



## Technical Note

SPIRE Spacecraft-Instrument  
Alignment Matrix (SPIRE SIAM)

**Ref:** SPIRE-RAL-NOT-002881  
**Issue:** 2.0  
**Date:** 25/07/2008  
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**TITLE:** SPIRE Spacecraft-Instrument Alignment Matrix (SIAM)

**By:** Marc Ferlet (RAL)

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### CHANGE RECORD

ISSUE	DATE	SECTION	REASON FOR CHANGE
0.1	28/03/07	All	First draft, not released
1.0	23/05/07	All	First release
1.1	24/05/07	All	Typo corrected, added references
1.2	30/05/07	All	Aperture S55 is now assigned to parallel mode.
1.3	18/07/07	4	Addition of SIAM file data for the Parallel Mode
1.4	30/07/07	2 & Appendix 1	Correction to SSW E5 found similar to SSW C5 due to typo in source code generating LOS
1.5	11/09/07	4	Reference to PACS document added
2.0	25/07/08	1,2,3 & 4 + Appendix 1	General update after new generation of SIAM based on updated model including ground alignment results and flight telescope optical prescription data

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  2. SIAM file data
  3. Additional SIAM file data (SLW)
  4. Parallel Mode
- Appendix 1      **SPIRE Pixel Tables and SIAM Apertures**
- Appendix 2      **SPIRE Aperture Identifiers**
- Appendix 3      **DCM Generation Code**
- ATTACHMENT:** text file "SPIRE SIAM v2.0.txt"



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#### APPLICABLE AND REFERENCE DOCUMENTS

- AD1** "ICD: Herschel Spacecraft / Instrument Alignment History", PT-HMOC-FD-ICD-2111-OPS-GFT issue 1.3 (07/02/06)
- AD2** IID-B Herschel/Planck Instrument Interface Document – Part B Instrument "SPIRE", SCI-PT-IIDB/SPIRE-02124, issue 3.3 (21/06/04)
- RD1** SPIRE Design Description, SPIRE-RAL-PRJ-000620 issue 2.0 (15/05/03)
- RD2** SPIRE PACS Parallel Mode Observers' Manual, HERSCHEL-HSC-DOC-0883 v1.0 (01/02/07)
- RD3** Herschel instrument alignment wrt CVV – Test Report, HP-2-ASED-TR-0219 issue 1.0 (19/10/07)
- RD4** SPIRE alignment data summary, SPIRE-RAL-NOT-002876 issue 1.1 (28/03/07)
- RD5** Optical Interface Control Document, HER.NT-0167.T.ASTR issue 06 Rev 00 (06/12/2006)



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This note reports on the generation of the Spacecraft-Instrument Alignment Matrix (SIAM) file data, as defined in AD1, for the Herschel/SPIRE instrument. This new issue includes update of the model used to generate the SIAM file data. The model has been locally modified to take into account the updated HSO telescope optical prescription and the results of the ground alignment at instrument and CVV level.

### 1. General description

The main components in the SIAM file are the Direction Cosine Matrices (DCM) for the individual pixels or “apertures”. The following scheme, in a bottom-up approach, is used for their generation:

#### \* Step 1:

The arrangement (relative geometric location) of SPIRE detectors of different bands listed as relevant “apertures” for the SIAM file are taken from the relevant SPIRE BDA EIDP and implemented at the relevant detector focal planes of the official (configuration control) optical models (BOLSP509 and BOLPHOT155 respectively) for SPIRE Spectrometer and Photometer channels (see RD1).

#### \* Step 2:

Backward raytraces are performed in order to find the intercept of each relevant “apertures” with the telescope focal surface at SPIRE entrance focal plane. This is done in the official ESA coordinate system (as defined by the optical interface, see the ICDs in AD2). These are reported in details in Appendix 1.

This approach allows finding what each detector actually see and therefore points towards rather than what they are expected to receive/collect and allows taking into account the second order effect (non perfect telecentricity, residual field distortion) compared to a linear first-order plate-scale-based approach.

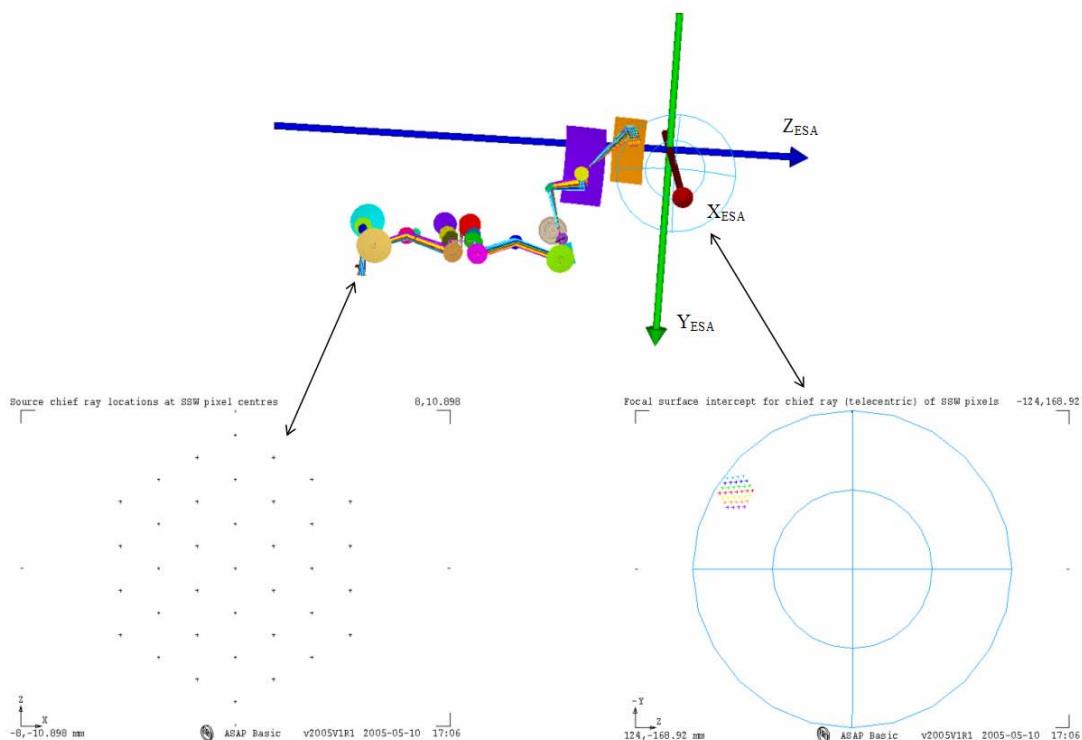


Figure 1: From detector layout at focal plane to optical interface plane with telescope



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#### \* **Step 3:**

Coordinates intercepts are then checked with measured data during ILT (PFM4 test campaign) when available for the relevant "apertures". ILT tests are bound to be performed in same coordinate system by the constraint of the set optical interface. The ESA coordinate system for the telescope is actually similar in axis orientation with the Herschel Spacecraft coordinate system as defined in AD1.

#### \* **Step 4:**

Instrument tilts and lateral shifts as measured during the ground alignment campaign at CVV level and reported in RD3 are used as input to define respectively translation and rotation of the instrument model compared to its nominal position and orientation. In more details, from RD3 table 6-7, the rotation about Y and Z are respectively of  $-5.56'$  and  $-2.84'$ , although there is an ambiguity with the sign of the equivalent pupil shift in Y direction compared to the text around table 6-7 in RD3.

**NB:** the location of the centre of rotation is not mentioned and as it is applied in RD3 as a direct pupil shear, it is assumed that this rotation centre is at the optical interface surface i.e. the nominal telescope focal surface and at the FoV centre/reference taken here as the nominal design location of PSW E8.

Additionally the tilts of the internal chief ray as measured at instrument level for all SPIRE models (see RD4) adds the following rotations (about same assumed centre of rotation as above):  $0.92'$  about Y and  $-2.23'$  about Z. This is also reported in RD3 table 6-9 but for the sake of generating the total pupil mismatch table 6-11 which is not relevant for the pointing.

Finally the reported measured lateral shift of SPIRE ( $-1.21\text{mm}$  in Y and  $+0.26\text{mm}$  in Z from table 6-8 in RD3) are applied to the instrument model here. Defocus or variations along X are not applied as small/negligible in front of the telescope focus uncertainty and being dominantly along X, have very low impact on the on-sky pointing.

#### \* **Step 5:**

Confirmed intercepts are then further raytrace backward through the HSO telescope, up to far-field object-space of the telescope (on-sky region) where the geometric centroid of the individual "apertures" beam is now defined in term of direction cosine vector, representing the "apertures" line-of-sight (LOS). These are reported in details in Appendix 1. The HSO telescope optical model used now is based on the data related to the flight configuration as defined under the "Flight 70K" label in the telescope OICD (see RD5) and includes variations in lateral position of M2 and TFS, curvature of M1, M2 and TFS, conic constant of M2, separation M1-M2 and M1-TFS compared to the nominal design values previously used.

**NB:** all variations/displacements are made comparatively to M1 whose surface normal at vertex is maintained as the reference spacecraft X axis.

#### \* **Step 6:**

A Cartesian system based on right-handed orthonormal vector triad (u,v,w) is generated around the LOS for each aperture. The vector u is given by the respective direction cosine vector of the "aperture". The vectors v and w are obtained via the orthonormalisation procedure given in section 1.2.2 of AD1. The DCM is then generated first through individual coefficients as expressed in section 7.1.2 of AD1 and checked by an alternative more direct method.

A Matlab script, user-fed by the LOS for each "aperture", performing these computations is given in Appendix 3, along side its standard output on an example. Multiple verification of (u,v,w) orthonormality and of DCM orthonormality as a 3x3 rotation matrix is also performed by the script.

This completes the process of generating the main data, i.e. the DCM, for each "aperture".

## 2. SIAM file data

This section used to be a place-holder for the listing of the SIAM field data, in the format defined by AD1, for the nominal detector list in Appendix 2.



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After discussion with ESA, the SIAM file data are now delivered as a single external separate text file containing all the matrix values for all SPIRE “apertures” and in the defined format. Attached to the previous of this note was text file “**SPIRE SIAM v1.5.txt**” in consistence with the note history version. It is now the text file labelled “**SPIRE SIAM v2.0.txt**”.

### 3. Additional SIAM file data (SLW)

Initially only the SSW detectors may have been thought to be relevant for the SPIRE Spectrometer channel because some SSW detectors were originally co-aligned with SLW ones. Actually since the inclusion of the field lenses in the Spectrometer optics (see RD1), the detector plane focal ratio changed and is now different between SLW and SSW, leading to non-perfect co-alignment of most detectors between these 2 bands except the central ones. So while SLW-C3 and SSW-D4 still share the same SPIRE aperture (viz. S24), there is a possible need for the SIAM file data to take into account the remaining SLW detectors as well.

AD1 (in its Annex A) allows up to 75 different elements to be included. From Appendix 2, it can be seen that nominally only 54 are used so that additional 18 for SLW detectors will still fit in the total allocation of the SIAM file for SPIRE. The same procedure as described in section 1 was applied and resulting SIAM file data for these “apertures” (link with SPIRE SLW detectors can be found from table at the end of Appendix 1 with completed look-up table detector label/SIAM file number in Appendix 2) are included in the same, now external, text file “**SPIRE SIAM v2.0.txt**”.

### 4. Parallel Mode

In the Parallel Mode, PACS and SPIRE are operating in photometry mode simultaneously by definition (see RD2). The nominal LOS is logically at the centre/middle of the respective SPIRE and PACS Photometer FoV. For SPIRE, “aperture” PSW E8 at the centre of the SPIRE Photometer FoV, is used as reference. Its SIAM matrix data is under label S14 above. For PACS, aperture P01\_0 (Photometer centre of field) is taken  $\Delta_x=202.0 \text{ mm}^1$ ,  $\Delta_y=-0.26 \text{ mm}$ ,  $\Delta_z=84.49 \text{ mm}$ , as defined by ESA (see email from Miguel Sanchez ESA/SCI-OPS, 12/07/2008).

Using the updated telescope model, the LOS of PACS reference aperture is found: [0.9999961, 2.20E-04, -2.77E-03]. And this is averaged with the vector LOS (see Appendix 1, Table 1) defining the pointing on-sky of PSW E8 for SPIRE, leading to the “middle” LSO pointing vector [0.99999924, 0.000216184, 0.000323386]. This latter one is then fed into step 6 of the procedure described in section 1 in order to generate the resulting DCM.

The SIAM file data to be used for the Parallel Mode aperture S55 has also been included in “**SPIRE SIAM v2.0.txt**”.

<sup>1</sup> This value is probably wrong as we expect more ~220mm but being along X this is not important as discussed in section 1 step 4.



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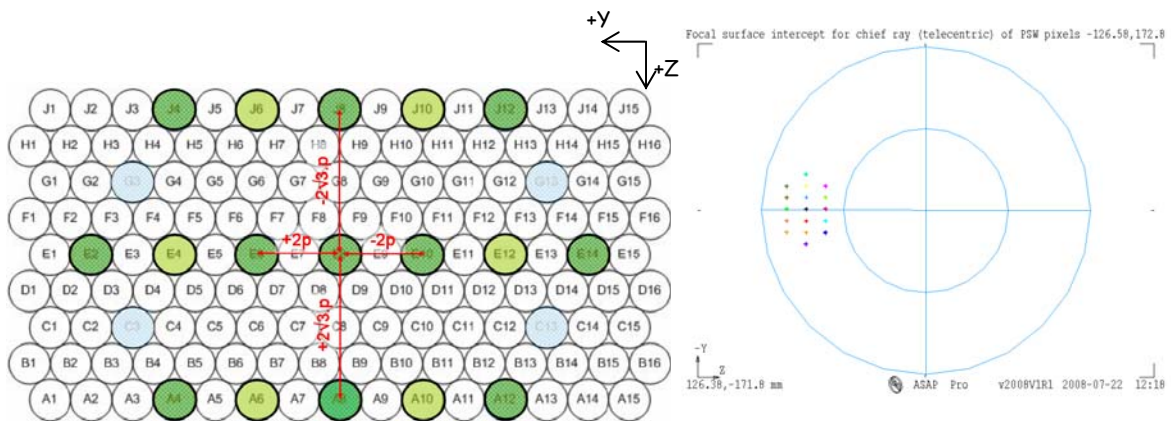
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### Appendix 1 SPIRE Pixel Tables and SIAM Apertures

Below are given tables linking the pixel labelling as per PFM4 (last ILT performance test campaign on flight model including optical test data that can be used in relation to pixel location) and the SPIRE SIAM “aperture” list, given in Appendix 2, for the relevant SPIRE spectral bands (PSW, SSW and SLW). Illustration of the pixel labelling and related position in respective array and at telescope focal plane is also given.

- PSW band: only the 17 detectors listed in the SPIRE SIAM “aperture” list are reported here



**Figure 2:** Left: Layout of PSW detector arrangement and labels as used in ILT. The bold circled ones are the one relevant for the SIAM file. Right: Image of their centres (seen from M2) at the telescope focal plane in the official coordinate system.

#Case	of	SPIRE	Phot	PSW		#Case	of	SPIRE	Phot	PSW	
#PixelNo	Xesa	Yesa	Zesa	PFM4 label	#PixelNo	Aesa	Besa	Cesa			SIAM file ID
1	226.43	-1.21	-89.82	<b>E8</b>	1	0.999994100	0.000211900	0.003421500			14
2	226.61	7.50	-89.85	<b>E6</b>	2	0.999994100	-0.000084000	0.003423000			5
3	226.72	-9.92	-89.84	<b>E10</b>	3	0.999994000	0.000515400	0.003411700			6
4	227.28	16.23	-89.93	<b>E4</b>	4	0.999994100	-0.000384000	0.003416000			13
5	227.51	-18.65	-89.92	<b>E12</b>	5	0.999993900	0.000827100	0.003404400			15
6	228.44	24.97	-90.06	<b>E2</b>	6	0.999993900	-0.000692000	0.003410300			4
7	228.77	-27.39	-90.04	<b>E14</b>	7	0.999993500	0.001137900	0.003409000			7
8	219.15	-1.20	-75.18	<b>A8</b>	8	0.999995800	0.000215500	0.002886400			2
9	219.34	7.61	-75.21	<b>A6</b>	9	0.999995800	-0.000088000	0.002888000			11
10	219.45	-10.01	-75.20	<b>A10</b>	10	0.999995700	0.000524040	0.002881110			12
11	220.01	16.43	-75.27	<b>A4</b>	11	0.999995800	-0.000394300	0.002885200			1
12	220.23	-18.83	-75.25	<b>A12</b>	12	0.999995500	0.000832980	0.002882250			3
13	235.07	-1.23	-104.59	<b>J8</b>	13	0.999992200	0.000212260	0.003950370			9
14	235.26	7.42	-104.62	<b>J6</b>	14	0.999992200	-0.000081700	0.003951650			16
15	235.37	-9.87	-104.62	<b>J10</b>	15	0.999992100	0.000513420	0.003940920			17
16	235.93	16.07	-104.72	<b>J4</b>	16	0.999992100	-0.000379300	0.003944600			8
17	236.16	-18.53	-104.71	<b>J12</b>	17	0.999991900	0.000823550	0.003937490			10

**Table 1:** Summary of the Telescope focal plane intercepts (in mm in ESA coordinate system) and the direction cosine vector coordinates for PSW detectors. The SIAM file identifier is added to allow link and traceability with respective relevant detector.

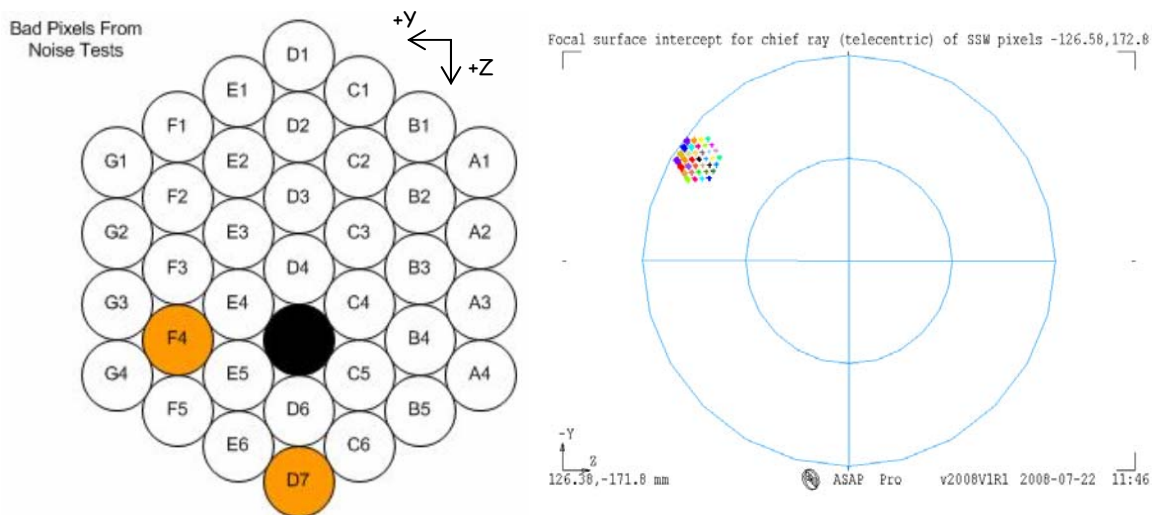


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- SSW band: all 37 detectors are included



**Figure 3:** Left: Layout of SSW detector arrangement and labels as used in ILT. Right: Image of their centres (seen from M2) at the telescope focal plane in the official coordinate system

#Case of SPIRE Spectro SSW	#Case of SPIRE Spectro SSW	SIAM file ID
#PixelNo Xesa Yesa Zesa PFM4 label	#PixelNo Aesa Besa Cesa	
1 238.03 -61.61 -89.53 D4	1 0.999991400 0.002344800 0.003425600	24
2 240.29 -61.27 -93.81 D3	2 0.999990900 0.002334700 0.003580300	37
3 235.93 -61.96 -85.34 D5	3 0.999991900 0.002356500 0.003275600	48
4 242.73 -60.95 -98.18 D2	4 0.999990300 0.002323000 0.003739600	34
5 233.97 -62.33 -81.23 D6	5 0.999992300 0.002370100 0.003128200	51
6 245.36 -60.65 -102.65 D1	6 0.999989700 0.002313900 0.003904200	18
7 232.15 -62.69 -77.17 D7	7 0.999992700 0.002385300 0.002987100	30
8 241.33 -69.30 -90.00 B3	8 0.999990700 0.002606700 0.003437400	25
9 243.53 -68.88 -94.23 B2	9 0.999990200 0.002593300 0.003587700	38
10 239.30 -69.74 -85.77 B4	10 0.999991100 0.002622430 0.003290260	49
11 245.90 -68.48 -98.55 B1	11 0.999989700 0.002579060 0.003742260	35
12 237.42 -70.19 -81.82 B5	12 0.999991600 0.002637920 0.003145800	52
13 235.35 -53.74 -89.66 F3	13 0.999992000 0.002070040 0.003419490	23
14 237.71 -53.50 -94.01 F2	14 0.999991500 0.002063720 0.003576580	36
15 233.17 -54.00 -85.41 F4	15 0.999992500 0.002078040 0.003266980	47
16 240.24 -53.27 -98.46 F1	16 0.999990900 0.002057640 0.003739050	33
17 231.13 -54.26 -81.22 F5	17 0.999993000 0.002089160 0.003118250	50
18 240.69 -65.28 -91.80 C3	18 0.999990800 0.002469430 0.003506270	41
19 238.55 -65.67 -87.60 C4	19 0.999991300 0.002483090 0.003355640	45
20 243.01 -64.91 -96.10 C2	20 0.999990300 0.002457080 0.003660670	21
21 236.57 -66.08 -83.48 C5	21 0.999991700 0.002497990 0.003209590	28
22 245.51 -64.56 -100.51 C1	22 0.999989700 0.002445340 0.003819470	32
23 234.72 -66.49 -79.43 C6	23 0.999992100 0.002513320 0.003065070	54
24 237.74 -57.55 -91.66 E3	24 0.999991400 0.002204920 0.003499190	40
25 235.52 -57.85 -87.40 E4	25 0.999992000 0.002215230 0.003344460	44
26 240.13 -57.27 -96.02 E2	26 0.999990900 0.002196440 0.003657320	20
27 233.45 -58.16 -83.21 E5	27 0.999992400 0.002225660 0.003194910	27
28 242.71 -57.00 -100.48 E1	28 0.999990300 0.002188490 0.003821230	31
29 231.53 -58.48 -79.10 E6	29 0.999992800 0.002237980 0.003048810	53
30 244.28 -72.85 -92.55 A2	30 0.999990100 0.002732590 0.003522450	42
31 242.20 -73.32 -88.40 A3	31 0.999990500 0.002747540 0.003374280	46
32 246.52 -72.38 -96.79 A1	32 0.999989600 0.002718430 0.003673550	22
33 240.27 -73.79 -84.34 A4	33 0.999991000 0.002764830 0.003230940	29
34 235.46 -49.64 -92.16 G2	34 0.999992000 0.001924010 0.003502070	39
35 233.14 -49.83 -87.82 G3	35 0.999992500 0.001930250 0.003346450	43
36 237.95 -49.47 -96.59 G1	36 0.999991400 0.001920350 0.003662370	19
37 230.96 -50.06 -83.54 G4	37 0.999993000 0.001937180 0.003194870	26

**Table 2:** Summary of the Telescope focal plane intercepts (in mm in ESA coordinate system) and the direction cosine vector coordinates for SSW detectors. The SIAM file identifier is added to allow link and traceability with respective relevant detector.



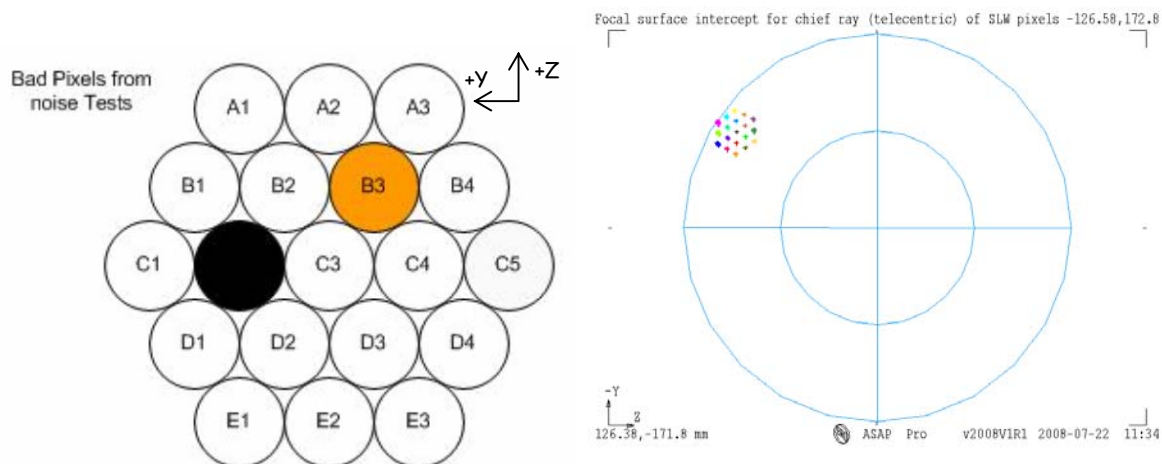


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**- SLW band: all detectors are included (see section 3 for justification)**



**Figure 4:** Left: Layout of SLW detector arrangement and labels as used in ILT. Right: Image of their centres (seen from M2) at the telescope focal plane in the official coordinate system

#Case #PixelNo	of Xesa	SPIRE Yesa	Spectro Zesa	SLW PFM4 label	#Case #PixelNo	of Aesa	SPIRE Besa	Spectro Cesa	SLW	SIAM file ID
1	238.02	-61.61	-89.53	C3	1	0.999991400	0.002344800	0.003425500		56
2	235.60	-54.55	-89.63	C2	2	0.999991900	0.002095400	0.003425300		57
3	240.96	-68.51	-89.93	C4	3	0.999990700	0.002586600	0.003442400		58
4	233.70	-47.31	-90.23	C1	4	0.999992400	0.001842600	0.003441500		59
5	244.37	-75.23	-90.82	C5	5	0.999990000	0.002825100	0.003473500		60
6	239.88	-57.70	-95.33	D2	6	0.999991000	0.002204200	0.003626800		61
7	242.46	-64.56	-95.40	D3	7	0.999990400	0.002445200	0.003633900		62
8	237.86	-50.71	-95.79	D1	8	0.999991500	0.001957700	0.003637900		63
9	245.56	-71.27	-95.98	D4	9	0.999989700	0.002681000	0.003656100		64
10	244.51	-60.72	-101.25	E2	10	0.999990000	0.002309760	0.003836010		65
11	242.26	-53.77	-101.51	E1	11	0.999990500	0.002051600	0.003833190		66
12	247.23	-67.37	-101.48	E3	12	0.999989400	0.002544040	0.003850470		67
13	233.89	-58.51	-83.84	B2	13	0.999992300	0.002240840	0.003221200		68
14	236.68	-65.62	-84.07	B3	14	0.999991700	0.002490710	0.003232210		69
15	231.61	-51.22	-84.11	B1	15	0.999992800	0.001982790	0.003227400		70
16	239.95	-72.55	-84.78	B4	16	0.999991000	0.002734460	0.003257690		71
17	232.68	-62.58	-78.36	A2	17	0.999992600	0.002385740	0.003019540		72
18	230.09	-55.56	-78.20	A1	18	0.999993100	0.002149070	0.003020480		73
19	235.80	-69.73	-78.91	A3	19	0.999991900	0.002634190	0.003040760		

**Table 3:** Summary of the Telescope focal plane intercepts (in mm in ESA coordinate system) and the direction cosine vector coordinates for SLW detectors. The SIAM file identifier is added to allow link and traceability with respective relevant detector.



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## Appendix 2 SPIRE Aperture Identifiers

Nominal list of SIAM aperture identifiers are listed below with their SPIRE detector counterparts. The additional SLW aperture identifiers are highlighted in yellow.

<i>Aperture</i>	<i>Description</i>
S01_s	PSW Array: Bolometer A4 Co-aligned
S02_s	PSW Array: Bolometer A8 Co-aligned
S03_s	PSW Array: Bolometer A12 Co-aligned
S04_s	PSW Array: Bolometer E2 Co-aligned
S05_s	PSW Array: Bolometer E6 Co-aligned
S06_s	PSW Array: Bolometer E10 Co-aligned
S07_s	PSW Array: Bolometer E14 Co-aligned
S08_s	PSW Array: Bolometer J4 Co-aligned
S09_s	PSW Array: Bolometer J8 Co-aligned
S10_s	PSW Array: Bolometer J12 Co-aligned
S11_s	PSW Array: Bolometer A6
S12_s	PSW Array: Bolometer A10
S13_s	PSW Array: Bolometer E4
S14_s	PSW Array: Bolometer E8
S15_s	PSW Array: Bolometer E12
S16_s	PSW Array: Bolometer J6
S17_s	PSW Array: Bolometer J10
S18_s	SSW Array: Bolometer D1 Co-aligned
S19_s	SSW Array: Bolometer G1 Co-aligned
S20_s	SSW Array: Bolometer E2 Co-aligned
S21_s	SSW Array: Bolometer C2 Co-aligned
S22_s	SSW Array: Bolometer A1 Co-aligned
S23_s	SSW Array: Bolometer F3 Co-aligned
S24_s	SSW Array: Bolometer D4 Co-aligned
S25_s	SSW Array: Bolometer B3 Co-aligned
S26_s	SSW Array: Bolometer G4 Co-aligned
S27_s	SSW Array: Bolometer E5 Co-aligned
S28_s	SSW Array: Bolometer C5 Co-aligned
S29_s	SSW Array: Bolometer A4 Co-aligned
S30_s	SSW Array: Bolometer D7 Co-aligned
S31_s	SSW Array: Bolometer E1
S32_s	SSW Array: Bolometer C1
S33_s	SSW Array: Bolometer F1
S34_s	SSW Array: Bolometer D2
S35_s	SSW Array: Bolometer B1
S36_s	SSW Array: Bolometer F2
S37_s	SSW Array: Bolometer D3
S38_s	SSW Array: Bolometer B2
S39_s	SSW Array: Bolometer G2
S40_s	SSW Array: Bolometer E3
S41_s	SSW Array: Bolometer C3
S42_s	SSW Array: Bolometer A2
S43_s	SSW Array: Bolometer G3
S44_s	SSW Array: Bolometer E4
S45_s	SSW Array: Bolometer C4
S46_s	SSW Array: Bolometer A3
S47_s	SSW Array: Bolometer F4
S48_s	SSW Array: Bolometer D5
S49_s	SSW Array: Bolometer B4
S50_s	SSW Array: Bolometer F5
S51_s	SSW Array: Bolometer D6
S52_s	SSW Array: Bolometer B5
S53_s	SSW Array: Bolometer E6
S54_s	SSW Array: Bolometer C6



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#### S55\_s SPIRE Parallel Mode

S56_s	SLW Array: Bolometer C2
S57_s	SLW Array: Bolometer C4
S58_s	SLW Array: Bolometer C1
S59_s	SLW Array: Bolometer C5
S60_s	SLW Array: Bolometer D2
S61_s	SLW Array: Bolometer D3
S62_s	SLW Array: Bolometer D1
S63_s	SLW Array: Bolometer D4
S64_s	SLW Array: Bolometer E2
S65_s	SLW Array: Bolometer E1
S66_s	SLW Array: Bolometer E3
S67_s	SLW Array: Bolometer B2
S68_s	SLW Array: Bolometer B3
S69_s	SLW Array: Bolometer B1
S70_s	SLW Array: Bolometer B4
S71_s	SLW Array: Bolometer A2
S72_s	SLW Array: Bolometer A1
S73_s	SLW Array: Bolometer A3



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### Appendix 3 DCM Generation Code

Below is given the Matlab script used to generate DCM from and its screen output (in the case of PSW E8).

```
%
% SPIRE_SIAM_generator.m
% Matlab script to generate matrix of SIAM file
% Marc Ferlet, RAL/SSTD, March 07
%

% initialisation
clear all
close all

DCM=zeros(3);

x=[1;0;0]; % X_SCA reference vector
y=[0;1;0]; % Y_SCA reference vector
z=[0;0;1]; % Z_SCA reference vector

disp(' ');
disp('*****');
disp('          SPIRE SIAM file generator          ');
disp('          Marc Ferlet, STFC-RAL/SSTD, March 07          ');
disp('*****');
disp(' ');

% generation of the orthonormal INS vectors, based on LOS for a given aperture
disp(' ');
u=input('-> Enter the aperture LOS: '); % Dir cos of pixel LOS from ASAP model; example of PSWE8 is [0.999994 0 0.0031855]

u=u.'; % transposition for ease of handling below
u=u/norm(u); % normalisation (not necessary as already done by definition of dir cos vector)

v=y-sum(u.*y)*u; % orthogonalisation of y wrt u=LOS
v=v/norm(v); % normalisation

w=cross(u,v); % generation of last orthogonal vector of the INS right-hand triad (u,v,w)

% manual (i.e. not vectorised) generation of the DCM
% by generation of the matrix element through individual vector scalar products
DCM(1,1)=sum(u.*x);
DCM(2,1)=sum(v.*x);
DCM(3,1)=sum(w.*x);

DCM(1,2)=sum(u.*y);
DCM(2,2)=sum(v.*y);
DCM(3,2)=sum(w.*y);

DCM(1,3)=sum(u.*z);
DCM(2,3)=sum(v.*z);
DCM(3,3)=sum(w.*z);

format +;format long e

disp(' ');disp(' And the Direction Cosine Matrix is: ');
DCM % print the matrix in long format

% for verification/validation of orthonormalisation procedure
format
disp(' ');disp('-> Verification of :');disp(' ');
disp(' => Dot products on INS=(u,v,w) basis vectors (should be 0): ');
sum(u.*v)
sum(u.*w)
sum(v.*w)
disp(' ');disp(' => Cross-products in INS=(u,v,w) basis (should be [0 0 0]): ');
(cross(u,v)-w).'
```



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```
(cross(v,w)-u).'  

(cross(w,u)-v).'  

disp(' '); disp(' => Determinant of DCM (should be 1: ');det(DCM)  

disp(' '); disp(' => Orthogonality of DCM (should be I_3 matrix: ');DCM*DCM.'  

disp(' '); disp(' => Transfer from INS=(u,v,w) to SCA=(x,y,z) (should be [0 0 0]): ');  

(DCM*u-x).'  

(DCM*v-y).'  

(DCM*w-z).'  

disp(' '); disp(' => Transfer from SCA=(x,y,z) to INS=(u,v,w) (should be [0 0 0]): ');  

(DCM.*x-u).'  

(DCM.*y-v).'  

(DCM.*z-w).'  

disp(' ');disp(' -> Alternative (more direct/vectorised) way to generate the DCM: ');  

format long e;DCM_altern=[u./x(1);v./y(2);w./z(3)]  

disp(' ');  

format long;DCM-DCM_altern % this should be 0 / verification that the 2 methods give the same result  

return;
```

```
*****  

*           SPIRE SIAM file generator           *  

*           Marc Ferlet, STFC-RAL/SSTD, March 07           *  

*****
```

-> Enter the aperture LOS: [0.999994 0 0.0031855]

And the Direction Cosine Matrix is:

```
DCM =  

  9.999949262726043e-001      0  3.185502950659085e-003  

      0  1.000000000000000e+000      0  

-3.185502950659085e-003      0  9.999949262726043e-001
```

-> Verification of :

=> Dot products on INS=(u,v,w) basis vectors (should be 0):

```
ans =  

  0
```

```
ans =  

  0
```

```
ans =  

  0
```

=> Cross-products in INS=(u,v,w) basis (should be [0 0 0]):

```
ans =  

  0  0  0
```

```
ans =  

  0  0  0
```

```
ans =  

  0  0  0
```

=> Determinant of DCM (should be 1):

```
ans =  

  1
```

=> Orthogonality of DCM (should be I\_3 matrix):



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ans =

```
1 0 0
0 1 0
0 0 1
```

=> Transfer from INS=(u,v,w) to SCA=(x,y,z):

ans =

```
0 0 0
```

ans =

```
0 0 0
```

ans =

```
0 0 0
```

=> Transfer from SCA=(x,y,z) to INS=(u,v,w) (should be [0 0 0]):

ans =

```
0 0 0
```

ans =

```
0 0 0
```

ans =

```
0 0 0
```

-> Alternative (more direct/vectorised) way to generate the DCM:

DCM\_altern =

```
9.999949262726043e-001    0  3.185502950659085e-003
      0  1.000000000000000e+000    0
-3.185502950659085e-003    0  9.999949262726043e-001
```

verif =

```
0 0 0
0 0 0
0 0 0
```