SPIRE SCIENTIFIC REQUIREMENTS **VERSION 3.0 November 21 2000**
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1 Introduction

This document summarises the scientific requirements for the major programmes that SPIRE is expected to be used for, and attempts to place these in the context of the technical specification of the instrument. Areas of potential conflict and trade-off are identified and discussed. We also briefly discuss primary verification tasks. Although feedhorn-coupled bolometers have been selected for SPIRE, this document does not make any specific assumption concerning the detector technology.

1.1 SPIRE technical description

For the purposes of this document we assume that the instrument includes:

(i) a photometer/camera with a *minimum* FOV of 4 x 4 arcminutes with a goal of 4 x 8 arcminutes, with three wavelength channels centred at 250, 350 and 500 μm that observe the same area of sky simultaneously;

(ii) an intensity beam-splitting imaging Fourier transform spectrometer, with full background compensation, with a FOV of 2.6x2.6 arcminutes, a *minimum* wavelength range 200-400 μm and a goal of 200-670 μm with variable resolution (requirement: 0.4-2 cm^{-1}; goal: 0.04-2 cm^{-1});

(iii) a chopping/steering mirror.

1.2 Performance specifications

Tables 1 and 2 list the performance specifications for the photometer and spectrometer, based on the SPIRE proposal and the evaluation of the FIRST Science Evaluation Committee (FSEC).

Table 1: Photometer specifications

	250 μm	**350 μm**	**500 μm**
Filter pass-band ($\lambda/\Delta\lambda$)	3	3	3
Field-of-view (arcminutes) - Requirement **- Goal**	4 x 4 4 x 8	4 x 4 4 x 8	4 x 4 4 x 8
Beam FWHM (arcsec)	18	25	36
Point source observation: **1**σ **1 hr limiting flux density (mJy)**	0.6	0.6	0.7
Mapping observation: **1**σ **1 hr limiting flux density (mJy)** **for fully sampled map of FOV**	1.4	1.5	1.9

Table 2: Spectrometer specifications

Wavelength range (mm)		SW Band: 200-300 (TBC) LW Band: 300-670 (TBC)
Max. resolution (cm^{-1})	**Requirement** **Goal**	0.4 0.04
Min resolution (cm^{-1})	**Requirement** **Goal**	2 4
Field of view (arcminutes)	**Requirement** **Goal**	2 x 2 2.6 x 2.6
Beam FWHM (arcsec)		SW Band: 18 LW Band: 35 (TBC)
Line spectroscopy (point source observation): **1s :1 hr limiting line flux (W m^{-2})**		SW Band: 7.6×10^{-18} LW Band: 7.0×10^{-18} (300 µm) 7.0×10^{-18} (400 µm) 1.4×10^{-17} (670 µm)
Line spectroscopy (mapping observation): **1 s ; 1 hr limiting line flux for fully sampled FOV map (W m^{-2})**		SW Band: 1.8×10^{-17} LW Band: 1.7×10^{-17} (300 µm) 1.7×10^{-17} (400 µm) 3.4×10^{-17} (670 µm)
Spectrophotometry 1 cm^{-1} resolution **(point source observation)** **1s :1 hr limiting flux density (mJy)**		SW Band: 25 LW Band: 23 (300 µm) 23 (400 µm) 46 (670 µm)
Spectrophotometry 1 cm^{-1} resolution **(point source observation)** **1 s ; 1 hr limiting flux density for fully sampled FOV map (mJy)**		SW Band: 59 LW Band: 57 (300 µm) 57 (300 µm) 114 (670 µm)

2 SPIRE scientific goals

The scientific case for SPIRE is laid out in detail in the proposal. It is quite clear that the highest scientific priorities are: (a) deep surveys to search for the galaxies (assumed to be mostly at high redshift) which make up the FIR extragalactic background radiation; (b) deep surveys of local molecular clouds to find pre- and proto-stellar sources and determine their mass and luminosity functions; (c) follow-up spectrophotometric observations of the objects discovered in these surveys. Therefore in this document highest priority is given to performance specifications for SPIRE that will improve its efficiency in achieving these goals.

2.1 SPIRE extragalactic surveys

The goal of the extragalactic deep survey is to cover a large area of sky (nominally 60 square degrees) to a depth that is at the confusion limit for galaxies. The confusion limit is dictated by the diffraction-limited angular resolution of the telescope. If the confusion limit proves to be higher than expected then a somewhat larger area may be covered and conversely if it is 0.3 lower a smaller area may be covered. Thus the technical constraints are to cover a large area of sky to a given depth as rapidly, efficiently and uniformly as possible, and to detect a large number of sources in more than one band, so that photometric redshifts can be determined and good statistics obtained on evolution and star formation history even when the population is broken down into at least 6 sub-samples, for example by type or redshift interval. It is envisaged that a substantial amount of FIRST observing time will be devoted to extragalactic surveys. The SPIRE proposal specified a capability of a confusion-limited survey of 60 sq. deg. of the sky in an observing time of six months. The required 5-σ sensitivity limits depend on the source count model, but were specified at 15 - 20 mJy (weakly dependent on wavelength). The scientific requirement is therefore that SPIRE's photometric survey performance be as good as this or better.

Requirement SRD-R 1: The photometer should be capable of diffraction-limited extragalactic blind surveys of at least 60 sq. deg. of the sky, to 1-σ detection limit of 3 mJy in all bands with an observing time of six months or less.

2.2 SPIRE galactic survey

SPIRE will make unbiased surveys of nearby molecular clouds to detect complete samples of pre-, proto- and young- stellar objects comprising hundreds of objects, ranging from bright, ultra-compact HII regions around massive young stars to very faint, low-mass, pre-stellar condensations. The primary scientific goals are to be sensitive enough to detect the faint objects and cover a large area in a reasonable time (one month or less), but also to have sufficient dynamic range to simultaneously measure the bright sources. Confusion may be even more of a problem than for the extragalactic survey, so again resolution is a prime scientific driver.

Requirement SRD-R 2: The photometer should be capable of a galactic survey covering 1 deg. sq. to a 1-σ depth of 3 mJy at 250 μm within an observing time of one month or less.

Note: The sensitivity level needed to meet SRD-R 1 is such that SRD R 2 can easily be met.

2.3 Follow-up spectrophometric observations

Follow-up spectrophotometric observations of the sources identified in the surveys will also be important. For the extragalactic survey this will allow redshifts to be determined, and if possible physical conditions of the gas in these distant sources. The objects themselves will be point-like, however there may be more than one in a single field-of-view. For the galactic survey follow-up spectrophotometric observations will again be vital, however, unlike the extragalactic survey sources, it is likely that spectrophometric mapping will be required.

2.4 SPIRE observations of known sources

SPIRE does however have other important scientific goals, and these are discussed after the requirements for the deep survey and follow-up programmes. Any programmes whose requirements clash with those of the deep survey work are identified and discussed. In general however, since the deep surveys require high sensitivity, high angular resolution and stable performance for deep integrations, almost all other programmes benefit from the specification required for the deep surveys. Some of the programmes, such as submillimetre spectroscopic surveys of previously known sources, may push the required spectral resolution to somewhat higher values than required for survey follow up however.

2.5 Planck survey follow-up

A possibly very important scientific area not identified as a priority at the time of the proposal is follow-up of sources identified in the Planck survey. Since the resolution of the Planck survey is comparatively poor, and it is possible that radio and/or optical/IR follow-up observations will not be sensitive enough, it is essential that SPIRE be able to make follow-up observations to identify the sources at better angular resolution and also to make spectrophotometric observations of their SED as redshift indicators.

2.6 Coordinated observations with PACS

The baseline for operation is that neither SPIRE nor PACS can be operated whilst HIFI is, however it may be possible for SPIRE not only to make observations which are coordinated with PACS in a scientific sense, but also simultaneously. The implications of this possibility therefore are addressed below.

3 Imaging photometric surveys

3.1 Camera filters

The camera has three fixed filters, one for each array, at present these are specified to be centred at 250, 350 and 500 mm with bandwidths of 1/3 the centre frequency. These choices however were more or less arbitrary and need to be reconsidered in more detail. The limited modelling that has been done so far suggests they are close to optimum. Another possibility is that we add a fourth detector array to allow a wider wavelength coverage, possibly extending both the short *and* long wavelength coverage. For the extragalactic survey where we wish to maximise the number of high-redshift sources there is no advantage in pushing to shorter wavelengths, however for the galactic survey this might be advantageous for temperature determination if it meant a larger area coverage than supplied by PACS. It is likely however that in the end we are limited by data rate to a fixed number of detectors *in total*. In which case extra wavelength coverage may have to be traded off against filling more of the field and for both the extragalactic and galactic surveys maximising the total number of sources is the highest priority.

3.2 Spectrophotometer filters

The FTS detector arrays split the total band into two. Making the bands broad maximises spectral coverage but will degrade spatial resolution at the higher frequency end of the spectrum. There is a case for pushing the lower wavelength limit to shorter wavelengths to get better coverage of the peak of the grey-body spectra of galactic sources, but this would be at the expense of performance degradation due to higher photon noise in the shorter wavelength channel. The broad passband of the lower frequency channel also means that the sensitivity cannot be optimal over the full wavelength range.

3.3 Confusion noise limits

The confusion limit is a function of the pixel beam-width: Condon (1974) showed that the confusion flux limit increases as the 4/3 power of the beam-width (or the 2/3 power of the beam area) for a Euclidean slope number count. Deep surveys will integrate down to the.5 confusion limit or possibly slightly beyond in order to allow a noise probability density [P(D)] analysis. The scientific requirements here therefore are (a) maximum sensitivity (b) maximum resolution in the main beam. This is always traded-off against sidelobe suppression, since sidelobe suppression *inevitably* degrades main-beam resolution. For the deep extragalactic surveys sidelobe suppression is less important than main-beam resolution, however for the galactic surveys it is not so clear cut as there may well be low-mass stars in the close vicinity of bright high-mass objects (c) the ability to cover large areas of sky contiguously - this may have impact on detector speed and bandwidth if we undertake some form of rapid scanning observing mode (see below).

Requirement SRD-R 3: Maximising the 'mapping speed' at which confusion limit is reached over a large area of sky is the primary science driver. This means maximising sensitivity and field-of-view (FOV) but NOT at the expense of spatial resolution.

Spatial chopping in which the absolute values of the signal levels at the two positions are not recorded, but only the difference between them, makes the confusion noise worse, far more so than small changes in beam pattern. Simulations by Oliver and Todd suggest that the confusion noise limit is about a factor 1.6 worse for a chopped compared to an unchopped image with the same beam size. This is consistent with the confusion scaling purely with the effective increase in (beam area)2/3 .

Requirement SRD-R 4: **The photometer observing modes should provide a mechanism for telemetering undifferenced samples to the ground.**

3.4 Point-spread function

This depends on the edge-taper in the case of the feed horns and on the pupil truncation in the case of the filled arrays. Needs careful optical modelling. Critical sampling versus oversampling needs to be traded off by means of detailed numerical simulations, including model detector psf. Even for a fully-sampled array it is highly likely we will wish to undertake oversampling, in order to obtain high s/n measurements and allow for bad pixels and noise spikes. This leads to the requirement that, even for filled arrays we require the chopping mirror to make over-sampled ('jiggled' or 'micro-stepped') images. In general it is more important to minimise aberrations to the psf than field distortion, however this is only true within the limit set in 2.4. There may be a trade-off between total throughput and aberrations which will need to be looked at in detail. However, unless the throughput improves significantly faster than linearly with the degradation in resolution then it is more important to minimise aberrations. A requirement is that we are able to measure the psf to very high accuracy in-orbit, as well as on the ground so that contributions from satellite jitter can be separated from the intrinsic psf.

Requirement SRD-R 5: **The photometer should have an observing mode that permits accurate measurement of the point spread function.**

3.5 Field distortion

In the optical design field distortion also needs to be constrained so that one part of the FOV does not have much worse psf than the rest. A requirement here is that the field distortion is never sufficient to mean that when performing a jiggle pattern one part of the array is left less than critically sampled. This implies **that distortion must be less than ~10% across the FOV**. Detailed trade-offs between aberration and distortion can only be made by direct interaction between optical designer and consortium scientists.

Requirement SRD-R 6: Optical field distortion should be less than 10% across the photometer field of view.

3.6 Field-of-view

The required FOV is 4 x 4 arcminutes, however the total available focal plane is much larger than this, therefore photons are arriving in the SPIRE focal plane and being wasted. The scientific requirement is therefore that we cover the largest area of focal plane as possible with detectors. Hence the 4 x 8 arcminutes goal in Table 1. This is true regardless of whether we chop or not. However, if we are limited by data rate or other practicalities then FOV may have to be traded off against number of wavelength channels.

Requirement SRD-R 7: **The photometer field of view shall be at least 4 x 4 arcminutes, with a goal of 4 x 8 arcminutes.**

3.7 Crosstalk

The optical crosstalk is a function of the sidelobe suppression and the error lobe due to the surface of the primary mirror. In the case of SPIRE, the telescope wavefront error specification of 10 microns is such that the error lobe will be small even at 250 microns.

For electrical crosstalk to nearest neighbours, the requirement is not stringent since the optical crosstalk is large anyway - it is crosstalk to distant neighbours that requires tight specification.

For extragalactic deep surveys, where signal dynamic range is low, there is not a strong crosstalk requirement. For mapping of faint diffuse galactic emission, crosstalk due to bright point sources in the field presents a much bigger problem, and it is this that dictates the crosstalk requirement for SPIRE. To allow a signal dynamic range of 1000 or better, electrical crosstalk should be less than 0.1%.

Requirement SRD-R 8: For 2Fl feedhorns, crosstalk shall be less than 1% (goal 0.5%) for adjacent detectors and 0.1% or less (goal 0.05%) for all non-adjacent detectors in the same array; for 0.5Fl pixels, the requirement is 5% (goal 2%) to adjacent detectors and 0.1% (goal 0.05%) to all others. (Note: This requirement is under review).

3.8 Chopping constraints

It is clear that even for the filled arrays SPIRE requires a ‘chopping mirror’ that can move rapidly in steps as small as 2 arcsec (roughly 1/10 beam FWHM at 250 microns). The maximum chop throw required is one half of the total field or ~ 4 arcminutes. The minimum should be somewhat less than one beam FWHM at the shortest wavelength.

Requirement SRD-R 9: **The maximum available chop throw shall be at least 4 arcminutes; the minimum shall 10 arcseconds or less.**

3.9 Array uniformity

This affects both photometric accuracy but also the time taken to reach a uniform depth. Detectors with anomalously low sensitivity tend to contribute little to the final quality of the data set. There is a need to separate gain variation, i.e. flat-fielding, from actual NEP variation. There is no scientific requirement on the gain variation as long as it is consistent and measurable. Drifts can be taken out in real-time by using the internal calibrator in any case. Achieved S/N for a given integration time scales with NEP.

Requirement SRD-R 10: The rms detector NEP variation across any photometer array should be less than 20%.

3.10 Dynamic range for sky signals

This is not really an issue for extragalactic deep survey. However it may be for galactic surveys, although since all very bright sources are already known from IRAS the survey could simply be designed to avoid them. The dynamic range should be is limited by crosstalk rather than by the electronics, which implies an instantaneous dynamic range of 4000, which is 12 bits. Note however that for very bright sources we may also need some form of gain changing (or more bits) in order to prevent saturation.

Requirement SRD-R 11: The photometer dynamic range for astronomical signals shall be 12 bits or higher.

3.11 Photometric accuracy

Absolute: This is the overall accuracy compared to other instruments and other wavebands. SPIRE data will be combined with measurements using other facilities, and a reliable absolute calibration scale for all of the facilities will be important. A requirement should be 15% with a goal of 10%.

Requirement SRD-R 12: SPIRE absolute photometric accuracy shall be 15% or better at all wavelengths, with a goal of 10%.

Relative: This is the repeatability of a measurement both across the array(s) and also in time. For the deep surveys this is not a major problem, as S/N on faint objects will be low, however, for some other programmes it is crucial that repeatability be very high.

Requirement SRD-R 13: The relative photometric accuracy should be 10% or better with a goal or 5%.

3.12 Linearity

This is clearly related to dynamic range and photometric accuracy. The detector response must be linear, or have a pre-determined and repeatable non-linear response over the full dynamic range to within the required photometric accuracy.

Requirement SRD-R 14: SPIRE photometric measurements shall be linear to 5% over a dynamic range of 4000 for astronomical signals.

3.13 Array-co-alignment

For the large-area surveys it is not crucial that the arrays be accurately co-aligned as long as the relative alignment is well-determined (to within pixel/4). A more stringent requirement is set by the need to carry out simultaneous three-band photometry on compact sources.

4 Observations of sources with known positions

Having identified large samples of objects in the surveys, the next highest scientific priority is to make follow-up observations to determine their spectral energy distribution, redshifts, and if bright enough, make spectrophotometric emission line measurements to determining physical conditions within the line-emitting gas in these objects. The requirements here are also the same as for pointed observations of previously-known objects, both galactic and extragalactic.

4.1 Photometry (R~3)

Photometry is performed with the photometer/camera arrays. All the requirements identified above for the surveys apply except that we now know where we are pointing. In the case of the feed-horn arrays jiggling may not be required for point sources, or else a smaller jiggle pattern than to fully-sample the field.

4.1.1 Array co-alignment

An additional constraint for pointed observations if the feedhorn option is selected is that the arrays be co-aligned to within 2.0 arcsec with a goal of 1 arcsec. An alignment accuracy of 1 arcsec corresponds to loss of less than 1% of peak signal for a Gaussian beam profile at 250 µm while 2 arcsec would result in a 4% loss of signal at 250 µm. Form observations that require photometric accuracy greater than 4%, a 5-point point or 7-point mapping observation can be carried out.

Requirement SRD-R 15: For feedhorn detectors, the overlapping sets of three detectors at the three wavelengths should be co-aligned to within 2.0 arcsecond on the sky (goal = 1 arcsec).

4.2 Low-resolution ($\lambda/\Delta\lambda$ ~ 20) and medium resolution ($\lambda/\Delta\lambda$ ~ 100) spectrophotometry

This is performed with the spectrometer arrays. Because these have a smaller FOV than the camera, it is currently not possible to observe all sources in a single camera field in a single spectrometer field. A requirement is to be able to follow-up survey sources as rapidly as possible. This leads to the conclusion that sensitivity is more important than spectral resolution, field-of-view, or sidelobe suppression. The sensitivity should be limited by the thermal background from the FIRST telescope. The thermal background that determines this noise level depends on the passband of the FTS, so that there is an inevitable compromise between sensitivity and wavelength coverage. In particular, extension of the coverage to long wavelengths results in an increase in background that affects sensitivity across the whole band. This compromise may require further scientific and technical evaluation.

Requirement SRD-R 16: The spectrometer design shall be optimised for sensitivity to point sources but shall have an imaging capability with the largest possible field of view that can be accommodated.

Requirement SRD-R 17: The sensitivity of the FTS at any spectral resolution up to the goal value shall be limited by the photon noise from the FIRST telescope within the chosen passband

The dynamic range and photometric accuracy requirements are the same as for the camera.

Requirement SRD-R 18: The spectrometer dynamic range for astronomical signals shall be 12 bits or higher.

Requirement SRD-R 19: The FTS absolute photometric accuracy at the required spectral resolution shall be 15% or better at all wavelengths, with a goal of 10%.

For an FTS, the spectrum is all on a single pixel at a time, so there is no additional constraint on, for example, spectral crosstalk, over and above the same imaging requirements on psf, crosstalk, chopping, dynamic range and linearity described above for any of the spectrophometric observations.

An additional constraint is the minimum spectral resolution as it should impact on the sampling accuracy required for the mirror position. To be able to measure the spectral energy distributions of dust sources with sufficient resolution, a minimum resolution of 2 cm^{-1} (which corresponds to R = 20 at 250 μm) will be needed.

Requirement SRD-R 20: The FTS shall be capable of making spectrophotometric measurements with a resolution of 2 cm^{-1}, with a goal of 4 cm^{-1}.

There is a calibration requirement that if possible there be some overlap between the minimum wavelength covered by the SPIRE spectrometer and the maximum wavelength covered by PACS. Cross-calibrating overall spectra of sources measured by a combination of the two instruments will be very much easier if there is a region of overlap. Extension to shorter wavelengths would also be scientifically useful for follow-up observations of galactic survey sources, since PACS cannot do low-resolution broad-band spectrophotometry.

One additional constraint is on the spectral line profile which clearly is required to be constant in time and not subject to variations caused by variable scanning speed etc. We also have a requirement that the width of the instrument response function does not change more than 10 % across the FOV.

Requirement SRD-R 21: The width of the FTS instrument response function at the required spectral resolution shall be uniform to within 10% across the field of view.

4.3 High-resolution spectrophotometry ($\lambda/\Delta\lambda > 100$)

High resolution spectrophotometry is a goal and not a requirement for SPIRE, however clearly it is beneficial for some scientific programmes provided it does not compromise performance in the lower-resolution modes.

Requirement SRD-R 22: The maximum spectral resolution of the FTS shall be at least 0.4 cm^{-1} with a goal of 0.04 cm^{-1}.

5 Other scientific programmes

These are of lower-priority for SPIRE and do not drive the scientific requirements.

5.1 Solar system objects

Solar system observations require high sensitivity often in the very close presence of the extremely bright planet, which means high dynamic range and low crosstalk. This may require gain-switching.
It also requires non-sidereal tracking which is a satellite rather than instrument requirement.

5.2 Variability Studies

5.2.1 Short-term

This means staring at the same source or region and monitoring the signal for, e.g., a day or a few hours. So the requirement is on stability of a given array detector. Typically these programmes require very high stability, ~ 1% which may not be achievable.

5.2.2 Long-term

This involves going back to the same source on a weekly, monthly or longer time-scale to determine whether its flux has varied, ideally the spec would be the same as for short-term, i.e. ~1%. However this is probably unrealistic and a target of 5% might be just about achievable.

6 Observing modes

The observing modes must be able to fulfil all the scientific requirements above, this is complicated by the different detector options, however at this stage we must be able to cover all possibilities. The observing modes requirements constrain both the satellite and the instrument.

6.1 Imaging the FOV

For the feedhorn array option the focal plane is under-sampled and so the steering/chopping mirror will have to undertake a 'jiggle' pattern to fill in the gaps. Since however we have three arrays imaging the same FOV and the longest wavelength detectors are a factor two bigger than the shortest and twice as far apart, in order to obtain a fully-sampled image at all three wavelengths with the feedhorn arrays we will actually have to take a 64-position 'jiggle' image.

Some form of 'jiggling' or 'micro-stepping' is required even for the filled arrays and as (a) their filling factor is never 100% and (b) oversampling can improve image quality and allow effects of spikes and bad pixels to be overcome in the data reduction.

Requirement SRD-R 23: The SPIRE photometer shall have an observing mode capable of implementing a 64-point jiggle map to produce a fully sampled image of a 4 x 4 arcminute region.

6.2 Surveying large areas

There are two basic options, both of which may need to be implemented.

Making individual jiggle-maps and then stepping the satellite to take a similar image of an adjacent field with some overlap at the edges, building up a large field in this manner.

Scanning continuously over a large area of sky, this may have implications for speed and bandwidth of detectors**.** The scanning may be undertaken either whilst also chopping a small distance (say 2 –4 beam widths) in which case the detector output is essentially the differential of the angular structure in the region being scanned, the signal is spread over a range of frequencies either side of the chop frequency, analogous to an amplitude modulated signal with the chop frequency being the carrier **OR** if the detectors are fast enough and the electronic bandwidth is broad enough, the scanning could be undertaken without chopping, in which case the sky structure spectrum is undifferentiated and simply shifts wholesale away from DC by the speed of scanning with the highest frequency signal corresponding to the scan speed in angles/sec divided by the resolution of the telescope at that wavelength.

In the case of the feedhorn arrays, it is still possible to create a fully-sampled image of the sky in a single-scan even for 2Fλ arrays by scanning in the appropriate direction. This does require the arrays to be correctly co-aligned so that they all produce fully-sampled images at the same time.

6.3 Point-source photometry

In the case of the feed-horn arrays when measuring a point-source one may wish to avoid wasting observing time by making a fully-sampled image but to make a very small jiggle, similar to that for imaging with the filled arrays as described above. A suitable way to do this is to implement a five- or seven-point jiggle map with an angular spacing somewhat greater than the positional uncertainty.

Requirement SRD-R 24: The photometer observing modes shall include provision for 5-point or 7-point jiggle maps for accurate point source photometry.

6.4 Pointing

The satellite absolute pointing accuracy as specified is not adequate for SPIRE . Therefore we require a 'peaking up' mode, to be performed by the chopping mirror. This may be useful even for filled arrays. However, for survey observations then the telescope pointing accuracy after slewing from a ‘nearby’ pointing source needs to be considerably better than the satellite absolute pointing.

Requirement SRD-R 25: The photometer shall have a "peak-up" observing mode capable of being implemented using the beam steering mirror.

6.5 FTS observing modes

A major difference between FTS and camera observing modes is that there is no need for spatial chopping since the FTS mirrors provide signal modulation. There is only one basic FTS observing mode, since the scanning speed is a fixed function of detector speed. However we can select different resolving powers and we can choose different oversampling factors. There is an issue of flux compensation as well: the acquired interferograms result from the difference between the celestial source spectrum and the internal FTS calibration source spectrum. For extended sources or crowded fields, spectrophotometric mapping will also be undertaken. The nature of this observing mode is very dependent on the choice of detector arrays.

7 Verification

In order to ensure that SPIRE is capable of delivering the required scientific performance, we need verification of crucial performance parameters as early as possible. We do not attempt in this document to specify detailed verification procedures, rather we attempt to identify those parameters that can and **must** be verified on the ground.

7.1 Sensitivity

Sensitivity must be demonstrated not just by testing detectors outside SPIRE, but by measuring performance of SPIRE *as an instrument*. This requires the closest possible simulation of observations of real external sources under simulated background as close as possible to those in space so that the total instrument throughput and coupling to external optics is included. This is the most fundamental measurement that must be made during ground AIV.

7.1.1 Instrument spectral response

It is essential to make spectral measurements of the instrument response in order to check that the filter passbands are as specified but also as a diagnostic tool to check for any problems caused by cavity resonances being set up which can cause fringing in the filter passbands as seen in the case of SCUBA.

7.1.2 Uniformity

This must also be measured so that any problems with the detectors are completely understood and controlled prior to delivery.

7.1.3 Optics

The optical performance of SPIRE itself must be verified on the ground, using a telescope simulator.

8 Summary of SPIRE Scientific Requirements

Requirement SRD-R 1: The photometer should be capable of diffraction-limited extragalactic blind surveys of at least 60 sq. deg. of the sky, to 1-σ detection limit of 3 mJy in all bands with an observing time of six months or less.

Requirement SRD-R 2: The photometer should be capable of a galactic survey covering 1 deg. sq. to a 1-σ depth of 3 mJy at 250 λm within an observing time of one month or less.

Requirement SRD-R 3: Maximising the 'mapping speed' at which confusion limit is reached over a large area of sky is the primary science driver. This means maximising sensitivity and field-of-view (FOV) but NOT at the expense of spatial resolution.

Requirement SRD-R 4: The photometer observing modes should provide a mechanism for telemetering undifferenced samples to the ground.

Requirement SRD-R 5: The photometer should have an observing mode that permits accurate measurement of the point spread function.

Requirement SRD-R 6: Optical field distortion should be less than 10% across the photometer field of view.

Requirement SRD-R 7: The photometer field of view shall be at least 4 x 4 arcminutes, with a goal of 4 x 8 arcminutes.

Requirement SRD-R 8: For 2Fλ feedhorns, crosstalk shall be less than 1% (goal 0.5%) for adjacent detectors and 0.1% or less (goal 0.05%) for all non-adjacent detectors in the same array; for 0.5Fλ pixels, the requirement is 5% (goal 2%) to adjacent detectors and 0.1% (goal 0.05%) to all others. (Note: This requirement is under review).

Requirement SRD-R 9: The maximum available chop throw shall be at least 4 arcminutes; the minimum shall 10 arcseconds or less.

Requirement SRD-R 10: The rms detector NEP variation across any photometer array should be less than 20%.

Requirement SRD-R 11: The photometer dynamic range for astronomical signals shall be 12 bits or higher.

Requirement SRD-R 12: SPIRE absolute photometric accuracy shall be 15% or better at all wavelengths, with a goal of 10%.

Requirement SRD-R 13: The relative photometric accuracy should be 10% or better with a goal or 5%.

Requirement SRD-R 14: SPIRE photometric measurements shall be linear to 5% over a dynamic range of 4000 for astronomical signals.

Requirement SRD-R 15: For feedhorn detectors, the overlapping sets of three detectors at the three wavelengths should be co-aligned to within 2.0 arcsecond on the sky (goal = 1 arcsec).

Requirement SRD-R 16: The spectrometer design shall be optimised for optimum sensitivity to point sources but shall have an imaging capability with the largest possible field of view that can be accommodated.

Requirement SRD-R 17: The sensitivity of the FTS at any spectral resolution up to the goal value shall be limited by the photon noise from the FIRST telescope within the chosen passband.

Requirement SRD-R 18: The spectrometer dynamic range for astronomical signals shall be 12 bits or higher.

Requirement SRD-R 19: The FTS absolute photometric accuracy at the required spectral resolution shall be 15% or better at all wavelengths, with a goal of 10%.

Requirement SRD-R 20: The FTS shall be capable of making spectrophotometric measurements with a resolution of 2 cm^{-1}, with a goal of 4 cm^{-1}.

Requirement SRD-R 21: The width of the FTS instrument response function at the required spectral resolution shall be uniform to within 10% across the field of view.

Requirement SRD-R 22: The maximum spectral resolution of the FTS shall be at least 0.4 cm^{-1} with a goal of 0.04 cm^{-1}.

Requirement SRD-R 23: The SPIRE photometer shall have an observing mode capable of implementing a 64-point jiggle map to produce a fully sampled image of a 4 x 4 arcminute region.

Requirement SRD-R 24: The photometer observing modes shall include provision for 5-point or 7-point jiggle maps for accurate point source photometry.

Requirement SRD-R 25: The photometer shall have a "peak-up" observing mode capable of being implemented using the beam steering mirror.