SUBJECT: **Updated SPIRE requirements on the Cryostat aperture sizes**

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KEYWORDS: **optical clearance, misalignment, cryostat**

COMMENTS: **This document updates SPIRE requirements on the clearance required between SPIRE instrument beams and cryostat apertures, and using the latest data for aperture locations. Allowance for the emerging HERSCHEL-SPIRE misalignment budget has been included.**

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1. INTRODUCTION

This note updates RD1, which defined the method for determining requirements that SPIRE has on the size and shape of the apertures at any point in the space between SPIRE and the HERSCHEL telescope primary mirror, including making allowance for uncertainty in the alignment of the SPIRE instrument relative to the HERSCHEL telescope and cryostat assembly. The latest requirements are in response to the definition of important HERSCHEL/cryostat aperture planes, detailed in RD2 (reproduced as annex 1) and tabulated below.

The details of the derived beam clearance boundaries or 'exclusion zones', which are several mm outside the estimated worst-case for the misalignment of SPIRE to HERSCHEL, are given in section 5. The requirement that the space within these exclusion zones remain clear of relatively warm cryostat and telescope structure imposes a requirement that the cryostat apertures and primary mirror hole be sized accordingly to clear these regions.

For a note on the two main co-ordinate systems used to define cryostat planes, see the section at the end of this note.

2. REFERENCE DOCUMENTS

Document	Document number/reference	Document title
RD1	SPIRE-RAL-NOT-000993	Cryostat aperture size requirements including the effects of SPIRE-HERSCHEL misalignments
RD2	E-mail, 18 March, 2002, from edgar.Hoelzle@astrium-space.com	Axial positions for footprint analysis

3. AXIAL POSITIONS FOR BEAM FOOTPRINT ANALYSIS

Table 1

Location	ESA X_ co-ordinate (mm)	Radius (mm) of aperture located at this position	Estimated[1] 20% oversize to sub-pupil radius
M1 vertex	1252	162.5	11.9 mm
CVV aperture	729	140	6.0
Heat shield 3	603.61	140	4.6
Heat shield 2	571.61	140	4.2
Heat shield 1	536.61	140	3.8
Instrument shield	505.81	140	3.5

The telescope focus is at X=202 and the surface of the optical bench mounting plane is at X=0.0

[1] See algorithm in section 5

4. INCLUDING MISALIGNMENTS INTO BEAM FOOTPRINT CALCULATIONS

Allowance for misalignments (displacements and tilts) was made as described in RD1. We chose values for the maximum sizes (amplitudes) of lateral displacements and axial tilts (per axis) that were consistent with producing pupil shifts at M2 within a stated maximum size with a certain confidence level. This maximum size was set as 9.3 mm and the confidence level set at >99%. The figure of 9.3 mm results from root-sum-squaring components 6.3 mm (SPIRE instrument budget) and 6.8 mm (lateral telescope alignment budget). The displacement and tilt amplitudes (per axis) were chosen as –5 to +5 mm and –3.22 to +3.22 arc minutes. Monte Carlo calculations were made of 1000 random displacements and tilts drawn from uniform distributions having these limits and the optical beams defining the SPIRE detectors' views were perturbed accordingly. A composite set of perturbed beams covering a range expected to occur >99% of the time was constructed and used to determine footprints at the required aperture locations.

5. OVERSIZING MARGINS TO ALLOW FOR DIFFRACTION

After establishing a beam footprint at a particular aperture location, a margin was added to make some allowance for diffraction. The size of this margin was determined using the following simple algorithm:

$$\Delta(X) = (X - 202) * \left(\frac{180}{2638} - \frac{150}{2638}\right) mm$$

X - 202 is the location of the aperture plane above the telescope focus, with X taken from table 1. The algorithm essentially determines the difference between a cone converging on a nominally 150 mm radius M2 located at 2638 mm above the telescope focus and a 20% oversize cone that converges on a 20% oversized M2 having radius1.2*150mm. These margins are listed in table 1,

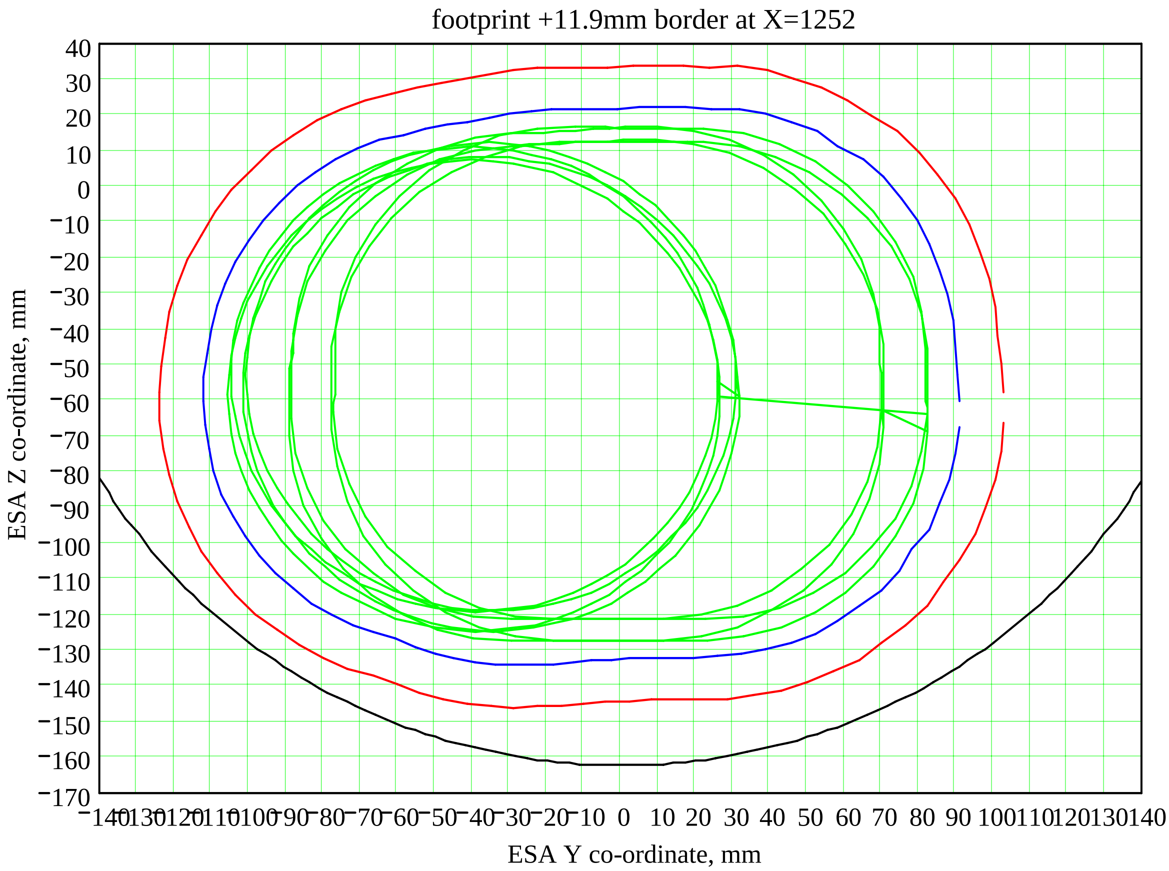
6. RESULTS

At each aperture axial location specified in table 1, a plot is shown which displays:

- In green, the footprint of the perfectly aligned composite beam from the photometer and the spectrometer (including chop and jiggle to both extremes, 8 beams in all)
- In blue, the 'probable footprint' of the beams when misaligned over a range of possible values covering 99% of the possible cases
- In red, an 'exclusion zone' defined as the 'probable footprint' with an added border whose width is proportional to the distance of the aperture plane from the telescope focus, as defined using the algorithm in section 5 and as listed in table 1.
- In black, a circle representing the aperture presently planned for that location (see table 1).

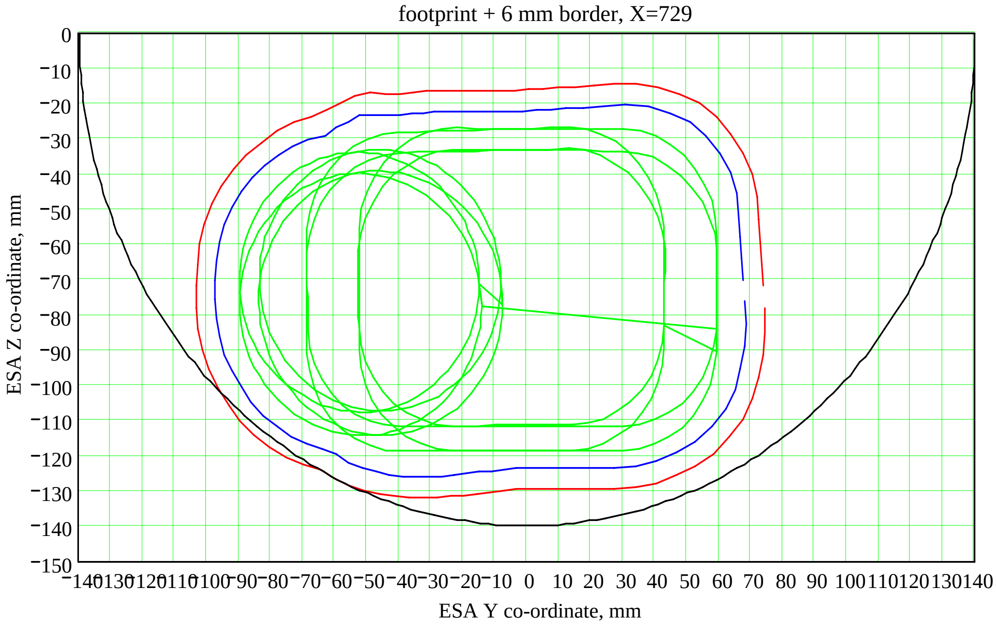
Accompanying this plot are further plots showing, the sector of the aperture boundary that falls within or near this provisional 'exclusion zone' and, where necessary, the amount by which the exclusion zone overlaps this aperture.

6.1. M1 vertex plane at X=1252 mm

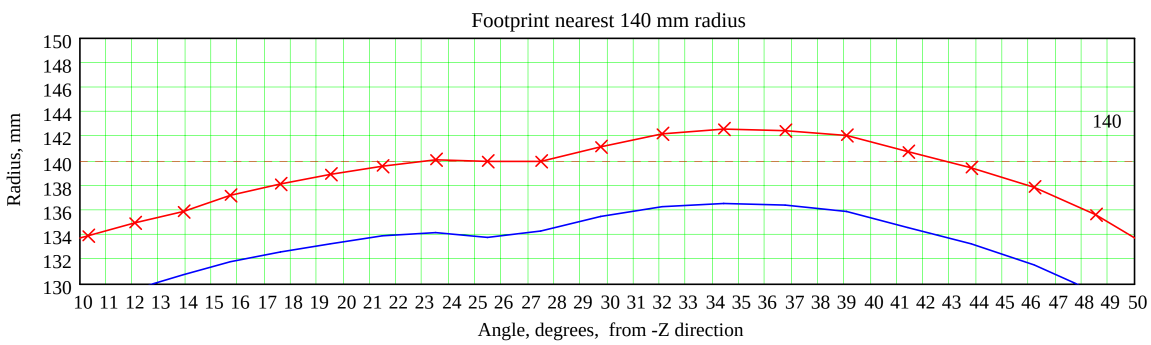


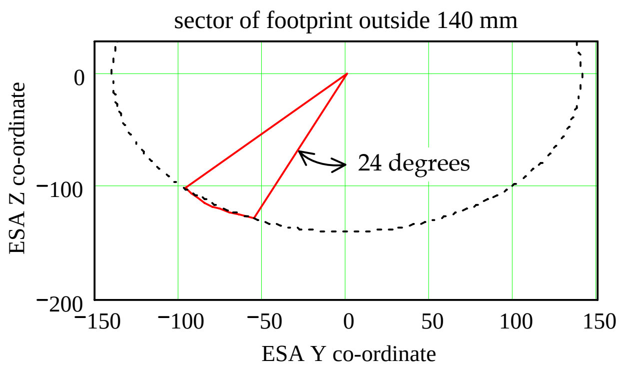
The margin added to this footprint is 11.9 mm. The beam 'exclusion zone' is shown falling within a circle radius 162.5 mm, which was taken from the most recent ASAP model of the telescope and which represents the radius of the hole in a baffle located at the M2 vertex. Based on the present design, there appears to be adequate clearance between the SPIRE 'exclusion zone' and the edge of this baffle.

6.2. CVV aperture plane at X=729 mm

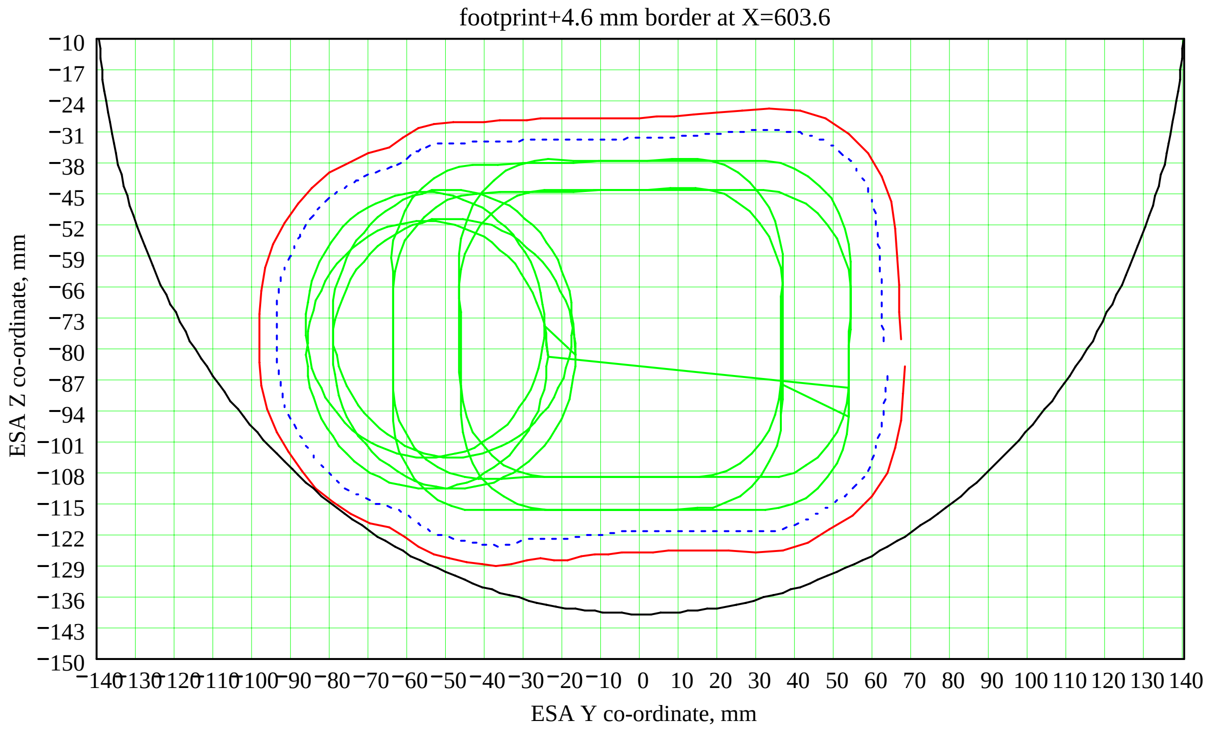


The margin added to this footprint is 6 mm. The 'exclusion zone' is shown falling partially outside a circle radius 140 mm, which represents the present CVV aperture. The plot below shows the overlapping sector in more detail. The extreme point of the edge of the footprint is at 142.6 mm from the telescope axis and occurs in a direction at about 34 degrees measured from the –Z direction. The sector extends from about 24 to 44 degrees.

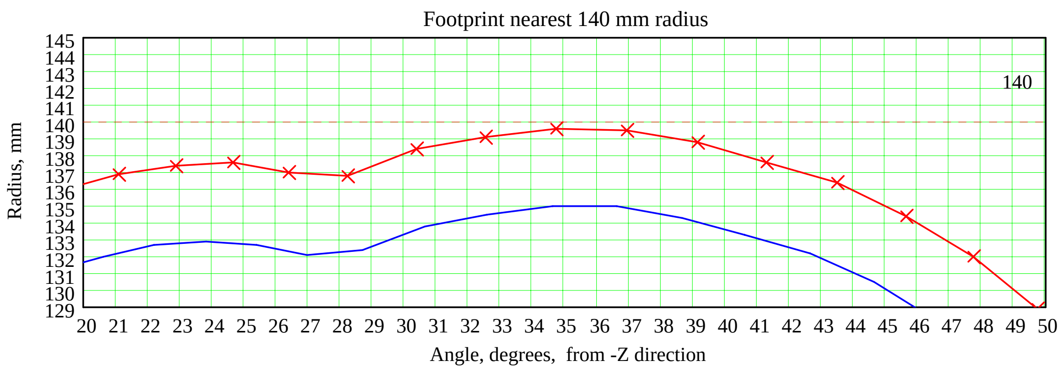




6.3. Heat Shield #3 plane at X=603.61 mm



The margin added to this footprint is 4.6 mm. The beam 'exclusion zone' is shown falling inside a circle radius 140 mm, which represents the present radius for the aperture in heat shield #3. The region nearest the 140 mm radius aperture is shown below. The point on the 'exclusion zone' boundary nearest the aperture boundary is at radius 139.6 mm, measured from the telescope axis.



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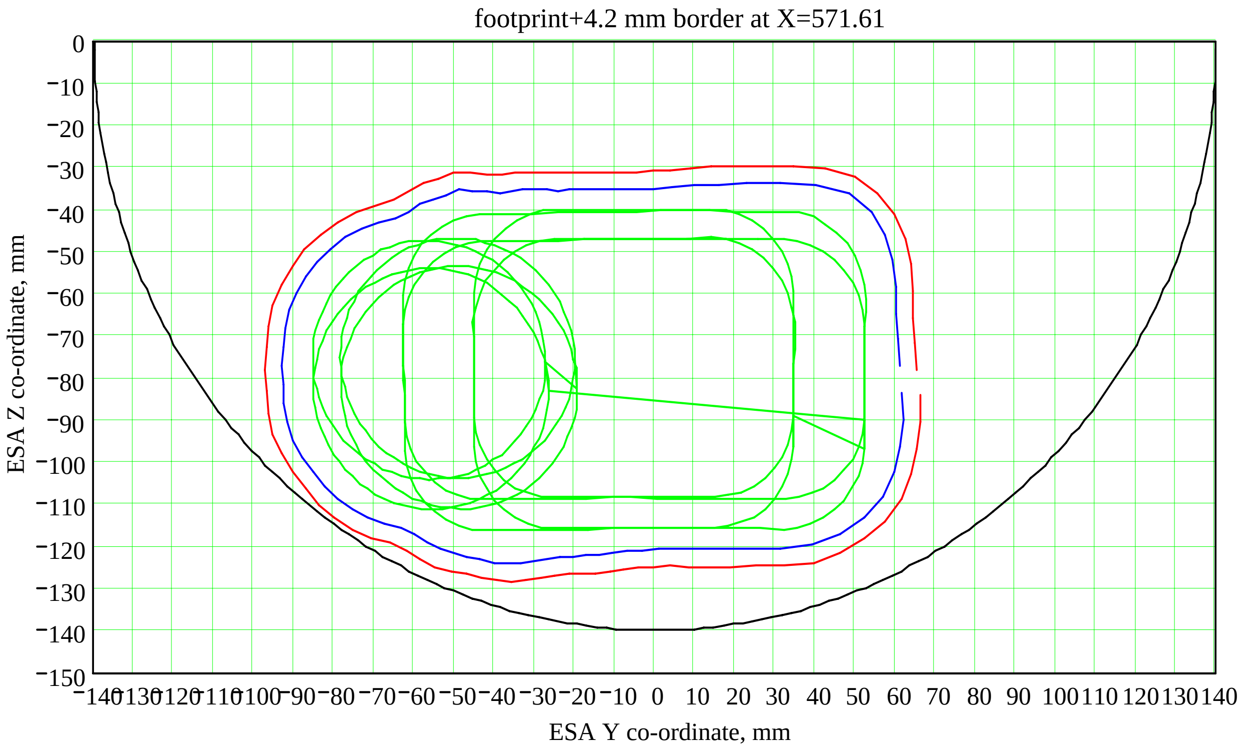
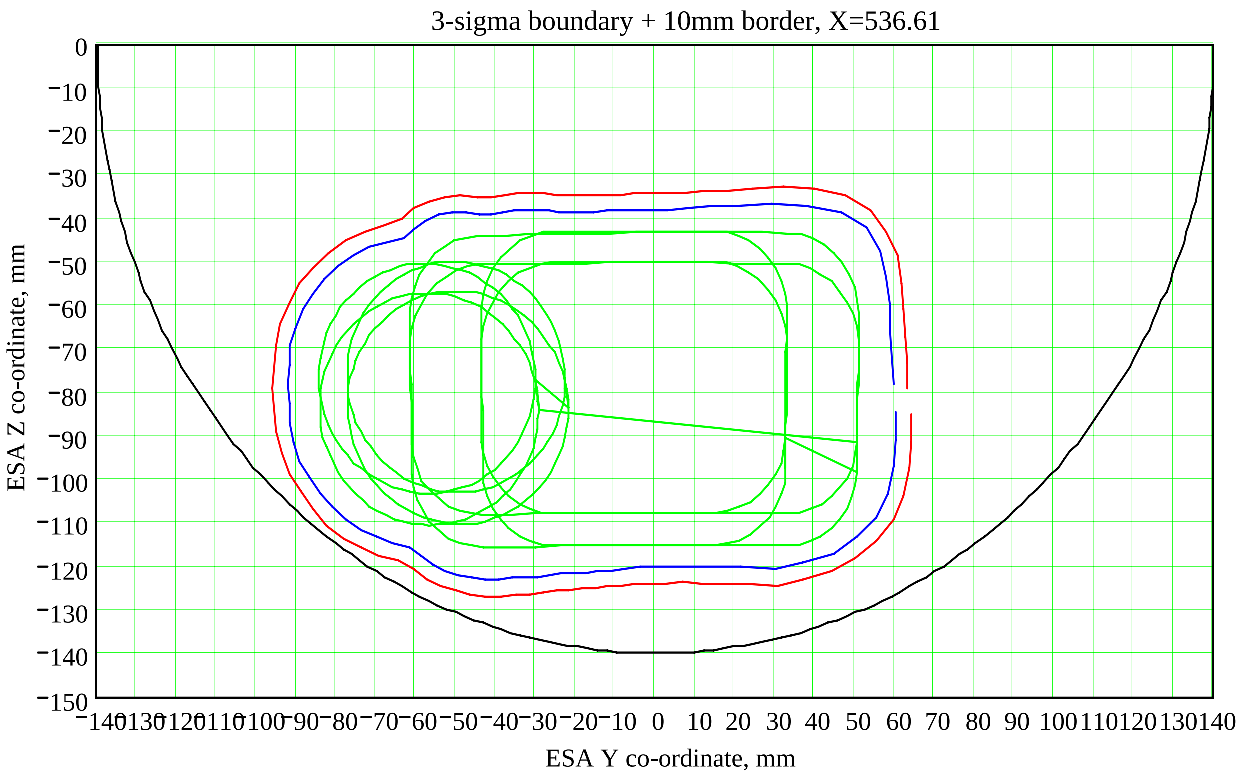
6.4. Heat Shield #2 plane at X=571.61 mm



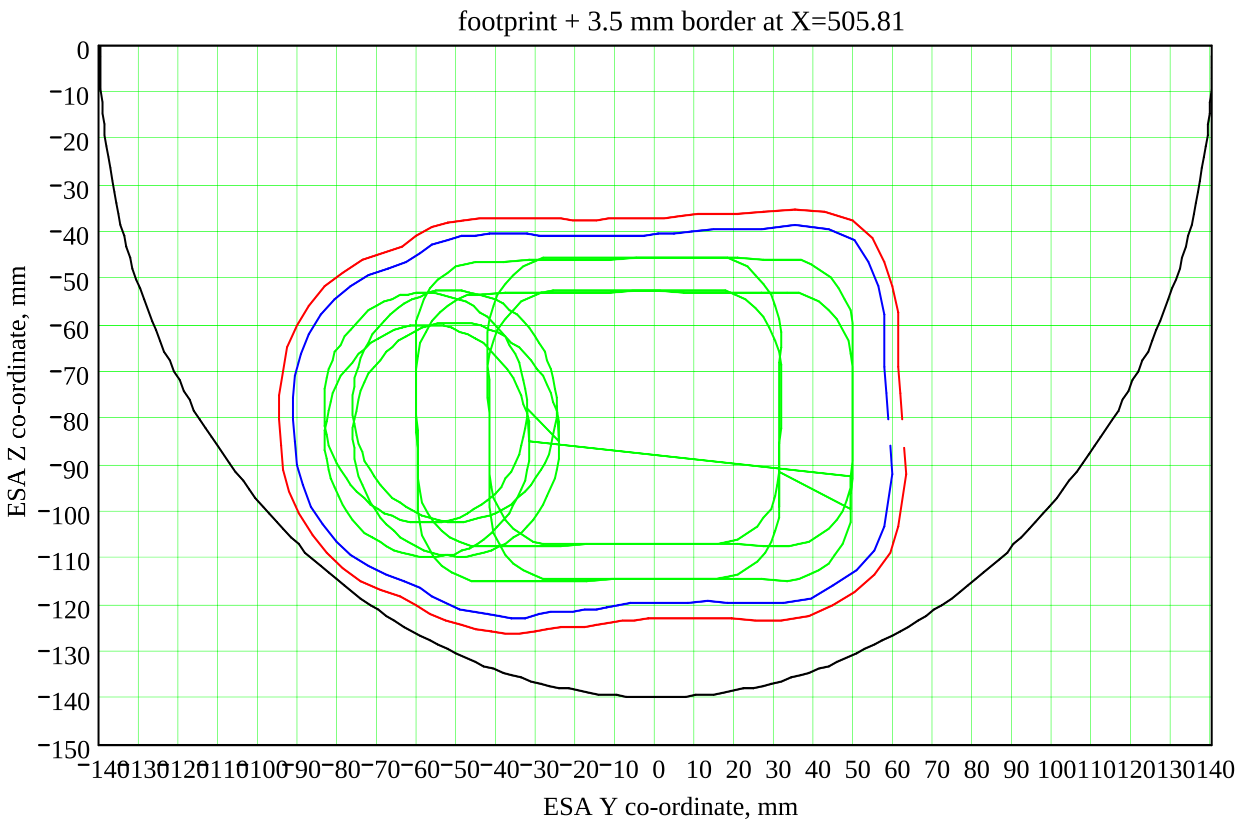
The margin added to this footprint is 4.2 mm. The beam 'exclusion zone' is shown falling inside a circle radius 140 mm, which represents the present radius for the aperture in heat shield #2.

6.5. Heat Shield #1 plane at X=536.61 mm



The margin added to this footprint is 3.8 mm. The beam ‘exclusion zone’ is shown falling inside a circle radius 140 mm, which represents the present radius for the aperture in heat shield #1.

6.6. Instrument shield plane at X=505.81 mm



The margin added to this footprint is 3.5 mm. The beam 'exclusion zone' is shown falling inside a circle radius 140 mm, which represents the present radius for the aperture in instrument shield.

7. SPIRE REQUIREMENTS ON CRYOSTAT AND M1 HOLE RADII

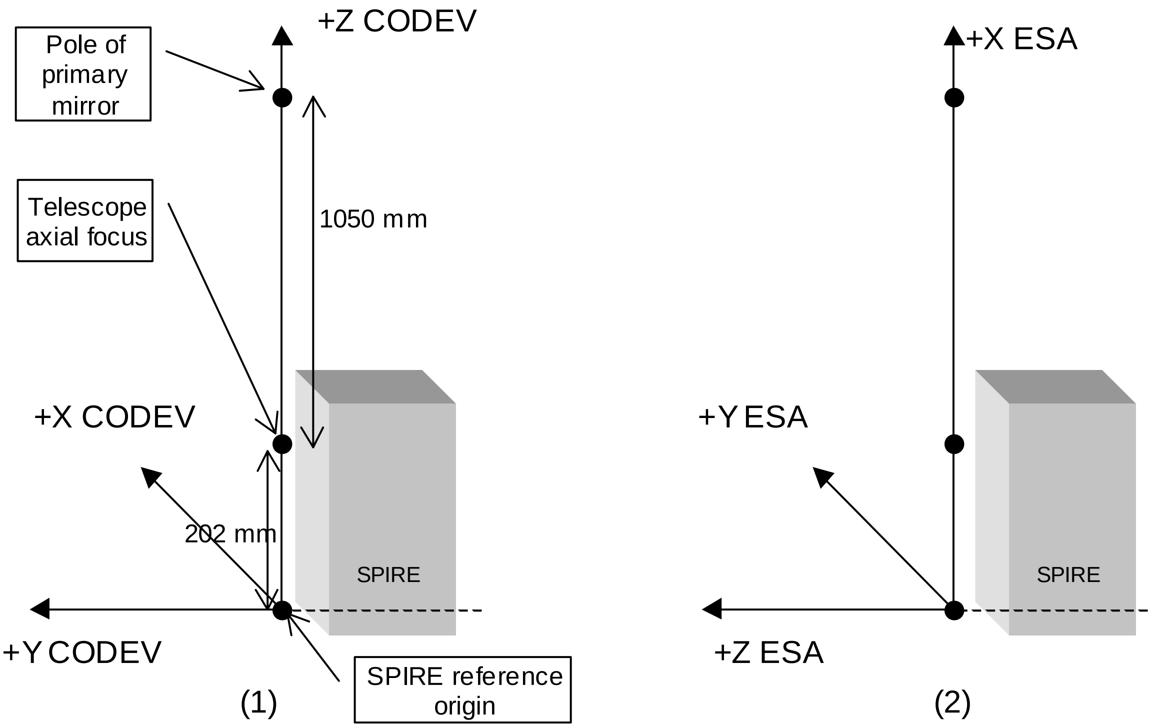
1. SPIRE requires that a clearance boundary be generated by adding a minimum clearance margin to the 3-sigma composite beam boundary that is computed using the tilt and displacement misalignments that result in lateral pupil misalignments at M2 being less than or equal to 9.3 mm with 99% confidence. The clearance margin is computed using the simple algorithm given in section 5.

2. Whatever the size computed for the clearance boundary in whatever plane, SPIRE requires that the edges of cryostat apertures and primary mirror hole structure remain on or outside the clearance boundary computed in that plane.

3. If the magnitude of the lateral displacement budget changes significantly, as a result of further developments in the alignment scheme, from its present magnitude of 9.3 mm, then the clearance boundaries should be recomputed.

8. A NOTE ON CO-ORDINATE REFERENCE FRAME USED

Two different co-ordinate systems are used from time to time in beam footprint analysis. They are indicated in the figure below. When the location of a plane normal to the telescope axis is specified, it may be given a Z-value, indicating that the first co-ordinate system is being used. RD1 occasionally uses this system, which is naturally derived from the CODEV model used to generate the original ray data, so the figures taken from that note use a Z-value to locate the sectional plane. Points in these sectional planes are located using X- and Y-co-ordinates.



Reference co-ordinate systems used.

For consistency with the co-ordinate system adopted within the mechanical design CAD platform used by SPIRE, the sectional plane data are now given in the ESA-oriented reference frame, which is the second one shown. In this frame, a plane normal to the telescope axis is given an X-value. The points in this plane are then located using Y- and Z-co-ordinates. These are the co-ordinates used in this note.

Both systems locate their origin of co-ordinates at the same point, which is on the telescope axis 202 mm below the telescope axial focus, which itself is designed to be located 1050 mm below the pole of the primary mirror.

9. ANNEX 1

From: Hoelzle, Edgar ED171 [Edgar.Hoelzle@astrium-space.com]
Sent: 18 March 2002 15:49
To: 'A.G.Richards@rl.ac.uk'; 'C.K.Wafelbakker@sron.nl';
'ngeis@mpe.mpg.de'
Cc: 'Daniel.de.Chambure@esa.int'; 'Philippe.P.Martin@space.alcatel.fr';
TOULEMONT, Yves
Subject: Axial positions for footprint analysis

Dear colleagues,

please find enclosed the axial positions of various HPLM elements for your footprint analysis: With the optical bench mounting plane used as reference, in a sequence top - down the values are:

M2 vertex:	X = 2839.998 mm
M1 vertex:	X = 1252.0 mm
CVV aperture:	X = 729.0 mm, Dia 280.0 mm
Heat shield 3:	X = 603.61 mm, Dia = 280 mm
Heat shield 2:	X = 571.61 mm, Dia = 280 mm
Heat shield 1:	X = 536.61 mm, Dia = 280 mm
Instrument shield:	X = 505.81 mm, Dia = 2.80 mm
Telescope focus	X = 202.0 mm

Opt. bench mountg. plane: X = 0.0 mm

Should any inconsistencies arise, please notify us immediately.

With this mail we close action item No. 8 of the Alignment Meeting held on
March 11th, 2002 at ESTEC.
Formal close-out by fax will follow by end of this week.

I have to ask Yves Toulemont to check the telescope parameters and eventually correct these should they have been changed recently:

Separation M1 - M2 vertices: 1587.998 mm
separation M1 vertex - focus: 1050 mm

Best regards

Edgar Hoelzle