
Commissioning Phase: No
PV Phase: No
Routine Phase: No
Definitely needed?: Yes

3.3 Spectrometer Specific Tables

3.3.1 ZPD For Each Detector

ID: CALT-S01
Req Source: IA-ZPD
Table Description: A lookup table relating detector identifier to the optical encoder and LVDT ZPD position for that detector
Measurement description: A set of scans are taken of a continuum source illuminating one of the two import ports.
Analysis: A continuum source will give a sinc function interferogram, the position is found by fitting the central peak.
Astronomical Source Req: SCAL against a black patch of the sky could be a good dedicated measurement although useful information on ZPD can be derived from all collected interferograms. Hence dedicated test runs may not be necessary.
Phase:
ILT: Yes, ILT-PERF-ZPD
Commissioning Phase: Possibly
PV Phase: Yes, if not done in commissioning, with dedicated observation

Routine Phase: Yes, regularly via any suitable users science data
Definitely needed?: Possibly, may be used for information rather than direct calibration.

3.3.2 Mirror Position Counter to Mechanical Position

ID: CALT-S02
Req Source: IA-MMP
Table Description: Lookup table to convert mirror mechanical position counter to mechanical position
Measurement description: No dedicated measurement required?
Analysis: The warm electronics gives this directly.
Astronomical Source Req: None
Phase:
ILT: Will be done at subsystem level, and will be repeated at ILT via ILT-FUNC-SMEC-05, ILT-FUNC-SMEC-06 and ILT-FUNC-SMEC-07
Commissioning Phase: Yes via functional tests
PV Phase: No
Routine Phase: No
Definitely needed?: Yes

3.3.3 LVDT to Mechanical Position

ID: CALT-S03
Req Source: IA-LMP
Table Description: Lookup table to convert LVDT position to mechanical position
Measurement description: No dedicated measurement required?
Analysis: The warm electronics gives this directly.
Astronomical Source Req: None
Phase:
ILT: Will be done at subsystem level, and will be repeated at ILT via ILT-FUNC-SMEC-05, ILT-FUNC-SMEC-06 and ILT-FUNC-SMEC-07
Commissioning Phase: Yes via functional tests
PV Phase: No
Routine Phase: No
Definitely needed?: Yes

3.3.4 Mechanical Position to OPD

ID: CALT-S04
Req Source: IA-OPD
Table Description: Lookup table to convert mechanical position to OPD
Measurement description: The SMEC will be scanned over its full range with a bright line source in the beam of one input port, the other input port may not need to be illuminated for ground test but it may require SCAL nulling in flight.
Analysis: A line source will give a cosine function in the interfogram, we know the ZPD so the offsets of the fringe positions give the OPD.
Astronomical Source Req: A bright line source with a low background. A stable maser near the Nyquist frequency (shorter wavelength gives better accuracy) and an ideal interferometer would be ideal. It may not be able to find a single line source. Doublets and triplets may possibly be feasible, though. However, it is important to note that the interference pattern will not be a straightforward cosine since natural apodization S05, S08 will occur. Rather than inspecting the interferogram it is also valuable to look at the spectrum: The quality of the line shape of the shortest wavelength observed will indicate the quality of the metrology.

Phase:

ILT: **:** ILT-PERF-SFC, ILT-PERF-SFL
Commissioning Phase: Possibly
PV Phase: Yes, if not done in commissioning phase
Routine Phase: Yes, 2-3 times during the mission

Definitely needed?: Yes

3.3.5 Apodisation Map

ID: CALT-S05
Req Source: IA-SAD
Table Description: Apodisation vs SMEC position for each detector.
Measurement description: The SMEC is scanned full distance over a single line source.
Analysis: The fringe contrast is derived as a function of he SMEC position for each detector. This is then used as the apodisation map.
Astronomical Source Req: Bright single line source with a low background, if no single line source is available one with the minimum number of lines will be adopted.
Phase:

ILT: **:** ILT-PERF-SMC, ILT-PERF-SML, ILT-PERF-SFC
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission

Definitely needed?: Yes

3.3.6 Spectral Resolution vs Scan Range

ID: CALT-S06
Req Source: TECR-011, uplink??
Table Description: Lookup table to convert scan range to spectral resolution, should get away with one entry per range per array, but OPD differences between detectors may necessitate individual entries per detector.
Measurement description: The SMEC will be scanned over various ranges using an unresolved line source.
Analysis: For unresolved lines the resolution falls out directly.
Astronomical Source Req: Unresolved line source with multiple lines.
Phase:

ILT: **:** ILT-PERF-SMC, ILT-PERF-SML, ILT-PERF-SFC
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission

Definitely needed?: Yes

3.3.7 Spectral Resolution vs Wavelength

ID: CALT-S07
Req Source: TECR-011
Table Description: The variation of spectral resolution with wavelength also needs to be mapped. The behaviour of the achievable spectral resolution will be a factor in deciding whether observing modes can be "optimized" for SED or line measurement.
Measurement description: The SMEC will be scanned over various ranges using an unresolved line source.
Analysis: For unresolved lines the resolution falls out directly.

Astronomical Source Req: Unresolved line source with multiple lines.
Phase:

ILT: **:** ILT-PERF-SMC, ILT-PERF-SML, ILT-PERF-SFC
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission

Definitely needed?: Possibly

3.3.8 Spectrometer Spectral Response

ID: CALT-S08
Req Source: IA-SSR
Table Description: Spectrometer spectral response, one value in spectral domain per detector per resolution element per resolution mode. As this covers a significant parameter space the number of tables and table format is TBD. It is assumed that this will be applied after removing the effects of nulling.
Measurement description: A known continuum source is scanned with nominal scan settings.
Analysis: It is assumed the SCAL setting is characterised sufficiently to remove nulling before dividing the resulting spectrum by the model to derive the spectrometer spectral response.
Astronomical Source Req: Prime calibrator.
Phase:

ILT: **:** ILT-PERF-SMC will scan the SMEC with an extended source, ILT-PERF-SML will do this for step and look mode. This will allow the derivation of the spectrometer RSRF in vacuum. ILT-PERF-DRB will do the scanning test with a point source outside the cryostat, it is not yet clear whether effects of the atmosphere can be sufficiently removed to derive a ground based point source RSRF.
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission

Definitely needed?: Yes

3.3.9 Spectral Response vs SMEC Speed

ID: CALT-S09
Req Source: IA??, TECR??
Table Description: TBD, likely to be a correction on the measured RSRF
Measurement description: The SMEC will be scanned at various speed settings over a range of resolution settings using a known continuum source.
Analysis: The RSRF will be derived in the same manner as for CALT-S09 and differences between the various scan speeds and the nominal speed found.
Astronomical Source Req: Prime calibrator
Phase:

ILT: **:** ILT-PERF-SMC
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, 3-4 times during the mission

Definitely needed?: Yes

3.3.10 Spectral Response Time Dependance

ID: CALT-S10

Req Source: IA-SRT
Table Description: Possible correction factors for changes in the spectrometer spectral response with time.
Measurement description: The SMEC will be scanned at the nominal resolution settings and at the nominal scan speed, each time this measurement is made.
Analysis: The resulting RSRF (derived the same way as CALT-09) derived from each measurement will be compared with the initial measurement. If the spectral response is time dependant, either one table or a set of tables will exist giving the response files referenced to time.
Astronomical Source Req: Prime calibrator
Phase:

ILT: **:** Not measured although initial RSRFs will be obtained
Commissioning Phase: No
PV Phase: Yes, once
Routine Phase: Yes, as often as observations of prime permit.

Definitely needed?: Possibly, depending on results of analysis

3.3.11 SCAL Commanded Current vs SCAL Temperature

ID: CALT-S11
Req Source: uplink?
Table Description: Two column table derived from functional test used to derive uplink settings.
Measurement description: SCAL 2 and SCAL 4 will be set at various levels and the temperature profile with time will be characterised.
Analysis: The final temperature reached and possibly time to reach it will be recorded in the table.
Astronomical Source Req: None
Phase:

ILT: ILT-FUNC-SCAL-01, ILT-FUNC-SCAL-02
Commissioning Phase: Yes, via functional test
PV Phase: No
Routine Phase: No

Definitely needed?: Yes

3.3.12 Detector Response vs SCAL Temperature

ID: CALT-S12
Req Source: uplink? IA?
Table Description: Characterisation of detector response to different SCAL currents/temperatures, actual table format depends on IA requirements.
Measurement description: SCAL will be run at various settings with the other port either blanked via the cold black body switched off or set to a dark patch of sky i.e. telescope background. The SMEC is fixed at ZPD.
Analysis: Signal per setting per detector.
Astronomical Source Req: A dark patch of sky with high visibility throughout the mission (actually the telescope is the source!).
Phase:

ILT: ILT-PERF-CSC
Commissioning Phase: Possibly
PV Phase: Yes, if not done in commissioning phase
Routine Phase: Yes, 3-4 times during the mission

Definitely needed?: Yes

3.3.13 SCAL Spectrum Lookup Table

ID: CALT-S13
Req Source: IA-SCE
Table Description: SCAL power output spectrum lookup table or model. This and the actual detector response to that spectrum are needed for removal of nulling. This could either be implemented in IA as written here with CALT-S13 taking the response and CALT-S14 knowing the output spectrum or these two may be combined with scans on SCAL.
Measurement description: No measurement required.
Analysis: Output spectrum is referenced to different SCAL settings and measured temperatures.
Astronomical Source Req: None
Phase:
ILT: No
Commissioning Phase: No
PV Phase: No
Routine Phase: No
Definitely needed?: Possibly, depending on what is implemented for CALT-S13.

3.3.14 SCAL Temperature Drift

ID: CALT-S14
Req Source: IA-TDR
Table Description: TBD, SCAL should not drift making the necessity for this table unlikely, if it does, a strategy for correcting the spectrometer output will need to be adopted and the spectrum tables (CALT-S13, CALT-S14) may be sufficient.
Measurement description: No dedicated measurement, the SCAL thermistors gives the temperature directly.
Analysis: The temperature drift is measured directly.
Astronomical Source Req: None
Phase:
ILT: No
Commissioning Phase: No
PV Phase: No
Routine Phase: No
Definitely needed?: Possibly

3.4 Spatial Information Tables

3.4.1 Photometer Instrument Spatial Function

ID: CALT-A01
Req Source: IA-PSF, TECR-003
Table Description: TBD, this will be dependant on the IA requirements, we need to agree on where this is measured. The baseline for the tests is that for the spectrometer the central pixel plus three outside non-vignetted pixels will be characterised in detail and for the photometer the two central pixels plus four corner unvignetted pixels will be characterised. Interpolation could be done by software or further calibration table. How this information is presented to IA is also an open issue.

Measurement description: Fine sampling of the beam of each feedhorn using 7-point jiggle maps and 64-point jiggle maps. For the spectrometer the SMEC will be at ZPD. For the photometer, the source will also be scanned across the FOV at the scanning angle.
Analysis: The beam will be well characterised and compared to the PSF in the measured feedhorns, how this is implemented across the array is TBD and is dependent on IA requirements.
Astronomical Source Req: Bright non-varying point source.
Phase:

ILT: ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM
Commissioning Phase: No
PV Phase: Yes
Routine Phase: Possibly, there is no reason why it should change and will probably only be re-measured if there is evidence that it has changed.

Definitely needed?: Yes

3.4.2 Spectrometer Instrument Spatial Function and Off-axis Vignetting

ID: CALT-A02
Req Source: IA-PSF, TECR-003
Table Description:
Measurement description: Spectrally scan SCEC over beam
Analysis:
Astronomical Source Req: Bright non-varying point source.
Phase:

ILT: ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM
Commissioning Phase: No
PV Phase: Yes
Routine Phase: Possibly, there is no reason why it should change and will probably only be re-measured if there is evidence that it has changed.

Definitely needed?: Yes

3.4.3 Photometer Instrument Throughput

ID: CALT-A03
Req Source: TECR-001
Table Description: Instrument throughput, one number per detector.
Measurement description: Will be done with a combination of pupil scanning and FOV scanning.
Analysis: See calibration requirements document.
Astronomical Source Req: Bright non-varying point source
Phase:

ILT: ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM, ILT-PERF-OPI
Commissioning Phase: No
PV Phase: Yes (FOV scanning only)
Routine Phase: Possibly, there is no reason why it should change and will probably only be re-measured if there is evidence that it has changed.

Definitely needed?: Yes

3.4.4 Spectrometer Instrument Throughput

ID: CALT-A04
Req Source: TECR-002

Table Description: Instrument throughput, one number per detector, referenced to spectrometer ZPD plus TBD other SMEC positions.
Measurement description: Will be done with a combination of pupil scanning and FOV scanning.
Analysis: See calibration requirements document.
Astronomical Source Req: Bright non-varying point source
Phase:

> *ILT:* ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM, ILT-PERF-OPI
> *Commissioning Phase:* No
> *PV Phase:* Yes (FOV scanning only)
> *Routine Phase:* Possibly, there is no reason why it should change and will probably only be re-measured if there is evidence that it has changed.

Definitely needed?: Yes

3.4.5 Electrical Crosstalk

ID: CALT-A05
Req Source: IA-ECT
Table Description: TBD, if present, electrical crosstalk will be apparent from the fact that the pixels are grouped in four in one wire. The crosstalk table could consist of pixel id plus pixel ids of the other three pixels and their crosstalk levels.
Measurement description: See cryoharness test plan
Analysis: See cryoharness test plan.
Astronomical Source Req: None
Phase:

> *ILT:* Dedicated test, detailed in cryoharness test plan.
> *Commissioning Phase:* No
> *PV Phase:* No
> *Routine Phase:* No

Definitely needed?: Possibly

3.4.6 Optical Crosstalk

ID: CALT-A06
Req Source: IA-OCT
Table Description: TBD, optical crosstalk will be apparent if the PSF for a particular pixel is deviant from the PSF for other pixels in that part of the array, this may appear as ghosts. If this is a smooth function it may not be possible to distinguish the PSF from the crosstalk.
Measurement description: Same as CALT-A01
Analysis: Crosstalk will be apparent from local variation of PSF.
Astronomical Source Req: Bright non-varying point source.
Phase:

> *ILT:* ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM
> *Commissioning Phase:* No
> *PV Phase:* Yes
> *Routine Phase:* Possibly, there is no reason why it should change and will probably only be re-measured if there is evidence that it has changed.

Definitely needed?: Possibly, depending on outcome of analysis.

3.4.7 Photometer Flatfield

ID: CALT-A07
Req Source: IA-PFF

Table Description: Photometer flat fields, response of each detector referred to one detector in the same array.
Measurement description: TBD, if PCAL produces enough flux then this would be an ideal source to monitor the flatfield, on the ground the cold black body can be used. As no astronomical source is flat, this may be done in flight via scanning a point source over each pixel in turn.
Analysis: The relative response across the array is mapped and the response of the reference pixel noted.
Astronomical Source Req: Bright non-varying point source
Phase:

ILT: ILT-PERF-DAL-P
Commissioning Phase: No
PV Phase: Yes
Routine Phase: Yes, frequency of measurement TBD and may depend on method adopted

Definitely needed?: Yes

3.4.8 Spectrometer Flatfield

ID: CALT-A08
Req Source: IA-SFF
Table Description: Spectrometer flat field, response of each detector referred to the central detector in the same array at a TBD set of given SMEC positions
Measurement description: TBD, if PCAL produces enough flux then this would be an ideal source to monitor the flatfield, on the ground the cold black body can be used. As no astronomical source is flat, this may be done in flight via scanning a point source over each pixel in turn. It is likely that this will be referenced to the ZPD.
Analysis: The relative response across the array is mapped and the response of the reference pixel noted.
Astronomical Source Req: Bright non-varying point source.
Phase:

ILT: ILT-PERF-DAL-S
Commissioning Phase: No
PV Phase: Yes
Routine Phase: Yes, frequency of measurement TBD and may depend on method adopted

Definitely needed?: Yes

3.4.9 Temporal Stability of Flatfield

ID: CALT-A09
Req Source: TECR-009
Table Description: TBD, the table, if needed will convey the drift rate in the flat field. This could be done via a set of coefficients for each pixel or via flat field tables at given times.
Measurement description: This will be obtained via regular flatfield measurements either using PCAL or FOV scanning of a point source.
Analysis: Temporal changes in detector response are mapped either on a per pixel basis or using a set of flat field frames.
Astronomical Source Req: Bright non-varying point source
Phase:

ILT: ILT-PERF-DAL
Commissioning Phase: No

PV Phase: Yes
Routine Phase: Yes, frequency of measurement TBD and may depend on method adopted
Definitely needed?: Yes

3.4.10 Detector Positions

ID: CALT-A10
Req Source: IA-DSO
Table Description: Detector spatial offset positions. One set of offsets will be needed for each detector and these will relate that detector's pointing to the spacecraft boresight.
Measurement description: This will be established by scanning a point source over the FOV.
Analysis: In test the centroid of the raster will be found in telescope simulator coordinates, and conversion tables exist to convert these to angular offsets. In flight the position will be initially calculated in spacecraft coordinates then converted to angular offsets.
Astronomical Source Req: Bright non-variable point source, for the spectrometer this will need to be a continuum source.
Phase:
ILT: ILT-PERF-OPI, ILT-PERF- OSB, ILT-PERF-OSL, ILT-PERF-BSM
Commissioning Phase: Yes – boresight wrt centre of array will be established
PV Phase: Possibly, via FOV mapping, but this should not have changed from ground measurements
Routine Phase: No
Definitely needed?: Yes

3.4.11 Instrument Vignetted Pixel Mask

ID: CALT-A11
Req Source: IA-VIG
Table Description: 1-D table for each array, the column indicating identifiers of vignetted pixels in the FOV with the BSM centred and the SMEC at ZPD. IA may require these identifiers because it may choose to ignore vignetted pixels or process the data from them in a different way. If degree of vignetting is required this is likely to only be available via the optical modelling as test, at least at ILT level will not be able to distinguish between detector response and vignetting.
Measurement description: No measurement needed, this is a design constraint.
Analysis: Astronomical Source Req: None
Phase:
ILT: No
Commissioning Phase: No
PV Phase: No
Routine Phase: No
Definitely needed?: Possibly, depending on IA implementation

3.5 BSM Related Tables

3.5.1 Commanded ADU vs BSM Position Closed Loop

ID: CALT-B01
Req Source: uplink??
Table Description: Two column table

Measurement description: This will be measured via functional test?
Analysis: Measured directly by the test.
Astronomical Source Req: None
Phase:
ILT: ILT-FUNC-BSM-02, ILT-FUNC-BSM-03?
Commissioning Phase: Yes, via repeat of functional test
PV Phase: No
Routine Phase: No
Definitely needed?: Yes

3.5.2 Commanded ADU vs BSM Position Open Loop

ID: CALT-B02
Req Source: uplink??
Table Description: Two column table
Measurement description: Will be measured directly by functional test??
Analysis: Measured directly??
Astronomical Source Req: None
Phase:
ILT: ??
Commissioning Phase: Yes, via repeat of functional test
PV Phase: No
Routine Phase: No
Definitely needed?: Yes

3.5.3 Commanded Position vs Readout Position Closed Loop

ID: CALT-B03
Req Source: uplink??
Table Description: Two column table
Measurement description: Will be measured directly by functional test.
Analysis: Table generated directly from telemetry.
Astronomical Source Req: None
Phase:
ILT: ILT-FUNC-BSM02
Commissioning Phase: Yes, via repeat of functional test
PV Phase: No
Routine Phase: No
Definitely needed?: Yes

3.5.4 Commanded Position vs Readout Position Open Loop

ID: CALT-B04
Req Source: uplink??
Table Description: Two column table
Measurement description: Will be measured directly by functional test.
Analysis: Table generated directly from telemetry.
Astronomical Source Req: None
Phase:
ILT: ILT-FUNC-BSM02
Commissioning Phase: Yes, via repeat of functional test
PV Phase: No
Routine Phase: No

Definitely needed?: Yes

3.5.5 Detector Positions in BSM coordinates

ID: CALT-B05
Req Source: IA??, uplink??
Table Description: A table giving the BSM chop and jiggle axis positions related to the centre of each detector pixel.
Measurement description: A point source is put on the centre of a pixel at the nominal BSM position for that pixel. A small raster is then done with the BSM to check that the BSM position is correct.
Analysis: The raster will be fitted to find the centre.
Astronomical Source Req: Bright non-varying point source, for the spectrometer this will need to be a continuum source.
Phase:

ILT: ILT-PERF-BSM, ILT-PERF-BCT
Commissioning Phase: Yes, small subset
PV Phase: Yes, may do more pixels
Routine Phase: Yes, 3-4 times during the mission to check for BSM positional stability.

Definitely needed?: Yes

3.5.6 BSM Vignetted Pixel Mask

ID: CALT-B06
Req Source: IACR-004
Table Description: TBD As the BSM moves away from centre, depending on direction, some pixels will get vignetted. This should be recorded in a table but the format of this table is TBD. This will determine possible chop pixels for uplink use and will be needed for the analysis of chopped scan maps.
Measurement description: Tricky! moving the BSM with an extended source might do the trick but the results might be ambiguous due to straylight paths in the instrument, therefore a point source may have to be used.
Analysis: Will be measured directly.
Astronomical Source Req: Bright non-varying point source, for the spectrometer this will need to be a continuum source.
Phase:

ILT: ILT-PERF-BVG
Commissioning Phase: No
PV Phase: Yes, small subset of pixels compared with ground results
Routine Phase: No

Definitely needed?: Possibly

3.6 External Tables

3.6.1 Colour Correction Reference Spectra

ID: CALT-G01
Req Source: IA
Table Description: Reference spectra or default colour corrections for a given spectral type. Each spectrum may be a separate two column table wavelength plus flux or a set of reference spectra may be grouped into one table, wavelength plus flux columns for a set of black body temperatures.

Measurement description: No measurement needed
Analysis: Will be generated from simple models plus possibly sources from the literature.
Astronomical Source Req: None
Phase:
ILT: No
Commissioning Phase: No
PV Phase: No
Routine Phase: No
Definitely needed?: Possibly

3.6.2 Other Photometric System Response Curves

ID: CALT-G02
Req Source: IA
Table Description: Response curves for another photometric system?
Measurement description: No measurement needed
Analysis: Will be compiled from literature
Astronomical Source Req: None
Phase:
ILT: No
Commissioning Phase: No
PV Phase: No
Routine Phase: No
Definitely needed?: Possibly

3.6.3 Line Database

ID: CALT-G03
Req Source: IA
Table Description: List of astronomical lines in SPIRE range, one table, two columns, rest wavelength and species.
Measurement description: No measurement needed
Analysis: Will be compiled from literature.
Astronomical Source Req: None
Phase:
ILT: No
Commissioning Phase: No
PV Phase: No
Routine Phase: No
Definitely needed?: Possibly

4. Cross Reference Tables

4.1 Cross Reference Table Between IA and Calibration Requirements

IACR-001	CALT-D01
IACR-002	CALT-D02
IACR-003	CALT-A10
IACR-004	CALT-B06
IACR-005	CALT-S02
IACR-006	CALT-S03
IACR-007	CALT-S04
IACR-008	CALT-A09
IACR-009	CALT-D10
IACR-010	CALT-S14
IACR-011	CALT-S05
IACR-012	CALT-S04
IACR-013	CALT-D07
IACR-014	CALT-D09
IACR-015	CALT-D06
IACR-016	CALT-B05
IACR-017	CALT-A04
IACR-018	CALT-A05
IACR-019	CALT-S01
IACR-020	CALT-A06
IACR-021	CALT-A06
IACR-022	CALT-A07
IACR-023	CALT-D04
IACR-024	CALT-D12
IACR-025	CALT-S05
IACR-026	CALT-A02
IACR-027	CALT-D11
IACR-028	CALT-D05
IACR-029	CALT-D05
IACR-030	CALT-S08
IACR-031	CALT-S10
IACR-032	CALT-S09
IACR-033	CALT-P01
IACR-034	CALT-G01
IACR-035	CALT-G02
IACR-036	CALT-A01, CALT-A02
IACR-037	CALT-G03

4.2 Cross Reference between Cal Tables and tests

Cal Table ID	Tests
CALT-D01	ILT-PERF-DAL, ILT-PERF-DNA
CALT-D02	ILT-PERF-DNA, ILT-PERF-DNC, ILT-PERF-DMA, ILT-PERF-DAL
CALT-D03	ILT-PERF-DMA
CALT-D04	ILT-PERF-CPC
CALT-D05	ILT-PERF-DAL, ILT-PERF-DRB
CALT-D06	ILT-PERF-DRB
CALT-D07	ILT-PERF-CPC
CALT-D08	ILT-PERF-CPC
CALT-D09	TBD
CALT-D10	None
CALT-D11	ILT-PERF-DNC, ILT-PERF-DAL, ILT-PERF-DRB, ILT-PERF-OPI, ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM
CALT-D12	ILT-PERF-DRB, ILT-PERF-DRL
CALT-P01	ILT-PERF-DSR
CALT-S01	ILT-PERF-ZPD
CALT-S02	ILT-FUNC-SMEC-05, ILT-FUNC-SMEC-06, ILT-FUNC-SMEC07
CALT-S03	ILT-FUNC-SMEC-05, ILT-FUNC-SMEC-06, ILT-FUNC-SMEC07
CALT-S04	ILT-PERF-SFC, ILT-PERF-SFL
CALT-S05	ILT-PERF-SMC, ILT-PERF-SML, ILT-PERF-SFC
CALT-S06	ILT-PERF-SMC, ILT-PERF-SML, ILT-PERF-SFC
CALT-S07	ILT-PERF-SMC, ILT-PERF-SML, ILT-PERF-SFC
CALT-S08	ILT-PERF-SMC, ILT-PERF-SML, ILT-PERF-DRB
CALT-S09	ILT-PERF-SMC
CALT-S10	None
CALT-S11	TBD
CALT-S12	ILT-PERF-CSC
CALT-S13	ILT-PERF-CSC
CALT-S14	ILT-PERF-CST
CALT-A01	ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM
CALT-A02	
CALT-A03	ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM, ILT-PERF-OPI
CALT-A04	ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM, ILT-PERF-OPI
CALT-A05	Dedicated test, detailed in cryoharness test plan
CALT-A06	ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM
CALT-A07	ILT-PERF-DAL-P
CALT-A08	ILT-PERF-DAL-S
CALT-A09	ILT-PERF-DAL
CALT-A10	ILT-PERF-OSB, ILT-PERF-OSL, ILT-PERF-BSM
CALT-A11	None
CALT-B01	None
CALT-B02	None
CALT-B03	ILT-FUNC-BSM02
CALT-B04	ILT-FUNC-BSM02
CALT-B05	ILT-PERF-BSM, ILT-PERF-BCT
CALT-B06	ILT-PERF-BVG

CALT-G01	None
CALT-G02	None
CALT-G03	None

4.3 Cross Reference between Cal Tables, Source Requirements and flight phase

Cal Table ID	Observations	Com	PV	Routine
CALT-D01	None	N	N	N
CALT-D02	A dark patch of sky with good visibility throughout the mission.	P	Y	Y
CALT-D03	A dark patch of sky with high visibility throughout the mission	Y	Y	Y
CALT-D04	The prime calibrator	N	Y	Y
CALT-D05	The prime calibrator	N	Y	Y
CALT-D06	Bright non-varying continuum point source (continuum source needed for the spectrometer).	N	Y	Y
CALT-D07	A primary standard or well known secondary	Y	Y	Y
CALT-D08	A primary standard or well known secondary	Y	Y	Y
CALT-D09	Non-varying point source with good visibility	Y	Y	Y
CALT-D10	None	N	N	N
CALT-D11	The prime calibrator	P	Y	Y
CALT-D12	A set of 10-20 point like, of known flux, sources that cover the SPIRE operating range, may require different sources for the different photometer bands, a subset of the photometer sources will be used for the spectrometer.	N	Y	Y
CALT-P01	None	N	N	N
CALT-S01	A bright continuum only source will be suitable for the detailed measurement, any bright continuum source observed in routine phase can be used for checking.	P	Y	Y
CALT-S02	None	Y	N	N
CALT-S03	None	Y	N	N
CALT-S04	A bright line source with a low background.	P	Y	Y
CALT-S05	Bright single line source with a low background, if no single line source is available one with the minimum number of lines will be adopted.	N	Y	Y
CALT-S06	Unresolved line source with multiple lines.	N	Y	Y
CALT-S07	Unresolved line source with multiple lines.	N	Y	Y
CALT-S08	Prime calibrator	N	Y	Y
CALT-S09	Prime calibrator	N	Y	Y
CALT-S10	Prime calibrator	N	Y	Y
CALT-S11	None	Y	N	N
CALT-S12	A dark patch of sky with high visibility throughout the mission	P	Y	Y
CALT-S13	None	N	N	N
CALT-S14	None	N	N	N
CALT-A01	Bright non-varying point source	N	Y	P
CALT-A02				
CALT-A03	Bright non-varying point source	N	Y	P
CALT-A04	Bright non-varying point source	N	Y	P
CALT-A05	None	N	N	N

CALT-A06	Bright non-varying point source	N	Y	P
CALT-A07	Bright non-varying point source	N	Y	Y
CALT-A08	Bright non-varying point source	N	Y	Y
CALT-A09	Bright non-varying point source	N	Y	Y
CALT-A10	Bright non-variable point source, for the spectrometer this will need to be a continuum source.	Y	P	N
CALT-A11	None	N	N	N
CALT-B01	None	Y	N	N
CALT-B02	None	Y	N	N
CALT-B03	None	Y	N	N
CALT-B04	None	Y	N	N
CALT-B05	Bright non-varying point source, for the spectrometer this will need to be a continuum source.	Y	Y	Y
CALT-B06	Bright non-varying point source, for the spectrometer this will need to be a continuum source.	N	Y	N
CALT-G01	None	N	N	N
CALT-G02	None	N	N	N
CALT-G03	None	N	N	N