Title:

PLANCK REFLECTORS
Interface Control Document (ICD)
For the
Secondary Reflector FM

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1	30.05.2005	all	First issue
2	31.10.2005	all	Update with DRB comments
3	20.03.2006	§5.5 and §5.7	Update after final work completion

Table of Contents

1. Scope

This document, describes in the interfaces of the Planck Secondary Reflector Flight Model with respect to the telescope. The interfaces are defined considering mechanical, thermal, electrical, optical and operational characteristics.

2. Documents

2.1 Applicable Documents

AD1	Planck Telescope Primary Reflector/Secondary Reflector Specification SCI-PT-RS-07422
AD2	Planck Telescope Reflectors Contract, DSRI/100-12/2001

2.2 Reference Documents

RD 1 Mass and Power Budgets, PLA-ASED-RP-005

RD 2 Design Report, PLA-ASED-RP-001

RD 3 Mechanical Analyses Report, PLA-ASED-RP-003

RD 4 SR Interfaces at Operating Temperature, Drawing 2540-4200-00-A00O

RD 5 SR Interfaces at Room Temperature, Drawing 2540-4200-00-A00R

RD 6 Mechanical Ground Support Equipment Specification, PLA-ASED-RP-012

RD 7 Thermal hardware SR, Drawing 2540-4200-30-A00C

RD 8 Interface Measurement of the Planck SR FM PLA-ASED-TN-085

RD 9 Mass property determination on the SR FM, B-TR60-0278 (IABG)

RD 10 Marked-Up Thermal hardware Drawing

3. Abbreviations & Acronyms

ASED	Astrium GmbH
BOL	Begin of Life
CFRP	Carbon Fibre Reinforced Plastic
DSRI	Danish Space Research Institute
EOL	End of Life
FM	Flight Model
FEM	Finite Element Model
H/W	Hardware
ISM	Isostatic Mount
MLI	Multi Layer Insulation
OT	Operating Temperature
SR	Secondary Reflector
TBC	To be confirmed
TBD	To be defined

4. General Interfaces

4.1 Description of the Planck Reflectors

The Planck Primary and Secondary Reflectors are elliptical off-axis reflectors. The required contour accuracy is guaranteed by a sandwich design consisting of CFRP face sheets and a carbon fibre epoxy core with hexagonal cells. The front surface reflectivity is provided by a protected aluminium coating. The reflectors are designed to operate in the frequency range of 25 GHz to 1000 GHz in space at temperatures of around 40 K. Heaters for contamination release are foreseen on the rear side of the reflectors. The reflector rear side is covered with MLI. Each reflector is mounted via three isostatic mounts onto the interface plane of the telescope structure. For alignment purposes one removable optical cube and three removable reference spheres per reflector are provided.

A detailed description of the Planck Reflectors is provided in RD 2

4.2 Coordinate Systems OM_2

4.2.1 Secondary Reflector Reference System OM_2

The SR co-ordinate system ($O_{M2,}$ $X_{M2,}$ $Y_{M2,}$ Z_{M2}) is defined as follows, see chapter 11:

- The origin O_{M2} is the vertex of the SR.
- The X_{M2}-axis is tilted 10.1° with respect to X_{M1} and points towards the PR.
- $Z_{M2,}$ tilted by 10.1° w.r.t. Z_{M1}, points along the major ellipsoid axis with positive direction on the reflecting side of the SR.
- Y_{M2} completes the co-ordinate system.
-

4.2.2 Secondary Reflector Reference System OM_{2C}

The SR co-ordinate system ($O_{M2C,}$ $X_{M2C,}$ $Y_{M2C,}$ Z_{M2C}) is defined as follows, see chapter 11:

- The origin O_{M2C} is defined by an intersection of a perpendicular line through the intersection in the aperture plane of a line parallel to Z_{M2} which is shifted by 288.28 mm in negative X_{M2} direction and the ISM interface plane.
- The X_{M2C}-axis is in the ISM-I/F-plane pointing from O_{M2C} towards the ISM SR-A.
- Z_{M2C} is standing on the ISM-I/F-plane on O_{M2C} and is pointing normal away from the aperture.
- Y_{M2C} completes the co-ordinate system.

5. Mechanical Interfaces

Mounting and alignment interfaces are sketched in the picture below. In the following paragraphs these and other interfaces are discussed.

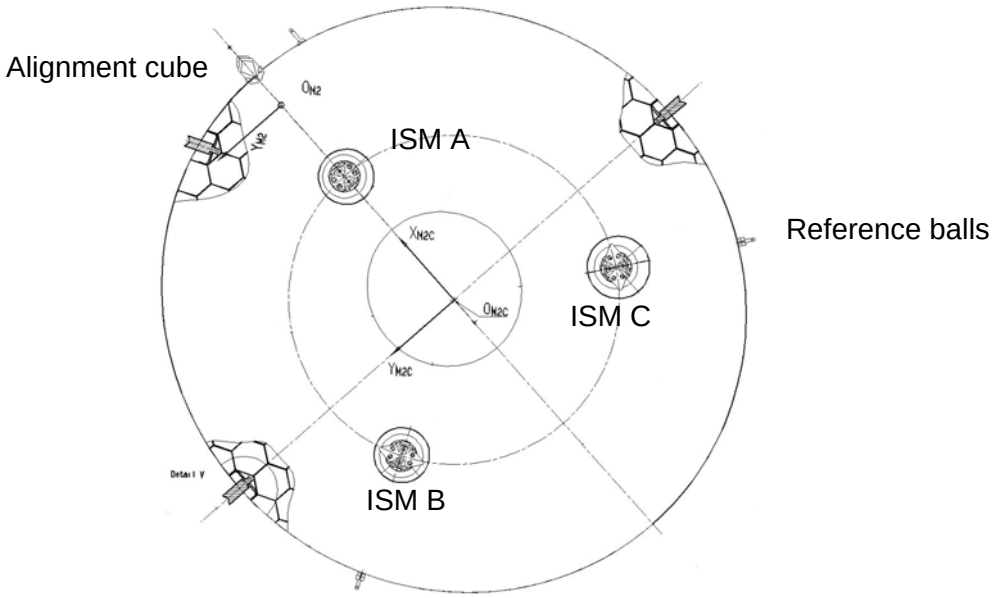


Figure 5-1: Interfaces on the SR

5.1 Dimensions

The Planck Secondary Reflector displays the following overall dimensions at nominal operational temperature:

-	Secondary Reflector	long axis:	1104.39 mm
		short axis:	1050.96 mm
		height:	307.29 mm including Thermal H/W
		thickness:	65 mm CFRP + 15 mm Thermal H/W

The envelope including the thermal hardware is shown in chapter 11.

5.2 Reflector Mounting Interfaces

5.2.1 General Mounting Interface Description

The mounting interfaces of the SR FM reflector comprise three ISM's (designated A, B, C as in the picture below) which together form the interface plane for reflector mounting onto the Planck Telescope structure. The ISMs are made of Titanium. There are two types of ISM which are used on the SR FM reflector to generate the interface plane, the short ISM and the long ISM, see Figure 5-2 and Figure 5-3.

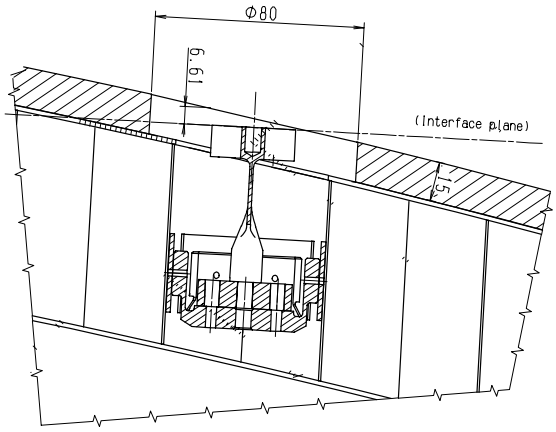


Figure 5-2: Short ISM embedded in reflector sandwich

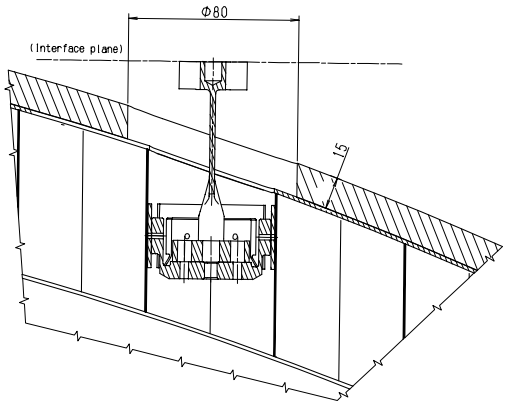


Figure 5-3 Long ISM embedded in reflector sandwich

The footprints of the interface attachment area of each of the ISM's show one central ∅8H7 fit hole and four M8 x 12mm threads for fixation. Each reflector is bolted to the telescope structure at each ISM interface with four M8 screws according to LN 29 949.

An example of the hole pattern for a short ISM is shown in Figure 5-4 below, an example of the hole pattern of a long ISM is depicted in Figure 5-5.

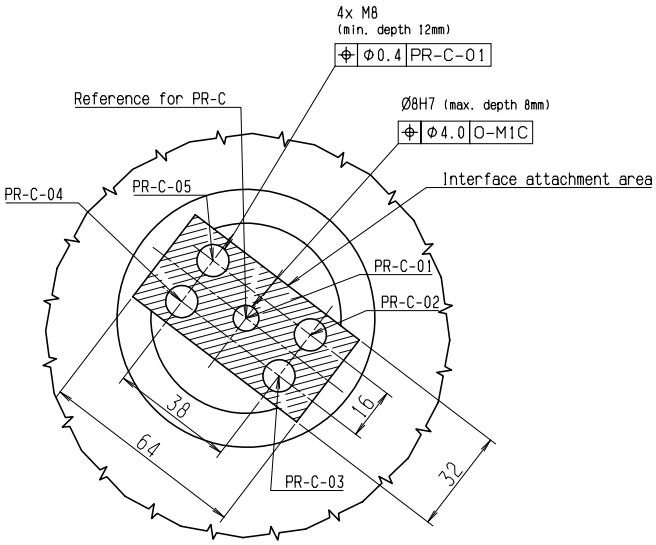


Figure 5-4 Hole Pattern of a Short ISM

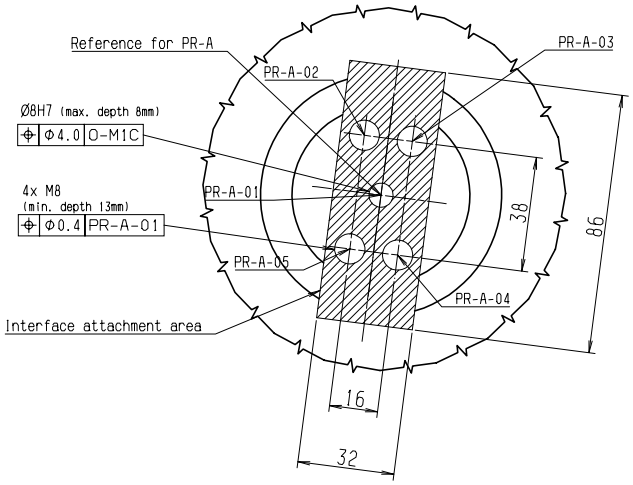


Figure 5-5 Hole Pattern of a Long ISM

5.2.2 Mounting Interface Positions

The designation of the ISM-interfaces is as follows:

Secondary Reflector – interface location – hole number

example: **S**econdary **R**eflector, ISM **A**, fit hole **1** → SR-A-1

The measured coordinates of the ISM's Center Holes in the M2C reflector co-ordinate system are:

SR-A-1: 303.878, 0, 0

SR-B-1: -151.563, 263.383, 0.11

SR-C-1: -152.577, -262.797, 0.11

The measured and transformed coordinates of the ISM-Center-Holes are:

SR-A-1	X_{Tel}	195,640	X_{M2C}	303,878	X_{M2}	-269,045
	Y_{Tel}	0,000	Y_{M2C}	0,000	Y_{M2}	0,000
	Z_{Tel}	1102,681	Z_{M2C}	0,000	Z_{M2}	39,275

SR-B-1	X_{Tel}	-138,649	X_{M2C}	-151.563	X_{M2}	-610,523
	Y_{Tel}	263,383	Y_{M2C}	263.383	Y_{M2}	263,383
	Z_{Tel}	793,364	Z_{M2C}	0.11	Z_{M2}	-261,087

SR-C-1	X_{Tel}	-139,393	X_{M2C}	-152.577	X_{M2}	-611,283
	Y_{Tel}	-262,797	Y_{M2C}	-262.797	Y_{M2}	-262.797
	Z_{Tel}	792,675	Z_{M2C}	0.11	Z_{M2}	-262,758

All positions of the ISM's are within the tolerance of ±2mm.

The local planarity of the ISM's is below the required 0.05mm. SR-B and SR-C are 0.11mm shifted w.r.t. SR-A.

The parallelity of SR-B and SR-C w.r.t. SR-A is <0.05mm

The associated position tolerances are given in chapter 11.

5.2.3 Measured Pinball Positions of the SR

For alignment purposes the SR FM is equipped with three ∅ 6 mm steel pin balls in the aperture plane. The locations of the reference pin balls are shown in the interface drawings RD 4 and RD 5.

The measured coordinates (Y_{M2C} axis pointing down during measurement, measured after the vibration tests) of the pin balls in the M2C system are:

Pinball 1: -283,000, 492,219, -290,237

Pinball 2: -284,351, -491,194, -290,272

Pinball 3: 568,776, -104,861, -281,203

The measured and transformed positions of the pinball centres are:

Pinball 1	X_{Tel}	-37,856	X_{M2C}	-283,000	X_{M2}	-516,876
	Y_{Tel}	492,219	Y_{M2C}	492,219	Y_{M2}	492,219
	Z_{Tel}	491,010	Z_{M2C}	-290,237	Z_{M2}	-566,730

Pinball 2	X_{Tel}	-38,824	X_{M2C}	-284,351	X_{M2}	-517,866
	Y_{Tel}	-491,194	Y_{M2C}	-491,194	Y_{M2}	-491,194
	Z_{Tel}	490,066	Z_{M2C}	-290,272	Z_{M2}	-567,651

Pinball 3	X_{Tel}	581,061	X_{M2C}	568,776	X_{M2}	115,648
	Y_{Tel}	-104,861	Y_{M2C}	-104,861	Y_{M2}	-104,861
	Z_{Tel}	1076,284	Z_{M2C}	-281,203	Z_{M2}	3,811

The reference pin balls are removable and shall be removed before flight, so that only a small interface bracket remains with the reflector.

The remaining bracket is shown in Figure 5-6.

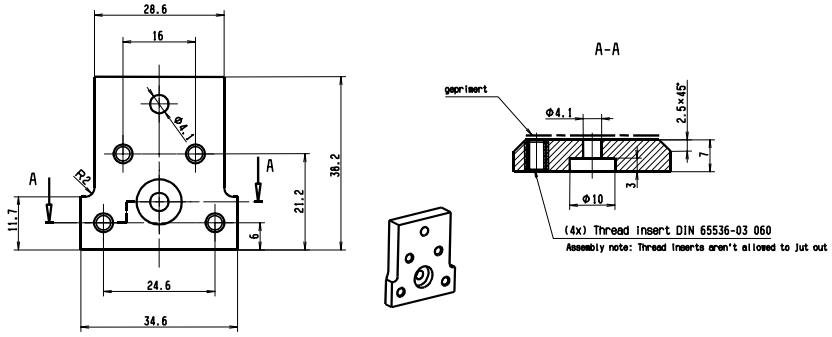


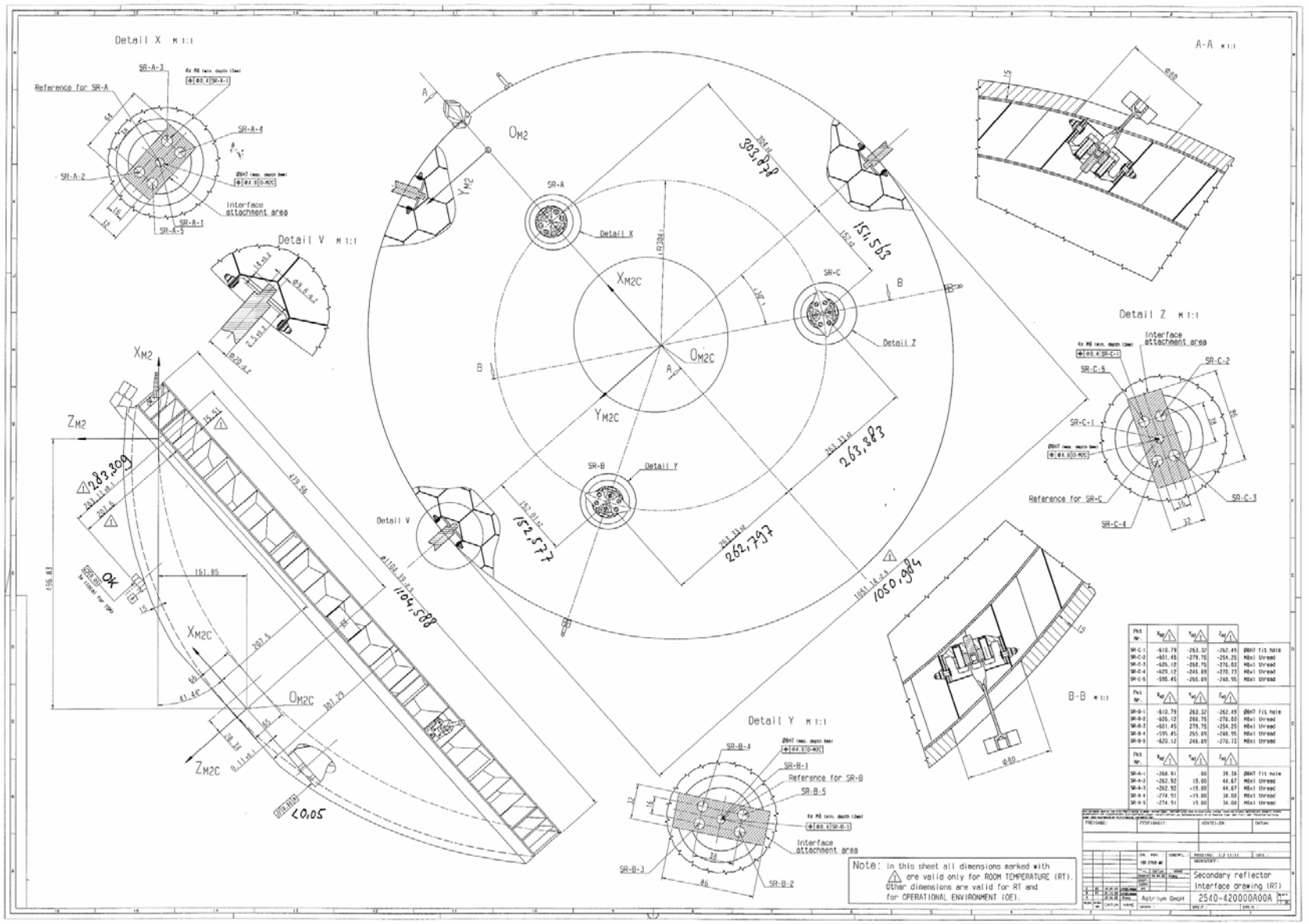
Figure 5-6 Remaining Pinball Attachment Plate

5.2.4 Measured Outer Dimensions of the SRFM

The length of the reflector is 1104.59mm, required is 1104.39-2.5mm.
The width of the reflector is 1050.98mm, required is 1050.96-2.5mm.

In the drawing on the next page all measured values are inserted.

5.2.5 Plan with measured Interface Positions



5.3 Hoisting and Handling Point Interfaces

The points for the hoisting device fixation are indicated in the interface drawings. Each reflector has three interfaces for mounting the hoisting device. A cross-sectional view of the reflector hoisting device mounted to the reflector is stated in the picture below.

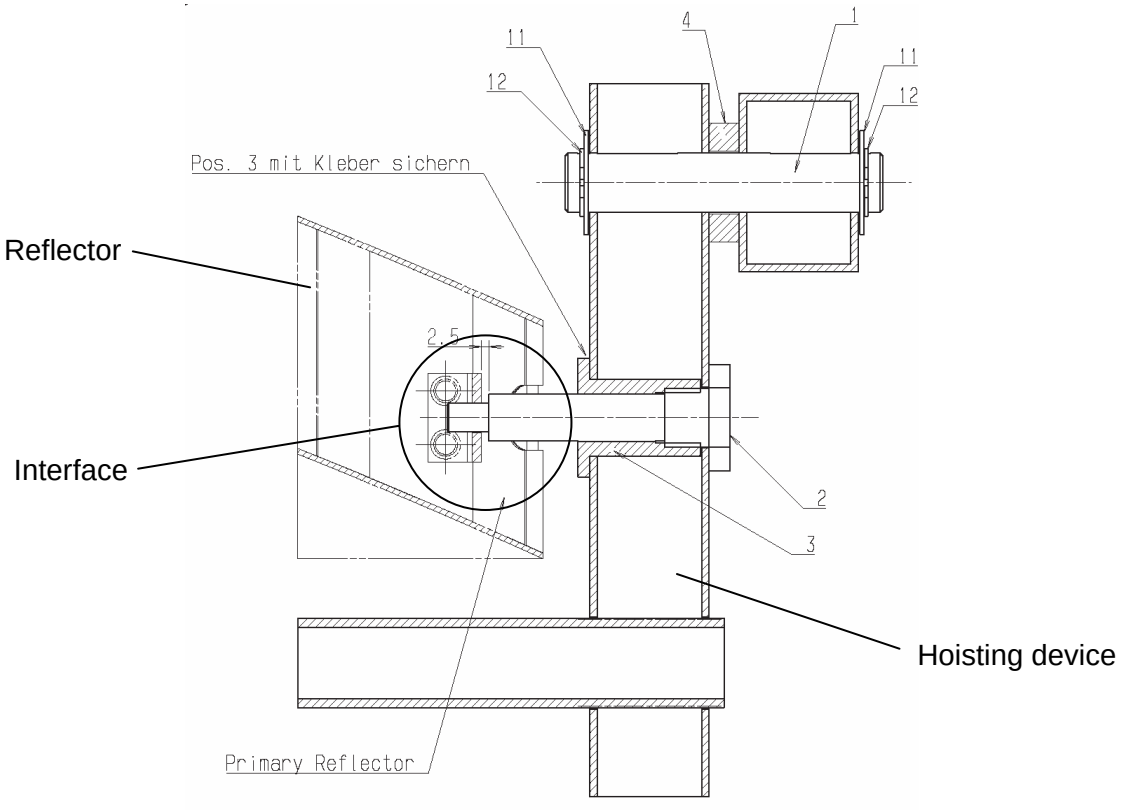
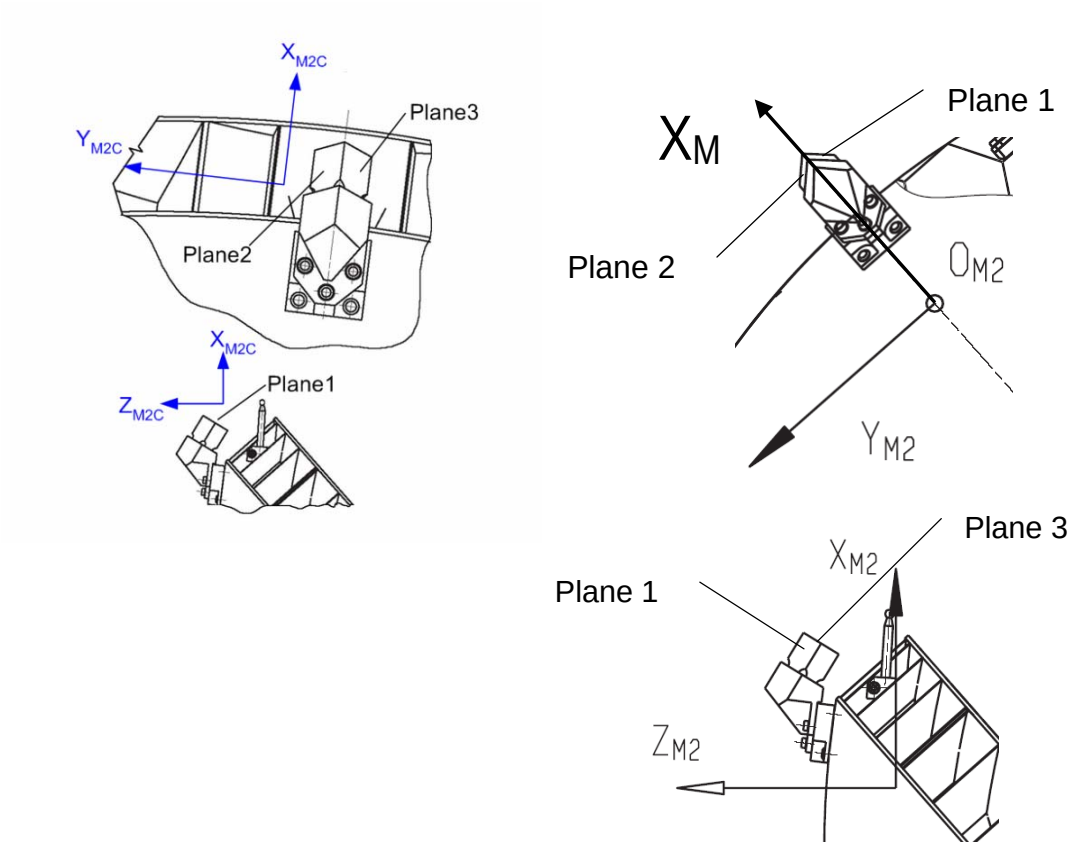


Figure 5-7: Cross-sectional view of the hoisting interface

5.4 Alignment Cube Interface

The alignment cube is depicted below:



The alignment cube interface data are given in Table 5-1 below:

normal vectors in the M2 system

	Plane 1	Plane 2	Plane 3
U	0.324	0.400	0.857
V	-0.725	0.687	-0.047
W	0.608	0.607	-0.513

inner midpoint coordinates in system M2 (10mm from plane 1, 10mm from plane 2, 10mm from plane 3)

X	88.472
Y	-3.507
Z	57.300

Table 5-1: SRFM Alignment Cube Interface Data

5.4.1 Alignment Cube Description

The SR is equipped with one optical alignment cube each. The alignment cubes are designed so that they are removable for launch. Only small INVAR adapter brackets remain with the reflectors. The locations of the alignment cubes can be extracted from the interface drawings.

The SR alignment cube adapter bracket remaining on the reflector is shown in Figure 5-8

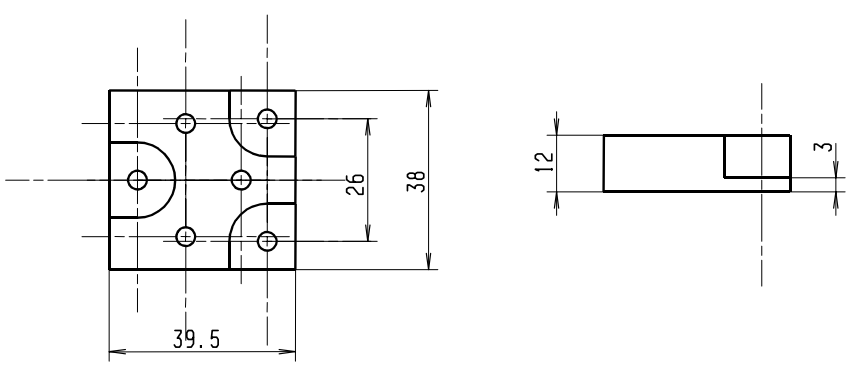


Figure 5-8 SR Alignment Cube Adapter Bracket

5.5 Thermistor Interface

The SR FM is equipped with 2 nominal temperature sensors (**TS1** and **TS3**) and 1 redundant sensor (**TS2**) for contamination control.

The SRFM is equipped with 4 more temperature sensors (**TC1** to **TC4**) for temperature control.

The temperature sensors are located according to the following table:

Sensor	**X_{M2C} / Y_{M2C}**	**Calibration No.**	
TS1	-420 mm / -50 mm	9904 AXI 27	nominal
TS2	-420 mm / 0 mm	9904 AXI 08	redundant
TS3	-420 mm/ +50 mm	9904 AXI 21	nominal
TC1	-200 mm / +200 mm	9907 AXM 48	nominal
TC2	+220 mm / +200 mm	9907 AXM 07	nominal
TC3	-200 mm / -200 mm	9907 AXJ 50	redundant
TC4	+220 mm / -220 mm	9907 AXL 95	redundant

The sensors lines are of brass AWG 28 and are routed via the ISM SR-C ($-X_{M2C}$, $-Y_{M2C}$) to the telescope. The sensor lines have bare ends.

5.6 Grounding Interface

The bonding I/F is built by AWG 26 (TBC) bonding straps with bare ends.

The grounding cable is routed on the reflector rear side below the MLI towards the ISM's on SR, hence the groundings are located near the ISM's (see RD 1 and RD 7).

The free length of the grounding straps after the ISM's is 1m.

5.7 Heater Harness Interface

The SR FM is equipped on its rear side with 18 foil heaters which are sitting on stand-offs. Each heater provides a nominal and a redundant circuit with an AWG 28 brass wire. The nominal and the redundant heater lines are grouped on reflector level. The electrical interface to the S/C are built by two pairs of brass AWG 24 lines with bare ends routed via the ISM SR-B ($-X_{M2C}$, $+Y_{M2C}$).

Measured Heater Group Resistances SRFM

Group 1 Heater No. 1 to Heater No. 6	main line	87.2	Ω
	redundant line	87.6	Ω
Group 2 Heater No. 7 to Heater No. 12	main line	87.5	Ω
	redundant line	87.4	Ω
Group 3 Heater No. 13 to Heater No. 18	main line	87.5	Ω
	redundant line	87.6	Ω

All heaters together	Main line	29.2 Ω
	Redundant line	31.4 Ω

6. Mass Properties

The detailed mass budget and the corresponding inertia of the Planck Reflectors are reported in RD 1 and RD 9. A summary is stated below.

6.1 Secondary Reflector Mass

The measured total mass (RD 9) of the Secondary Reflector FM including MLI, alignment cube and reference balls is:

13.54 kg

and with heaters 14.12 kg

The requirement (including heaters, excluding alignment cube and reference balls) is 14.500 kg.

The parts dismountable before flight (red flag items: mirror cube, reference balls) have a mass of 0.496 kg.

6.2 SR FM Center of Gravity and Moments of Inertia

The COG and the mass properties of the SRFM are given in the table below. The data are referring to the reflector reference system M2C:

		COG in system M2C			moments of inertia (axes parallel to M2C passing through COG)		
	mass (kg)	x (mm)	y (mm)	z (mm)	I_{xx} (kg*m^2)	I_{yy} (kg*m^2)	I_{zz} (kg*m^2)
SRFM (ICD)	13,54	15,2	-0,5	-127,6	1,10	1,28	2,15
heaters (catia)	0,58	4,5	0,0	-109,4	0,05	0,05	0,10
total	14,12	14,8	-0,5	-126,9	1,15	1,33	2,25

7. Thermal Interfaces

Reference is made to the thermal hardware drawings

2540-4200-30A00C, Iss. B Secondary Reflector Thermal Hardware

The reflector front side provides a low emissivity of ε = 0,02. The reflector rim is covered circumferentially with VDA coated and perforated Kapton foil with nominal ε = 0,05 (with an assumed variation of 0,025 to 0,1 considered in the thermal analysis)..

The reflector rear side is covered by MLI, with nominal ε = 0,05 (with an assumed variation of 0,025 to 0,1 considered in the thermal analysis).

Except for the harness the ISM's are the only conductive I/Fs to the telescope structure.

NOTE:

It is not allowed to use the ISM's for conductive cooling or heating; i.e. the temperature of the support structure has to be similar to the reflector temperature. Conductive cooling will cause irreparable damage to the reflectors.

8. Electrical Interface

Refer to Chapters 5.5; 5.6 and 5.7

9. Optical Interfaces

9.1 Reflector Front Surface

The front surfaces of the CFRP-reflector is coated with vacuum deposited aluminium as a reflective layer and a protection layer of PLASIL (silicon oxides). The emissivity of the reflective front surface is $\varepsilon \leq 0.05$ (nominal $\varepsilon = 0,02$)

The roughness of the reflector optical surface is

Rq < 1 µm RMS at any scale up to 0.8 mm

Rq < 2 µm RMS at any scale up to 10 mm

The reflectivity for the frequency range 25 GHz to 900 GHz is >99,5 % BOL and > 97,5 % EOL.

10. Operational Interfaces

10.1 Handling and Transportation

Reference is made to the document "Planck Reflectors Handling & Transportation Procedure", to be issued after CDR.

10.2 Hoisting Device Interface

Each Planck Reflector provides three handling/hoisting points at the reflector rim. These handling/hoisting points are designed to handle the fully equipped reflector during all AIT activities.

The design of the handling/hoisting interfaces are depicted in the interface drawings RD 4 to RD 5.

The hoisting devices for PR and SR are shown in the figures below.

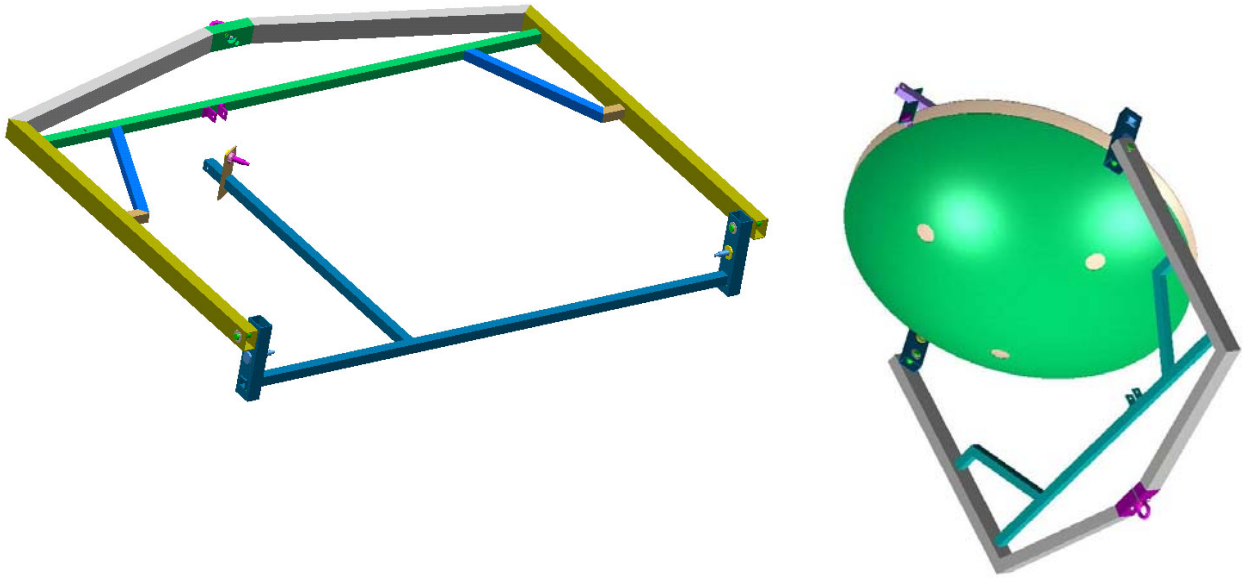


Figure 10-1: SR Hoisting Device

10.3 Transport Container Interface

Reference is made to the document "Planck Reflectors MGSE Specification", PLA-ASED-RP-012. In the pictures below one can see a view of the container opened and closed.

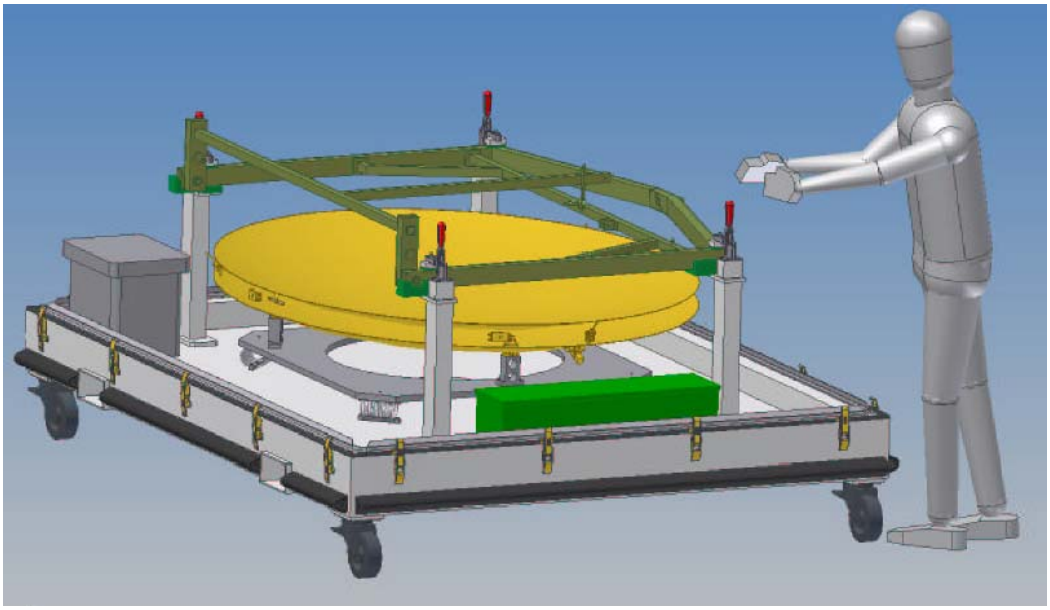


Figure 10-2: Opened transport container for the SR (incl. hoisting device)

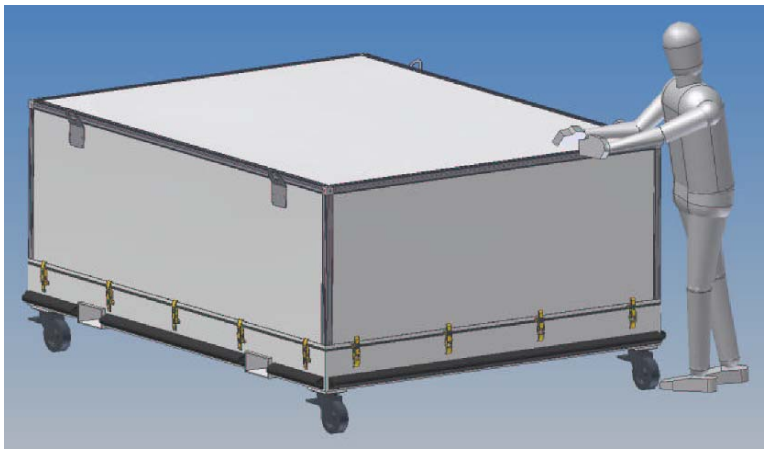


Figure 10-3: Closed transport container

10.4 Protection Cover

The front side of the reflector is protected by a foil cover against contamination. The cover is removable for testing and for flight. Cutouts in the cover at the rim provide access to the alignment cube, the reference balls and the hoisting brackets.

In the picture below one can see the different views of the protection cover.

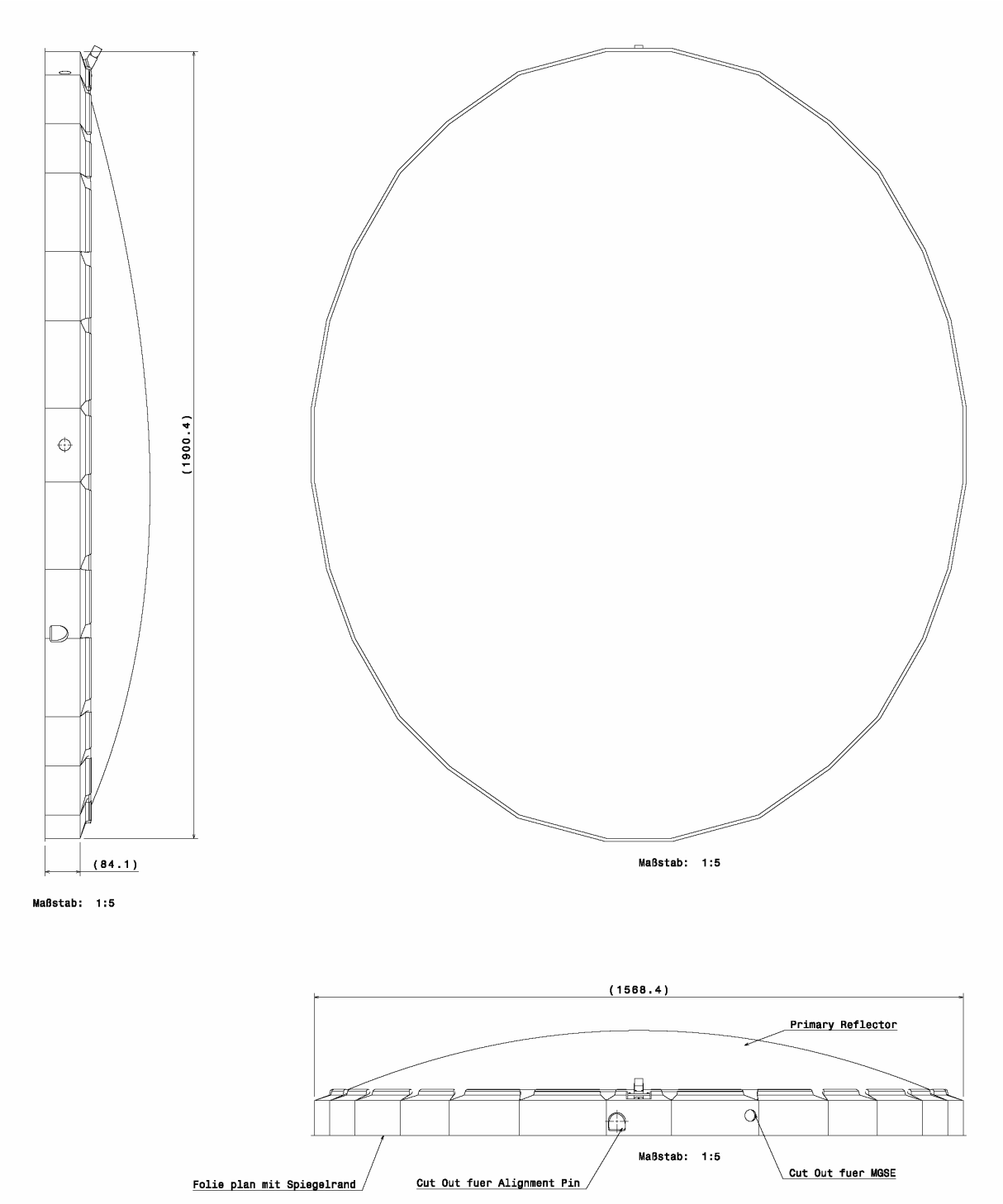


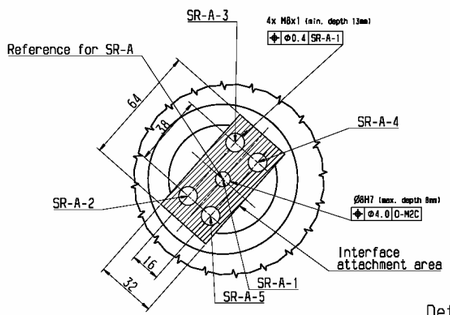
Figure 10-4: Protection cover

11. Interface Drawings Planck Reflectors

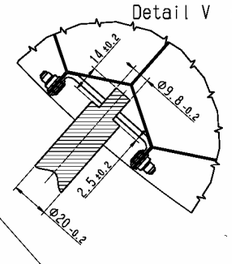
The below listed interface drawings are annexed hereafter:

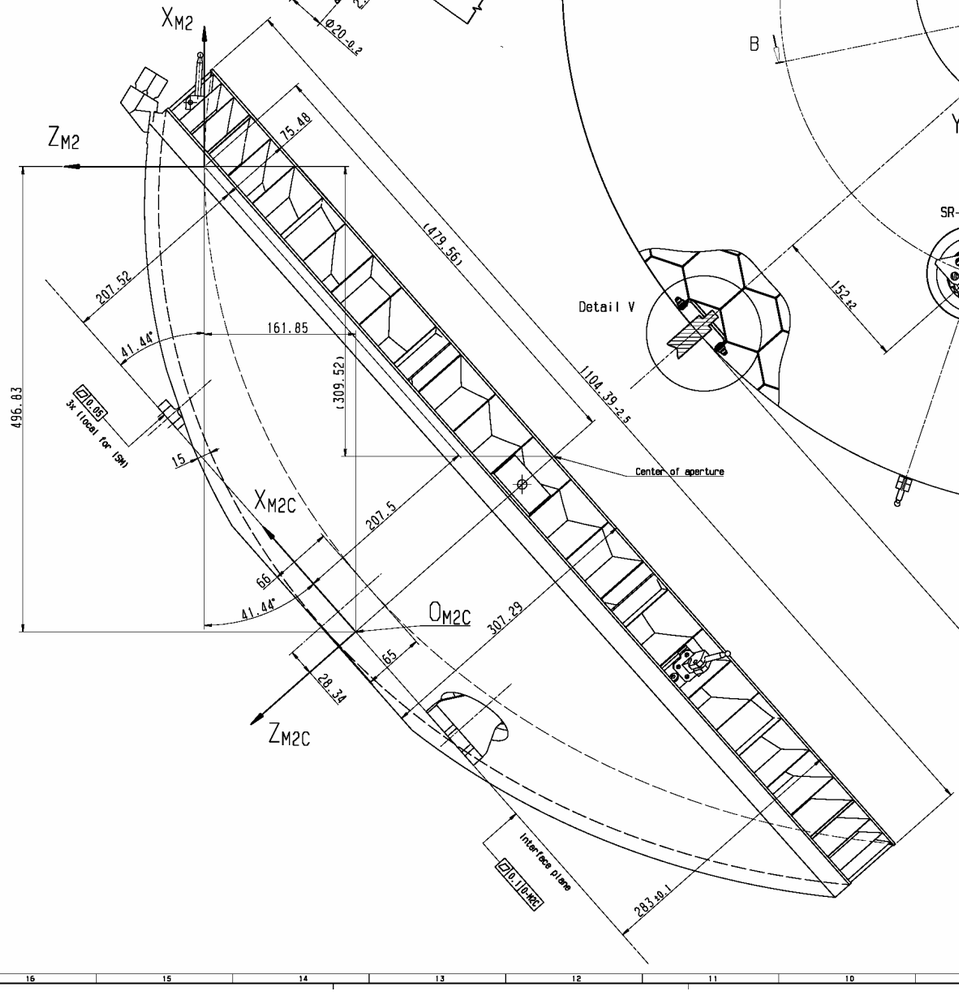
- RD 4 SR Interfaces at Operating Temperature, Drawing 2540-420000A00O, Iss. B
- RD 5 SR Interfaces at Room Temperature, Drawing 2540-420000A00A, Iss. C
- RD10 SR Thermal hardware Drawing, marked-up

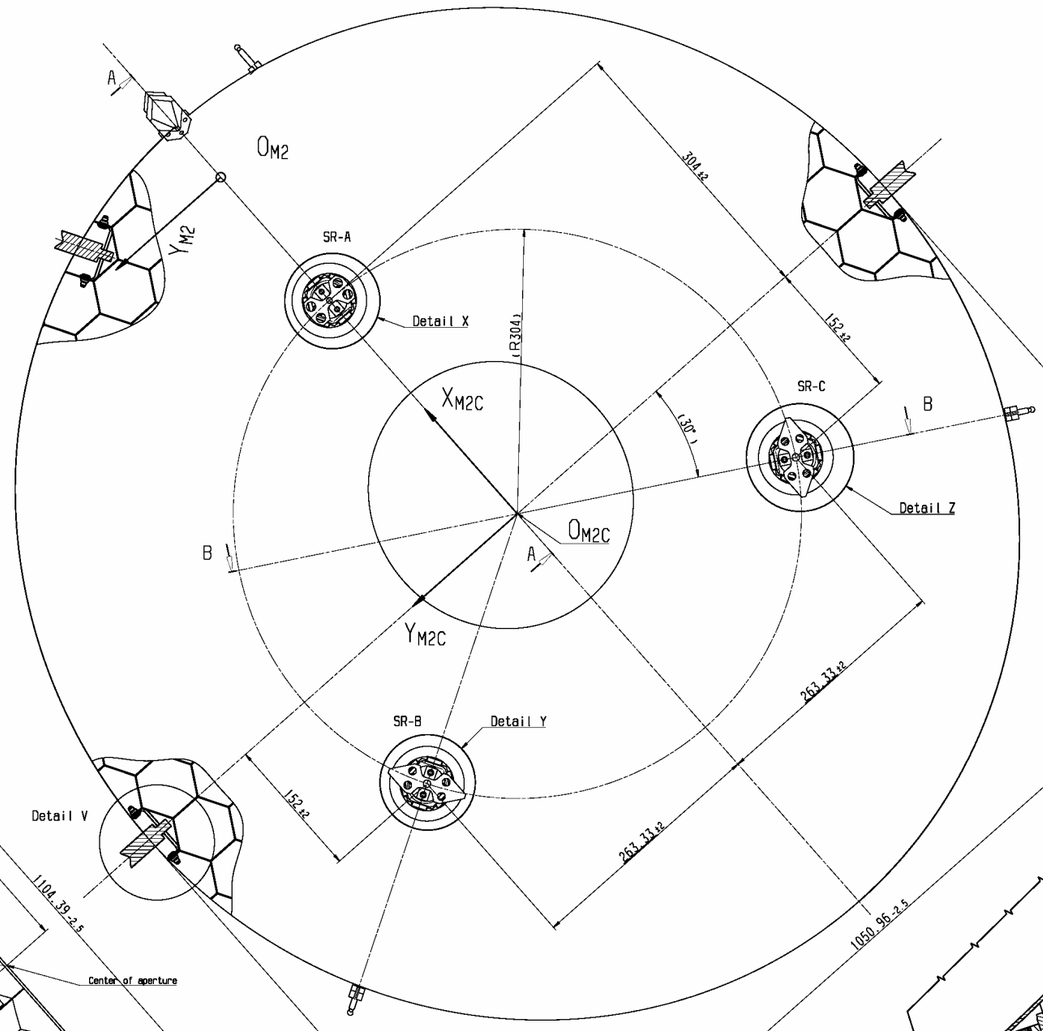
Detail X M 1:1



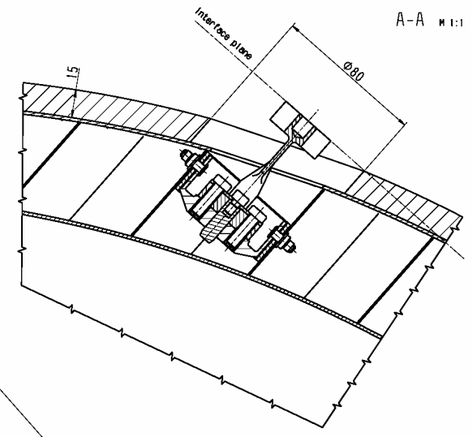
Detail V M 1:1



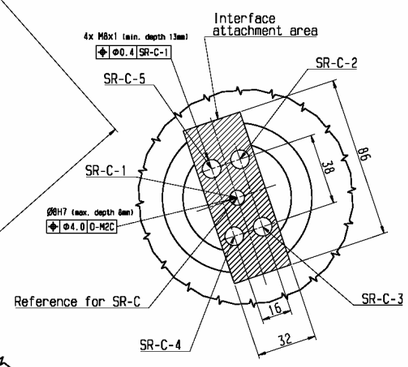


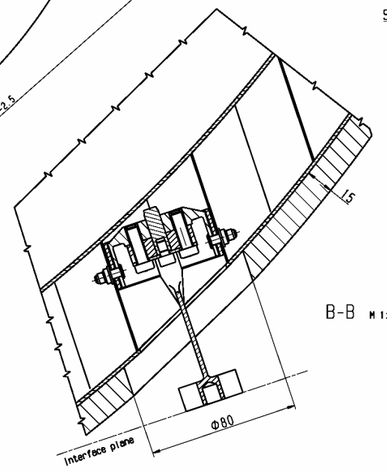


A-A M 1:1



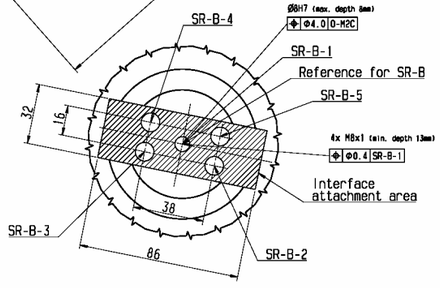
Detail Z M 1:1





B-B M 1:1

Detail Y M 1:1



Pkt Nr.	X_{M2} 1	Y_{M2} 1	Z_{M2} 1	
SR-C-1	-610.78	-263.27	-262.46	Ø8H7 fit hole
SR-C-2	-601.44	-279.70	-254.22	M8x1 thread
SR-C-3	-625.11	-260.70	-276.00	M8x1 thread
SR-C-4	-620.11	-245.84	-270.70	M8x1 thread
SR-C-5	-595.44	-265.84	-248.92	M8x1 thread

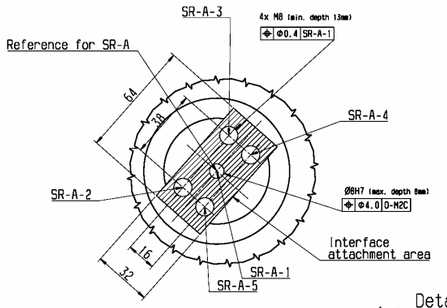
Pkt Nr.	X_{M2} 1	Y_{M2} 1	Z_{M2} 1	
SR-B-1	-610.78	263.27	-262.46	Ø8H7 fit hole
SR-B-2	-625.11	260.70	-276.00	M8x1 thread
SR-B-3	-601.44	279.70	-254.22	M8x1 thread
SR-B-4	-595.44	265.84	-248.92	M8x1 thread
SR-B-5	-620.11	245.84	-270.70	M8x1 thread

Pkt Nr.	X_{M2} 1	Y_{M2} 1	Z_{M2} 1	
SR-A-1	-268.95	.00	39.36	Ø8H7 fit hole
SR-A-2	-262.96	19.00	44.65	M8x1 thread
SR-A-3	-262.96	-19.00	44.65	M8x1 thread
SR-A-4	-274.95	-19.00	34.06	M8x1 thread
SR-A-5	-274.95	19.00	34.06	M8x1 thread

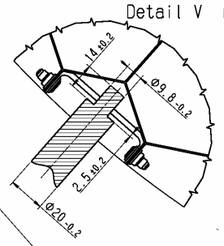
Note: in this sheet all dimensions are given in OPERATIONAL ENVIRONMENT

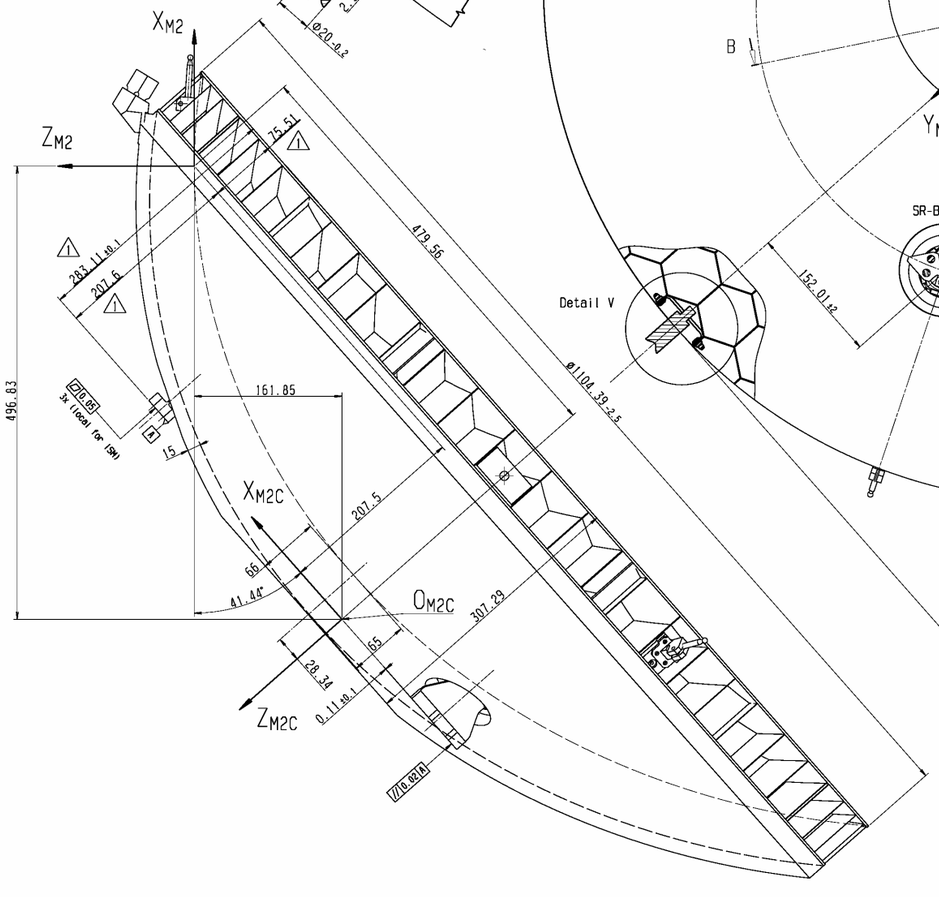
FREIGABE:	FESTTOKEIT:	VERTEILER:	DATUM:
ZUL. ANW.:	ÜBERFL.:	MASSTAB: 1:2 (1:1)	GEW.:
ISO 2768-mK		WERKSTOFF:	
DATUM	NAME	Secondary reflector Interface drawing (OE)	
Gezeichnet: 08.04.02	Ebeling		
Gepr.:			
Norm:			
PS			
B 01 21.11.02 Ebeling			
A - 08.04.02 Ebeling		Astrium GmbH	2540-420000A000 BLATT 1 1 BL
ÄNDG NR.	DATUM	NAME	URSPR.: ERS.F.: ERS.O.:

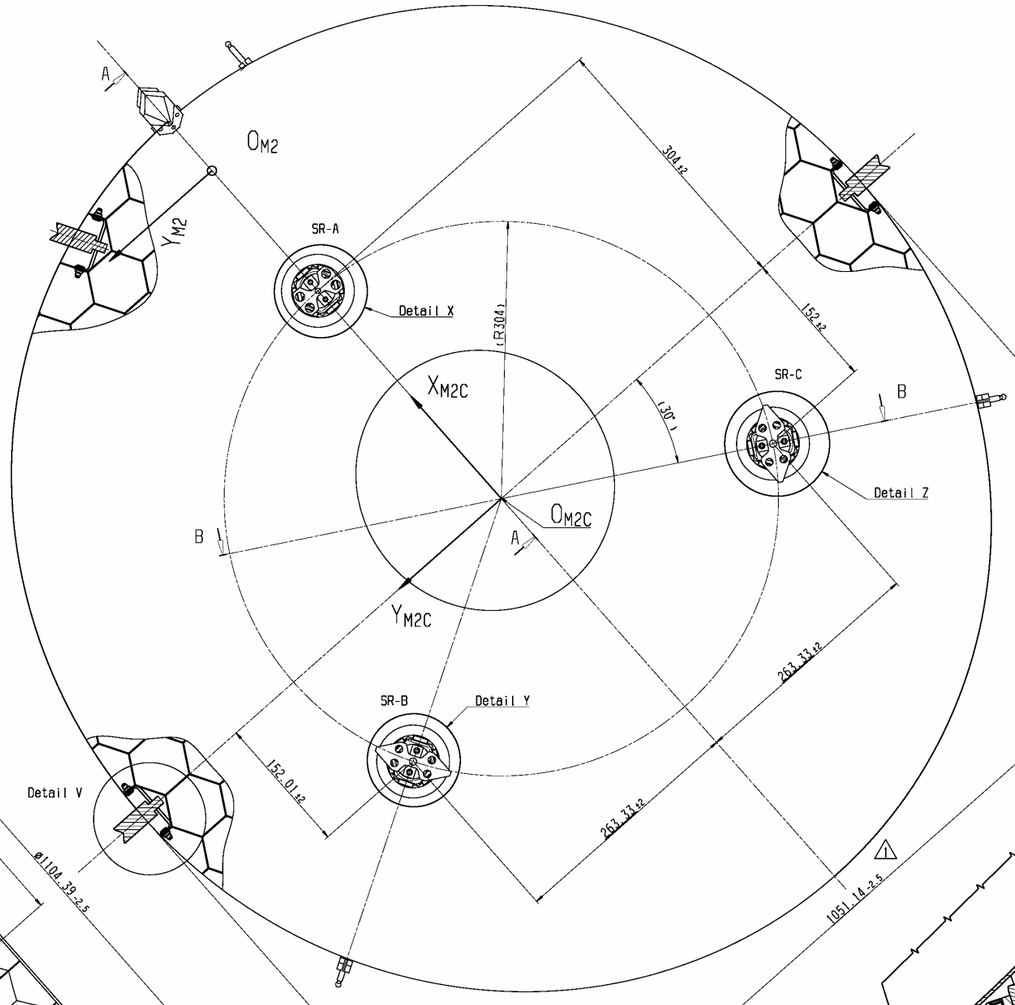
Detail X M 1:1



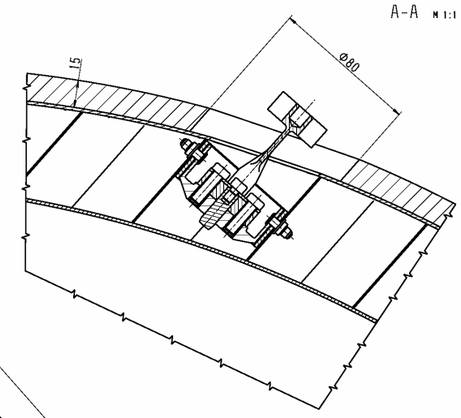
Detail V M 1:1



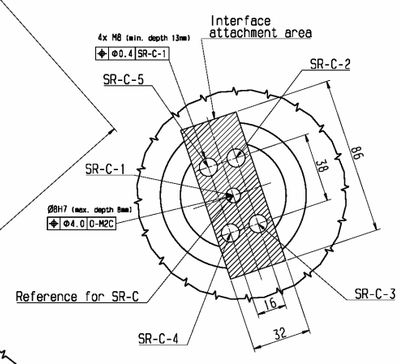


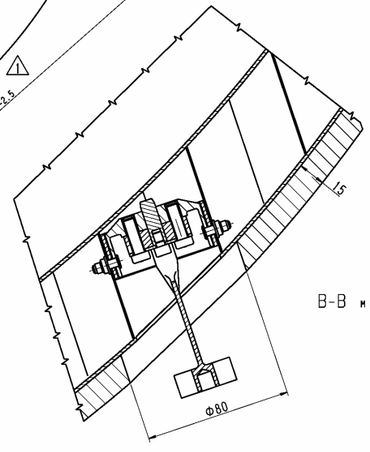


A-A M 1:1



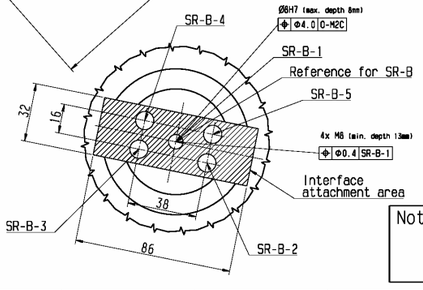
Detail Z M 1:1





B-B M 1:1

Detail Y M 1:1



Pkt Nr.	X_{M2} ⚠1	Y_{M2} ⚠1	Z_{M2} ⚠1	
SR-C-1	-610.79	-263.32	-262.49	Ø8H7 fit hole
SR-C-2	-601.45	-279.75	-254.25	M8x1 thread
SR-C-3	-626.12	-260.75	-276.03	M8x1 thread
SR-C-4	-620.12	-246.89	-270.73	M8x1 thread
SR-C-5	-595.45	-265.89	-248.95	M8x1 thread

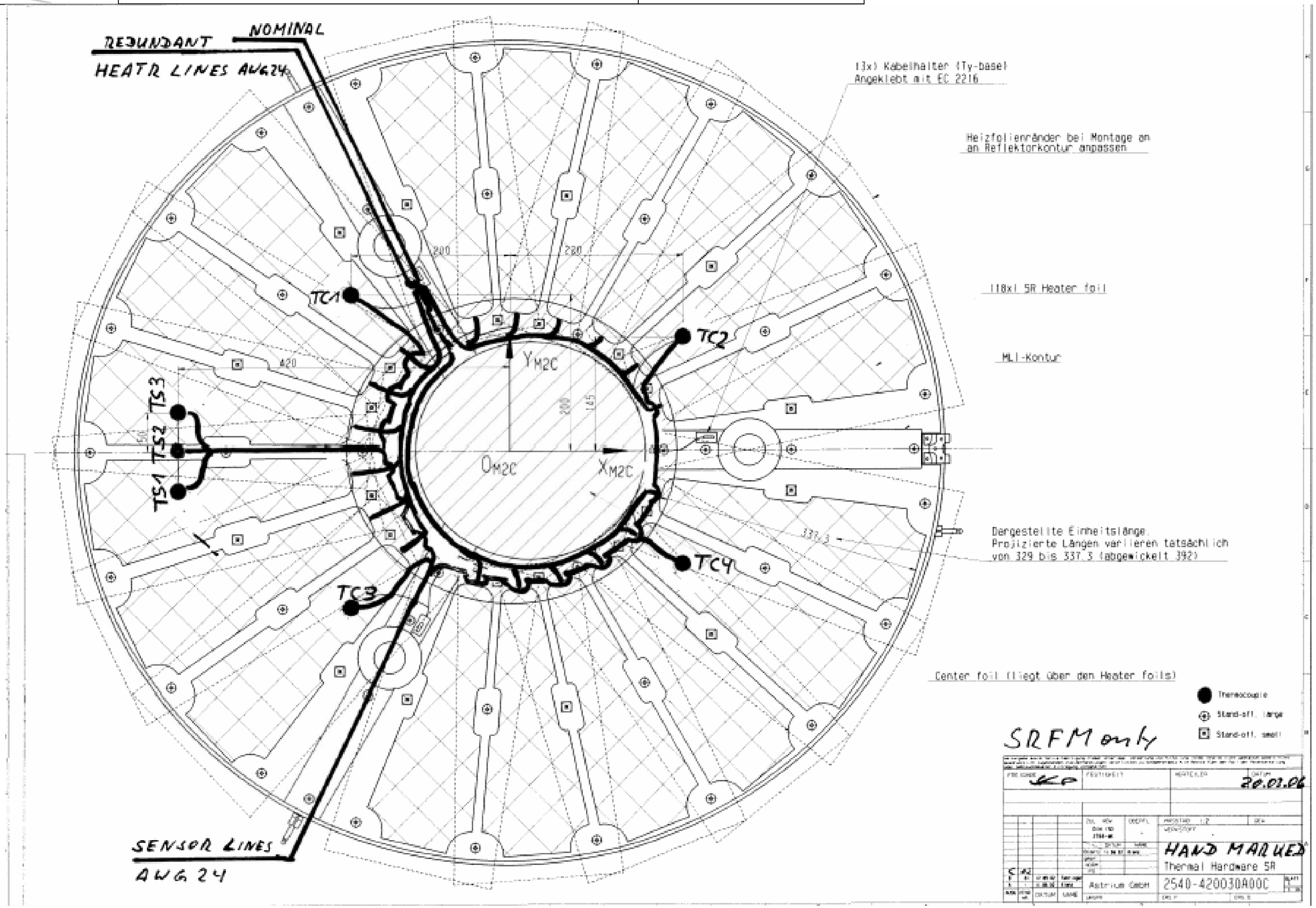
Pkt Nr.	X_{M2} ⚠1	Y_{M2} ⚠1	Z_{M2} ⚠1	
SR-B-1	-610.79	263.32	-262.49	Ø8H7 fit hole
SR-B-2	-626.12	260.75	-276.03	M8x1 thread
SR-B-3	-601.45	279.75	-254.25	M8x1 thread
SR-B-4	-595.45	265.89	-248.95	M8x1 thread
SR-B-5	-620.12	246.89	-270.73	M8x1 thread

Pkt Nr.	X_{M2} ⚠1	Y_{M2} ⚠1	Z_{M2} ⚠1	
SR-A-1	-268.91	.00	39.38	Ø8H7 fit hole
SR-A-2	-262.92	19.00	44.67	M8x1 thread
SR-A-3	-262.92	-19.00	44.67	M8x1 thread
SR-A-4	-274.91	-19.00	34.08	M8x1 thread
SR-A-5	-274.91	19.00	34.08	M8x1 thread

Note: in this sheet all dimensions marked with ⚠1 are valid only for ROOM TEMPERATURE (RT). Other dimensions are valid for RT and for OPERATIONAL ENVIRONMENT (OE).

FREIGABE:	FESTIGKEIT:	VERTEILER:	DATUM:

				ZUL. ABW. :	OBERFL. :	MASSTAB: 1:2 (1:1)	GEW.:
				ISO 2768-MK		WERKSTOFF:	
			DATUM	NAME			
			Gepr.:			Secondary reflector	
			QMZ:			Interface drawing (RT)	
			NORM:				
C	02	15.07.03	PS				
B	01	21.11.02					
A	-	22.04.02	Klaus	Astrium GmbH		2540-420000A00A	1 BL
AUSG.	ÄNDG NR.	DATUM	NAME	URSPRL. :		ERS.F. :	ERS.D. :


REDUNDANT
NOMINAL
HEATR LINES AWG24
(3x) Kabelhalter (Ty-base)
Angeklebt mit EC 2216
Heizfolienränder bei Montage an
an Reflektorkontur anpassen
(18x) 5R Heater foil
MLI-Kontur
TC1
TC2
TC3
TC4
TS1
TS2
TS3
YM2C
OM2C
XM2C
200
220
420
145
337.3
Dargestellte Einheitslänge.
Projizierte Längen variieren tatsächlich
von 329 bis 337.3 (abgewickelt 392)
Center foil (liegt über den Heater foils)
Thermocouple
Stand-off, large
Stand-off, small
SENSOR LINES
AWG 24
SRFM only
20.03.06
HAND MARKED
Thermal Hardware SR
Astrium GmbH
2540-420030A00C