Title:

Primary Reflector Flight Model
Interface Control Document

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1	26.07.2004	all	First issue
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3	20.03.2006	§ 5	Update after thermal hardware mounting (final work)

Table of Contents

1. Scope

This document, describes the interfaces of the Planck Primary Reflector FM 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/Primary Reflector Specification SCI-PT-RS-07422, issue 4, rev.1, 21 February 2002
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 Interface measurement on the Planck PR FM after CSL incident, PLA-ASED-TN-100

RD 3 3D measurement of the Planck PR FM surface, PLA-ASED-TR-031

RD 4 Mass properties test PRFM, B-TR60-0277

RD 5 Design Report, PLA-ASED-RP-001

RD 6 Mechanical Analyses Report, PLA-ASED-RP-003

RD 7 PR Interfaces at Operating Temperature, Drawing 2540-4100-00-A00O

RD 8 PR Interfaces at Room Temperature, Drawing 2540-4100-00-A00A

RD 9 Mechanical Ground Support Equipment Specification, PLA-ASED-RP-012

RD 10 Thermal hardware PR, Drawing 2540-4100-30-A00C

RD 11 Measurement of the Planck PRFM after the CSL incident

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
PR	Primary Reflector
FM	Qualification Model
SR	Primary Reflector
TBC	To be confirmed
TBD	To be defined

4. General Interfaces

4.1 Description of the Planck Reflectors

The Planck Primary Reflector is an elliptical off-axis reflector. 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 reflector is 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 reflector. Thermal sensors are provided for temperature monitoring. The rear side with heaters are covered by 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 5

4.2 Coordinate Systems

The PR co-ordinate system ($O_{M1,}$ $X_{M1,}$ $Y_{M1,}$ Z_{M1}) is defined as follows, see chapter 11:

- The origin O_{M1} is the vertex of the PR and is laying outside of the reflector surface
- The X_{M1}-axis is tilted 8.751° with respect to the telescope x-axis X_{Tel} and points towards the PR.
- $Z_{M1,}$ tilted by 8.751° w.r.t Z_{Tel}, points along the major ellipsoid axis with positive direction on the reflecting side of the PR.
- Y_{M1} completes the co-ordinate system.

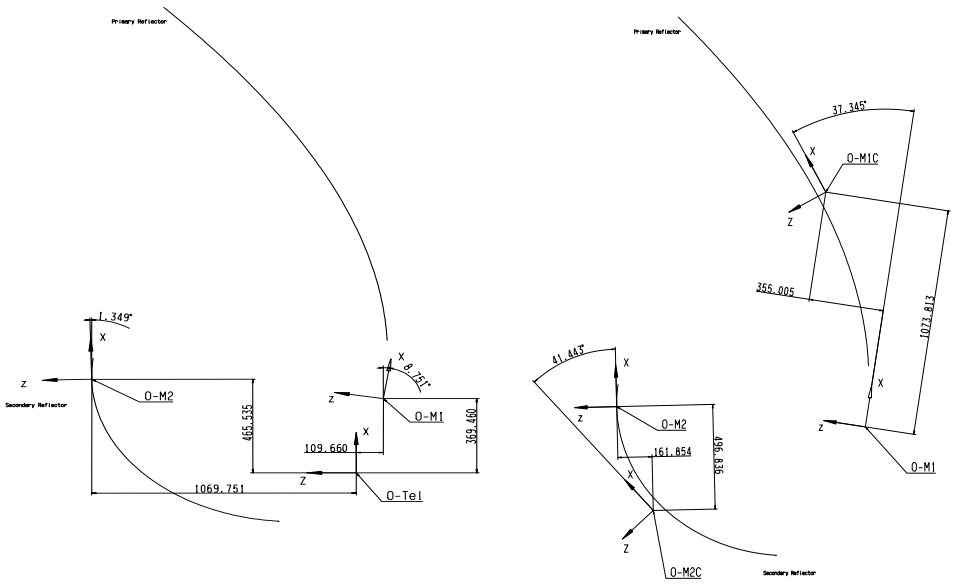


Figure 4.2-1 Telescope Reference Frame and OM1-System

5. Mechanical Interfaces

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

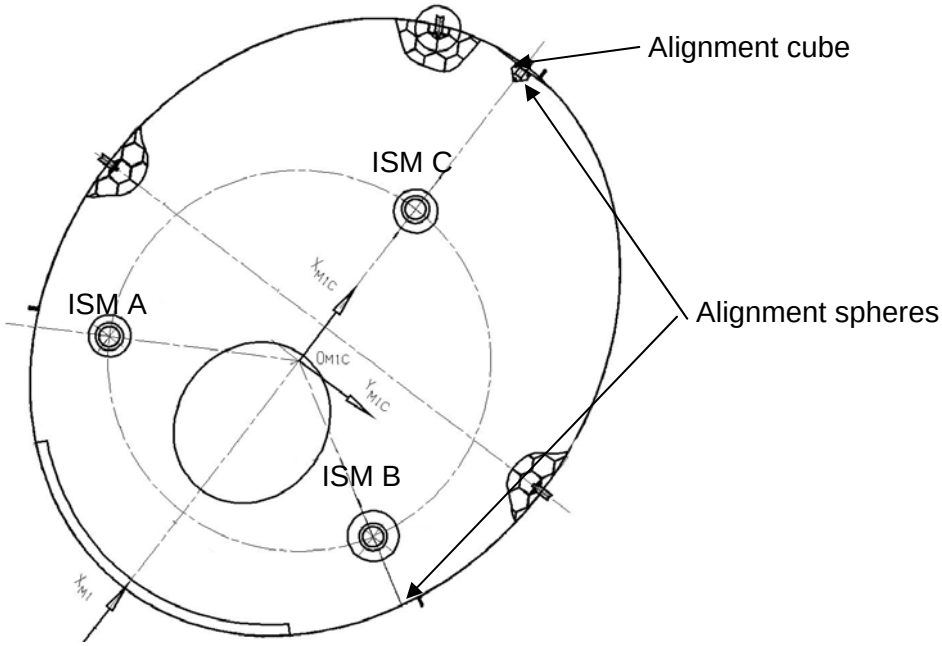


Figure 5-1: Mounting and alignment Interfaces of the PR

5.1 Dimensions

The Planck Reflectors display the following overall dimensions at nominal operational temperature:

-	Primary Reflector	long axis:	1886.940mm (RD 2)
		short axis:	1556.177mm (RD 2)
		height:	270 mm including Thermal H/W
		thickness:	81 mm CFRP + 15 mm Thermal H/W

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

5.2 Reflector Mounting Interfaces

The mounting interfaces of each 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. There are two types of ISM's which are used on both reflectors to generate the interface plane, the short ISM and the long ISM, see Figure 5-2 and Figure 5-3.

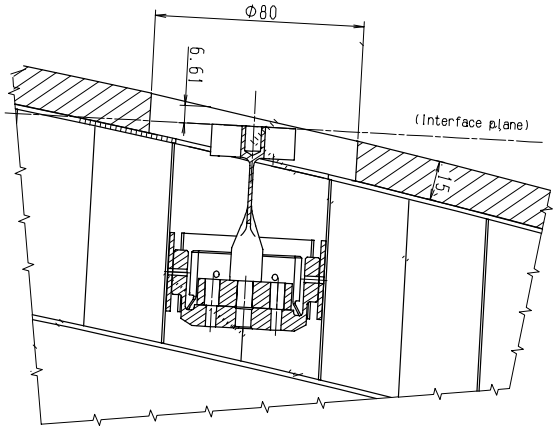


Figure 5-2: SHort ISM embedded in reflector sandwich

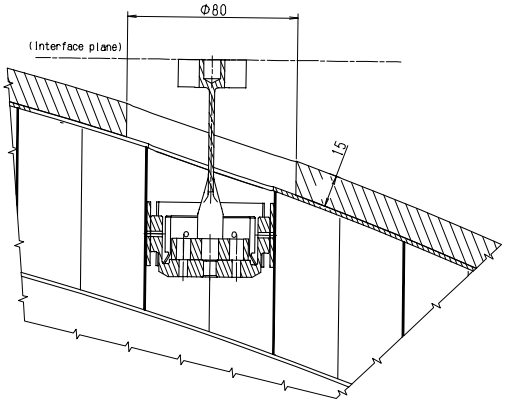


Figure 5-3 Long ISM embedded in reflector sandwich

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.

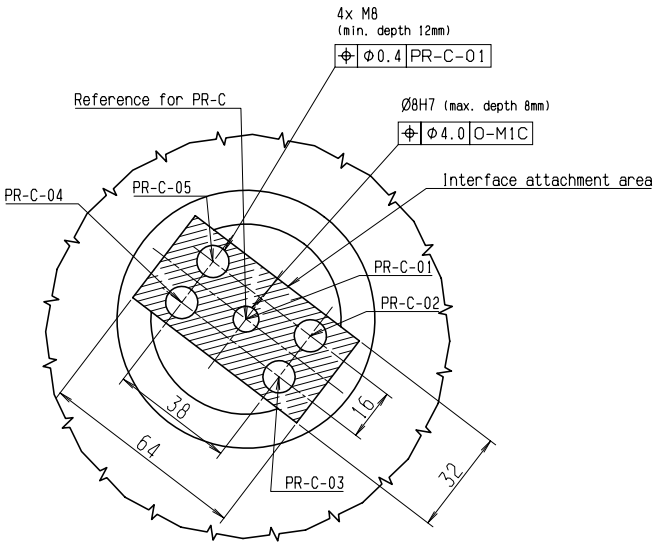


Figure 5-4 Hole Pattern of a Short ISM

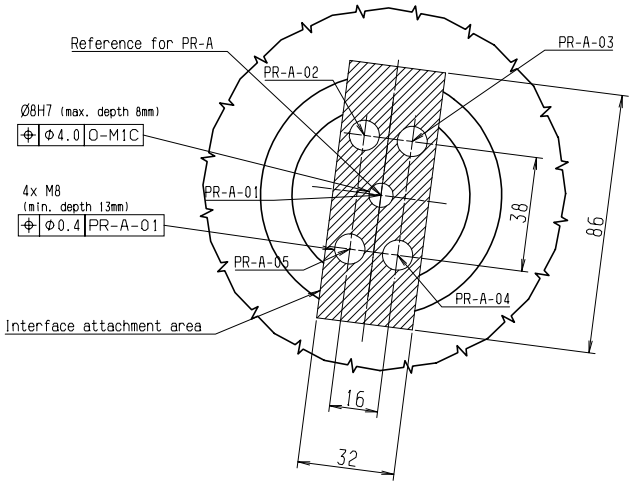


Figure 5-5 Hole Pattern of a Long ISM

5.2.1 Measured Mounting Interface Positions

The designation of the ISM-interfaces is as follows:

Primary or Primary Reflector – interface location – hole number

example: **P**rimary **R**eflector, ISM **A**, fit hole **1**→ PR-A-1

The measured coordinates (RD 2) of the ISM's Center Holes in the M1C reflector co-ordinate system are:

PR-A-1: -273.245, -473.717, -0.110

PR-B-1: -273.395, 473.631, -0.110

PR-C-1: 546.874, 0.000, 0.000

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

PR-A-1	X_{Tel}	1244.918	X_{M1C}	-273.245	X_{M1}	856.651
	Y_{Tel}	-473.717	Y_{M1C}	-473.717	Y_{M1}	-473.717
	Z_{Tel}	-53.030	Z_{M1C}	-0.110	Z_{M1}	189.164

PR-B-1	X_{Tel}	1244.786	X_{M1C}	-273.395	X_{M1}	856.531
	Y_{Tel}	473.631	Y_{M1C}	473.631	Y_{M1}	473.631
	Z_{Tel}	-53.101	Z_{M1C}	-0.110	Z_{M1}	189.073

PR-C-1	X_{Tel}	1964.956	X_{M1C}	546.874	X_{M1}	1508.576
	Y_{Tel}	0.000	Y_{M1C}	0.000	Y_{M1}	0.000
	Z_{Tel}	339.576	Z_{M1C}	0.000	Z_{M1}	686.746

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. PR-A and PR-B are 0.11mm shifted w.r.t. PR-C, 0.11mm is required. The parallelism of PR-A and PR-B w.r.t. PR-C is below 0.05mm.

The length of the reflector is 1886.686mm, required is 1887.1-2.5mm. The width of the reflector is 1556.015mm, required is 1556.26-2.5mm.

5.2.2 Measured Pinball Positions of the PRFM

For alignment purposes the PRFM 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 7 and RD 8.

The measured coordinates of the pinballs in the M1C system, after the CSL incident are (RD11):

Pinball 1: -345.689; -703.257; 218.117

Pinball 2: -343.714; 702.839; 216.143

Pinball 3: 1086.093; 52.291; 216.013

The measured and transformed positions of the pinball centres are:

Pinball 1	X_{Tel}	1076.687	X_{M1C}	-345.689	X_{M1}	666.679
	Y_{Tel}	-703.257	Y_{M1C}	-703.257	Y_{M1}	-703.257
	Z_{Tel}	103.909	Z_{M1C}	218.117	Z_{M1}	318.708

Pinball 2	X_{Tel}	1079.545	X_{M1C}	-343.714	X_{M1}	669.446
	Y_{Tel}	702.839	Y_{M1C}	702.839	Y_{M1}	702.839
	Z_{Tel}	103.121	Z_{M1C}	216.143	Z_{M1}	318.337

Pinball 3	X_{Tel}	2335.025	X_{M1C}	1086.093	X_{M1}	1806.218
	Y_{Tel}	52.291	Y_{M1C}	52.291	Y_{M1}	52.291
	Z_{Tel}	787.312	Z_{M1C}	216.013	Z_{M1}	1185.573

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.

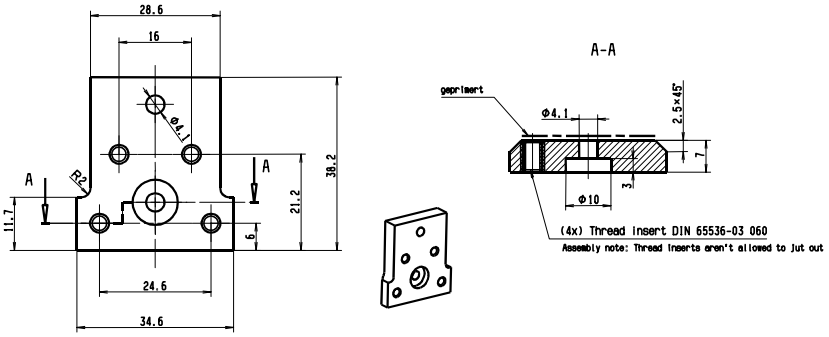


Figure 5-6 Remaining Pinball Attachment Plate

5.3 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.

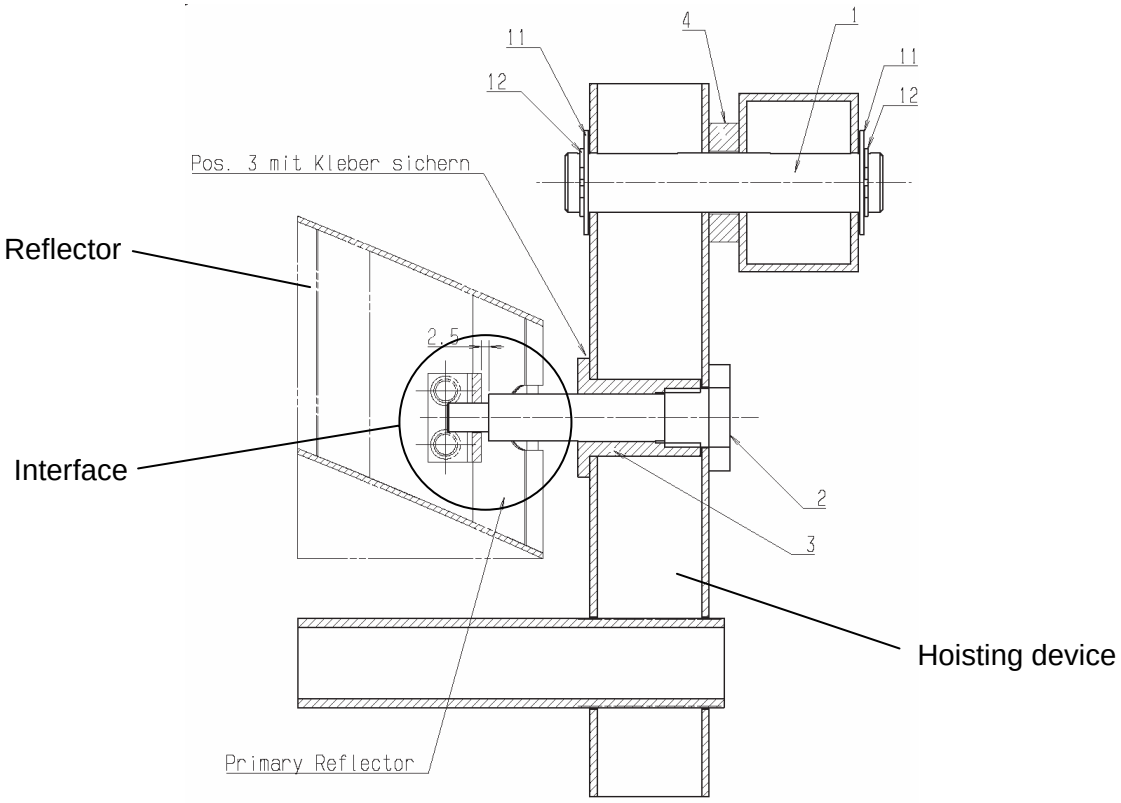


Figure 7: Cross-sectional view of the hoisting interface (PR)

5.4 Optical Cube Interface

PR will be 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 PR interface drawings. The exact co-ordinates for the cube are established by 3D-measurement and is given in the table in Chapter 9.2.

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

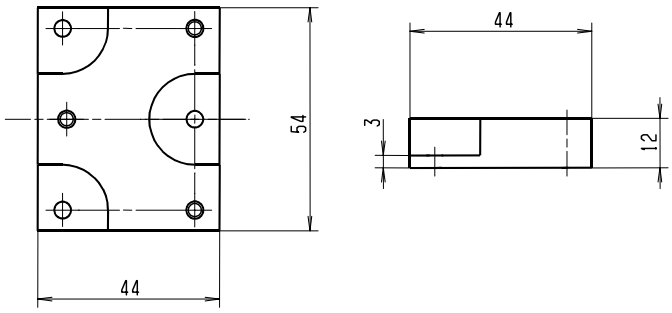


Figure 5-8 PR Alignment Cube Adapter Bracket

5.5 Thermistor Interface

For temperature monitoring and decontamination control the reflectors are equipped with thermal sensors according to the following scheme:

Thermistor	X, Y location in M1C system	Calibration No.	Function	Type
TS1	900, -50	9904 AXH 87	nominal	Decontamination Control
TS2	-900, 0	9904 AXH 84	redundant	Decontamination Control
TS3	900, 50	9904 AXH 96	nominal	Decontamination Control
TC1	-460, -410	9907 AXJ 41	nominal	Temperature Control
TC2	+220, -150	9907 AXM 06	nominal	Temperature Control
TC3	-460, +410	9904 AXI 20	redundant	Temperature Control
TC4	+220, +150	9904 AXI 18	redundant	Temperature Control

The respective cabling is of AWG 28 brass type. The 2-wire cables will be routed on the reflector rear sides below the heater mats and the MLI towards ISM PR-A. The cable length after the ISM will be 3m. The thermistor cables end in bare ends.

5.6 Grounding Interface

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

The grounding cables will be routed on the reflector rear sides below the heater mats and the MLI towards the ISM's on PR and SR, hence the groundings are located near the ISM's (see RD 10).

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

5.7 Heater Harness Interface

The PRFM is equipped on its rear side with foil heaters which are sitting on stand-offs as shown in RD10.

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 to the telescope/spacecraft via the ISM PR-B ($-X_{M1C}$, $+Y_{M1C}$).

Measured Heater Group Resistances PRFM

Group 1 Heater No. 1 to Heater No. 8	main line	60	Ω
	redundant line	60	Ω
Group 2 Heater No. 9 to Heater No. 14	main line	79.7	Ω
	redundant line	80.8	Ω
Group 3 Heater No. 15 to Heater No. 21	main line	68.5	Ω
	redundant line	68.8	Ω
Group 4 Heater No L1 to Heater No. L4	main line	96.0	Ω
	redundant line	95.0	Ω
Group 5 Heater No R1 to Heater No. R4	main line	96.0	Ω
	redundant line	96.0	Ω

All heaters together	Main line	18.0 Ω
	Redundant line	18.1 Ω

6. Mass Properties

6.1 Primary Reflector FM mass

The measured total mass (RD 4) of the PR FM including MLI, alignment cube and reference balls is:

27.84 kg

including heaters 29.24 kg

The requirement (incl. heaters, excl. alignment cube and reference balls) is 30.6kg. The dismountable parts (alignment cube & reference balls) have a mass of 0.428kg.

6.2 Primary reflector FM Centre of Gravity and Moments of Inertia

The mass properties of the PRFM are summarized in Table 6-1 below:

		COG in system M1C			moments of inertia (axes parallel to M1C 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)
PRFM (ICD)	27.84	125.8	0.2	88.6	4.67	6.87	10.87
heaters (catia)	1.40	153.4	0.0	56.6	0.24	0.33	0.56
total	29.24	127.1	0.2	87.1	4.91	7.20	11.43

Table 6-1: Mass Properties of the PRFM

7. Thermal Interfaces

Reference is made to the thermal hardware drawings

2540-4100-30A00C, Iss. B Primary Reflector Thermal Hardware

The reflector front sides provide a low emissivity of ε = 0,02. The edges and rear side are covered by VDA coated foils and by MLI respectively, both 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

The heater power needed for contamination release depends on the philosophy, see RD 1.

The nominal voltage for the heater mats is 28 V DC with a range between 26 V and 28 V.

The heater power values are:

	nominal	**worst case**	**redundant line**	**redundant line worst case**
PR	49,5 W	60 W	49,5 W	60 W

9. Optical Interfaces

9.1 Reflector Front Surface

The front surfaces of the CFRP-reflectors are coated with a vacuum deposited of aluminium as a reflective layer and a protection layer of PLASIL (silicon oxides).

The emissivity of the reflective front surface is $\boldsymbol{\varepsilon} \leq 0.05$ (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.

9.2 Alignment Cube

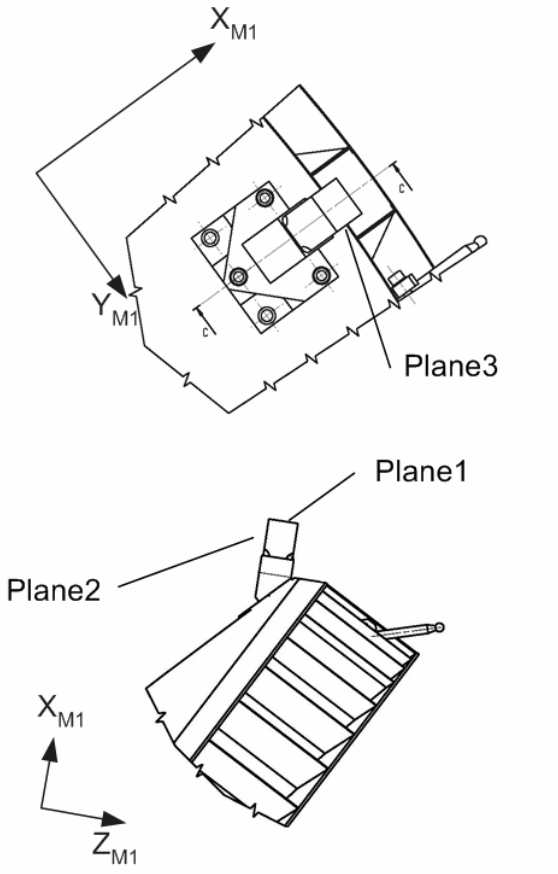
The planes on the reference cube have following normal vectors in the **M1** system (for plane numbering see picture below):

normal vectors in the M1 system

	Plane 1	Plane 2	Plane 3
U	0.988	0.157	-0.012
V	0.014	-0.009	1.000
W	0.157	-0.988	-0.012

inner midpoint coordinates in system M1 (10mm from plane 1, 10mm from plane 2, 10mm from plane 3)

X	1869.359
Y	0.253
Z	1079.885



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 7 to **Fehler! Verweisquelle konnte nicht gefunden werden.**.

The hoisting devices for PR is shown in the figure below.

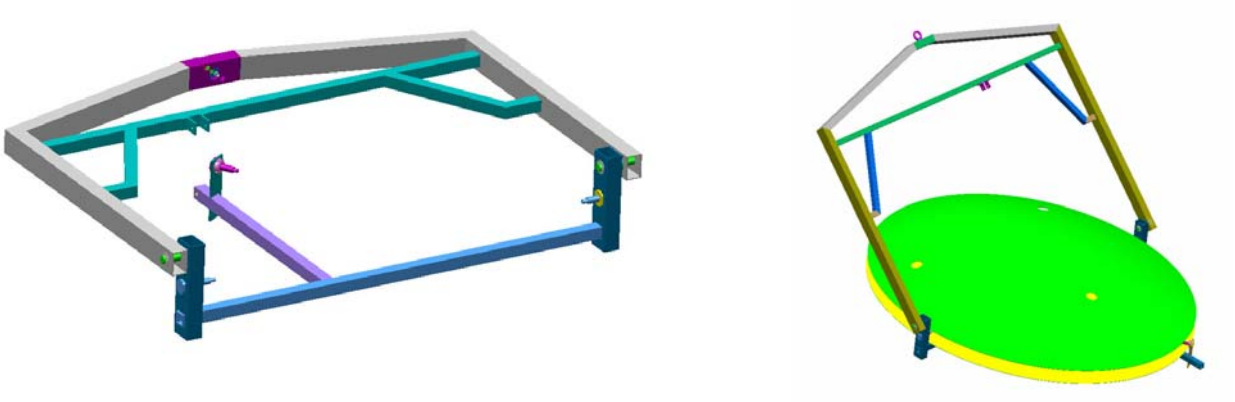


Figure 10-1: PR Hoisting Device

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.

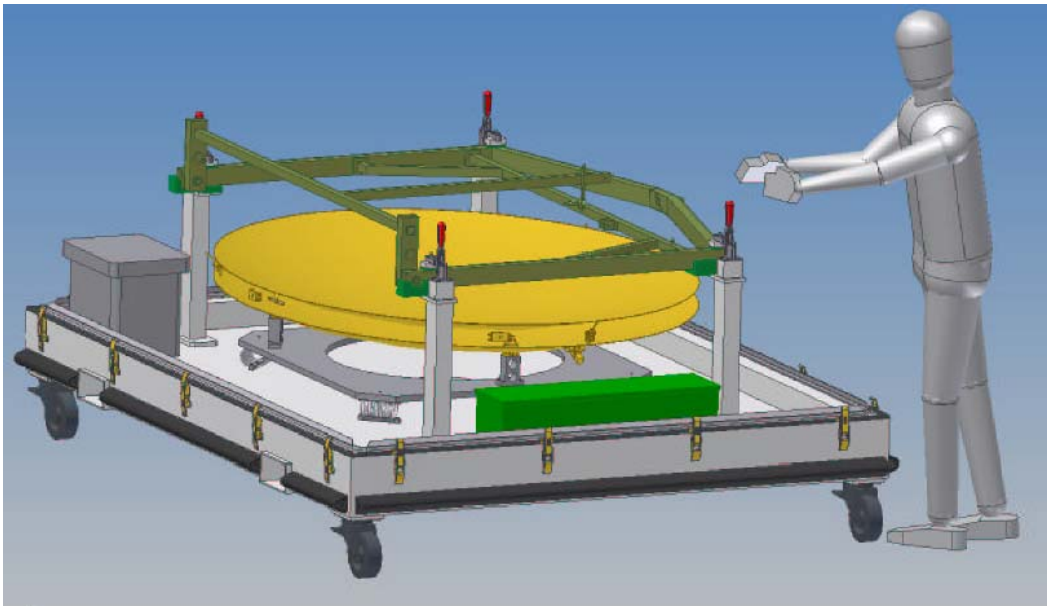


Figure 2: Opened transport container for the SR (incl. hoisting device)

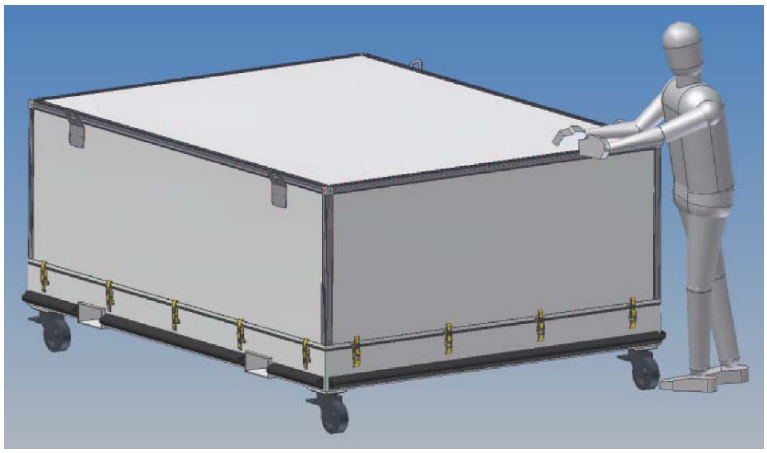


Figure 3: Closed transport container

10.4 Protection Cover

The front side of the reflectors will be protected by a foil cover against contamination. The cover is removable for testing and flight and will be attached to the reflectors with Velcro's and elastic cords. In the picture below one can see the different views of the protection cover.

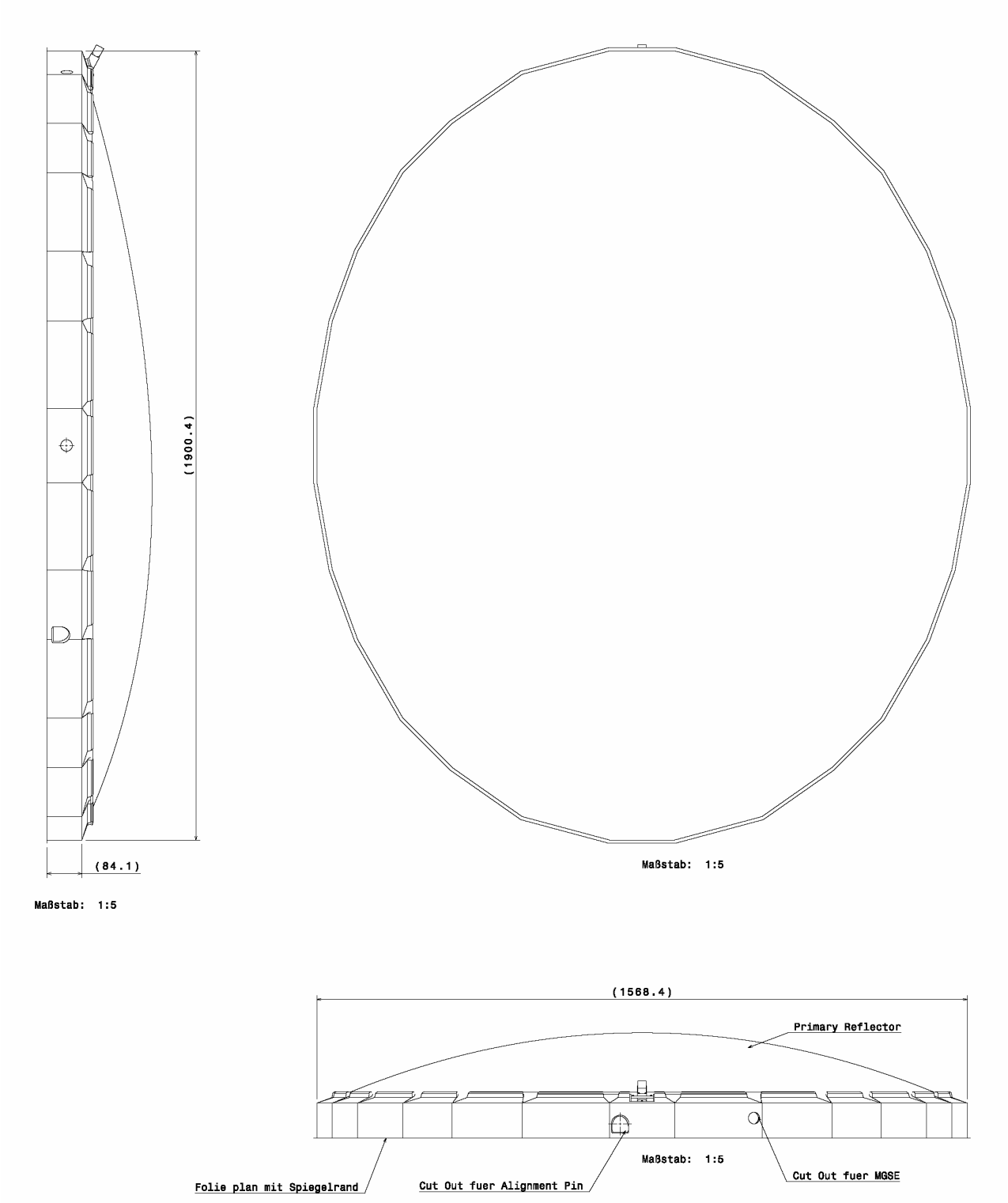
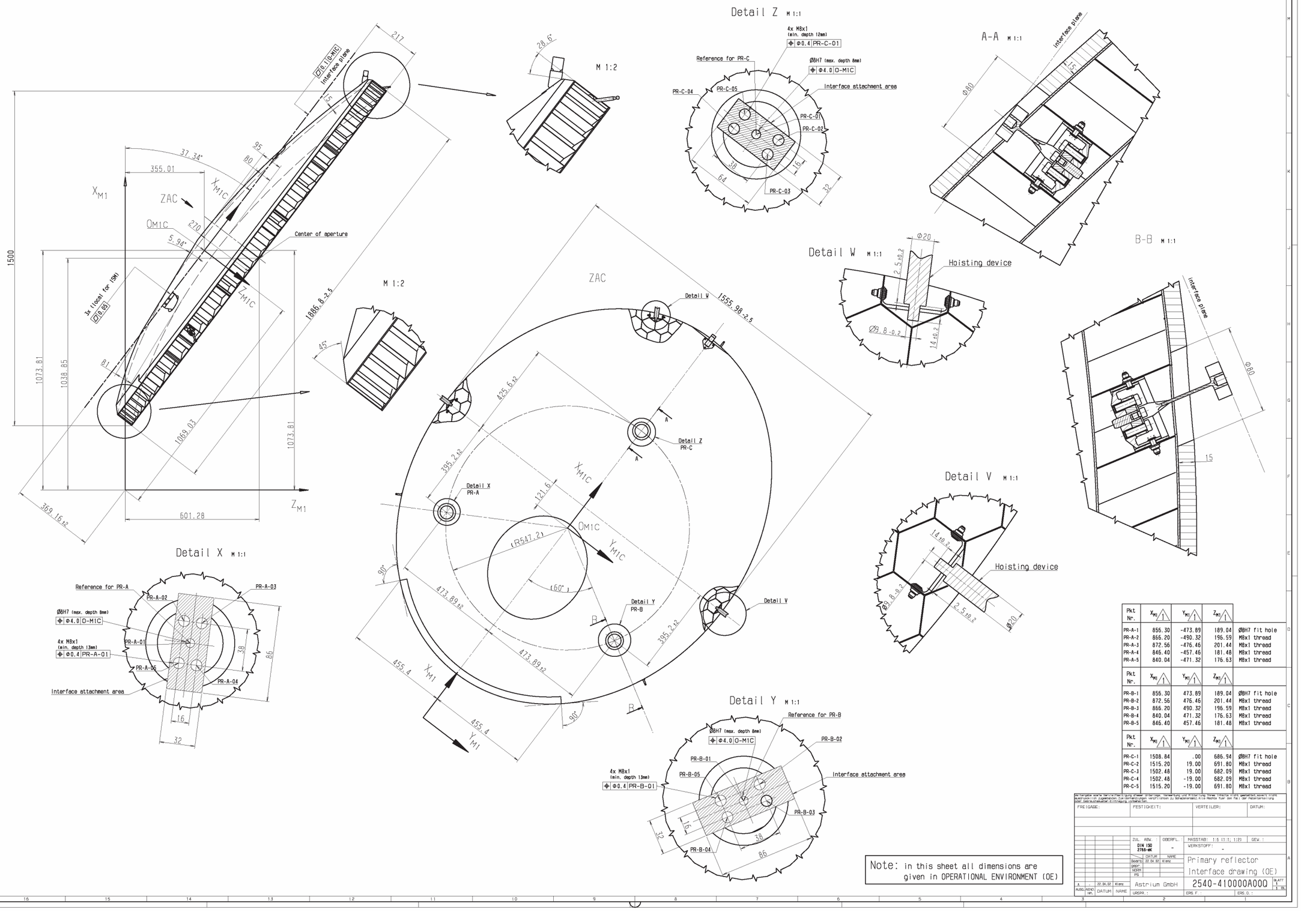


Figure 4: Protection cover of the PR

11. Interface Drawings Planck Reflectors

The below listed interface drawings are annexed hereafter:

- RD 7 PR Interfaces at Operating Temperature, Drawing 2540-410-000A00O
- RD 8 PR Interfaces at Room Temperature, Drawing 2540-410-000A00R
- RD 10 Thermal hardware PR, Drawing 2540-4100-30-A00C sheet, Iss. B



Pkt Nr.	X_{M1} 1	Y_{M1} 1	Z_{M1} 1	
PR-A-1	856.30	-473.89	189.04	Ø8H7 fit hole
PR-A-2	866.20	-490.32	196.59	M8x1 thread
PR-A-3	872.56	-476.46	201.44	M8x1 thread
PR-A-4	846.40	-457.46	181.48	M8x1 thread
PR-A-5	840.04	-471.32	176.63	M8x1 thread
Pkt Nr.	X_{M1} 1	Y_{M1} 1	Z_{M1} 1	
PR-B-1	856.30	473.89	189.04	Ø8H7 fit hole
PR-B-2	872.56	476.46	201.44	M8x1 thread
PR-B-3	866.20	490.32	196.59	M8x1 thread
PR-B-4	840.04	471.32	176.63	M8x1 thread
PR-B-5	846.40	457.46	181.48	M8x1 thread
Pkt Nr.	X_{M1} 1	Y_{M1} 1	Z_{M1} 1	
PR-C-1	1508.84	.00	686.94	Ø8H7 fit hole
PR-C-2	1515.20	19.00	691.80	M8x1 thread
PR-C-3	1502.48	19.00	682.09	M8x1 thread
PR-C-4	1502.48	-19.00	682.09	M8x1 thread
PR-C-5	1515.20	-19.00	691.80	M8x1 thread

Note: in this sheet all dimensions are given in OPERATIONAL ENVIRONMENT (OE)

FREIGABE: | FESTIGKEIT: | VERTEILER: | DATUM:

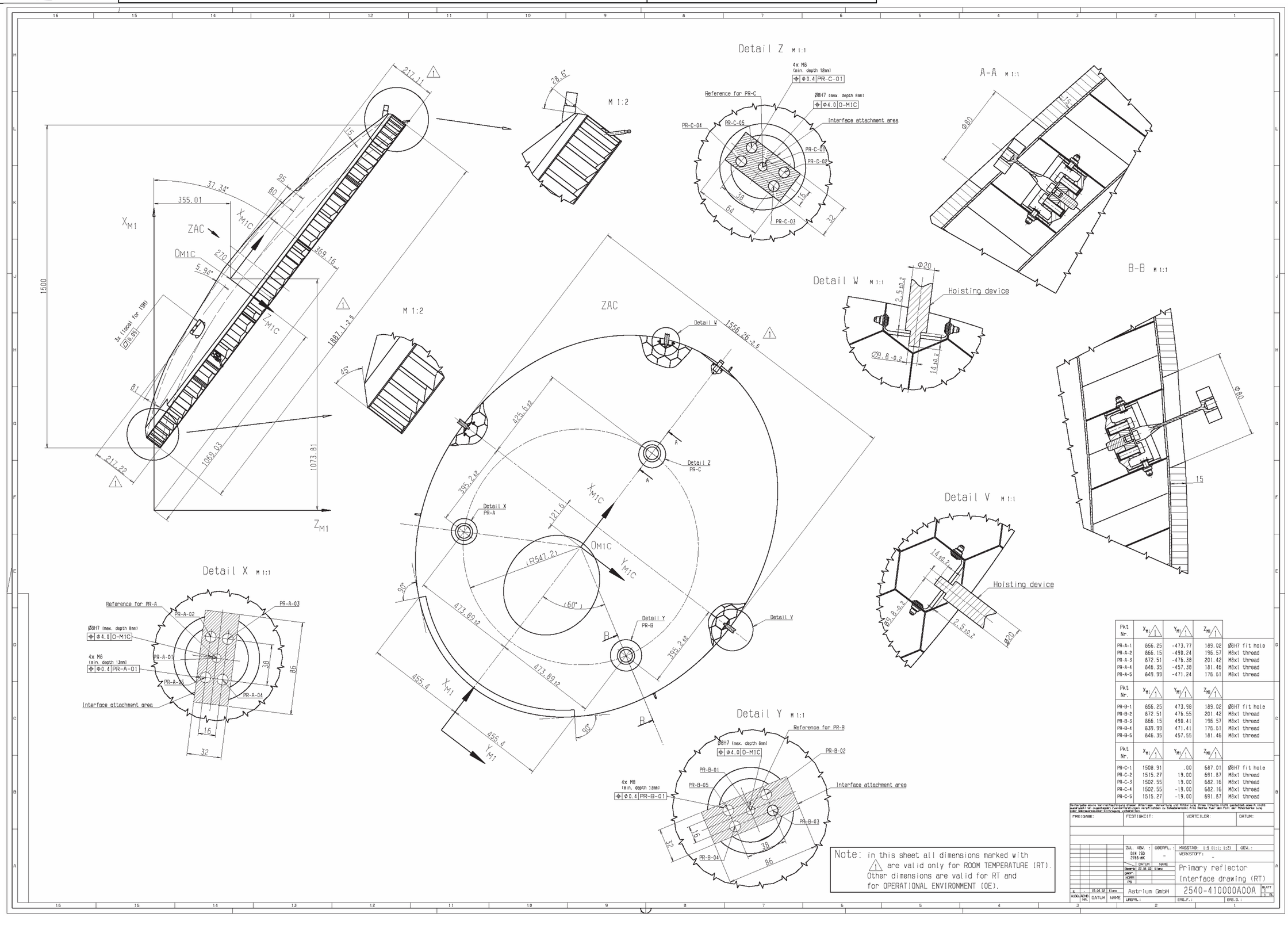
ZUL. ABW.: DIN ISO 2768-mK | OBERFL.: - | MASSTAB: 1:5 (1:1, 1:2) | GEW.: | WERKSTOFF: -

	DATUM	NAME
Bearb.	27.04.02	Klenz
Gepr.		
Norm		
PS		

Primary reflector Interface drawing (OE)

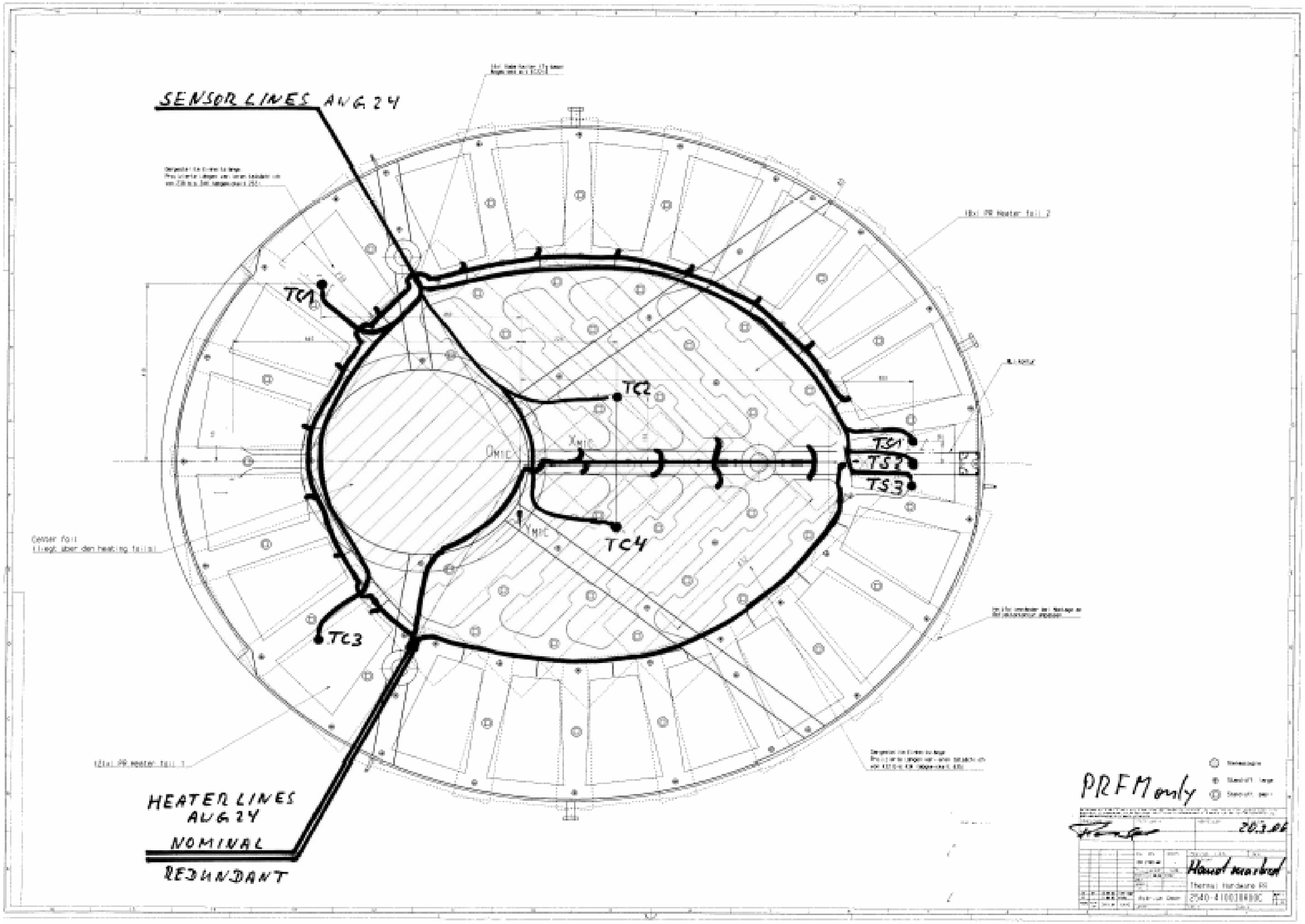
A - 27.04.02 Klenz | Astrium GmbH | 2540-410000A000 | BLATT 1 1 BL

AUSG./ÄNDERUNG IND. | DATUM | NAME | URSPR.: | ERS.F.: | ERS.O.:



Pkt Nr.	X_{M1} 1	Y_{M1} 1	Z_{M1} 1	
PR-A-1	656.25	-473.77	189.02	Ø8H7 fit hole
PR-A-2	666.15	-490.24	196.57	M8x1 thread
PR-A-3	672.51	-476.38	201.42	M8x1 thread
PR-A-4	646.35	-457.38	181.46	M8x1 thread
PR-A-5	649.99	-471.24	176.51	M8x1 thread
Pkt Nr.	X_{M1} 1	Y_{M1} 1	Z_{M1} 1	
PR-B-1	656.25	473.98	189.02	Ø8H7 fit hole
PR-B-2	672.51	476.55	201.42	M8x1 thread
PR-B-3	666.15	490.41	196.57	M8x1 thread
PR-B-4	639.99	471.41	176.51	M8x1 thread
PR-B-5	646.35	457.55	181.46	M8x1 thread
Pkt Nr.	X_{M1} 1	Y_{M1} 1	Z_{M1} 1	
PR-C-1	1508.91	.00	687.01	Ø8H7 fit hole
PR-C-2	1515.27	19.00	691.87	M8x1 thread
PR-C-3	1502.55	19.00	682.16	M8x1 thread
PR-C-4	1502.55	-19.00	682.16	M8x1 thread
PR-C-5	1515.27	-19.00	691.87	M8x1 thread

PREIGABE:	FESTIGKEIT:		VERTEILER:		DATUM:
ZUL. ABW: DIN ISO 2768-MK	OBERFL.: -	MASSTAB: 1:5 (1:1; 1:2)	GEW.:		
		VERKSTOFF: -			
	DATUM NAME	Primary reflector interface drawing (RT)			
Bearb. 22.04.02 Klenz					
gepr.					
NORM					
FREI					
4 22.04.02 Klenz	Astrium GmbH	2540-410000A00A	BLATT 1 1 BL		
ÄNDG INDEX NR. DATUM NAME	URSPR.:	ERS.F.:	ERS.D.:		


SENSOR LINES AUG 24
TC1
TC2
TC3
TC4
TS1
TS2
TS3
HEATER LINES
AUG 24
NOMINAL
REDUNDANT
PRFM only