SUBJECT: **HERSCHEL Telescope Working Group (Nov.2001) Actions closure**

PREPARED BY: **A G Richards, M. Ferlet**

KEYWORDS:

COMMENTS: **This document collects together the documentation generated to close actions 6 and 9 from the HWG held in mid-November 2001.**

DISTRIBUTION

V. Kirschner	(ESTEC)
D. de Chambure	(ESTEC)
B.Swinyard	(RAL)
M.Griffin	(Cardiff)
K.Dohlen,	(IGRAP, Marseille)
Project Office	(RAL)

1. INTRODUCTION

The following relevant actions were placed on instrument teams at the HERSCHEL Working Group meeting in Mid-November 2001:

```
Actions on all instrument teams
   According to my knowledge, none of the instrument teams has sent a
   Clarification of the critical paths of their instrument to ASED and ASEF
   (AI 6 due 7/12/01).

Actions on SPIRE team
   ESA (V.Kirschner) is still missing final input (scattered properties of
   all the surfaces of the instruments) to complete the SPIRE model (AI 9 due
   date ASAP).
```

The following sections provide the input necessary to complete the actions. An extra section details a change to the SPIRE ASAP model, which should be made.

2. ACTION 6: CRITICAL PATHS

In order to assist the contractor's ASAP analysis of the HERSCHEL payload, the following are suggestions for paths to be included in the ASAP study:

Starting surface / object	Target surface(s)
sunshade	Primary mirror + primary mirror hole
sunshade	Secondary mirror and secondary support structure
sunshade	Internal Cryostat surfaces
Primary mirror+associated surfaces (hole, edge etc)	SPIRE photometer detector
Secondary mirror and secondary support structure	SPIRE photometer detector
Internal cryostat surfaces, primary hole / baffle surfaces	SPIRE CM3 mirror, focal plane filter (PFIL1), direct or via reflection from M2
Internal cryostat surfaces, primary hole / baffle surfaces	SPIRE CM4 mirror* and surround, SPIRE photometer cold stop edge, PFIL2 filter between PM7 and PM8
Internal cryostat surfaces, primary hole / baffle surfaces	Internal SPIRE surfaces forward of focal plane filter PFIL1
Holes in cryostat shields for cables etc.	SPIRE entrance port , PFIL1 and CM3
Internal SPIRE surfaces forward of focal plane	SPIRE CM3 mirror, focal plane filter (PFIL1),
SPIRE PFIL1, CM3	SPIRE photometer detector
SPIRE CM4 surround	SPIRE photometer cold stop edge, photometer detector, PFIL2 filter between PM7 and PM8

This is not an exhaustive list, and should be supplemented by randomly generated paths to try and rule out other possible critical paths.

*N.B. The SPIRE mirror CM4 is slightly oversized compared to the image of the cold stop projected onto it, and it can be tilted about two orthogonal axes to vary the direction of SPIRE's view towards space. This will move SPIRE's view direction (as defined by the detector's view through the cold stop) towards the internal edges of cryostat holes and the hole in the primary mirror. [1] The tilt angles should be applied to the surfaces comprising CM4. The SPIRE APART model shows how the tilts can be applied. Extreme tilt values are likely to be +and -2.336 degrees and + and -0.573 degrees for 'Chop' and 'Jiggle' tilts respectively ('chop' moves the SPIRE FOV at 90 degrees to the plane of the SPIRE photometer's optics, jiggle moves the SPIRE FOV parallel to the plane of the SPIRE photometer's optics). It is likely that certain critical paths may arise when CM4 is at one extreme of its tilt movement.

3. ACTION 9: SURFACE SCATTERING PROPERTIES

3.1 Estimation of surface scattering properties in APART/ASAP – SPIRE model

This section attempts to give the ASAP definition of SPIRE optical components scattering properties, for further straylight analysis with APART/ASAP. Suggested models as well as related values are presented for the differents optical parts. The scripts specific to ASAP language are highlighted in blue.

3.1.1 ASAP in-field scatter model for the Herschel Telescope

```
INTERFACE 1 0
SCATTER BSDF 3.09  -1.52    !! CNES meas. on SIC
```

This is extracted from the ASAP Herschel Telescope model (file: *psf_scat.inr*) and this can be applicable for M1 and M2. From the comment in the original file, the b and s parameters of the SCATTER BSDF command comes from measurement by CNES (TBD if contamination effect is included) but the wavelength is set to 85µm in the file so extra wavelength scaling maybe required for the 200-670µm SPIRE spectral range.

3.1.2 ASAP coating properties of the SPIRE mirrors

```
COATING
  0.995 0  'MIRROR_REFLECTIVITY'
```

[1] See for example 'Angular scaling factors for the chop and jiggle movements of the BSM','SPIRE-RAL-NOT-001050,
'Cryostat aperture size requirements including the effects of SPRE-HERSCHEL misalignments', SPIRE-RAL-NOT-000993, and references therein.

This would be the main modifer of all the SPIRE mirrors, expected to reflect ~99.5%. The Al-alloy mirrors are specified to be of optical quality in the visible. Their surface micro-roughness (<<<1µm) is not contributing to the scattering level at FIR/sub-mm wavelength. For wavelength longer than ~5-10µm, such mirrors have a surface scattering level known[2] to be dominated by contribution from particulate contamination. And at a level of 500ppm for SPIRE optics obscuration factor from contamination (see SPIRE Cleanliness Plan, SPIRE-RAL-PRJ-1070), scattering from dust particles (assumed spherical) on mirror can be estimated via a Mie model.

3.1.2.1 ASAP Mie model of surface scattering from paticulate contamination

Below is listed an ASAP script for the definition and computation of Mie particles scattering level. It is the based on modified example BRO-ASAP file (ref.: *MIE_SCATTER_MIL1246C.inr*).

```
UNITS MM
WAVELENGTH 350.0 UM      !! Central wavelength for SPIRE

MEDIA
  2.1`0.15    'INDEX'          !! Define average index of refraction for the dust particles

!! MIL-STD 1246C particle distribution function that is used by the particle model

$FCN MSTD S=(_2-_1)*_+(_2+_1),
        N=10^(0.926*(LOG[_3]^2-LOG[S]^2)),
        N*2*.926*LOG[S]/S

SMIN=1              !! Smallest particle diameter
SMAX=500            !! Largest particle diameter

FRAC=5.0E-4         !! Fraction of the surface that is covered by particles (spec. geometric obscuration ratio)

CLEANLEV=350        !! Cleanliness level (compatible with value of frac from standard chart).

PIXELS 101          !! Sets the number of points in the bsdf plot produced by the particle model.

!! Define a particle model and plot the BSDF
MODEL
  PARTICLES MIE IND SMIN/2 SMAX/2 (FRAC) MSTD 250 (SMIN) (SMAX) (CLEANLEV) PLOT 0 15 30 45
RETURN
```

[2] See: P.R. Spyak, W.L.Wolfe, "*Scatter from particulate-contaminated mirrors, part 4: properties of scatter from dust for visible to far-infrared wavelengths*", Optical Engineering 31-8 (1992), pp.1775-1784.

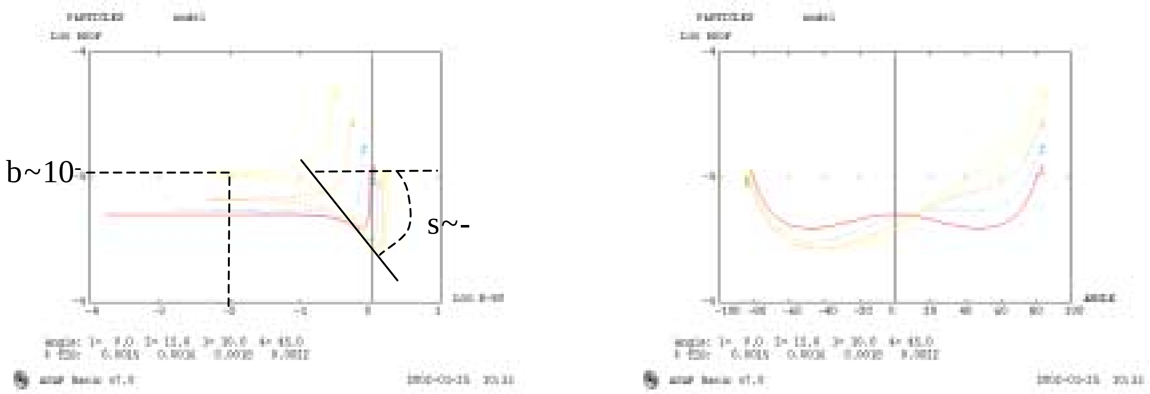

Figure 1: Surface BSDF in log-log plot (right) and log-lin plot (left) from ASAP Mie particles scatter model at 350µm.

This can require computation and may not be compliant with standard APART definition. This model is expected to give worst-case results. It can be used for wide-angle stray light analysis (i.e. out-of-field) but would also require the definition of importance sampling area and the complete instrument structure definition within APART/ASAP. As approximation, one can consider that the structure is thermalised at about the same temperature as the mirrors; temperature much lower than the telescope surfaces, limiting the background-photon noise. This may allow reduction of the analysis to in-field scatter only, to assess imaging quality/beam propagation eventual degradation due to optics scatter properties. This effect from contamination may also apply to transmissive components such as filters, on the top of their own structure- and material-dependent scattering properties (TBD).

3.1.2.2 ASAP in-field scatter model for SPIRE mirrors

This can be done, in first approximation, by fitting the above Mie model results (see Figure 1 above) with a basic Harvey model (through parameters *b* and *s*; this basic approach, i.e. without the Harvey shoulder or any anisotropy, should also be compliant with APART), which can be then used as in-field scatter model.

```
LEVEL 1

OBJECT ...                                        !! To be applied to all SPIRE mirrors (from CM3, spectro. & phot. channels)
 INTERFACE COATING 'MIRROR_REFLECTIVITY'          !! Main property of the reflecting surface
 SCATTER BSDF (B_coef) (S_coef)                   !! In-field scatter def. via basic Harvey model
```

where the *B_coef* and *S_coef* are given in the following table for in-band and band-edge (wrt SPIRE spectral range, wavelength-scaling can not be applied, re-computation required each time):

Wavelength(µm)	Estimated average index of dust	**B0_coef**	**B_coef**	**S_coef**	**L_coef**
150	1.8+i0.15	~ 7.10^{-4}	~ 7.10^{-5}	~ -1.0	~ 10^{-1}
350	2.1+i0.15	~ 8.10^{-5}	~ 10^{-5}	~ -0.7	~ 10^{-1}
750	2.3+i0.05	~ 10^{-5}	~ 3.10^{-6}	~ -0.5	~ 10^{-1}

With only 2 parameters, the fit may not be perfect but should still be able to help quantitatively with expected worst-case order-of-magnitude. The *S_coef* parameter is not in the –1 to –2 range usually quoted by BRO in ASAP and tend to give here a nearly Lambertian behaviour with a relatively low scattering level. Although the BSDF level from the Mie model increases for larger incidence angles (a fact not taken into account by the Harvey model), most of the SPIRE mirrors are reflecting with smaller than 45deg off-axis incidence angle. The above model definition should be seen as the superposition of the high specular contribution plus a low-level diffuse scattering level background generated from particulate contamination effect.
Improvement in the description of the above results can be obtained by using a Harvey model with shoulder parameter *l*. Below is an example of a possible ASAP implementation with the coefficients from the table above.

```
LEVEL 3                                     !! or more depending on complexity and computation time

MODEL 'MIRROR_SCATTER'                      !! Our-of-field scatter def. via Harvey model with shoulder parameter
  HARVEY (B0_coef) (S_coef) (L_coef)        !! From the estimated wavelength-dependent parameters above
RETURN

OBJECT …                                    !! To be applied to all SPIRE mirrors (from CM3, spectro. & phot. channels)
 INTERFACE COATING 'MIRROR_REFLECTIVITY'    !! Main property of the reflecting surface
 SCATTER MODEL 'MIRROR_SCATTER'
```

3.1.3 *ASAP scatter model for other reflective parts of SPIRE structure*

For the metallic structural parts surrounding the optics (cavity between SPIRE box aperture and instrument input focal plane), it is suggested to use:

```
COATING
  (1-0.3) 0  'STRUCTURE_REFLECTIVITY'       !! from material+cavity effective emissivity estimated ~30%
```

And scatter model:

```
LEVEL 3                                     !! or more depending on complexity and computation time

MODEL
  HARVEY 0.2 -0.2
```

or

```
 LAMBERTIAN 0.3
RETURN

OBJECT ...                                  !! To be applied to SPIRE structural parts
 INTERFACE COATING 'STRUCTURE_REFLECTIVITY' !! Main property of the surface
 SCATTER MODEL 'STRUCTURE_SCATTER'          !! Out-of-field scatter def. via basic scattering model
```

The above values are expected worst-case estimation for short SPIRE wavelengths and are influenced by the values related to the diffuse and reflective aluminium surfaces (Al, coated with AMES24E) used in the cryostat ASAP model (file: *Sunsh_Cryost_1.inr*). Again this should be seen as the superposition of a specular component and a diffuse and near uniform (relatively flat angular dependence) scatter term.

4. MODIFICATIONS TO THE GEOMETRY OF THE SPIRE ASAP MODEL

4.1 Surfaces 249 and 252

These surfaces at present represent an aperture in the SPIRE focal plane plate. A thermal filter, PFIL1, will cover this aperture so it is suggested that these surfaces be relabelled accordingly and made optical surfaces. In the APART model, the surfaces have surface normals in opposite directions for various reasons, but only one of them may be required to model PFIL1 in the ASAP model. A scattering coating is not yet available for it (but see the earlier section on scattering coatings). The geometry of the surfaces can remain unchanged.

4.2 Surface 276 – PFIL2

The size and orientation of this surface has changed. The geometry required to define it as an EDGE type surface is given below. This code should be substituted for the present geometry by replacing the equivalent statements in the ASAP file supplied as the APART-ASAP conversion of SPIRE.

```
!276
 EDGES
  RACETRACK Z   2578.335     0.000000     0.000000     0.000000     0.000000    SPLIT
  RACETRACK Z   2578.335     43.76000     34.07500     20.00000     20.00000    SPLIT
 OBJECT 276; 0.2 0.1 *RECT.PFIL2 FILTER
  FACETS -1 10
  MATRIX;  0.000000     1.000000     0.000000     0.000000
           2642.992     0.000000     0.4998992    -.8660837
           1361.608     0.000000     0.8660836    0.4998993
```