HERSCHEL / PLANCK

End of Life Cleanliness Analysis

Product Code : 000000

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ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORD*

ISSUE	DATE	§ : DESCRIPTION DES EVOLUTIONS *§ : CHANGE RECORD*	REDACTEUR *AUTHOR*
01	01/07/2002	First issue	H-P Team
02	27/11/2002	2nd issue after PDR and dedicated clarification meeting H-P-ASPI-MN-2106 (18/10/02) RID 8223 and 8370 -§3.2 reference documents update -§7.1.3.1.2.4.2: re-evaporation rate analysis -Tables 7.1-4, 7.1-5, 7.1-6, 7.1-7, 7.1-9: evaporation rate column canceled -§7.1.3.1.4: the out-gassing on the Herschel FPU is assessed -§7.1.3.2.2 N2 thruster contamination assessed on Herschel FPU -§7.1.3.4: equation correction as per RID-8223 of Herschel/Planck PDR -Renumbering of section 7.2 tables and figures -Table 7.2-2: the Planck cryo-struts are now cold -§7.2.3.1.3.1 Evaporation phenomenon is more clearly explained -Tables 7.2-4 to 7.2-15: Evaporation rate column canceled and cold cryo-struts taken into account -§7.2.3.2.2: N2 thruster contamination assessed on Planck FPU -§8: budgets and conclusions update -§8.2: addition of contamination on -X sides of Planck V-grooves	H-P Team
03	26/11/03	All in flight contamination results are updated -materials update -thruster plume contamination assessment revised -LOU transient analysis performed -micrometeoroids environnement updated	

1. TABLE OF CONTENTS

2. SCOPE

The cleanliness level on the critical elements of a spacecraft is an important issue of the design and verification. Indeed, there is a direct link between the cleanliness and some performances (mainly thermo-optical performances).

Cleanliness study covers both particulate contamination -"dust"- and molecular contamination.-water, "on-ground" contaminants as silicate, and thruster-plume contamination.

In the "Cleanliness End of life Needs" [RD2], a "top-down" approach is followed. Based on system level requirements, the maximum allowed contamination level is assessed. Allocations between molecular and particulate contamination is made. Instruments needs are also considered.

In this document, a "bottom-up" approach is followed. Based on the results of:

- Cleanliness Control Plans,
- Hypotheses for the launcher,
- In-orbit contamination analysis (outgassing and thruster-plume contamination assessment - it is the core of this document),

the contamination budget is build, and compared to the needs.

3. APPLICABLE/REFERENCE DOCUMENTS

3.1 Applicable document:

[AD1] "System Requirement Specification"
SCI-PT-RS-059111 Is/Rev 3/0

[AD2] "Planck Telescope Deign Specification"
SCI-PT-RS-05991 Issue 1

3.2 Reference documents:

[RD1] "ISO cleanliness Policy"
ISO-AS-1300-TN-0429 Is 1-Rev B

[RD2] "Cleanliness End of life Needs"
H-P-1-ASPI-TN-0197 1/0

[RD3] "Herschel Contamination Control Plan
HP-2-ASED-PL-0023

[RD4] "Planck Cleanliness Control Plan
H-P-1-ASPI-PL-0253

[RD5] "Collection of VBQC"
ESTEC TOS-QMC Report: 99/011

[RD6] "PPLM Radiative Environment description"
H-P-3-ASPI-TN-0190

[RD7] "Cleanliness team report"
H-P-1-1ASPI-RP-0394 issue 1 rev 1

[RD8] Cleanliness Requirements specification
H-P-1-ASPI-SP-0035, Issue 2 rev 2

[RD9] Herschel Telescope Requirements Specification
SCI-PT-RS-04671 Issue 6.0

[RD10] LOU windows assembly procurement specification
HP-2-ASED-PS-0033 Issue 3/0

[RD11] Permeation through CVV sealings
HP-2-ASED-TN-0034 Issue 2A

[RD12] Plume analysis for the XMM 20N hydrazine thruster
XMM-RIBBRE-TN-0002 (12/09/03)
[RD13] Contamine Application Manual
ASTRIUM S413/RT/DP/15.98
[RD14] Plume analysis for the 1N hydrazine thruster
CHT1N-RIBBRE-TN-0007
[RD15] H-PLM PM#15 and SCI-PT-19395
[RD16] solid particle environment for Herschel and Planck
EMA-02-027-GD-PLCK

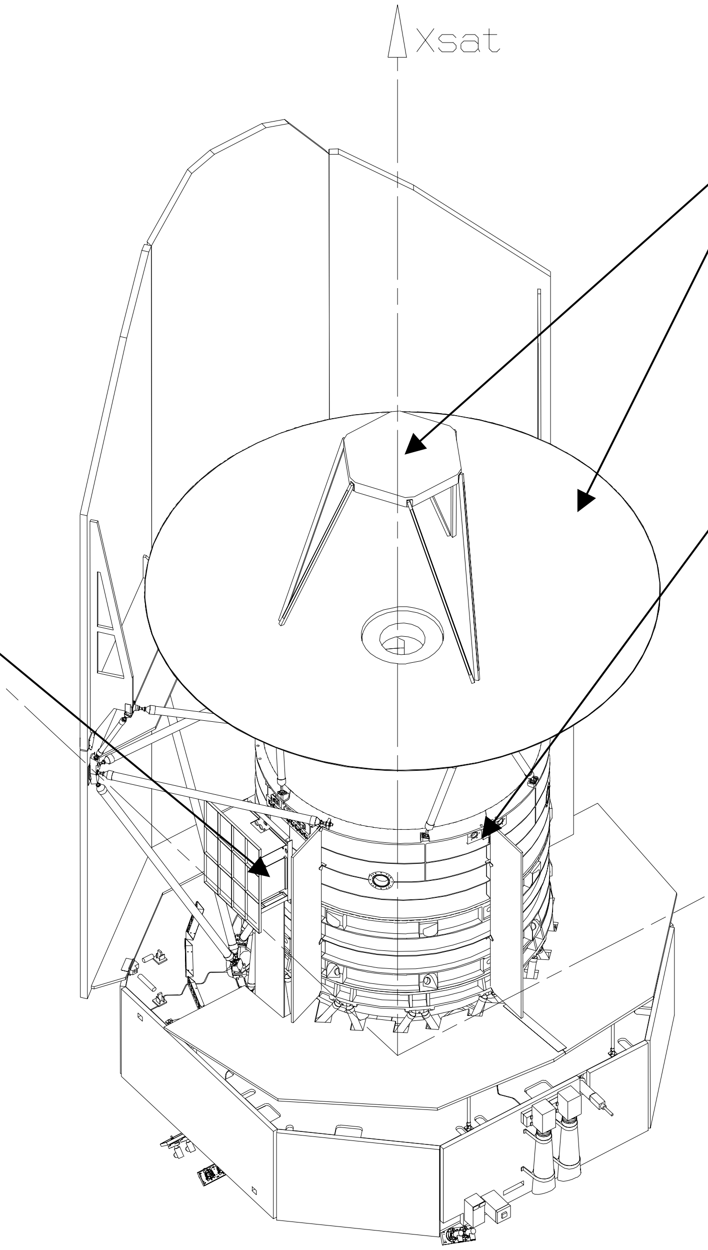
4. ABBREVIATION/ACRONYMS

CVV	**C**ryo-**V**acuum **V**essel
EOL	**E**nd **O**f **L**ife
HP	**H**erschel-**P**lanck
IR	**I**nfra**r**ed
LOU	**L**ocal **O**scillator **U**nit
N/A	**N**ot **A**pplicable
NC	**N**ot **C**alculated
PA	**P**roduct **A**ssurance
PLM	**P**ay**l**oad **M**odule
Ppm	**P**art **P**er **M**illion
S/C	**S**pace**c**raft
SRS	**S**ystem **R**equirements **S**pecification
TBC	**T**o **B**e **C**onfirmed
TBD	**T**o **B**e **D**efined
AOCS	**A**ttitude and **O**rbit **C**ontrol **S**ystem

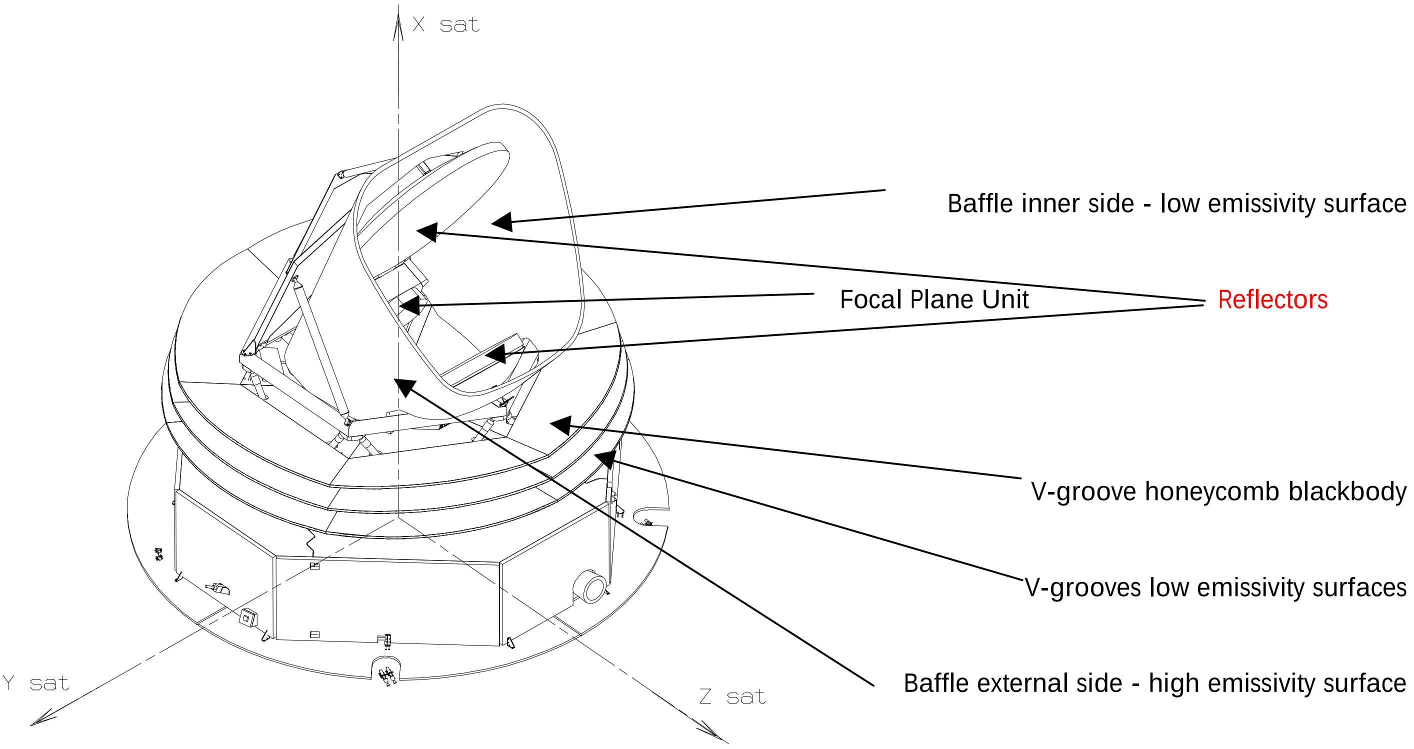
5. GEOMETRY AND CRITICAL ELEMENTS

This section describes the geometry and the indicates the critical elements (elements whose performance is degraded by contamination). For each one of these elements, a cleanliness need has been assessed (cf [RD2]), and a dedicated budget is built - this is the scope of this document.

5.1 Herschel



5.2 Planck


X sat
Y sat
Z sat
Baffle inner side - low emissivity surface
Focal Plane Unit
Reflectors
V-groove honeycomb blackbody
V-grooves low emissivity surfaces
Baffle external side - high emissivity surface

6. CLEANLINESS NEEDS

According to the Cleanliness End of life Needs analysis ([RD2]), the following table presents the maximum allowed contamination level at End of life, for the critical elements. These levels are the ones to which the contamination budgets have to be compared. This includes the instruments needs as expressed in the [RD7].

6.1 Herschel

EOL cleanliness level needs	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	
Telescope M1 (*)	$1.5\ 10^{-6}$	10^{-6}	10^{-6}	4650
Telescope M2 (*)	$1.5\ 10^{-6}$	10^{-6}	10^{-6}	4300
PACS FPU (outside)	$6\ 10^{-6}$			1500
SPIRE FPU (outside)	10^{-4}			No requirement yet
HIFI FPU (outside)	$6\ 10^{-6}$			1200
HIFI LOU CVV windows (**)	$8.5\ 10^{-6}$			1200
LOU inside (**)	$4\ 10^{-6}$			300

(*) 4.10^{-6} requested by the instruments

(**) not yet accepted by industry

6.2 Planck

EOL cleanliness level needs	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	

From instruments (system needs are not driving):

Focal Plane Unit(*)	$7\ 10^{-6}$	5000
Telescope PR	$4\ 10^{-6}$	5000
Telescope PR	$4\ 10^{-6}$	5000

from thermal needs:

Groove 1 (low emissivity surfaces)	$10\ 10^{-5}$	$1.4\ 10^{-5}$	$13\ 10^{-5}$	10 000
Groove 2	$15\ 10^{-5}$	$1.4\ 10^{-5}$	$13\ 10^{-5}$	10 000
Groove 3	$10\ 10^{-5}$	$10\ 10^{-5}$	$13\ 10^{-5}$	10 000
Groove 3 and baffle external side (high emissivity surfaces)	$3\ 10^{-5}$	$1.5\ 10^{-5}$	$3\ 10^{-5}$	15 000
Baffle (internal side)	$20\ 10^{-5}$	$5.6\ 10^{-5}$	$1\ 10^{-5}$	10 000

7. CLEANLINESS ANALYSIS

7.1 Herschel

This section presents the cleanliness analysis until End of Life for Herschel

7.1.1 Cleanliness level at the end of AIT

Considering the level at delivery and the contribution of the Herschel AIT sequence (described in document [RD3]), the contamination of the spacecraft at the end of AIT is :

contamination levels before launch	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	
M1	0	0	$2.87\ 10^{-7}$	1900
M2	0	0	$2.87\ 10^{-7}$	1900
Inside cryostat	0	0	$3\ 10^{-7}$	354.5
FPU and optical bench	$42\ 10^{-7}$	0	$30.5\ 10^{-7}$	375
Spacecraft	0	0	$15\ 10^{-7}$	2060

7.1.2 Cleanliness levels at the Beginning of life (just after launch)

The Alcatel hypotheses for the launcher contribution (from the encapsulation to the separation) are :

- 2300 PPM

- 4 10^{-7} g/cm^2 .

The particulate contamination has been negotiated with Arianespace see [RD15]

As the FPU and the inside of the cryostat can not be contaminated during the launch phase (closed areas), the contamination at Herschel beginning of life is :

contamination levels before launch	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	
M1	0	0	$6.87\ 10^{-7}$	2900
M2	0	0	$6.87\ 10^{-7}$	2900
Inside cryostat	0	0	$3\ 10^{-7}$	354.5
FPU and optical bench	0	0	$72.5\ 10^{-7}$	375
Spacecraft	0	0	$19\ 10^{-7}$	3060

7.1.3 In-orbit contamination

7.1.3.1 Outgassing

7.1.3.1.1 Introduction

During the satellite life the materials of all the sub-systems are submitted to the space environment. The conditions produced by the space environment can lead to the emission of polluting substances by the mediation of the outgassing phenomenon. This induced contamination can alter the sub-system initial properties and by the fact degrade the mission performances.

7.1.3.1.2 Hypotheses and modelisation

7.1.3.1.2.1 Modelisation

To fully take into consideration the outgassing phenomenon in contamination analyses, it is necessary to consider the way the materials will outgas during the satellite operating time with time and temperature dependencies. This level of detail can be reached by the use of the residence time method. This method have been coded in the OUTGASSING module of the ESABASE software.

One of the main inputs of this simulation method are the outgassing kinetic parameters for each material.

These parameters are determined with the VBQC system. This system allows to study the outgassing of a sample and the deposition of the contaminants under vacuum. The standard test performed with this system is a multi-step temperature test where the sample temperature is increased from 25°C to 125°C by step of 25°C every 24 hours.

The description of the operating system and the results accumulated by ESTEC during the last 10 years are available in the [RD5].

The TML and CVCM are mathematically described as a sum of 6 exponential functions (6 residence times), like shown in the equation below. The TML model is given for a sample at 25°C while the CVCM model is given at the temperature specified in the table as the 'temperature model'.

$$W = \sum_{i=1}^{6} W_{0,i} * (1 - e^{\frac{-t}{\tau_{0,i}}})$$

Where

W :	is either the TML or the CVCM
$W_{0,i}$:	is the Potential outgassing (resp. condensable) mass of the specie i (given in the tables of the RD([5]))
$\tau_{0,i}$:	is the time constant of the specie i (given in the tables of the annex of the [RD5])
t :	is the time (in hours)

Based on the previous equations it is possible to calculate the TML and CVCM at the desired temperature T, for a long term prediction.

$$W_T = \sum_{i=1}^{6} W_{0,i} * (1 - e^{\frac{-t}{\tau_{T,i}}})$$

With :

$$\tau_{T,i} = \tau_{0,i} * e^{Ke(T - T_{ref})}$$

Where

W_T :	is either the TML or CVCM at temperature T
$\tau_{T,i}$:	is the time constant of the specie i at the temperature T
$W_{0,i}$ and $\tau_{0,i}$:	are given in the table presented in the annex of the [RD5]
Ke:	is the residence time-temperature dependency coefficient
t :	is the time (in hours)
T:	is the surface temperature (in °C)
T_{ref} :	is the temperature of the TML (25°C) or CVCM model ('temperature model' in the table)

7.1.3.1.2.2 *Herschel inputs*

The main inputs for the Herschel outgassing simulations are the external configuration and the surfaces temperatures.

The external configuration consists in first, the geometrical configuration and second, in the materials arrangement.

The geometrical arrangement is based on the Herschel mechanical model. It is described in the simulation software with a collection of simple surfaces (rectangles, triangles, trapezes, cones, discs, …).

The ESABASE geometrical model is available in figure N°7.1-1

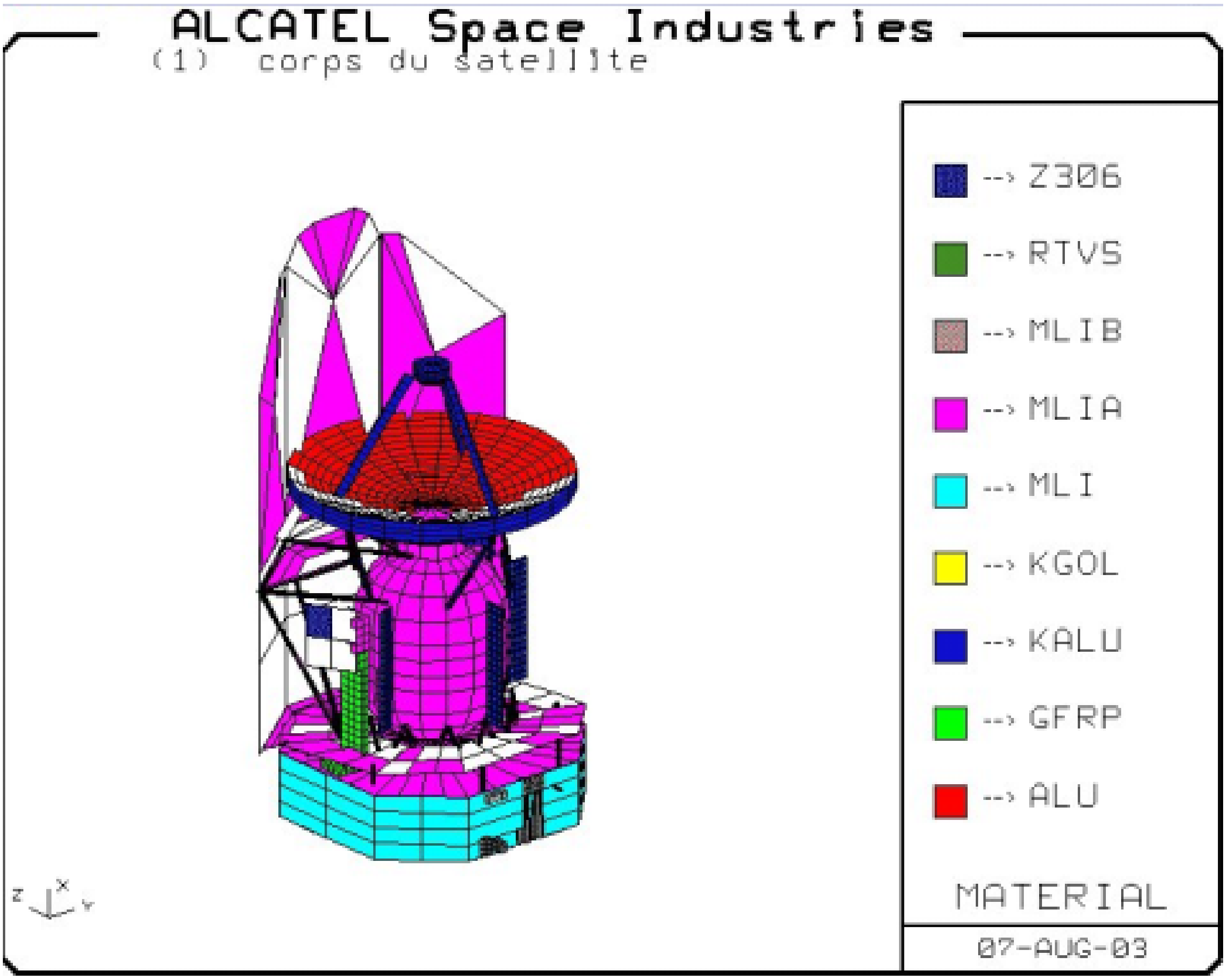


FIGURE 7.1-1- HERSCHEL- OUTGASSING MODEL

The materials implementation is the same as for the thermal model and is presented in table N°7.1-1.

Element	Material	Density (g/cm3)	Thickness (µm)	Unit	Comments
SVM upper face	MLI Alu	1,4	160	SVM	15 sheets
SVM lower face	MLI Kapton	1,4	160	SVM	10 sheets
SVM lateral panels	MLI Kapton	1,3	75	SVM	10 sheets
VMC camera	MLI black	1,4	100	SVM	10 sheets
FSS	MLI black	1,4	100	SVM	10 sheets
SAS	MLI black	1,4	100	SVM	10 sheets
TTC	MLI black	1,4	100	SVM	10 sheets
SREM	MLI black	1,4	100	SVM	10 sheets
HGA	MLI black	1,4	100	SVM	10 sheets
Star tracker support	MLI black	1,4	100	SVM	10 sheets
Star tracker baffle	MLI black	1,4	100	SVM	10 sheets
Star tracker box	MLI black	1,4	100	SVM	10 sheets
CVV external surface	Aluminium, MLI on +Z, black anodised on -Z side		n. a.		
CVV radiators	Aluminium, painted with **Aeroglaze Z306**	1,3	75		
CVV struts (PLM-SVM I/F struts)	GFRP wrapped in aluminised MLI	(CFRP) 2,05 (MLI) 1,4	(CFRP) 1800 (MLI) 100		
LOU WG	Metal		N/A		
LOU radiator	Z306	1,3	75	Intsrum.	
LOU	MLI	1,4	100	Intsrum.	20 sheets
LOU struts	GFRP	2,05	600		
SVM shield	CFRP sandwich with goldized Kapton foil	(CFRP) 1,68 (Kapton) 1,4	(CFRP) 520 (Kapton) 80		
SVM shield struts	GFRP wrapped in aluminised MLI	(GFRP) 2,05 (MLIA) 1,4	(GFRP) 1000 (MLIA) 100		
BOLA	Aluminised MLI	1,4	100	Instrum.	TBD sheets
Struts sun shield, I/F to SVM	CFRP wrapped in aluminised MLI	(CFRP)1,68 (MLIA) 1,4	(CFRP) 4000 (MLIA) 100		
Struts sun shield, all others	GFRP wrapped in aluminised MLI	(CFRP) 2,05 (MLIA) 1,4	(GFRP) 4800 (MLIA) 100		
Sun shield stiffners	CFRP sandwich +Aluminised MLI internal side	(MLI) 1,4	160		20 sheets
Sun shade external side	CFRP sandwich + OSR stuck by RTV S691	(glue) 1,42	(Glue) 210		
Sun shade internal side	CFRP sandwich +Aluminised MLI internal side	(MLI) 1,4	160		20 sheets
Sun shield external side	CFRP sandwich + solar cells stuck by RTV S691	(glue) 1,42	(Glue) 210		
Sun shield internal side	CFRP sandwich +Aluminised MLI internal side	(MLI) 1,4	160		20 sheets
M1 support struts	CFRP wrapped in aluminised kapton	(CFRP) 1,68 (Alu kapton) 1,4	(CFRP) 4900 (alu kapton) 80		
M1 support frame	CFRP wrapped in aluminised kapton	(CFRP) 1,68 (Alu kapton) 1,4	(CFRP) 1300 (alu kapton) 80		
M1 active side	SiC (or Alu)			Telescope	
M1 lateral side	Aluminised kapton	1,4	80	Telescope	
M1 rear side	Aluminised kapton	1,4	160	Telescope	20 sheets
M2 support struts	Aluminised kapton	1,4	80	Telescope	
M2 upper cylinder (+X)	Aluminised kapton	1,4	80	Telescope	
M2 lower cylinder (-X)	SiC (or Alu)			Telescope	

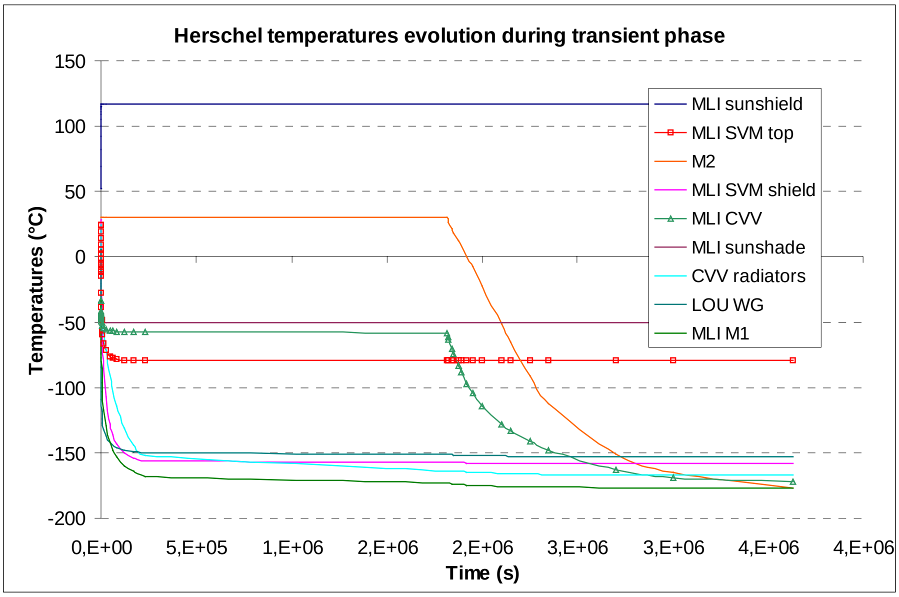
TABLE N°7.1-1- HERSCHEL- MATERIALS IMPLENTATION

The materials inside the hot SVM are listed in the table N°7.1-2.

Element	Material	Mass (kg)	Latest estimation (kg)
Alu NIDA panel	Glue BSL 312L	2	No longer outgassing
Equipment lateral panels	CFRP G969 M18	N/A	6,75
Equipment lateral panels glue	Glue BSL 319L	N/A	1,89
Internal black paint	Z306	2,145	2,56
Central tube	CFRP G969 M18 (0,8mm)	10	11,57
Central tube glue	Glue BSL 319L	1	1,3
Shear wall	CFRP G969 M18	6	5,74
Shear wall glue	Glue BSL 319L	0,6	0,76
Top platform	CFRP G801 M18	7	4,64
Top platform glue	Glue BSL 319L	1,8	2,38
Lower closure panel	CFRP G801 M18	6	3,24
Lower closure panel glue	Glue BSL 319L	1,4	1,55
Sub platform	CFRP G801 M18	6	1,12
Sub platform glue	Glue BSL 319L	0,6	0,83
Support propellant tanks	CFRP M55J M18	4,5	No longer outgassing
Support propellant tanks glue	Hysol 9321	0,5	No longer outgassing
RCS support panel	CFRP G801 M18	3	No longer outgassing
RCS support panel glue	Glue BSL 319L	0,5	No longer outgassing
Glue insert for potting	Stycast 1090/9	5	5
MLI internal (8m² tanks+ 4m² panels	MLI	1,68	1,68

Table N°7.1-2 - Herschel materials inside the SVM

The temperatures evolution during the transient phase are available in the figure hereunder.



The surfaces temperatures chosen for the simulations are those of the thermal hot case. This case corresponds to a hot SVM and a 'hot' HPLM. It is important to note that the 'hot' HPLM is only 2K hotter than the 'cold' HPLM. These temperatures are presented in the table N°7.1-3.

	PITCH 30	
Element	MIN	MAX
SVM upper face	204,16	214,93
	290,14	297,27
SVM lower face	278,86	320,43
	292,08	300,66
SVM lateral panels		
PANEL +Z	341,54	381,28
PANEL +Y+Z	322,39	355,16
PANEL+Y	132,08	248,50
PANEL +Y-Z	102,83	105,69
PANEL-Z	106,75	234,83
PANEL -Y-Z	102,66	116,40
PANEL-Y	109,59	163,17
PANEl-Y+Z	317,96	345,92
VMC camera	316,30	316,30
FSS	362,04	362,04
SAS (-Z)	205,77	205,77
SAS (+Z)		350,00
TTC 1 (+Z)		350,00
TTC 2 (-Z)		205,00
SREM	214,30	214,30
HGA		350,00
Star tracker support		147,00
Star tracker baffle	146,88	146,88
Star tracker box	139,22	139,22
Star tracker baffle	154,29	154,29
Star tracker box	146,98	146,98
CVV external surface	60,46	144,42
CVV radiators		
ON CVV	68,15	69,05
-Z	67,21	67,21
-Y	68,52	68,52
+Y	68,13	68,13
CVV struts (PLM-SVM I/F struts)	104,30	235,66
LOU WG	107,96	156,27
LOU radiator	125,40	125,40
	129,36	129,36
LOU	122,65	138,82
LOU struts		
	68,80	69,48
	130,31	130,31
SVM shield	119,23	119,63
	89,71	106,58
SVM shield struts		297,27
	290,14	297,27
	119,23	119,63
BOLA	123,17	137,94
Struts sun shield, I/F to SVM		347,50
	293,98	295,22
	347,50	347,50
Struts GS, I/F CVV?		347,50
	347,50	347,50
	68,88	69,54
Struts SSH, I/F CVV		267,90
	251,44	267,90
	68,88	69,39
Struts sun shield, all others		259,27
Sun shield stiffners	180,69	259,00
Sun shade external side	213,54	267,90
Sun shade internal side	157,28	192,51
Sun shield external side	347,50	369,17
Sun shield internal side	244,59	259,27
M1 support struts		
M1 support frame	79,20	79,20
M1 active side		
M1 lateral side		
M1 rear side	66,95	122,12
M2 support struts		
M2 upper cylinder (+X)	79,20	79,20
M2 lower cylinder (-X)		

TABLE 7.1-3- HERSCHEL- SURFACES TEMPERATURES

7.1.3.1.2.3 Herschel hypotheses

Ones of the inputs of this approach are the outgassing kinetic parameters for each implemented material. These parameters are determined by the help of the VBQC (Vacuum Balance Quartz Crystal) test, performed at ESTEC. The results of the tests already performed are available in an ESTEC report ([RD5]).

Some of these material characteristics are not available for the time being. Due to this lack of information a conversion had been applied in some cases. This conversion had been done following the materials expert pieces of advice and it is presented in the table N° 7.1-4. The first row of this table indicates the materials really present on the satellite, while the second row presents the materials that were chosen for the simulations, and the third row presents the VBQC test reference.

Materials on satellite	Simulated materials	VBQC test report
Kapton	Kapton	VBQC 3193/2
CFRP G969 M18	Cyanate composite	VBQC 3794
Aluminised MLI	Mylar DA foil	VBQC 3141
Nextel Suede coating 3101	Nextel Suede coating 3101	VBQC 3800
Nextel on open NIDA	Nextel Suede coating 3101	VBQC 3800
MLI	Kapton	VBQC 3193/2
MLI black	ASP Black Kapton	VBQC 3798
Glue BSL 312L	FM 73U	VBQC 3613
Kapton alu BO	Mylar DA BO	VBQC 3151
RTV S691	rtv s691	VBQC 3624
GFRP	Cyanate composite	VBQC 3794
Z306	Z306	VBQC 3148
Aluminised kapton	Mylar DA foil	VBQC 3141

TABLE 7.1-4 - HERSCHEL- OUTGASSING MATERIALS CONVERSION

No bake out is supposed for the all the simulated materials.

7.1.3.1.2.4 Herschel outgassing simulations

Various phases are distinguished and analyzed separately on Herschel satellite. These phases are the following:

- Transient phase (satellite cool down)
- Heating phase (M1, M2 at a temperature of 40°C during 3 weeks)
- Operational phase (temperatures equal to the nominal ones, output at 3 weeks, 3.5 years and 6 years)

The simulations were performed twice, once with only the external configuration materials taken into account and the second one with the consideration of the outgassing materials inside the hot SVM.

The materials inside the SVM were considered by the help of 75kg of CFRP (major material inside the SVM) uniformly located in the lateral surfaces of the SVM, which is thus a real worst case.

7.1.3.1.2.4.1 Transient phase

Due to the heating phase (3 weeks at 40°C) on the Herschel sensitive elements, M1 and M2, there is no contamination possible during the transient phase. The contamination will not remain on M1 and M2 due to the consideration of the re-evaporation phenomenon.

For the LOU which is a not covered and not heated element while sensitive, a specific approach is performed. Due to the fact that the temperature variations can not be taken into account by ESABASE/OUTGASSING, a specific Excel file was developed in order to cope with the need of estimating the contamination during the transient phase. This part of the analysis was performed in various steps. First, the temperature was discretised in very small intervals. Second, only the most outgassing elements of the satellite were selected for this study (Sunshield, sunshade, SVM top, M1, M2, CVV radiators, LOU wave guide, SVM shield and CVV). Third, the TML of each material presents on each surface was determined taking into consideration the historic of the outgassing phenomenon (ie: the amount of material already outgassed, and the amount still to outgas). Fourth, the LOU was suppressed and a factitious surface which represents the LOU aperture and the LOU window was designed, the viewing factors between this test surface and all the selected elements were determined by the help of ESARAD software. Fifth, the contamination due to the selected elements on the LOU surface was determined. The surfaces and mass values for each material are output of the ESABASE software.

The result of this analysis gives a molecular contamination of the **LOU test surface** during the transient phase of **1.23 E-5 g/cm² to 2.82E-5 g/cm²** depending on the MLI temperature.

7.1.3.1.2.4.2 Operational phase

The simulations were performed for the operational phase, ie for a hot SVM and a “hot” HPLM, the temperatures are output of the thermal model (see § 7.1.3.1.2.2).

The simulations were performed for the nominal lifetime (3.5 years) and for the extended lifetime (6 years). An additional point was extracted after 3 weeks.

On first hand, due to the lack of information concerning the re-evaporation phenomenon, it is not considered in the ESABASE simulations.

On the other hand, in order to be as close as possible of the reality, a re-evaporation estimation is done with the hypothesis of a contamination by water. The re-evaporation is estimated with the equation determining the vaporisation rate of a water splash under vacuum conditions.

$$\frac{dW}{dt} = 4{,}36.10^{-3} * P_s * A * S_1 * \sqrt{\frac{M}{T_s}} \quad \text{(in kg/s)}$$

With

Ps: vapour pressure of water (Pa)

S1: condensation coefficient (comprised between 0 and 1, chosen equal to 1 in our case)

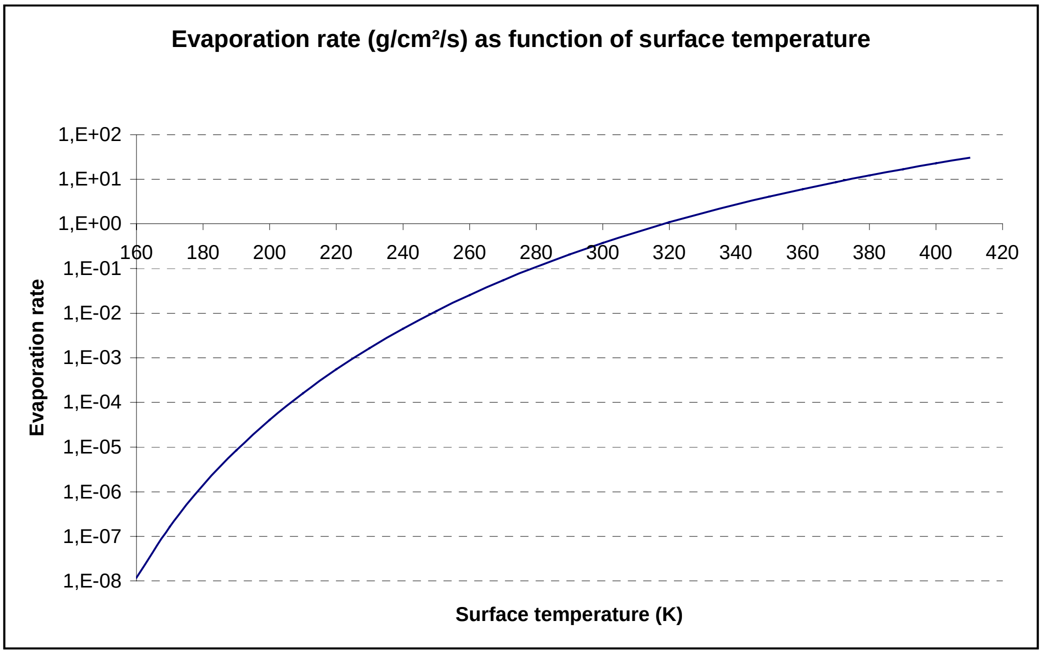
A: surface area

M: molecular mass (atomic mass unity)

Ts: surface temperature (K)

The re-evaporation phenomenon is estimated except for surfaces which temperature is lower than 159K (sticking temperature for water under vacuum conditions).

The results of the re-evaporation estimation are available in the figure hereunder that presents the evaporation rate as a function of the surface temperature.



The ESABASE results are available in table 7.1-5 to 7.1-9.

The maximum, minimum and average values represent the ESABASE results considering all the constituting nodes of a given element.

In order to know if the ESABASE contamination results presented in the different tables are really worst case or not, please refer, for each element, to the figure presenting the re-evaporation rate as a function of the surface temperature. This indication will permit to know if the re-evaporation phenomenon will be fast or not and if the contamination will stay on the contaminated element.

Considering the Herschel operational cases, it is also important to notice that most of the contamination is reached after 3 weeks. Only a slight variation of the amount of contaminants can be observed between 3 weeks and 3.5 years simulations results.

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLI	1,367	9,763	244,0	1,46E-05	2,98E-05	6,65E-07
SVM upper panel	MLIA	1,820	10,116	215,1	2,55E-06	4,14E-06	9,91E-07
SVM lower panel	MLI	1,416	10,116	320,1	2,41E-05	3,86E-05	1,19E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,57E-05	6,90E-05	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	3,02E-05	1,74E-04	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	8,49E-05	1,76E-04	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	7,45E-05	2,11E-04	0,00E+00
SAS #2	MLIB	0,016	0,112	205,1	1,47E-05	6,81E-05	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	4,91E-05	1,52E-04	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	5,65E-05	2,89E-04	0,00E+00
SREM	MLIB	0,014	0,097	214,1	4,48E-05	1,19E-04	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,24E-04	2,29E-04	6,67E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	2,81E-05	8,44E-05	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	3,12E-05	8,67E-05	0,00E+00
CVV external surface	MLIA	5,540	17,313	144,1	*3,95E-06*	*1,11E-05*	*0,00E+00*
CVV radiators	Z306	0,297	3,026	67,9	5,03E-07	3,81E-06	0,00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0,349	2,494	235,1	5,30E-06	3,32E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	1,71E-06	8,65E-06	0,00E+00
SVM shield +X	MLIA	1,813	8,242	106,2	3,66E-06	1,68E-05	9,30E-09
SVM shield -X	KGOL	0,907	8,242	119,2	1,18E-06	4,14E-06	1,07E-09
SVM shield struts	MLIA	0,080	0,568	297,1	5,44E-06	4,70E-05	0,00E+00
LOU	MLIA	0,093	0,665	122,2	4,24E-06	1,44E-05	3,74E-10
LOU radiator	Z306	0,098	1,000	125,2	3,76E-06	7,52E-06	2,55E-11
BOLA	MLIA	0,069	0,496	123,2	4,59E-07	1,98E-06	0,00E+00
Sun shield struts	MLIA	0,541	3,861	324,5	9,81E-06	5,67E-05	0,00E+00
Sun shield internal	MLIA	3,202	14,554	259,1	1,67E-04	3,56E-04	3,87E-06
Sun shield external	RTVS	4,337	14,554	369,1	2,45E-05	4,74E-05	0,00E+00
Sun Shade internal	MLIA	2,346	10,665	192,1	2,90E-05	3,56E-05	1,59E-05
Sun shade external	RTVS	3,177	10,665	267,1	1,33E-09	2,07E-09	0,00E+00
Sun shield Stiffners (int +ext)	MLIA	1,940	8,999	259,1	1,27E-05	3,35E-05	2,66E-07
Sun Shield lower struts	MLIA	0,013	0,074	259,1	4,68E-06	3,76E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	2,18E-06	1,54E-05	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	3,28E-06	1,94E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**3,01E-06**	**9,04E-06**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	79,2	1,97E-05	6,00E-05	0,00E+00
M1 lower surface	MLIA	3,032	6,892	122,2	4,42E-06	1,77E-05	0,00E+00
M1 lateral side 2	MLIA	1,544	7,018	122,2	5,70E-06	1,23E-05	0,00E+00
M2 support struts	KALU	0,059	0,528	79,2	1,86E-06	6,95E-06	0,00E+00
M2 support	KALU	0,118	0,007	79,2	9,43E-06	4,02E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	79,2	5,46E-06	9,34E-06	2,11E-06
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**3,32E-06**	**6,23E-06**	**0,00E+00**

TABLE 7.1-5 - HERSCHEL OUTGASSING CONTAMINATION OPERATIONAL PHASE (3WEEKS)

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75,124	9,763	244,0	1,52E-04	4,91E-04	1,09E-06
SVM upper panel	KALU	1,820	10,116	215,1	3,64E-06	1,19E-05	1,01E-06
SVM lower panel	MLI	1,416	10,116	320,1	4,02E-05	6,60E-05	1,86E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,61E-04	9,67E-04	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	1,03E-03	3,83E-03	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	1,60E-03	2,92E-03	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	1,11E-03	3,12E-03	3,87E-07
SAS #2	MLIB	0,016	0,112	205,1	1,20E-04	5,49E-04	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	5,52E-04	1,84E-03	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	5,33E-04	2,02E-03	0,00E+00
SREM	MLIB	0,014	0,097	214,1	2,45E-04	7,74E-04	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,81E-03	3,61E-03	6,28E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	9,59E-05	3,04E-04	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	1,03E-04	3,23E-04	0,00E+00
CVV external surface	KALU	5,540	17,313	144,1	*5,98E-06*	*1,71E-05*	*0,00E+00*
CVV radiators	Z306	0,297	3,026	67,9	6,75E-07	7,85E-06	0,00E+00
CVV struts (PLM-SVM I/F struts)	KALU	0,349	2,494	235,1	6,73E-06	4,22E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	1,90E-06	7,55E-06	0,00E+00
SVM shield +X	KALU	1,813	8,242	106,2	5,47E-06	1,72E-05	1,45E-08
SVM shield -X	KGOL	0,907	8,242	119,2	3,52E-06	1,56E-05	9,78E-10
SVM shield struts	KALU	0,080	0,568	297,1	6,73E-06	4,71E-05	0,00E+00
LOU	KALU	0,093	0,665	122,2	4,23E-06	1,59E-05	8,07E-11
LOU radiator	Z306	0,098	1,000	125,2	3,49E-06	6,98E-06	2,68E-11
BOLA	KALU	0,069	0,496	123,2	1,57E-07	4,73E-07	0,00E+00
Sun shield struts	KALU	0,541	3,861	324,5	1,07E-05	5,66E-05	0,00E+00
Sun shield internal	KALU	3,202	14,554	259,1	1,64E-04	3,49E-04	1,13E-06
Sun shield external	RTVS	4,337	14,554	369,1	3,03E-05	9,47E-05	0,00E+00
Sun Shade internal	KALU	2,346	10,665	192,1	4,15E-05	4,93E-05	3,43E-05
Sun shade external	RTVS	3,177	10,665	267,1	1,32E-09	2,05E-09	0,00E+00
Sun shield Stiffners (int +ext)	KALU	1,940	8,999	259,1	3,52E-05	2,47E-04	2,41E-07
Sun Shield lower struts	KALU	0,013	0,074	259,1	2,02E-05	1,75E-04	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	2,48E-06	1,61E-05	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	3,01E-06	1,69E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**2,62E-06**	**7,85E-06**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	79,2	1,99E-05	6,00E-05	0,00E+00
M1 lower surface	KALU	3,032	6,892	122,2	4,13E-06	1,65E-05	0,00E+00
M1 lateral side 2	KALU	1,544	7,018	122,2	5,40E-06	1,16E-05	0,00E+00
M2 support struts	KALU	0,059	0,528	79,2	1,41E-06	6,95E-06	0,00E+00
M2 support	KALU	0,118	0,007	79,2	1,07E-05	5,48E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	79,2	3,97E-06	6,51E-06	7,44E-09
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**2,01E-06**	**3,76E-06**	**0,00E+00**

TABLE 7.1-6 - HERSCHEL OUTGASSING CONTAMINATION OP PHASE WITH SVM MATERIALS (3WEEKS)

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLI	1,367	9,763	244,0	1,93E-05	3,15E-05	3,96E-06
SVM upper panel	MLIA	1,820	10,116	215,1	5,37E-06	1,10E-05	3,45E-06
SVM lower panel	MLI	1,416	10,116	320,1	2,50E-05	3,99E-05	1,26E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,60E-05	7,05E-05	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	3,09E-05	1,78E-04	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	8,68E-05	1,80E-04	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	7,66E-05	2,18E-04	0,00E+00
SAS #2	MLIB	0,016	0,112	205,1	1,81E-05	7,85E-05	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	5,02E-05	1,55E-04	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	6,10E-05	3,22E-04	0,00E+00
SREM	MLIB	0,014	0,097	214,1	5,64E-05	1,33E-04	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,27E-04	2,34E-04	8,07E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	3,77E-05	1,09E-04	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	3,63E-05	9,88E-05	0,00E+00
CVV external surface	MLIA	5,540	17,313	144,1	*7,15E-06*	*1,40E-05*	*0,00E+00*
CVV radiators	Z306	0,297	3,026	67,9	1,56E-06	1,76E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0,349	2,494	235,1	8,84E-06	4,02E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	6,23E-06	1,95E-05	0,00E+00
SVM shield +X	MLIA	1,813	8,242	106,2	6,25E-06	2,33E-05	2,51E-07
SVM shield -X	KGOL	0,907	8,242	119,2	4,47E-06	1,18E-05	5,97E-08
SVM shield struts	MLIA	0,080	0,568	297,1	1,02E-05	5,64E-05	0,00E+00
LOU	MLIA	0,093	0,665	122,2	7,65E-06	1,72E-05	2,31E-08
LOU radiator	Z306	0,098	1,000	125,2	8,50E-06	1,70E-05	1,87E-09
BOLA	MLIA	0,069	0,496	123,2	8,59E-06	2,73E-05	0,00E+00
Sun shield struts	MLIA	0,541	3,861	324,5	1,16E-05	6,86E-05	0,00E+00
Sun shield internal	MLIA	3,202	14,554	259,1	1,69E-04	3,56E-04	4,69E-06
Sun shield external	RTVS	4,337	14,554	369,1	2,88E-05	5,32E-05	0,00E+00
Sun Shade internal	MLIA	2,346	10,665	192,1	6,52E-05	9,04E-05	2,03E-05
Sun shade external	RTVS	3,177	10,665	267,1	8,04E-08	1,26E-07	0,00E+00
Sun shield Stiffners (int +ext)	MLIA	1,940	8,999	259,1	1,50E-05	4,06E-05	3,94E-07
Sun Shield lower struts	MLIA	0,013	0,074	259,1	7,46E-06	4,56E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	2,54E-06	1,83E-05	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	3,83E-06	2,30E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**3,64E-06**	**1,09E-05**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	79,2	2,37E-05	7,26E-05	0,00E+00
M1 lower surface	MLIA	3,032	6,892	122,2	5,36E-06	2,14E-05	0,00E+00
M1 lateral side 2	MLIA	1,544	7,018	122,2	6,83E-06	1,49E-05	0,00E+00
M2 support struts	KALU	0,059	0,528	79,2	2,33E-06	8,41E-06	0,00E+00
M2 support	KALU	0,118	0,007	79,2	1,14E-05	4,86E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	79,2	6,61E-06	1,13E-05	2,56E-06
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**4,02E-06**	**7,54E-06**	**0,00E+00**

TABLE 7.1-6 - HERSCHEL OUTGASSING CONTAMINATION OPERATIONAL PHASE (3.5 YEARS)

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	####	9,763	244,0	2,30E-04	5,91E-04	5,96E-06
SVM upper panel	KALU	1,820	10,116	215,1	8,51E-06	2,75E-05	3,82E-06
SVM lower panel	MLI	1,416	10,116	320,1	4,44E-05	8,58E-05	2,02E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,63E-04	9,39E-04	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	1,08E-03	3,99E-03	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	1,67E-03	3,05E-03	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	1,16E-03	3,25E-03	4,01E-07
SAS #2	MLIB	0,016	0,112	205,1	3,12E-04	1,50E-03	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	5,75E-04	1,91E-03	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	9,54E-04	5,53E-03	0,00E+00
SREM	MLIB	0,014	0,097	214,1	6,66E-04	2,11E-03	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,90E-03	3,77E-03	7,60E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	2,69E-04	8,34E-04	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	2,69E-04	8,84E-04	0,00E+00
CVV external surface	KALU	5,540	17,313	144,1	*1,24E-05*	*4,08E-05*	*0,00E+00*
CVV radiators	Z306	0,297	3,026	67,9	1,44E-06	1,63E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	KALU	0,349	2,494	235,1	1,06E-05	5,10E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	7,73E-06	2,78E-05	0,00E+00
SVM shield +X	KALU	1,813	8,242	106,2	7,65E-06	2,33E-05	2,38E-07
SVM shield -X	KGOL	0,907	8,242	119,2	8,04E-06	4,14E-05	5,45E-08
SVM shield struts	KALU	0,080	0,568	297,1	1,12E-05	5,17E-05	0,00E+00
LOU	KALU	0,093	0,665	122,2	7,73E-06	2,13E-05	4,90E-09
LOU radiator	Z306	0,098	1,000	125,2	8,75E-06	1,75E-05	1,87E-09
BOLA	KALU	0,069	0,496	123,2	7,78E-06	2,50E-05	0,00E+00
Sun shield struts	KALU	0,541	3,861	324,5	1,19E-05	6,83E-05	0,00E+00
Sun shield internal	KALU	3,202	14,554	259,1	1,66E-04	3,04E-04	1,38E-06
Sun shield external	RTVS	4,337	14,554	369,1	3,18E-05	1,12E-04	0,00E+00
Sun Shade internal	KALU	2,346	10,665	192,1	7,87E-05	1,03E-04	3,85E-05
Sun shade external	RTVS	3,177	10,665	267,1	8,41E-08	1,28E-07	0,00E+00
Sun shield Stiffners (int +ext)	KALU	1,940	8,999	259,1	4,08E-05	2,93E-04	3,50E-07
Sun Shield lower struts	KALU	0,013	0,074	259,1	7,70E-06	4,56E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	3,58E-06	2,00E-05	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	3,69E-06	2,20E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**2,99E-06**	**8,96E-06**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	79,2	2,33E-05	7,26E-05	0,00E+00
M1 lower surface	KALU	3,032	6,892	122,2	5,02E-06	2,01E-05	0,00E+00
M1 lateral side 2	KALU	1,544	7,018	122,2	6,81E-06	1,50E-05	0,00E+00
M2 support struts	KALU	0,059	0,528	79,2	2,14E-06	9,47E-06	0,00E+00
M2 support	KALU	0,118	0,007	79,2	1,09E-05	5,80E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	79,2	4,37E-06	6,70E-06	9,01E-09
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**2,29E-06**	**4,56E-06**	**0,00E+00**

TABLE 7.1-7 - HERSCHEL OUTGASSING CONTAMINATION OP PHASE WITH SVM MATERIALS (3.5 YEARS)

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLI	1,367	9,763	244,0	2,04E-05	3,18E-05	5,37E-06
SVM upper panel	MLIA	1,820	10,116	215,1	6,28E-06	1,53E-05	3,87E-06
SVM lower panel	MLI	1,416	10,116	320,1	2,50E-05	4,00E-05	1,27E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,60E-05	7,07E-05	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	3,10E-05	1,79E-04	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	8,70E-05	1,80E-04	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	7,68E-05	2,18E-04	0,00E+00
SAS #2	MLIB	0,016	0,112	205,1	1,91E-05	7,86E-05	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	5,03E-05	1,55E-04	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	6,11E-05	3,22E-04	0,00E+00
SREM	MLIB	0,014	0,097	214,1	5,83E-05	1,33E-04	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,27E-04	2,35E-04	8,07E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	4,07E-05	1,19E-04	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	3,75E-05	1,00E-04	0,00E+00
CVV external surface	MLIA	5,540	17,313	144,1	8,30E-06	1,89E-05	0,00E+00
CVV radiators	Z306	0,297	3,026	67,9	2,05E-06	2,59E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0,349	2,494	235,1	9,56E-06	4,02E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	8,50E-06	2,70E-05	0,00E+00
SVM shield +X	MLIA	1,813	8,242	106,2	6,69E-06	2,36E-05	2,52E-07
SVM shield -X	KGOL	0,907	8,242	119,2	6,16E-06	1,55E-05	9,62E-08
SVM shield struts	MLIA	0,080	0,568	297,1	1,22E-05	8,78E-05	0,00E+00
LOU	MLIA	0,093	0,665	122,2	9,22E-06	2,59E-05	3,96E-08
LOU radiator	Z306	0,098	1,000	125,2	1,10E-05	2,20E-05	3,22E-09
BOLA	MLIA	0,069	0,496	123,2	1,30E-05	4,26E-05	0,00E+00
Sun shield struts	MLIA	0,541	3,861	324,5	1,20E-05	6,86E-05	0,00E+00
Sun shield internal	MLIA	3,202	14,554	259,1	1,69E-04	3,56E-04	4,69E-06
Sun shield external	RTVS	4,337	14,554	369,1	2,89E-05	5,37E-05	0,00E+00
Sun Shade internal	MLIA	2,346	10,665	192,1	7,50E-05	1,06E-04	2,08E-05
Sun shade external	RTVS	3,177	10,665	267,1	1,38E-07	2,15E-07	0,00E+00
Sun shield Stiffners (int +ext)	MLIA	1,940	8,999	259,1	1,52E-05	4,06E-05	4,75E-07
Sun Shield lower struts	MLIA	0,013	0,074	259,1	8,60E-06	4,56E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	2,57E-06	1,84E-05	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	3,85E-06	2,32E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**3,65E-06**	**1,09E-05**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	79,2	2,37E-05	7,27E-05	0,00E+00
M1 lower surface	MLIA	3,032	6,892	122,2	5,40E-06	2,16E-05	0,00E+00
M1 lateral side 2	MLIA	1,544	7,018	122,2	6,84E-06	1,49E-05	3,23E-13
M2 support struts	KALU	0,059	0,528	79,2	2,36E-06	8,41E-06	0,00E+00
M2 support	KALU	0,118	0,007	79,2	1,14E-05	4,86E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	79,2	6,62E-06	1,13E-05	2,56E-06
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**4,02E-06**	**7,55E-06**	**0,00E+00**

TABLE 7.1-8 - HERSCHEL OUTGASSING CONTAMINATION OPERATIONAL PHASE (6 YEARS)

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75,124	9,763	244,0	2,36E-04	5,92E-04	7,95E-06
SVM upper panel	KALU	1,820	10,116	215,1	9,70E-06	2,87E-05	4,46E-06
SVM lower panel	MLI	1,416	10,116	320,1	4,49E-05	8,85E-05	2,02E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,63E-04	9,39E-04	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	1,08E-03	3,99E-03	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	1,67E-03	3,05E-03	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	1,16E-03	3,25E-03	4,01E-07
SAS #2	MLIB	0,016	0,112	205,1	3,31E-04	1,59E-03	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	5,75E-04	1,91E-03	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	9,91E-04	5,86E-03	0,00E+00
SREM	MLIB	0,014	0,097	214,1	7,04E-04	2,24E-03	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,90E-03	3,77E-03	7,60E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	2,88E-04	8,91E-04	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	2,86E-04	9,38E-04	0,00E+00
CVV external surface	KALU	5,540	17,313	144,1	1,38E-05	4,17E-05	0,00E+00
CVV radiators	Z306	0,297	3,026	67,9	1,89E-06	2,39E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	KALU	0,349	2,494	235,1	1,14E-05	5,11E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	1,07E-05	3,95E-05	0,00E+00
SVM shield +X	KALU	1,813	8,242	106,2	8,13E-06	2,35E-05	2,39E-07
SVM shield -X	KGOL	0,907	8,242	119,2	9,73E-06	4,55E-05	8,78E-08
SVM shield struts	KALU	0,080	0,568	297,1	1,32E-05	6,82E-05	0,00E+00
LOU	KALU	0,093	0,665	122,2	9,28E-06	2,50E-05	8,38E-09
LOU radiator	Z306	0,098	1,000	125,2	1,14E-05	2,27E-05	3,22E-09
BOLA	KALU	0,069	0,496	123,2	1,19E-05	3,89E-05	0,00E+00
Sun shield struts	KALU	0,541	3,861	324,5	1,23E-05	6,84E-05	0,00E+00
Sun shield internal	KALU	3,202	14,554	259,1	1,66E-04	3,04E-04	1,38E-06
Sun shield external	RTVS	4,337	14,554	369,1	3,18E-05	1,12E-04	0,00E+00
Sun Shade internal	KALU	2,346	10,665	192,1	8,89E-05	1,18E-04	3,89E-05
Sun shade external	RTVS	3,177	10,665	267,1	1,44E-07	2,19E-07	0,00E+00
Sun shield Stiffners (int +ext)	KALU	1,940	8,999	259,1	4,09E-05	2,94E-04	4,19E-07
Sun Shield lower struts	KALU	0,013	0,074	259,1	8,83E-06	4,57E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	3,62E-06	2,02E-05	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	3,71E-06	2,21E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**2,99E-06**	**8,96E-06**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	79,2	2,34E-05	7,27E-05	0,00E+00
M1 lower surface	KALU	3,032	6,892	122,2	5,06E-06	2,03E-05	0,00E+00
M1 lateral side 2	KALU	1,544	7,018	122,2	6,82E-06	1,50E-05	4,39E-13
M2 support struts	KALU	0,059	0,528	79,2	2,16E-06	9,47E-06	0,00E+00
M2 support	KALU	0,118	0,007	79,2	1,09E-05	5,80E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	79,2	4,37E-06	6,70E-06	9,01E-09
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**2,29E-06**	**4,56E-06**	**0,00E+00**

TABLE 7.1-9 - HERSCHEL OUTGASSING CONTAMINATION OP PHASE WITH SVM MATERIALS (6 YEARS)

7.1.3.1.2.4.3 Heating phase

An outgassing simulation was performed with ESABASE software, taking into consideration the telescope (M1, M2) heating during 3 weeks at 40°C, while the other parts of the Herschel satellite stay at the operational temperatures.

The results of the simulations are available in table N°7.1-10 and table N°7.1-11. The contaminant re-evaporation has to be estimated as presented in the previous paragraph. The difference between the results obtained with the telescope heating phase and the results obtained for the operational conditions after 3 weeks are available in table 7.1-12 and 7.1-13 .

In order to estimate the amount of contamination on Herschel satellite at the end of nominal life (3.5 years) and with the consideration of the heating phase, the contamination is calculated by subtracting the results of nominal contamination after 3 weeks to the nominal results of contamination after 3.5 years and by adding the results of the simulations of the heating phase after 3 weeks. This can be done with the hypothesis of a complete evaporation during the heating phase (hypothesis validated with the evaporation rate found for an heated equipment at 40°C in paragraph 7.1.3.1.2.4.2).

These results are available in table N°7.1-14 and N°7.1-15.

These results show the heating imperative on Herschel Satellite in order to meet the specifications.

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLI	1,367	9,763	244,0	1,51E-05	3,08E-05	8,62E-07
SVM upper panel	MLIA	1,820	10,116	215,1	2,61E-06	4,14E-06	1,00E-06
SVM lower panel	MLI	1,416	10,116	320,1	2,49E-05	3,99E-05	1,23E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,57E-05	6,89E-05	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	3,02E-05	1,74E-04	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	8,49E-05	1,76E-04	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	7,55E-05	2,16E-04	0,00E+00
SAS #2	MLIB	0,016	0,112	205,1	1,47E-05	6,77E-05	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	4,91E-05	1,51E-04	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	5,85E-05	3,00E-04	0,00E+00
SREM	MLIB	0,014	0,097	214,1	4,48E-05	1,19E-04	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,24E-04	2,29E-04	6,72E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	2,81E-05	8,41E-05	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	3,17E-05	8,65E-05	0,00E+00
CVV external surface	MLIA	5,540	17,313	144,1	*1,34E-05*	*6,94E-05*	*0,00E+00*
CVV radiators	Z306	0,297	3,026	67,9	3,75E-06	4,08E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0,349	2,494	235,1	6,45E-06	3,40E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	2,42E-06	1,09E-05	0,00E+00
SVM shield +X	MLIA	1,813	8,242	106,2	5,50E-06	1,76E-05	9,26E-09
SVM shield -X	KGOL	0,907	8,242	119,2	1,18E-06	4,20E-06	1,07E-09
SVM shield struts	MLIA	0,080	0,568	297,1	5,68E-06	4,70E-05	0,00E+00
LOU	MLIA	0,093	0,665	122,2	7,56E-06	3,14E-05	3,68E-10
LOU radiator	Z306	0,098	1,000	125,2	6,59E-06	1,32E-05	2,55E-11
BOLA	MLIA	0,069	0,496	123,2	4,51E-07	1,94E-06	0,00E+00
Sun shield struts	MLIA	0,541	3,861	324,5	1,65E-05	9,79E-05	0,00E+00
Sun shield internal	MLIA	3,202	14,554	259,1	1,71E-04	3,57E-04	3,90E-06
Sun shield external	RTVS	4,337	14,554	369,1	2,46E-05	4,84E-05	0,00E+00
Sun Shade internal	MLIA	2,346	10,665	192,1	3,12E-05	3,81E-05	1,75E-05
Sun shade external	RTVS	3,177	10,665	267,1	1,33E-09	2,07E-09	0,00E+00
Sun shield Stiffners (int +ext)	MLIA	1,940	8,999	259,1	2,08E-05	6,73E-05	2,65E-07
Sun Shield lower struts	MLIA	0,013	0,074	259,1	4,69E-06	3,76E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	1,29E-05	1,09E-04	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	2,09E-05	5,73E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**313,1**	**2,61E-05**	**6,68E-05**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	313,1	1,86E-05	2,84E-05	0,00E+00
M1 lower surface	MLIA	3,032	6,892	313,1	1,91E-05	3,88E-05	9,02E-12
M1 lateral side 2	MLIA	1,544	7,018	313,1	1,97E-05	4,17E-05	8,66E-06
M2 support struts	KALU	0,059	0,528	313,1	2,23E-06	5,64E-06	0,00E+00
M2 support	KALU	0,118	0,007	313,1	1,07E-05	3,54E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	313,1	6,86E-06	1,20E-05	3,66E-06
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**313,1**	**8,32E-06**	**1,61E-05**	**0,00E+00**

TABLE 7.1-10 - HERSCHEL OUTGASSING CONTAMINATION HEATING PHASE (3 WEEKS)

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75,124	9,763	244,0	1,56E-04	5,02E-04	1,24E-06
SVM upper panel	KALU	1,820	10,116	215,1	3,66E-06	1,23E-05	1,01E-06
SVM lower panel	MLI	1,416	10,116	320,1	4,09E-05	6,74E-05	1,87E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,56E-04	8,99E-04	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	1,03E-03	3,82E-03	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	1,60E-03	2,92E-03	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	1,11E-03	3,12E-03	3,86E-07
SAS #2	MLIB	0,016	0,112	205,1	1,19E-04	5,49E-04	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	5,49E-04	1,82E-03	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	5,41E-04	2,09E-03	0,00E+00
SREM	MLIB	0,014	0,097	214,1	2,45E-04	7,74E-04	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,82E-03	3,61E-03	6,18E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	9,62E-05	3,02E-04	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	1,02E-04	3,22E-04	0,00E+00
CVV external surface	KALU	5,540	17,313	144,1	*1,51E-05*	*6,74E-05*	*0,00E+00*
CVV radiators	Z306	0,297	3,026	67,9	2,92E-06	2,92E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	KALU	0,349	2,494	235,1	7,25E-06	4,24E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	2,92E-06	1,36E-05	0,00E+00
SVM shield +X	KALU	1,813	8,242	106,2	6,52E-06	1,79E-05	1,46E-08
SVM shield -X	KGOL	0,907	8,242	119,2	2,60E-06	1,57E-05	9,72E-10
SVM shield struts	KALU	0,080	0,568	297,1	6,86E-06	4,75E-05	0,00E+00
LOU	KALU	0,093	0,665	122,2	7,94E-06	3,75E-05	2,57E-10
LOU radiator	Z306	0,098	1,000	125,2	6,19E-06	1,24E-05	2,55E-11
BOLA	KALU	0,069	0,496	123,2	3,24E-07	1,26E-06	0,00E+00
Sun shield struts	KALU	0,541	3,861	324,5	1,59E-05	8,35E-05	0,00E+00
Sun shield internal	KALU	3,202	14,554	259,1	1,72E-04	3,13E-04	2,75E-06
Sun shield external	RTVS	4,337	14,554	369,1	2,78E-05	1,07E-04	0,00E+00
Sun Shade internal	KALU	2,346	10,665	192,1	4,15E-05	4,87E-05	3,54E-05
Sun shade external	RTVS	3,177	10,665	267,1	1,39E-09	2,11E-09	0,00E+00
Sun shield Stiffners (int +ext)	KALU	1,940	8,999	259,1	4,13E-05	2,46E-04	2,40E-07
Sun Shield lower struts	KALU	0,013	0,074	259,1	4,91E-06	3,76E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	1,36E-05	1,04E-04	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	2,15E-05	5,73E-05	0,00E+00
M1 active side	**KALU**	**2,324**	**20,760**	**313,1**	**2,94E-05**	**6,69E-05**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	313,1	2,16E-05	5,20E-05	0,00E+00
M1 lower surface	KALU	3,032	6,892	313,1	2,79E-05	4,52E-05	9,02E-12
M1 lateral side 2	KALU	1,544	7,018	313,1	3,33E-05	4,44E-05	1,11E-05
M2 support struts	KALU	0,059	0,528	313,1	1,43E-05	3,28E-05	0,00E+00
M2 support	KALU	0,118	0,007	313,1	2,50E-05	5,00E-05	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	313,1	7,80E-06	1,44E-05	2,59E-06
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**313,1**	**1,15E-05**	**1,87E-05**	**0,00E+00**

TABLE 7.1-11 - HERSCHEL OUTGASSING CONTAMINATION HEATING PHASE WITH SVM MATERIALS (3 WEEKS)

Element	Material	Mass (kg)	Surface (m²)	Heating temperature (K)	Nominal temperature (K)	Delta temperature	Average contamination (kg/m²)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLI	1,367	9,763	244,0	244,0	0,0	4,92E-06	4,92E-07	0,0	1,97E-07
SVM upper panel	MLIA	1,820	10,116	215,1	215,1	0,0	6,06E-07	6,06E-08	0,0	9,10E-09
SVM lower panel	MLI	1,416	10,116	320,1	320,1	0,0	7,71E-06	7,71E-07	0,0	3,10E-07
VMC Camera	MLIB	0,005	0,035	316,1	316,1	0,0	-3,33E-08	-3,33E-09	0,0	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	362,1	0,0	0,00E+00	0,00E+00	0,0	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	362,1	0,0	-3,33E-07	-3,33E-08	0,0	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	350,1	0,0	9,98E-06	9,98E-07	0,0	0,00E+00
SAS #2	MLIB	0,016	0,112	205,1	205,1	0,0	9,73E-08	9,73E-09	0,0	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	350,1	0,0	-7,78E-08	-7,78E-09	0,0	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	205,1	0,0	2,02E-05	2,02E-06	0,0	0,00E+00
SREM	MLIB	0,014	0,097	214,1	214,1	0,0	-6,33E-07	-6,33E-08	0,0	0,00E+00
HGA	MLIB	0,006	0,041	350,1	350,1	0,0	1,83E-08	1,83E-09	0,0	5,50E-09
Star Tracker #1	MLIB	0,054	0,389	144,4	144,4	0,0	1,19E-07	1,19E-08	0,0	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	143,8	0,0	5,42E-06	5,42E-07	0,0	0,00E+00
CVV external surface	MLIA	5,540	17,313	144,1	*144,1*	*0,0*	*9,47E-05*	*9,47E-06*	0,0	0,00E+00
CVV radiators	Z306	0,297	3,026	67,9	67,9	0,0	3,25E-05	3,25E-06	0,0	0,00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0,349	2,494	235,1	235,1	0,0	1,15E-05	1,15E-06	0,0	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	156,1	0,0	7,18E-06	7,18E-07	0,0	0,00E+00
SVM shield +X	MLIA	1,813	8,242	106,2	106,2	0,0	1,84E-05	1,84E-06	0,0	-4,40E-11
SVM shield -X	KGOL	0,907	8,242	119,2	119,2	0,0	2,12E-08	2,12E-09	0,0	-5,00E-12
SVM shield struts	MLIA	0,080	0,568	297,1	297,1	0,0	2,37E-06	2,37E-07	0,0	0,00E+00
LOU	MLIA	0,093	0,665	122,2	122,2	0,0	3,33E-05	3,33E-06	0,0	-6,50E-12
LOU radiator	Z306	0,098	1,000	125,2	125,2	0,0	2,83E-05	2,83E-06	0,0	0,00E+00
BOLA	MLIA	0,069	0,496	123,2	123,2	0,0	-7,73E-08	-7,73E-09	0,0	0,00E+00
Sun shield struts	MLIA	0,541	3,861	324,5	324,5	0,0	6,68E-05	6,68E-06	0,0	0,00E+00
Sun shield internal	MLIA	3,202	14,554	259,1	259,1	0,0	4,57E-05	4,57E-06	0,0	2,50E-08
Sun shield external	RTVS	4,337	14,554	369,1	369,1	0,0	1,49E-06	1,49E-07	0,0	0,00E+00
Sun Shade internal	MLIA	2,346	10,665	192,1	192,1	0,0	2,15E-05	2,15E-06	0,0	1,65E-06
Sun shade external	RTVS	3,177	10,665	267,1	267,1	0,0	0,00E+00	0,00E+00	0,0	0,00E+00
Sun shield Stiffners (int +ext)	MLIA	1,940	8,999	259,1	259,1	0,0	8,14E-05	8,14E-06	0,0	-1,30E-09
Sun Shield lower struts	MLIA	0,013	0,074	259,1	259,1	0,0	1,05E-07	1,05E-08	0,0	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	79,2	0,0	1,07E-04	1,07E-05	0,0	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	79,2	0,0	1,76E-04	1,76E-05	0,0	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**313,1**	**79,2**	**233,9**	**-3,01E-05**	**-3,01E-06**	**0,0**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	313,1	79,2	233,9	-1,97E-04	-1,97E-05	0,0	0,00E+00
M1 lower surface	MLIA	3,032	6,892	313,1	122,2	190,9	-4,42E-05	-4,42E-06	0,0	0,00E+00
M1 lateral side 2	MLIA	1,544	7,018	313,1	122,2	190,9	-5,70E-05	-5,70E-06	0,0	0,00E+00
M2 support struts	KALU	0,059	0,528	313,1	79,2	233,9	-1,86E-05	-1,86E-06	0,0	0,00E+00
M2 support	KALU	0,118	0,007	313,1	79,2	233,9	-9,43E-05	-9,43E-06	0,0	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	313,1	79,2	233,9	-5,46E-05	-5,46E-06	0,0	-2,11E-06
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**313,1**	**79,2**	**233,9**	**-3,32E-05**	**-3,32E-06**	**0,0**	**0,00E+00**

TABLE 7.1-12 - HERSCHEL OUTGASSING CONTAMINATION DIFFERENCE BETWEEN HEATING AND NOMINAL PHASES (3 WEEKS)

Element	Material	Mass (kg)	Surface (m²)	Heating temperature (K)	Nominal temperature (K)	Delta temperature	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75,1	9,8	244,0	244,0	0,0	3,53E-06	1,17E-05	1,50E-07
SVM upper panel	KALU	1,8	10,1	215,1	215,1	0,0	2,49E-08	4,20E-07	-2,00E-09
SVM lower panel	MLI	1,4	10,1	320,1	320,1	0,0	6,95E-07	1,40E-06	1,60E-07
VMC Camera	MLIB	0,0	0,0	316,1	316,1	0,0	-5,18E-06	-6,73E-05	0,00E+00
FSS #1	MLIB	0,0	0,0	362,1	362,1	0,0	-8,33E-07	-3,00E-06	0,00E+00
FSS #2	MLIB	0,0	0,0	362,1	362,1	0,0	-2,33E-06	2,00E-06	0,00E+00
SAS #1	MLIB	0,0	0,1	350,1	350,1	0,0	-1,23E-06	-2,00E-06	-5,00E-10
SAS #2	MLIB	0,0	0,1	205,1	205,1	0,0	-3,28E-07	-3,00E-07	0,00E+00
TTC #1	MLIB	0,0	0,0	350,1	350,1	0,0	-2,80E-06	-1,40E-05	0,00E+00
TTC #2	MLIB	0,0	0,0	205,1	205,1	0,0	8,15E-06	6,30E-05	0,00E+00
SREM	MLIB	0,0	0,1	214,1	214,1	0,0	-5,77E-07	0,00E+00	0,00E+00
HGA	MLIB	0,0	0,0	350,1	350,1	0,0	7,33E-06	3,00E-06	-1,01E-08
Star Tracker #1	MLIB	0,1	0,4	144,4	144,4	0,0	3,63E-07	-1,90E-06	0,00E+00
Star Tracker #2	MLIB	0,1	0,4	143,8	143,8	0,0	-1,34E-07	-1,50E-06	0,00E+00
CVV external surface	KALU	5,5	17,3	144,1	144,1	0,0	*9,08E-06*	5,03E-05	0,00E+00
CVV radiators	Z306	0,3	3,0	67,9	67,9	0,0	2,24E-06	2,14E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	KALU	0,3	2,5	235,1	235,1	0,0	5,15E-07	2,00E-06	0,00E+00
LOU WG	GFRP	3,6	0,1	156,1	156,1	0,0	1,01E-06	6,02E-06	0,00E+00
SVM shield +X	KALU	1,8	8,2	106,2	106,2	0,0	1,05E-06	6,90E-07	1,00E-10
SVM shield -X	KGOL	0,9	8,2	119,2	119,2	0,0	-9,23E-07	1,40E-07	-6,30E-12
SVM shield struts	KALU	0,1	0,6	297,1	297,1	0,0	1,31E-07	4,00E-07	0,00E+00
LOU	KALU	0,1	0,7	122,2	122,2	0,0	3,71E-06	2,16E-05	1,76E-10
LOU radiator	Z306	0,1	1,0	125,2	125,2	0,0	2,70E-06	5,40E-06	-1,31E-12
BOLA	KALU	0,1	0,5	123,2	123,2	0,0	1,67E-07	7,91E-07	0,00E+00
Sun shield struts	KALU	0,5	3,9	324,5	324,5	0,0	5,22E-06	2,69E-05	0,00E+00
Sun shield internal	KALU	3,2	14,6	259,1	259,1	0,0	7,62E-06	-3,62E-05	1,62E-06
Sun shield external	RTVS	4,3	14,6	369,1	369,1	0,0	-2,46E-06	1,19E-05	0,00E+00
Sun Shade internal	KALU	2,3	10,7	192,1	192,1	0,0	-3,33E-08	-5,50E-07	1,16E-06
Sun shade external	RTVS	3,2	10,7	267,1	267,1	0,0	6,80E-11	6,40E-11	0,00E+00
Sun shield Stiffners (int +ext)	KALU	1,9	9,0	259,1	259,1	0,0	6,12E-06	-1,30E-06	-1,70E-09
Sun Shield lower struts	KALU	0,0	0,1	259,1	259,1	0,0	-1,53E-05	-1,38E-04	0,00E+00
M1 support struts	KALU	0,1	1,3	79,2	79,2	0,0	1,11E-05	8,80E-05	0,00E+00
M1 frame	KALU	0,2	1,8	79,2	79,2	0,0	1,85E-05	4,04E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,0**	**20,8**	**313,1**	**79,2**	**233,9**	**-2,62E-06**	**-7,85E-06**	**0,00E+00**
M1 lateral side 1	KALU	0,6	5,1	313,1	79,2	233,9	-1,99E-05	-6,00E-05	0,00E+00
M1 lower surface	KALU	3,0	6,9	313,1	122,2	190,9	-4,13E-06	-1,65E-05	0,00E+00
M1 lateral side 2	KALU	1,5	7,0	313,1	122,2	190,9	-5,40E-06	-1,16E-05	0,00E+00
M2 support struts	KALU	0,1	0,5	313,1	79,2	233,9	-1,41E-06	-6,95E-06	0,00E+00
M2 support	KALU	0,1	0,0	313,1	79,2	233,9	-1,07E-05	-5,48E-05	0,00E+00
M2 upper cylinder	KALU	0,1	0,5	313,1	79,2	233,9	-3,97E-06	-6,51E-06	-7,44E-09
M2 lower cylinder	**NO OUTGASSING**	**0,0**	**0,3**	**313,1**	**79,2**	**233,9**	**-2,01E-06**	**-3,76E-06**	**0,00E+00**

TABLE 7.1-13 - HERSCHEL OUTGASSING CONTAMINATION DIFFERENCE BETWEEN HEATING AND NOMINAL PHASES WITH SVM MATERIALS (3 WEEKS)

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLI	1,367	9,763	244,0	1,98E-05	3,25E-05	4,16E-06
SVM upper panel	MLIA	1,820	10,116	215,1	5,43E-06	1,10E-05	3,46E-06
SVM lower panel	MLI	1,416	10,116	320,1	2,58E-05	4,12E-05	1,30E-05
VMC Camera	MLIB	0,005	0,035	316,1	1,60E-05	7,04E-05	0,00E+00
FSS #1	MLIB	0,005	0,034	362,1	3,09E-05	1,78E-04	0,00E+00
FSS #2	MLIB	0,005	0,034	362,1	8,67E-05	1,80E-04	0,00E+00
SAS #1	MLIB	0,016	0,112	350,1	7,76E-05	2,23E-04	0,00E+00
SAS #2	MLIB	0,016	0,112	205,1	1,81E-05	7,81E-05	0,00E+00
TTC #1	MLIB	0,005	0,039	350,1	5,02E-05	1,54E-04	0,00E+00
TTC #2	MLIB	0,005	0,039	205,1	6,30E-05	3,33E-04	0,00E+00
SREM	MLIB	0,014	0,097	214,1	5,63E-05	1,32E-04	0,00E+00
HGA	MLIB	0,006	0,041	350,1	1,27E-04	2,34E-04	8,12E-07
Star Tracker #1	MLIB	0,054	0,389	144,4	3,77E-05	1,09E-04	0,00E+00
Star Tracker #2	MLIB	0,054	0,389	143,8	3,68E-05	9,86E-05	0,00E+00
CVV external surface	MLIA	5,540	17,313	144,1	1,66E-05	7,23E-05	0,00E+00
CVV radiators	Z306	0,297	3,026	67,9	4,81E-06	5,46E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0,349	2,494	235,1	9,98E-06	4,10E-04	0,00E+00
LOU WG	GFRP	3,589	0,098	156,1	6,95E-06	2,18E-05	0,00E+00
SVM shield +X	MLIA	1,813	8,242	106,2	8,09E-06	2,41E-05	2,51E-07
SVM shield -X	KGOL	0,907	8,242	119,2	4,47E-06	1,18E-05	5,97E-08
SVM shield struts	MLIA	0,080	0,568	297,1	1,05E-05	5,64E-05	0,00E+00
LOU	MLIA	0,093	0,665	122,2	1,10E-05	3,42E-05	2,31E-08
LOU radiator	Z306	0,098	1,000	125,2	1,13E-05	2,27E-05	1,87E-09
BOLA	MLIA	0,069	0,496	123,2	8,58E-06	2,73E-05	0,00E+00
Sun shield struts	MLIA	0,541	3,861	324,5	1,83E-05	1,10E-04	0,00E+00
Sun shield internal	MLIA	3,202	14,554	259,1	1,73E-04	3,57E-04	4,71E-06
Sun shield external	RTVS	4,337	14,554	369,1	2,90E-05	5,41E-05	0,00E+00
Sun Shade internal	MLIA	2,346	10,665	192,1	6,74E-05	9,28E-05	2,19E-05
Sun shade external	RTVS	3,177	10,665	267,1	8,04E-08	1,26E-07	0,00E+00
Sun shield Stiffners (int +ext)	MLIA	1,940	8,999	259,1	2,32E-05	7,44E-05	3,93E-07
Sun Shield lower struts	MLIA	0,013	0,074	259,1	7,47E-06	4,56E-05	0,00E+00
M1 support struts	KALU	0,143	1,275	79,2	1,33E-05	1,12E-04	0,00E+00
M1 frame	KALU	0,199	1,775	79,2	2,14E-05	6,09E-05	0,00E+00
M1 active side	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**6,31E-07**	**1,89E-06**	**0,00E+00**
M1 lateral side 1	KALU	0,566	5,052	79,2	4,05E-06	1,26E-05	0,00E+00
M1 lower surface	MLIA	3,032	6,892	122,2	9,40E-07	3,76E-06	0,00E+00
M1 lateral side 2	MLIA	1,544	7,018	122,2	1,13E-06	2,56E-06	0,00E+00
M2 support struts	KALU	0,059	0,528	79,2	2,70E-06	1,46E-06	0,00E+00
M2 support	KALU	0,118	0,007	79,2	1,27E-05	8,46E-06	0,00E+00
M2 upper cylinder	KALU	0,062	0,549	79,2	1,15E-06	1,96E-06	4,45E-07
M2 lower cylinder	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**6,99E-07**	**1,31E-06**	**0,00E+00**

TABLE 7.1-14 - HERSCHEL OUTGASSING CONTAMINATION WITH HEATING PHASE CONSIDERATION (3.5 YEARS)

Element	Node number	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	1-8	CFRP	75,124	9,763	244,0	2,34E-04	6,03E-04	6,11E-06
SVM upper panel	9-16	KALU	1,820	10,116	215,1	8,53E-06	2,79E-05	3,81E-06
SVM lower panel	17-24	MLI	1,416	10,116	320,1	4,50E-05	8,72E-05	2,03E-05
VMC Camera	25-30	MLIB	0,005	0,035	316,1	1,57E-04	8,72E-04	0,00E+00
FSS #1	31-36	MLIB	0,005	0,034	362,1	1,07E-03	3,99E-03	0,00E+00
FSS #2	37-42	MLIB	0,005	0,034	362,1	1,67E-03	3,05E-03	0,00E+00
SAS #1	43-48	MLIB	0,016	0,112	350,1	1,16E-03	3,25E-03	4,01E-07
SAS #2	49-54	MLIB	0,016	0,112	205,1	3,12E-04	1,50E-03	0,00E+00
TTC #1	55-63	MLIB	0,005	0,039	350,1	5,72E-04	1,90E-03	0,00E+00
TTC #2	64-72	MLIB	0,005	0,039	205,1	9,62E-04	5,60E-03	0,00E+00
SREM	73-78	MLIB	0,014	0,097	214,1	6,65E-04	2,11E-03	0,00E+00
HGA	79-81	MLIB	0,006	0,041	350,1	1,91E-03	3,77E-03	7,50E-07
Star Tracker #1	88-96	MLIB	0,054	0,389	144,4	2,69E-04	8,32E-04	0,00E+00
Star Tracker #2	97-105	MLIB	0,054	0,389	143,8	2,69E-04	8,83E-04	0,00E+00
CVV external surface	106-117	KALU	5,540	17,313	144,1	2,14E-05	9,11E-05	0,00E+00
CVV radiators	118-135	Z306	0,297	3,026	67,9	3,68E-06	3,77E-05	0,00E+00
CVV struts (PLM-SVM I/F struts)	136-207	KALU	0,349	2,494	235,1	1,11E-05	5,12E-04	0,00E+00
LOU WG	208-225	GFRP	3,589	0,098	156,1	8,75E-06	3,38E-05	0,00E+00
SVM shield +X	226-240 par pas de 2	KALU	1,813	8,242	106,2	8,70E-06	2,40E-05	2,38E-07
SVM shield -X	227-241 par pas de 2	KGOL	0,907	8,242	119,2	7,11E-06	4,15E-05	5,45E-08
SVM shield struts	242-283	KALU	0,080	0,568	297,1	1,14E-05	5,21E-05	0,00E+00
LOU	284-289	KALU	0,093	0,665	122,2	1,14E-05	4,29E-05	5,08E-09
LOU radiator	290-291	Z306	0,098	1,000	125,2	1,14E-05	2,29E-05	1,87E-09
BOLA	292-297	KALU	0,069	0,496	123,2	7,94E-06	2,58E-05	0,00E+00
Sun shield struts	298-339	KALU	0,541	3,861	324,5	1,71E-05	9,52E-05	0,00E+00
Sun shield internal	340-347 ; 356-360 ; 366-370	KALU	3,202	14,554	259,1	1,74E-04	2,68E-04	3,00E-06
Sun shield external	348-355 ; 361-365 ; 371-375	RTVS	4,337	14,554	369,1	2,93E-05	1,24E-04	0,00E+00
Sun Shade internal	376-378-380	KALU	2,346	10,665	192,1	7,86E-05	1,02E-04	3,97E-05
Sun shade external	377-379-381	RTVS	3,177	10,665	267,1	8,42E-08	1,28E-07	0,00E+00
Sun shield Stiffners (int +ext)	382-401	KALU	1,940	8,999	259,1	4,69E-05	2,92E-04	3,49E-07
Sun Shield lower struts	402-410	KALU	0,013	0,074	259,1	-7,58E-06	-9,21E-05	0,00E+00
M1 support struts	411-428	KALU	0,143	1,275	79,2	1,47E-05	1,08E-04	0,00E+00
M1 frame	429-446	KALU	0,199	1,775	79,2	2,22E-05	6,24E-05	0,00E+00
M1 active side	**447-449**	**NO OUTGASSING**	**0,000**	**20,760**	**79,2**	**3,71E-07**	**1,11E-06**	**0,00E+00**
M1 lateral side 1	450-453	KALU	0,566	5,052	79,2	3,49E-06	1,26E-05	0,00E+00
M1 lower surface	454-457	KALU	3,032	6,892	122,2	8,88E-07	3,55E-06	0,00E+00
M1 lateral side 2	458-460	KALU	1,544	7,018	122,2	1,41E-06	3,41E-06	0,00E+00
M2 support struts	461-466	KALU	0,059	0,528	79,2	1,51E-05	2,52E-06	0,00E+00
M2 support	467-478	KALU	0,118	0,007	79,2	2,52E-05	3,13E-06	0,00E+00
M2 upper cylinder	479-481	KALU	0,062	0,549	79,2	3,99E-07	1,84E-07	1,57E-09
M2 lower cylinder	**482-484**	**NO OUTGASSING**	**0,000**	**0,314**	**79,2**	**2,77E-07**	**7,93E-07**	**0,00E+00**

TABLE 7.1-15 - HERSCHEL OUTGASSING CONTAMINATION WITH HEATING PHASE CONSIDERATION WITH SVM MATERIALS (3.5 YEARS)

7.1.3.1.3 *Outgassing contamination increase assessment*

The contamination increase assessment due to the in orbit materials outgassing for the operational phase without heating and at the nominal end of life (3.5 years) is summarised in the table N°7.1-16.

Contamination increase due to outgassing	Molecular (g/cm^2)		
	H_20	NH_3	On ground contaminants
M1	$3.64\ 10^{-6}$	N/A	N/A
M2	$4.02\ 10^{-6}$	N/A	N/A

TABLE 7.1-16 - HERSCHEL- CONTAMINATION INCREASE DUE TO MATERIALS OUTGASING WITHOUT HEATING PHASE

By taking into consideration the telescope heating phase, the contamination increase assessment due to materials outgassing for the operational phase and at the nominal end of life (3.5 years) is minimised. The results with heating consideration (total evaporation of the materials deposit on M1 and M2 during the first 3 weeks) are summarised in the table N°7.1-17.

Contamination increase due to outgassing	Molecular (g/cm^2)		
	H_20	NH_3	On ground contaminants
M1	$6.31\ 10^{-7}$	N/A	N/A
M2	$6.99\ 10^{-7}$	N/A	N/A

TABLE 7.1-17 - HERSCHEL- CONTAMINATION INCREASE DUE TO MATERIALS OUTGASING WITH HEATING PHASE

7.1.3.1.4 *Conclusion*

The decontamination phase consists in heating the telescope during 3 weeks at a temperature of 40°C. The 3 weeks period chosen for the heating phase is well adapted to the Herschel cleanliness requirement. According to this, the contamination budget due to this phase is presented in table 7.1-18.

Contamination increase due to outgassing	Molecular (g/cm^2)		
	H_2O	NH_3	On ground contaminants
M1	$6.31\ 10^{-7}$	N/A	N/A
M2	$6.99\ 10^{-7}$	N/A	N/A

TABLE 7.1-18 - HERSCHEL- BASELINE CONTAMINATION INCREASE DUE TO MATERIALS OUTGASING WITH HEATING PHASE

The contamination level seen by the FPU can be assessed by considering the level seen by M1 ($6.31\ 10^{-7}$ g/cm2) multiplied by an attenuation factor due to the fact that the water enters the cavity through the M1 hole (380mm diameter), and is condensed on the hole optical bench (1630mm diameter) this attenuation factor is 0.054 (as per section § 7.1.3.2.2), which gives a contamination level of $3.41\ 10^{-8}$ g/cm2 of water on the FPU at EOL.

7.1.3.2 Thruster-plume

7.1.3.2.1 *Hypotheses*

The selected thrusters for the Herschel satellite are the 20 N hydrazine thrusters manufactured by ASTRIUM.

The plume composition of an hydrazine catalytic thruster is available in Table N° 7.1-19.

COMPONENT	FORMULA	PROPORTION
Ammonia	NH3	34.31%
Nitrogen	N2	57.86%
Hydrogen	H2	6.22%
Water	H2O	0.65%
Hydrazine	N2H4	0.46%
Aniline	C6H5NH2	0.50%

TABLE 7.1-19 - HERSCHEL – MASSIC COMPOSITION OF AN HYDRAZINE CATALYTIC THRUSTER PLUME

The sticking temperatures of these plume components are presented in table 7.1-20.

COMPONENT	STICKING TEMPERATURE (K)
Ammonia	102
Nitrogen	26
Hydrogen	4
Water	159
Hydrazine	165
Aniline	190

TABLE 7.1-20 - HERSCHEL - STICKING TEMPERATURES OF THE PLUME COMPONENT

The table N°7.1-21 shows the thruster utilisation strategy for Herschel satellite.

MANOEUVRE	Fuel mass (kg)	Thruster
Compensation for perigee velocity variation	16.5	A1 or A2
Removal of launcher dispersion	68.4	A1 or A2
Manœuvre on day 12 from perigee	6.8	A1 or A2
Mid course correction	4.7	A1 or A2
Orbit maintenance for mission lifetime	8.9	A1 or A2
Orbit maintenance due to attitude control	8.7	A1 or A2
Attitude control	16.7	C1 or C2 or C3 or C4

TABLE N°7.1-21 – HERSCHEL - THRUSTERS UTILISATION STRATEGY

To compute the worst case for the chemical thrusters contamination, the following scenario has to be used:

- 114 kg on the worst contaminating thruster A1 or A2
- 17 kg on the worst contamination thruster C1, C2, C3 or C4 and 15 kg for attitude control during delta-V manoeuvres representing 32 kg to be computed for the worst contaminating thruster C1, C2, C3 or C4.

The positions and the orientations of the Herschel 20N thrusters are presented in table N°7.1-22 and in figure N°7.1-4 with respect to the conventions presented in figure N°7.1-2 and N°7.1-3.

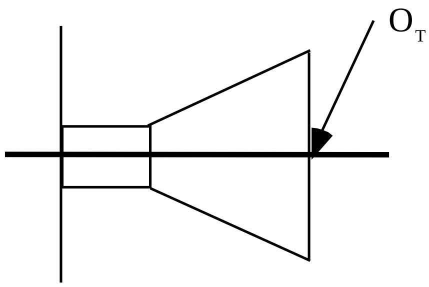


FIGURE 7.1-2 DEFINITION OF THE THRUSTER REFERENCE POINT

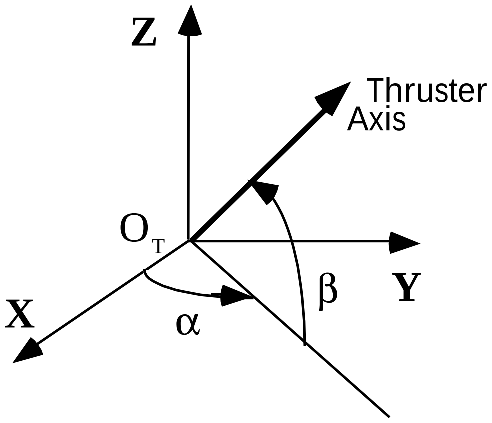


FIGURE 7.1- 3 DEFINITION OF THE THRUSTER ORIENTATION

Thruster		A1A	A2A	C1A	C2A	C3A	C4A	A1B	A2B	C1B	C2B	C3B	C4B
Coordinates	XT	-149,1	-192,2	-147,8	-147,8	-147,8	-147,8	-141,3	-164,5	-147,8	-147,8	-147,8	-147,8
of the thruster	YT	583,5	-789,0	1700,0	1700,0	-1700,0	-1700,0	671,7	-877,5	1610,0	1610,0	-1610,0	-1610,0
(mm)	ZT	1671,0	-1684,1	-595,4	595,4	595,4	-595,4	1651,9	-1674,4	-595,4	595,4	595,4	-595,4
Orientation	α	165,1	-160,5	0,0	0,0	0,0	0,0	162,9	-158,3	0,0	0,0	0,0	0,0
(degrees)	β	36,85	-35,05	-125,0	125,0	125,0	-125,0	36,3	-34,8	-125,0	125,0	125,0	-125,0

TABLE 7.1-22 HERSCHEL THRUSTERS POSITIONS AND ORIENTATIONS

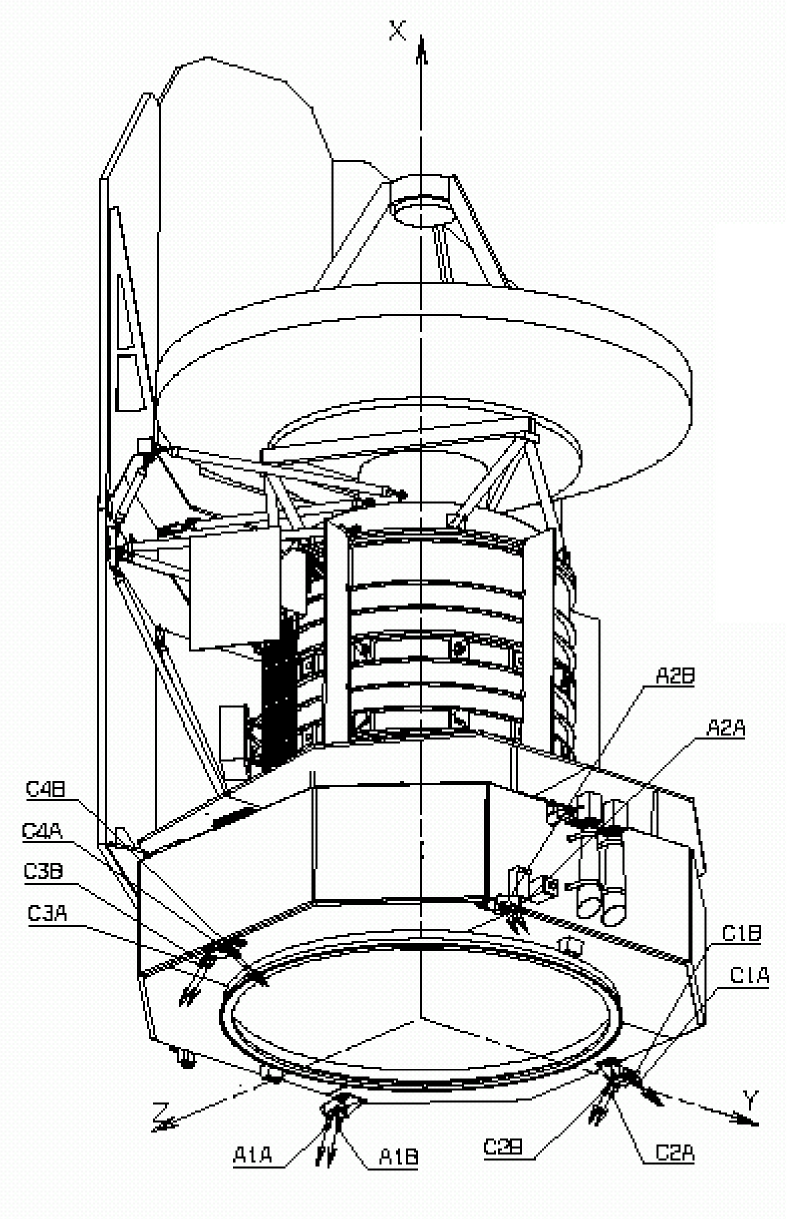


FIGURE N°7.1-4 HERSCHEL THRUSTERS DEFINITION

The hydrazine 20 N thruster definition is available in [RD13].

The main characteristics are recalled for information in table N° 7.1-23.

Thruster			20N
Fuel	-	-	N_2H_4
Chamber pressure	Pc	[Bar]	9.3
Chamber temperature	Tc	[K]	1156
Molar mass	W	[g/mol]	13.689
Adiabatic coefficient	γ	[-]	1.358
Viscosity at T0	Bμo	[Poiseuille]	3.899E-3
Exponent of the Sutherland law	ωv	[-]	0.698451
Prandtl number	Pr	[-]	0.4087
Throat radius	RSTAR	[m]	0.0021
Convergence radius	RCURV1 (1)	[-]	2.14
Convergence angle	TTA1	[°]	38
Divergence radius	RCURV2 (1)	[-]	2.14
Divergence angle	TTA2	[°]	28.92
Exit radius	REXIT (1)	[-]	7.7143
Exit distance	ZEXIT	[-]	22.0952
Contour parameter for circle	IWALL	[-]	3
Exit angle	TTEXIT	[°]	5
Area ratio	Ae/A	[-]	59.5

TABLE 7.1-23 - 20N THRUSTER MAIN CHARACTERISTICS

7.1.3.2.2 Herschel analysis

The simulations of the contamination due to UPS activation are performed with the CONTAMINE software. This software was developed under CNES contract. It permits to simulate first, the contaminants propagation from the reaction chamber to the satellite surfaces, and second the interactions between the contaminants and the satellite surfaces (deposits and surfaces properties modifications).

This software is interfaced with PLUMFLOW, which was also developed under CNES contract. The PLUMFLOW software calculates the flow inside the chemical thrusters. It is constituted by 9 modules.

- ODE: calculates the chemical equilibrium inside the combustion chamber and inside the thruster divergent
- NAVIER: determines the flow characteristics in the thruster and in the near field region

- TPPLUME: calculates the flow in the continuous part of the jet
- SESJET: evaluates the flow gaseous characteristics, to have a first order of magnitude of the different quantities
- MATFLOW: calculates the streamlines resulting from NAVIER and TPPLUME, and extend them in the far field region
- TRAJET: permits a 2D flow characteristics visualization
- CEC: permits to gather or add contaminant species generated by the ODE module from PLUMFLOW in order to limit or modify the species to be taken into further computation
- MCLIP: computes the thruster flow field at the vicinity of the nozzle lip with a transient regime taking into account each specie from the stream. It permits a good modeling of the expansion of the limit layer in the thruster backflow.
- DROPLET: modelises the droplets or particles propagation in a thruster plume. It takes into account not only the droplets and particles from the chamber but also the droplets ejected at the thruster nozzle lip

The ODE calculations are performed in order to determine a reaction temperature for a given reactants by minimising the Gibbs free energy at a given pressure leading to a number of reaction products and associated gas mixture properties. In the real hydrazine decomposition, a reaction kinetic is involved with a fast exothermic decomposition of N_2H_4 into NH_3 and H_2, followed by a slower endothermic dissociation of NH_3 in H_2 and N_2. The real exhaust gas composition depends on the catalytic bed (quality, thickness, material, grain size, …) and the catalytic bed load (specific mass flux). Typically molar fractions of 0.2 NH_3, 0.27 N_2 and 0.52 H_2 are reached at the catalytic bed exit whereas the ODE analysis leads to mole fractions of 0.001 NH_3, 0.333 N_2 and 0.666 H_2.

The reaction kinetics (rates of change) cannot be analysed with ODE, only the equilibrium state can be. However during the expansion of the gas mixture, frozen conditions might be assumed with a frozen gas composition in spite of temperature varying mixture properties. This is realistic because of the short time residence inside the nozzle due to the high velocity expansion.

In order to meet the real temperature inside the chamber, either the propellant reaction enthalpy can be adjusted, or the composition and chamber temperature might be set by others means and the given properties (chamber pressure and temperature, specific heat, dynamic viscosity, specific heat ratio, …) are given as inputs for the nozzle/plume flow via the NAVIER inputs namelist $GASPROP.

For this analysis the second solution was chosen. The gas properties retained for the simulations are presented in the table 7.1-23.

The CONTAMINE software is shared in 5 different modules, these modules are presented here after.

- PROPEC: computes the gaseous contaminants propagation which are ejected by the thrusters towards the satellite surfaces in a free molecular regime. It takes into account several contaminant species
- DROPEC: computes the droplets / particles propagation which are ejected towards the satellite surfaces
- PICS: integrates the gaseous contaminants and the particles / droplets ones on the satellite surfaces over the satellite lifetime
- SURFACE: evaluates the influence of the gaseous contaminants on the properties of the satellite surfaces
- DROPSURF: evaluates the influence of the droplets / particles contaminants on the properties of the satellite surfaces

For more details on the CONTAMINE software please refer to [RD13].

Knowing that the hydrazine are 'clean' thrusters in term of exhaust products contamination, only the gaseous contamination is investigated.

For the Herschel simulations only the five main contributors (NH3, N2, N2H4, H2O and H2) for contamination are investigated.

The SURFACE and DROPSURF modules do not work properly, for instance only the cumulative contamination is presented in the following tables.

All the thrusters strategies have been done. The worst case in term of contamination is found with the A2A and C1A thrusters.

The results are presented in table N°7.1-24.

Element	Contamination by H2 (g/cm²)	Contamination by	Contamination by	Contamination by	Contamination by
SVM_lat_-Z	0	7,49E-08	0	3,70E-09	3,96E-06
SVM_lat_-Y	0	0	0	0	3,18E-11
SVM_lat_-Y-Z	0	4,84E-12	0	2,61E-13	3,62E-10
Tank	0	7,85E-10	0	3,51E-11	8,93E-08
CVV_upper_cyl	0	2,34E-10	0	9,35E-12	1,89E-08
CVV_Rad+Y	0	1,80E-10	0	6,89E-12	1,73E-08
CVV_Rad-Z	0	1,76E-12	0	9,86E-14	1,13E-10
CVV_Rad-Y	0	1,52E-12	0	5,85E-14	4,24E-10
CVV_Strut1	0	4,18E-13	0	2,07E-14	5,55E-10
CVV_Strut2	0	2,09E-13	0	1,03E-14	9,44E-10
CVV_Strut3	0	2,08E-12	0	7,49E-14	2,72E-09
CVV_Strut4	0	3,17E-12	0	1,53E-13	3,09E-09
CVV_Strut5	0	1,50E-11	0	7,06E-13	5,20E-09
CVV_Strut6	0	1,85E-11	0	8,94E-13	3,85E-09
CVV_Strut7	0	1,50E-11	0	6,73E-13	2,22E-09
CVV_Strut8	0	5,85E-12	0	2,32E-13	1,33E-09
CVV_Strut9	0	2,74E-12	0	1,39E-13	1,28E-09
CVV_Strut10	0	1,07E-11	0	5,40E-13	1,14E-09
CVV_Strut11	0	1,87E-12	0	8,59E-14	4,43E-10
CVV_Strut12	0	7,63E-13	0	2,87E-14	1,99E-09
CVV_Strut13	0	4,18E-13	0	2,07E-14	2,96E-10
CVV_Strut14	0	2,09E-13	0	1,01E-14	3,90E-10
CVV_Strut15	0	0	0	0	1,15E-10
CVV_Strut16	0	0	0	0	7,83E-11
CVV_Strut17	0	0	0	0	4,86E-11
CVV_Strut18	0	0	0	0	4,85E-12
CVV_Strut19	0	0	0	0	3,87E-11
CVV_Strut20	0	0	0	0	7,77E-11
CVV_Strut21	0	0	0	0	1,07E-10
CVV_Strut22	0	0	0	0	1,26E-10
CVV_Strut23	0	0	0	0	1,61E-10
CVV_Strut24	0	4,18E-13	0	2,04E-14	3,40E-10
LOU_WG1	0	8,61E-14	0	2,00E-15	1,29E-10
LOU_WG2	0	1,72E-13	0	1,50E-15	5,47E-10
LOU_WG3	0	2,09E-13	0	1,03E-14	4,56E-11
SVMS+X	0	3,25E-10	0	1,47E-11	4,31E-08
SVMS-X	0	6,02E-10	0	4,29E-11	9,97E-09
LOU	**0**	**1,53E-12**	**0**	**7,13E-14**	**0**
LOU_Rad_Side1	0	1,03E-11	0	4,93E-13	0
SShade1_int	0	3,38E-09	0	1,92E-10	0
Sshade2_int	0	1,10E-09	0	6,07E-11	0
Sshade3_int	0	1,83E-08	0	6,71E-10	0
Raid	0	0	0	4,58E-12	0
LowSS_S3	0	2,09E-13	0	1,03E-14	0
M1_S1	0	1,24E-11	0	7,09E-13	7,43E-10
M1_S2	0	8,53E-12	0	4,16E-13	5,50E-10
M1_S3	0	3,29E-12	0	1,86E-13	4,63E-10
M1_S4	0	1,14E-11	0	5,69E-13	9,90E-10
M1_S5	0	7,69E-11	0	3,38E-12	5,94E-09
M1_S6	0	9,29E-11	0	3,65E-12	6,86E-09
M1_frame1	0	4,09E-11	0	1,61E-12	4,41E-09
M1_frame2	0	5,62E-11	0	2,23E-12	4,03E-09
M1_frame3	0	5,10E-12	0	1,98E-13	5,97E-10
M1_front	**0**	**0**	**0**	**0**	**0**
M1_LatSurf	0	7,05E-10	0	3,19E-11	5,46E-08
M1_lowsurf	0	1,00E-08	0	5,76E-10	6,49E-07
M2_support_S1	0	2,06E-11	0	1,17E-12	1,31E-09
M2_support_S2	0	2,69E-11	0	1,59E-12	1,69E-09
M2_support_S3	0	2,17E-11	0	1,25E-12	1,39E-09
M2upper	0	2,56E-11	0	1,43E-12	1,65E-09
M2lower	**0**	**1,03E-11**	**0**	**6,01E-13**	**6,59E-10**

TABLE 7.1-24 HERSCHEL – CHEMICAL THRUSTERS CONTAMINATION WORST CASE

7.1.3.2.3 *Contamination increase assessment due to plume*

The contamination increase assessment due to the plume is presented in the table N°7.1-25.

Contamination due to thruster plume	Molecular (g/cm2)				
	H_2	H_2O	N_2	N_2H_4	NH_3
FPU	-	-	-	-	-
M1	-	-	-	-	-
M2	-	1.03E-11	-	6.01E-13	6.59E-10

TABLE 7.1-25 - HERSCHEL TELESCOPE CONTAMINATION INCREASE ASSESSMENT DUE TO PLUME

The telescope contamination by plume components is very low.

7.1.3.3 Particulate redistribution

At the beginning of in-orbit life, the particulate contamination level on each element of a group is the same. This is due to the fact that the redistribution has already been taken into account during launch. The only remaining redistribution which can occur is the one coming from the telescope + baffles cavities (having around 5000ppm worst case) into the open and clean cryostat. This redistribution can be assessed in the way the in-orbit redistribution was quantified in the frame of ISO (cf. ISO cleanliness Policy).

With a given initial cleanliness of 3000ppm, Andreozzi (1980) has calculated that 9 particle per hour are redistributed on a surface of 30m^2.

The surface sunshade+telescope being approximately 20m^2 large, and the cleanliness of the Telescope+sunshade being approximately 5000ppm worst case, the total amount N of redistributed particles is:

$$N = \frac{20}{30} * \frac{5000}{3000} 10 * lifetime(hours) = 306600 \ particles$$

the cryostat aperture size being 290mm diameter, $306600 * \frac{\pi * 0.290^2}{4} * \frac{1}{20} = 1013 \ particles$ enter the cryostat.

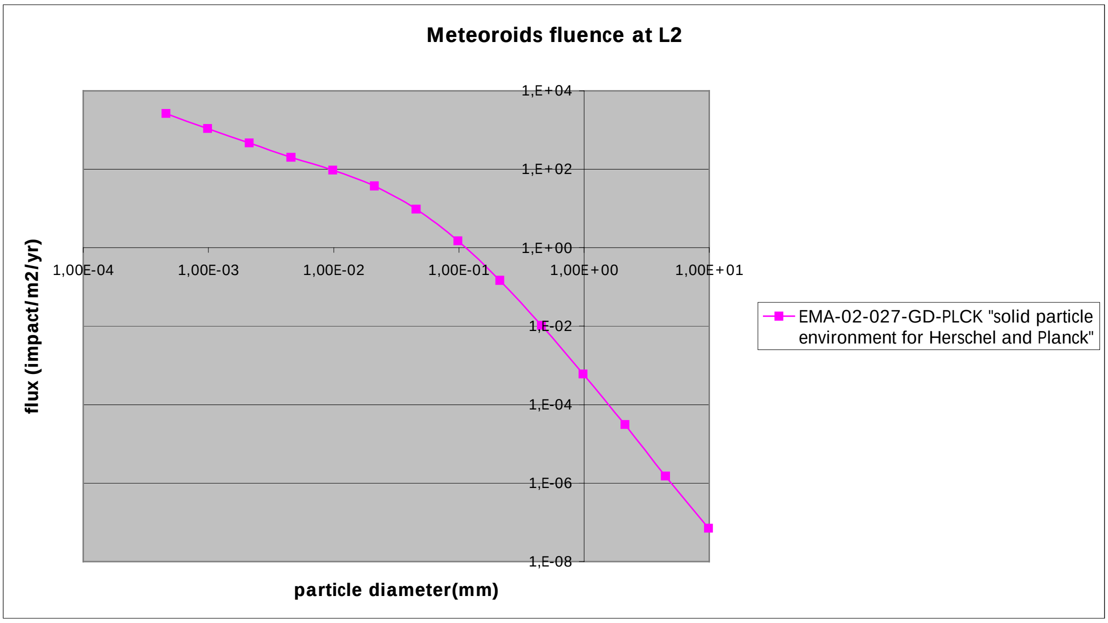
With an average particle diameter of 20µm, and a cryostat aperture of around 290mm diameter, this leads to an increase of the cryostat particulate contamination of:

$$OF_{eq} = 1013 \left(\frac{0.02}{290} \right)^2 = 5 \ ppm$$

If we ignore that the instruments not directly at the cryostat aperture location, and that not all the particles which enter the cryostat will fall on the instruments, then the instrument contamination increase due to redistribution is estimated to be around 5ppm during the 3.5 years lifetime.

7.1.3.4 Micrometeoroids

The distribution of micrometeoroids around L2 is the following (see [RD16])



This means that the total particle surface which hits Herschel telescope is:

$$impact\ surface = Herschel\ aperture\ surface * lifetime * \int_{particle\ size\ range} flux * \frac{\pi\phi^2}{4} d\phi$$

Taking into account the assumption (due to J. Mac Donnel in 1979 and used in the frame of ISO programme (cf. [RD1]) that the pit diameter is 4 times the micrometeoroid diameter, we have the following obscuration factor:

$$OF_{eq} = \frac{4 * impact\ surface}{Herschel\ aperture\ surface} = 4 * lifetime * \int_{particle\ size\ range} flux * \frac{\pi\phi^2}{4} d\phi$$

this leads to a total of 3.43ppm whatever the surface.

The fact that no surface "sees" indeed a complete hemisphere has been neglected.

7.2 Planck

This section presents the cleanliness analysis until End of Life for Planck satellite.

7.2.1 Cleanliness level at the end of AIT

Considering the level at delivery and the contribution of the Planck AIT sequence (described in document [RD4]), the contamination of the spacecraft at the end of AIT is :

contamination levels at the end of AIT	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	
Focal Plane Unit	$3.14\ 10^{-6}$			830
Telescope PR	$6.4\ 10^{-7}$			1430
Telescope PR	$6.4\ 10^{-7}$			1430
Groove 1 (low emissivity surfaces)	0	0	$1.39\ 10^{-6}$	1000
Groove 2	0	0	$1.39\ 10^{-6}$	1000
Groove 3	0	0	$1.39\ 10^{-6}$	1000
Groove 3 and baffle external side (high emissivity surfaces)	0	0	$1.36\ 10^{-6}$	1000
Baffle (internal side)	0	0	$7.1\ 10^{-7}$	2205
spacecraft	0	0	$2\ 10^{-6}$	2135

It seems not realistic to assume that, inside the optical cavity, the particulate contamination will stay inhomogeneous. This concerns the reflectors, the FPU and the internal side of the baffle. So a mean particulate is calculated considering the ratio of the surfaces. The following values have been used :

- Baffle inner side: 8m²
- Primary reflector: 2.4m²
- Secondary reflector: 1.1m²
- FPU: 0.8m²

Considering the particulate redistribution inside the optical cavity with these surfaces, the contamination of the spacecraft at the end of AIT is :

Contamination levels at the end of AIT	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	
Focal Plane Unit	3.14 10^{-6}			1895
Telescope PR	6.4 10^{-7}			1895
Telescope PR	6.4 10^{-7}			1895
Groove 1 (low emissivity surfaces)	0	0	1.39 10^{-6}	1000
Groove 2	0	0	1.39 10^{-6}	1000
Groove 3	0	0	1.39 10^{-6}	1000
Groove 3 and baffle external side (high emissivity surfaces)	0	0	1.36 10^{-6}	1000
Baffle (internal side)	0	0	7.1 10^{-7}	1895
spacecraft	0	0	2 10^{-6}	2135

7.2.2 Cleanliness levels at the Beginning of life (just after launch)

For the launcher contribution (from the encapsulation to the separation), the Alcatel hypotheses are :

- 1000 PPM

- 4 10^{-7} g/cm^2 .

The particulate contamination has to be negotiated with Arianespace.

Considering these two points, the contamination at Planck beginning of life is :

contamination levels at the end of AIT	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	
Focal Plane Unit	3.54 10^{-6}			2895
Telescope PR	10.4 10^{-7}			2895
Telescope PR	10.4 10^{-7}			2895
Groove 1 (low emissivity surfaces)	0	0	1.79 10^{-6}	2000
Groove 2	0	0	1.79 10^{-6}	2000
Groove 3	0	0	1.79 10^{-6}	2000
Groove 3 and baffle external side (high emissivity surfaces)	0	0	1.76 10^{-6}	2000
Baffle (internal side)	0	0	1.11 10^{-6}	2895
Spacecraft	0	0	2.4 10^{-6}	3135

7.2.3 In-orbit contamination

7.2.3.1 Outgassing

7.2.3.1.1 Introduction

During the satellite lifetime the materials of all the sub-systems are submitted to space environment. The conditions induced by the space environment can lead to the emission of polluting substances by the mediation of the outgassing phenomenon. This induced contamination can alter the sub-system initial properties and by the fact degrade the mission performances.

7.2.3.1.2 Hypotheses and modelisation

7.2.3.1.2.1 Modelisation

As for the Herschel satellite, the residence time mathematical modelisation of outgassing phenomenon is chosen (for more details concerning this method please refer to §7.1.3.1.2.1 of this document).

7.2.3.1.2.2 Planck input

The main input of the Planck outgassing simulations are the external configuration and the surfaces temperature.

The external configuration is constituted first of the external geometry and second of the materials arrangement.

The external geometry is extracted from the Planck mechanical model. It is described for the ESABASE simulations by a collection of elementary surfaces (rectangles, triangles, cones, trapezes, discs, …).

The ESABASE geometrical model is available in figure N°7.2-1.

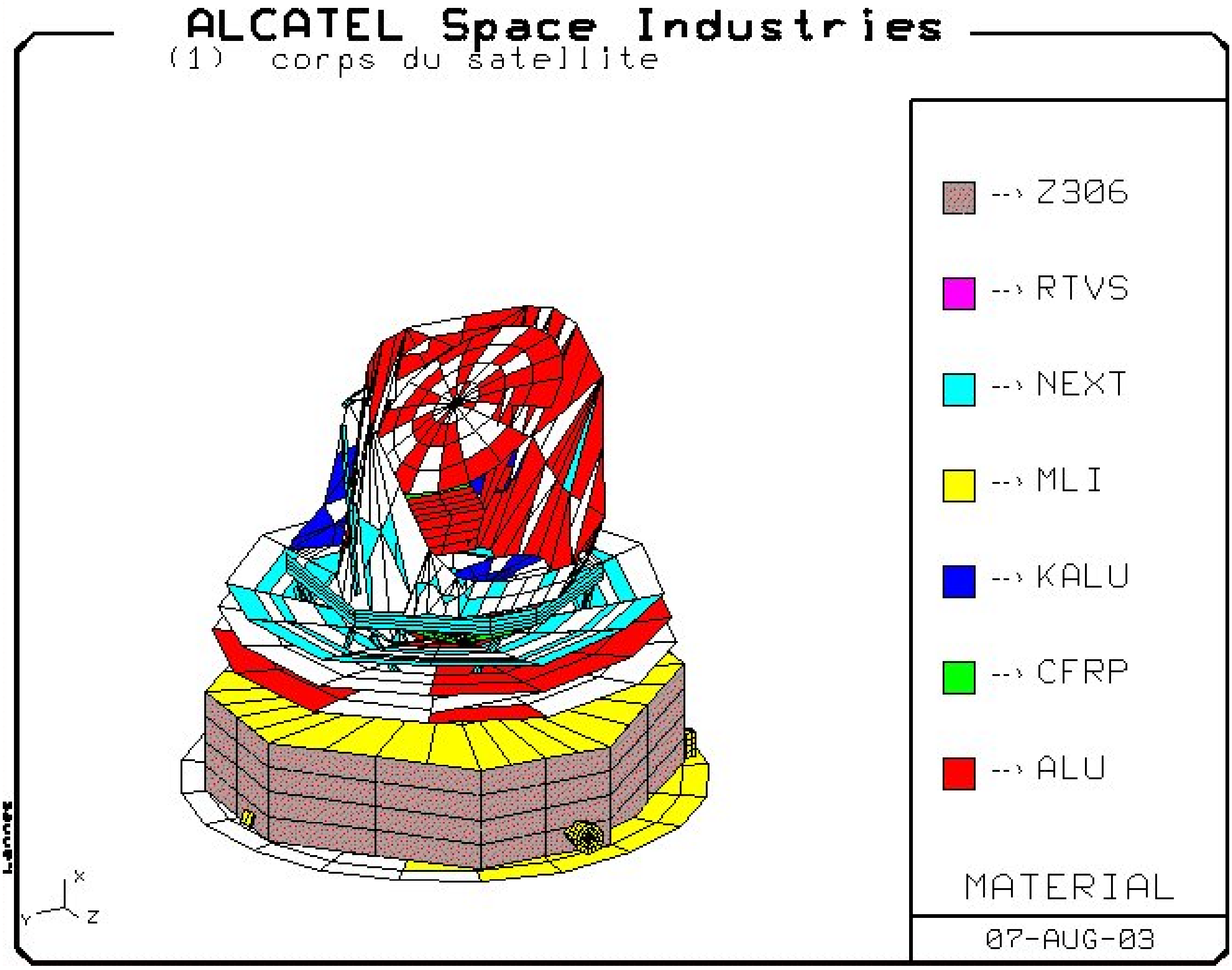


FIGURE 7.2-1 - PLANCK- OUTGASSING MODEL

The materials implementation is presented in the table N°7.2-1.

Element	Material	Thickness (µm)	Density (g/cm3)
Solar array active side	RTVS	210	1,42
Solar array rear side	MLI	160	1,4
SVM lateral panels	Z306 black paint	75	1,3
SVM upper panel	MLI	160	1,4
STM	MLI	100	1,4
Sensors	MLI	100	1,4
BEU	MLI + Z306 on -Z side	200, paint 125	1,4
PAU	MLI	100	1,4
Cryogenic struts	GFRP Glass-Epoxy (50 mm, thickness 1,55 mm) black painted with Nextel Suede 3101 + 20% for WG lower support	paint 125	paint 1,4
Groove N°1 +X	Alu MIRO 27	N/A	N/A
Groove N°1 -X	Alu MIRO 27	80	1,4
Groove N°2 +X	Alu MIRO 27	N/A	N/A
Groove N°2 -X	Alu MIRO 27	80	1,4
Groove N°3 +X	aluminium for the internal baffle part, and open NIDA black painted (with Nextel Suede coating 3101) for the external baffle part	paint 125	paint 1,4
Groove N°3 -X	Alu MIRO 27	80	1,4
Frame	M55J/Cyanate ester (section 90 x 90 mm, thickness 2,5 mm) black painted with Nextel Suede 3101	paint 125	paint 1,4
FPU	Alu	N/A	N/A
Wave guides	CFRP	1000	1,8
Struts supporting M1	M55J-Epoxy (48 mm length/ thickness 1,15 mm) black painted with Nextel Suede 3101	paint 125	paint 1,4
M1 support panel internal side	Aluminised kapton	80	1,4
M1 support panel external side	Panneau Sandwich Nida (Al skin CFRP M40B/Cyanate Ester thickness 1.9mm) black painted with Nextel Suede 3101	paint 125	paint 1,4
Baffle internal side	Alu MIRO 27	80	1,4
Baffle external side	Open NIDA (hyp: surface * 4) Black painted (Nextel Suede 3101)	paint 125	paint 1,4
M2 support	Nida Al skin, CFRP M40B/Cyanate Ester thickness 1 mm	2000	1,8
Struts supporting M2	M55J-Epoxy (64 mm length, thickness 2,76 mm), black painted with nextel	2760, paint 125	1,8
M2 active side	Aluminium	N/A	N/A
M2 rear side	Aluminised kapton	80	1,4
M1 active side	Aluminium	N/A	N/A
M1 rear side	Aluminised kapton	80	1,4

TABLE 7.2-1 - PLANCK- MATERIALS IMPLEMENTATION

The materials inside the hot SVM are listed in the table N°7.2-2.

Element	Material	Mass (kg)	Latest estimation (kg)
Alu NIDA panel	Glue BSL 312L	2	No longer outgassing
Equipment lateral panels	CFRP G969 M18	N/A	6,75
Equipment lateral panels glue	Glue BSL 319L	N/A	1,89
Internal black paint	Z306	2,145	2,56
Central tube	CFRP G969 M18 (0,8mm)	10	11,57
Central tube glue	Glue BSL 319L	1	1,3
Shear wall	CFRP G969 M18	6	5,74
Shear wall glue	Glue BSL 319L	0,6	0,76
Top platform	CFRP G801 M18	7	4,64
Top platform glue	Glue BSL 319L	1,8	2,38
Lower closure panel	CFRP G801 M18	6	3,24
Lower closure panel glue	Glue BSL 319L	1,4	1,55
Sub platform	CFRP G801 M18	6	1,12
Sub platform glue	Glue BSL 319L	0,6	0,83
Support propellant tanks	CFRP M55J M18	4,5	No longer outgassing
Support propellant tanks glue	Hysol 9321	0,5	No longer outgassing
RCS support panel	CFRP G801 M18	3	No longer outgassing
RCS support panel glue	Glue BSL 319L	0,5	No longer outgassing
Glue insert for potting	Stycast 1090/9	5	5
MLI internal (8m² tanks+ 4m² panels)	MLI	1,68	1,68

TABLE N°7.2-2 - PLANCK MATERIALS INSIDE THE SVM

The temperatures evolution during the Planck mission can be separated in three major phases:

- the launch phase
- the transient phase
- the operational phase

During the launch phase, the temperatures are supposed to be equal to 20°C during 133m minutes.

Concerning the cool down (or transient) phase, the temperatures vary very quickly. The temperatures evolution on various elements is presented in figure N°7.2-2. These temperatures are the output of the thermal analysis.

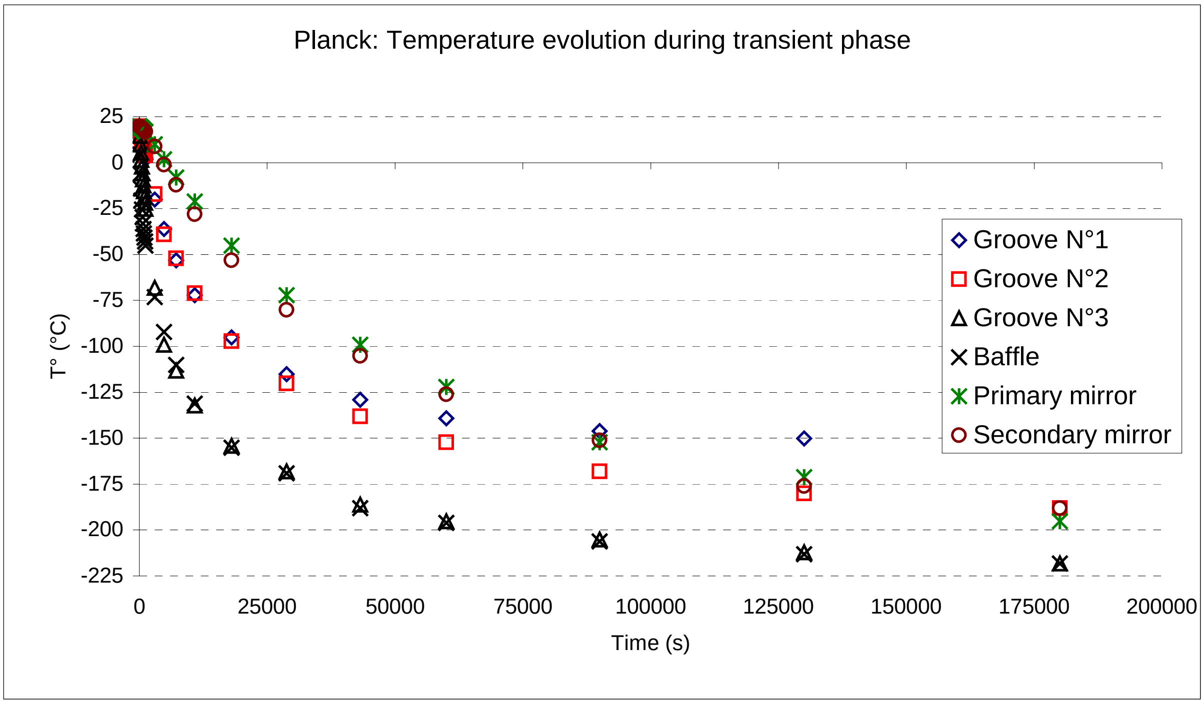


FIGURE 7.2-2 - PLANCK – TEMPERATURE EVOLUTION DURING THE TRANSIENT PHASE

The operational surfaces temperatures are those of the [RD6], and are presented in table N°7.2-3.

Element	Temperature (K)
GS front side	395,1
GS rear side	311,1
SVM lateral	311,1
SVM upper	300,1
Groove #1 +X	117,2
Groove #1 -X	117,2
Groove #2 +X	83,2
Groove #2 -X	83,2
Groove #3 +X (Nextel)	44,2
Groove #3 +X (Alu)	44,2
Groove #3 -X	44,2
Cryo Struts	60,2
Cadre	46,2
FPU (active side)	20,1
PAU	303,1
Wave guide	88,36
M1 support rear side	46,2
M1 support towards M1	46,2
M1 support struts	46,2
Baffle internal side	90,4
Baffle external side	90,4
M2 support	40,2
M2 support struts	40,2
M2 front side	40,2
M2 rear side	40,2
STM	311,1
Sensor #1	311,1
Sensor #2	311,1
Sensor #3	311,1
Sensor #4	311,1
BEU	301,1
BEU Z306	301,1
M1 front face	38,2
M1 rear face	38,2

TABLE 7.2-3 - PLANCK- OPERATIONAL TEMPERATURES

7.2.3.1.2.3 Planck hypotheses

Ones of the input of this approach are the outgassing kinetic parameters for each implemented material. These parameters are determined by the help of the VBQC (Vacuum Balance Quartz Crystal) test, performed at ESTEC. The results of the tests already performed are available in an ESTEC report ([RD5]).

Some of these material characteristics are not available for the time being. Due to this lack of information a conversion had been applied in some cases. This conversion had been done following the materials expert pieces of advice and it is presented in the table N°7.2-4. The first row of this table indicates the materials really present on the satellite, while the second row presents the materials that were chosen for the simulations.

Materials on satellite	Simulated materials	VBQC test report
Kapton	Kapton	VBQC 3193/2
CFRP G969 M18	Cyanate composite	VBQC 3794
Aluminised MLI	Mylar DA foil	VBQC 3141
Nextel Suede coating 3101	Nextel Suede coating 3101	VBQC 3800
Nextel on open NIDA	Nextel Suede coating 3101	VBQC 3800
MLI	Kapton	VBQC 3193/2
MLI black	ASP Black Kapton	VBQC 3798
Glue BSL 312L	FM 73U	VBQC 3613
Kapton alu BO	Mylar DA BO	VBQC 3151
RTV S691	rtv s691	VBQC 3624
GFRP	Cyanate composite	VBQC 3794
Z306	Z306	VBQC 3148
Aluminised kapton	Mylar DA foil	VBQC 3141

TABLE 7.2-4 - PLANCK- OUTGASSING MATERIALS CONVERSION

7.2.3.1.3 Planck outgassing simulations

It is supposed in the outgassing simulations that the materials have not been baked out.

Like for the temperatures, various phases are distinguished and analysed separately on Planck satellite.

These phases are the following:

- Launch phase (all equipment at 20°C during 133 minutes)
- Transient phase (satellite cool down)
- Heating phase (M1, M2 and FPU at 40°C during 2 weeks)
- Operational phase (temperatures equal to the nominal ones, output at 2 weeks, 21 months and 2.5 years)

All the simulations performed for the Planck satellite outgassing estimation are summarised on the following sketch (figure N°7.2-3).

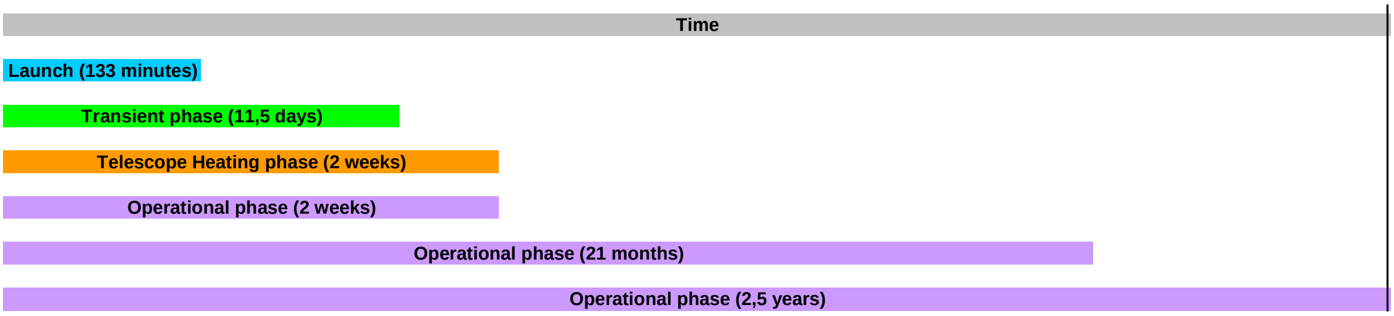


FIGURE 7.2-3 - PLANCK OUTGASSING SIMULATIONS STRATEGY

The simulations are performed with ESABASE/OUTGASSING software, except for the transient phase where an Excel file permits the calculation of the TML as a function of time.

The simulations were performed twice, once with only the external configuration materials taken into consideration and the second one with the consideration of the outgassing materials inside the hot SVM.

The materials inside the SVM were considered by the help of 75kg of CFRP (major material inside the SVM) uniformly located in the lateral surfaces of the SVM.

On first hand, as for the Herschel simulations and due to the lack of information concerning the re-evaporation phenomenon, it is not considered in the ESABASE simulations.

On the other hand, in order to be closest to the reality, a re-evaporation estimation is done with the hypothesis of a contamination by water. The re-evaporation is estimated with the equation determining the vaporization rate of a water splash under vacuum conditions.

$$\frac{dW}{dt} = 4{,}36.10^{-3} * P_s * A * S_1 * \sqrt{\frac{M}{T_s}} \quad \text{(in kg/s)}$$

WITH

Ps: vapor pressure of water (Pa)

S_1: condensation coefficient (comprised between 0 and 1, chosen equal to 1 in our case)

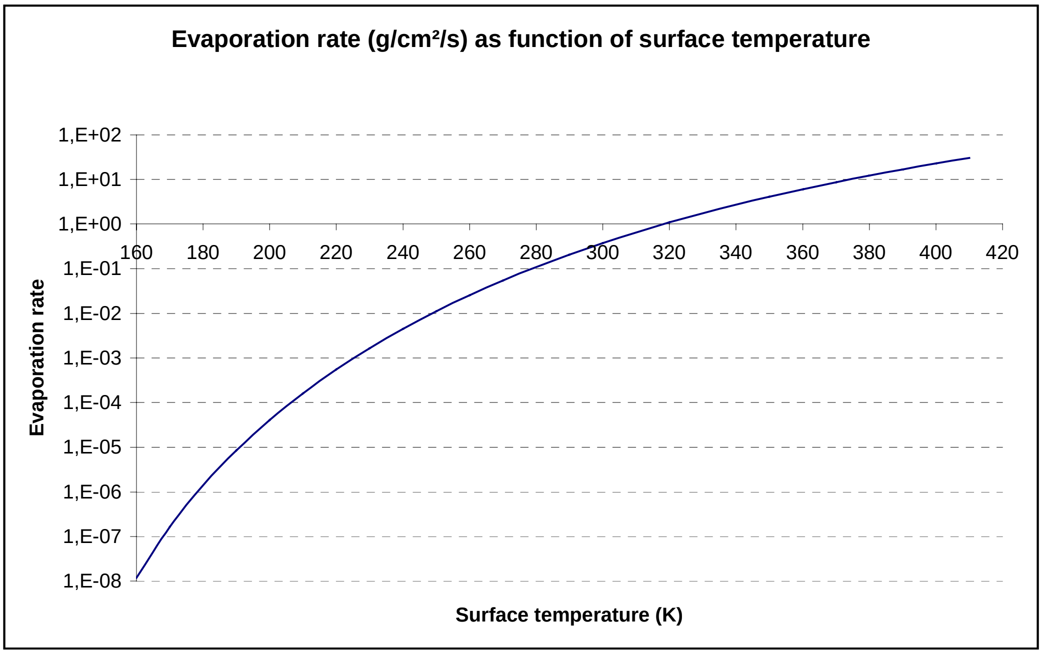
A: surface area

M: molecular mass (atomic mass unity)

Ts: surface temperature (K)

The re-evaporation phenomenon is estimated except for surfaces which temperature is lower than 159K (sticking temperature for water under vacuum conditions).

The results of the re-evaporation estimation are available in the figure hereunder that presents the evaporation rate as a function of the surface temperature.



The maximum, minimum and average values represent the ESABASE results considering all the constituting nodes of a given element.

In order to know if the ESABASE contamination results presented in the different tables are really worst cases or not, please refer, for each element, to the figure presenting the re-evaporation rate as a function of the surface temperature. This indication will permit to know if the re-evaporation phenomenon will be fast or not and if the contamination will stay on the contaminated element.

7.2.3.1.3.1 Launch phase

Like presented in the introduction paragraph, the launch phase consists in 133 minutes flight with the satellite under the SYLDA and by this fact, all the equipment are submitted to a 20°C temperature.

The results of the ESABASE simulations are presented in table N°7.2-5 and N°7.2-6.

By the help of the figure presented in the previous paragraph, the re-evaporation rate can be estimated to 0.252 g/cm²/s. This estimation leads to a time for a complete re-evaporation at the maximum location of 20ms. For this reason the contamination due to outgassing during the launch phase will be neglected in the following.

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	293,1	1,21E-07	1,21E-07	1,21E-07
GS rear side	MLI	3,103	13,850	293,1	1,94E-06	1,94E-06	1,94E-06
SVM lateral	Z306	0,957	9,763	293,1	2,63E-06	3,24E-06	1,58E-06
SVM upper	MLI	2,266	10,116	293,1	5,46E-06	1,36E-05	1,17E-06
Groove #1 +X	NO OUTGASSING	0,000	10,590	293,1	0,00E+00	0,00E+00	0,00E+00
Groove #1 -X	NO OUTGASSING	0,000	10,590	293,1	3,73E-07	7,75E-07	0,00E+00
Groove #2 +X	NO OUTGASSING	0,000	10,098	293,1	1,88E-07	1,13E-06	0,00E+00
Groove #2 -X	NO OUTGASSING	0,000	10,098	293,1	9,23E-08	5,54E-07	0,00E+00
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	293,1	3,48E-10	4,91E-10	3,01E-10
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	293,1	0,00E+00	0,00E+00	0,00E+00
Groove #3 -X	NO OUTGASSING	0,000	8,060	293,1	4,15E-04	4,20E-04	4,09E-04
Cryo Struts	NEXTEL	0,278	1,589	293,1	4,67E-05	4,30E-04	0,00E+00
Cadre	NEXTEL	0,191	1,094	293,1	1,22E-06	7,67E-06	0,00E+00
FPU (active side)	NO OUTGASSING	0,000	0,260	293,1	4,36E-06	4,36E-06	4,36E-06
PAU	MLI	0,118	0,844	293,1	3,54E-05	6,02E-05	2,33E-05
Wave guide	CFRP	8,888	4,937	293,1	3,58E-05	1,64E-04	0,00E+00
M1 support rear side	NEXTEL	0,545	3,112	293,1	4,78E-05	2,08E-04	8,84E-06
M1 support towards M1	KALU	0,349	3,112	293,1	1,00E-04	2,78E-04	4,00E-05
M1 support struts	NEXTEL	0,348	1,990	293,1	6,89E-05	4,31E-04	0,00E+00
Baffle internal side	NO OUTGASSING	0,000	8,022	293,1	2,41E-04	4,78E-04	1,71E-05
Baffle external side	NEXTEL	5,615	8,022	293,1	2,38E-06	1,29E-05	0,00E+00
M2 support	CFRP	0,349	0,194	293,1	2,16E-06	1,01E-04	1,15E-06
M2 support struts	NEXTEL	0,032	0,184	293,1	8,07E-05	4,31E-03	0,00E+00
M2 front side	NO OUTGASSING	0,000	0,957	293,1	2,88E-05	2,88E-05	2,88E-05
M2 rear side	KALU	0,134	0,957	293,1	1,83E-06	1,83E-06	1,83E-06
STM	MLI	0,047	0,334	293,1	6,65E-06	6,65E-06	6,65E-06
Sensor #1	MLI	0,005	0,033	293,1	4,72E-05	8,96E-05	0,00E+00
Sensor #2	MLI	0,004	0,030	293,1	2,45E-05	9,41E-05	0,00E+00
Sensor #3	MLI	0,005	0,033	293,1	1,87E-05	8,88E-05	0,00E+00
Sensor #4	MLI	0,014	0,097	293,1	1,56E-05	5,23E-05	7,48E-08
BEU	MLI	0,130	0,465	293,1	3,69E-05	6,49E-05	1,94E-08
BEU Z306	Z306	0,006	0,058	293,1	3,87E-05	3,87E-05	3,87E-05
M1 front face	NO OUTGASSING	0,000	2,764	293,1	2,23E-05	7,55E-05	9,54E-06
M1 rear face	KALU	0,387	2,764	293,1	2,02E-06	5,27E-05	0,00E+00

TABLE 7.2-5 - PLANCK - OUTGASSING CONTAMINATION DURING LAUNCH PHASE

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	293,1	1,60E-07	1,60E-07	1,60E-07
GS rear side	MLI	3,103	13,850	293,1	1,22E-05	1,22E-05	1,22E-05
SVM lateral	CFRP	75,124	9,763	293,1	3,71E-06	4,56E-06	2,99E-06
SVM upper	MLI	2,266	10,116	293,1	5,53E-06	1,38E-05	1,18E-06
Groove #1 +X	NO OUTGASSING	0,000	10,590	293,1	0,00E+00	0,00E+00	0,00E+00
Groove #1 -X	NO OUTGASSING	0,000	10,590	293,1	3,72E-07	7,75E-07	0,00E+00
Groove #2 +X	NO OUTGASSING	0,000	10,098	293,1	1,88E-07	1,13E-06	0,00E+00
Groove #2 -X	NO OUTGASSING	0,000	10,098	293,1	1,03E-07	6,20E-07	0,00E+00
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	293,1	3,72E-10	5,23E-10	3,17E-10
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	293,1	0,00E+00	0,00E+00	0,00E+00
Groove #3 -X	NO OUTGASSING	0,000	8,060	293,1	4,15E-04	4,20E-04	4,09E-04
Cryo Struts	NEXTEL	0,278	1,589	293,1	4,67E-05	4,30E-04	0,00E+00
Cadre	NEXTEL	0,191	1,094	293,1	1,24E-06	7,73E-06	0,00E+00
FPU (active side)	NO OUTGASSING	0,000	0,260	293,1	4,36E-06	4,36E-06	4,36E-06
PAU	MLI	0,118	0,844	293,1	3,54E-05	6,02E-05	2,33E-05
Wave guide	CFRP	8,888	4,937	293,1	3,59E-05	1,64E-04	0,00E+00
M1 support rear side	NEXTEL	0,545	3,112	293,1	4,79E-05	2,08E-04	8,91E-06
M1 support towards M1	KALU	0,349	3,112	293,1	1,00E-04	2,78E-04	4,00E-05
M1 support struts	NEXTEL	0,348	1,990	293,1	6,89E-05	4,31E-04	0,00E+00
Baffle internal side	NO OUTGASSING	0,000	8,022	293,1	2,41E-04	4,78E-04	1,71E-05
Baffle external side	NEXTEL	5,615	8,022	293,1	2,39E-06	1,30E-05	0,00E+00
M2 support	CFRP	0,349	0,194	293,1	2,19E-06	1,01E-04	1,18E-06
M2 support struts	NEXTEL	0,032	0,184	293,1	8,07E-05	4,31E-03	0,00E+00
M2 front side	NO OUTGASSING	0,000	0,957	293,1	2,88E-05	2,88E-05	2,88E-05
M2 rear side	KALU	0,134	0,957	293,1	1,83E-06	1,83E-06	1,83E-06
STM	MLI	0,047	0,334	293,1	2,70E-05	2,70E-05	2,70E-05
Sensor #1	MLI	0,005	0,033	293,1	2,34E-04	5,72E-04	0,00E+00
Sensor #2	MLI	0,004	0,030	293,1	1,43E-04	6,06E-04	0,00E+00
Sensor #3	MLI	0,005	0,033	293,1	9,92E-05	5,72E-04	0,00E+00
Sensor #4	MLI	0,014	0,097	293,1	9,61E-05	3,12E-04	1,88E-07
BEU	MLI	0,130	0,465	293,1	3,71E-05	6,49E-05	2,06E-08
BEU Z306	Z306	0,006	0,058	293,1	3,87E-05	3,87E-05	3,87E-05
M1 front face	NO OUTGASSING	0,000	2,764	293,1	2,24E-05	7,55E-05	9,54E-06
M1 rear face	KALU	0,387	2,764	293,1	2,02E-06	5,27E-05	0,00E+00

TABLE 7.2-6 - PLANCK - OUTGASSING CONTAMINATION DURING LAUNCH PHASE WITH SVM INTERNAL MATERIALS

7.2.3.1.3.2 Transient phase

Due to the fact that the temperature variations can not be taken into account by ESABASE/OUTGASSING, a specific Excel file was developed in order to cope with the need of estimating the contamination during the transient phase. This part of the analysis was performed in various steps. First, the temperature was discretised in very small intervals. Second, only the most sensitive elements of the satellite were selected for this study (V-grooves, baffle, M1, M2). Third, the TML of each material presents on each surface was determined taking into consideration the historic of the outgassing phenomenon (ie: the amount of material already outgassed, and the amount still to outgas). Fourth, the viewing factors of all the selected elements were determined by the help of ESARAD software. Fifth, the contamination of the each element by all the others was determined. The surfaces and mass values for each material are output of the ESABASE software.

The results are presented in table N°7.2-7.

Sum-up	Contamination (kg/m²)	Contamination (g/cm²)
Groove #1+x	4,61E-07	4,61E-08
Groove #1 -x	0,00E+00	0,00E+00
Groove #2+x	5,55E-12	5,55E-13
Groove #2-x	1,47E-04	1,47E-05
Groove #3 +x (Nextel)	5,58E-08	5,58E-09
Groove #3 +x (Alu)	1,41E-05	1,41E-06
Groove #3-x	1,45E-04	1,45E-05
Baffle : internal	5,47E-06	5,47E-07
Baffle : external	5,95E-08	5,95E-09
PM front	2,12E-06	2,12E-07
PM rear	1,39E-06	1,39E-07
SM front	3,45E-06	3,45E-07
SM rear	1,16E-05	1,16E-06
FPU (active side)	5,05E-06	5,05E-07

TABLE 7.2-7 - PLANCK – OUTGASSING CONTAMINATION DURING TRANSIENT PHASE

7.2.3.1.3.3 Operational phase

The simulations were performed for the nominal lifetime (21 months) and for the extended lifetime (2.5 years). An additional point was extracted after 2 weeks. The re-evaporation phenomenon can be estimated for this phase except for surfaces which temperature was lower than 159K (sticking temperature for water under vacuum conditions) in the same way than the one exposed in the paragraph 7.2.3.1.3.

The results are available in Table N°7.2-8 to 7.2-13.

The contamination amount on sensitive elements such as V-groove #1 to #3 and FPU, primary and secondary mirrors is quite low (average values not greater than 5 10^{-7} g/cm² except with SVM internal materials hypothesis where contamination on M1 reaches 5.06 10^{-6} g/cm²).

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,43E-04	1,43E-04	1,43E-04
GS rear side	MLI	3,103	13,850	311,1	1,77E-06	1,77E-06	1,77E-06
SVM lateral	Z306	0,957	9,763	311,1	2,72E-05	4,01E-05	1,75E-05
SVM upper	MLI	2,266	10,116	300,1	1,89E-05	3,31E-05	1,11E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,73E-07	6,18E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	9,81E-09	5,88E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	1,45E-07	8,68E-07	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	5,03E-14	3,02E-13	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,13E-05	7,10E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	6,27E-09	4,39E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	20,1	0	0	0
PAU	MLI	0,118	0,844	303,1	4,26E-05	7,19E-05	2,44E-06
Wave guide	CFRP	8,888	4,937	88,4	1,16E-06	2,47E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	6,01E-07	3,17E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	9,14E-09	5,07E-08	0
M1 support struts	NEXTEL	0,348	1,990	46,2	6,30E-08	1,84E-06	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	2,19E-09	2,93E-08	0
Baffle external side	NEXTEL	5,615	8,022	90,4	4,59E-08	4,78E-07	0
M2 support	CFRP	0,349	0,194	40,2	4,15E-07	2,49E-05	8,40E-12
M2 support struts	NEXTEL	0,032	0,184	40,2	1,51E-12	9,05E-11	0
M2 front side	NO OUTGASSING	0,000	0,957	40,2	5,60E-09	5,60E-09	5,60E-09
M2 rear side	KALU	0,134	0,957	40,2	2,06E-12	2,06E-12	2,06E-12
STM	MLI	0,047	0,334	311,1	2,66E-05	2,66E-05	2,66E-05
Sensor #1	MLI	0,005	0,033	311,1	5,76E-05	1,13E-04	0
Sensor #2	MLI	0,004	0,030	311,1	3,07E-05	1,19E-04	0
Sensor #3	MLI	0,005	0,033	311,1	2,33E-05	1,14E-04	0
Sensor #4	MLI	0,014	0,097	311,1	8,98E-05	4,16E-04	9,86E-08
BEU	MLI	0,130	0,465	301,1	4,37E-05	7,65E-05	2,96E-06
BEU Z306	Z306	0,006	0,058	301,1	4,85E-05	4,85E-05	4,85E-05
M1 front face	NO OUTGASSING	0,000	2,764	38,2	2,93E-07	1,07E-05	0
M1 rear face	KALU	0,387	2,764	38,2	1,13E-13	4,72E-12	0

TABLE 7.2-8 - PLANCK – OUTGASSING CONTAMINATION AFTER 2WEEKS, OPERATIONAL CONDITIONS

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,46E-04	1,46E-04	1,46E-04
GS rear side	MLI	3,103	13,850	311,1	3,07E-05	3,07E-05	3,07E-05
SVM lateral	CFRP	75,124	9,763	311,1	3,59E-04	5,08E-04	1,75E-04
SVM upper	MLI	2,266	10,116	300,1	3,29E-05	7,69E-05	1,14E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,74E-07	6,20E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	9,88E-09	5,93E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	2,55E-06	1,53E-05	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	5,03E-14	3,02E-13	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,18E-05	7,13E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	8,85E-09	6,20E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	20,1	0	0	0
PAU	MLI	0,118	0,844	303,1	4,25E-05	7,19E-05	2,43E-06
Wave guide	CFRP	8,888	4,937	88,4	2,40E-06	3,75E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	8,58E-07	3,19E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	3,58E-08	9,06E-07	0
M1 support struts	NEXTEL	0,348	1,990	46,2	1,00E-06	3,24E-05	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	1,84E-09	2,93E-08	0
Baffle external side	NEXTEL	5,615	8,022	90,4	3,57E-07	5,07E-06	0
M2 support	CFRP	0,349	0,194	40,2	4,18E-07	2,51E-05	8,35E-12
M2 support struts	NEXTEL	0,032	0,184	40,2	0	0	0
M2 front side	NO OUTGASSING	0,000	0,957	40,2	5,61E-09	5,61E-09	5,61E-09
M2 rear side	KALU	0,134	0,957	40,2	2,76E-14	2,76E-14	2,76E-14
STM	MLI	0,047	0,334	311,1	1,82E-04	1,82E-04	1,82E-04
Sensor #1	MLI	0,005	0,033	311,1	7,37E-04	1,94E-03	0
Sensor #2	MLI	0,004	0,030	311,1	4,77E-04	2,04E-03	0
Sensor #3	MLI	0,005	0,033	311,1	3,39E-04	2,01E-03	0
Sensor #4	MLI	0,014	0,097	311,1	1,55E-03	7,31E-03	1,74E-06
BEU	MLI	0,130	0,465	301,1	6,70E-05	1,70E-04	2,94E-06
BEU Z306	Z306	0,006	0,058	301,1	4,84E-05	4,84E-05	4,84E-05
M1 front face	NO OUTGASSING	0,000	2,764	38,2	4,49E-06	1,82E-04	0
M1 rear face	KALU	0,387	2,764	38,2	1,13E-13	4,72E-12	0

TABLE 7.2-9 - PLANCK – OUTGASSING CONTAMINATION AFTER 2WEEKS, OP CONDITIONS WITH SVM INTERNAL MATERIALS

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,43E-04	1,43E-04	1,43E-04
GS rear side	MLI	3,103	13,850	311,1	2,20E-06	2,20E-06	2,20E-06
SVM lateral	Z306	0,957	9,763	311,1	3,25E-05	4,77E-05	2,08E-05
SVM upper	MLI	2,266	10,116	300,1	2,02E-05	3,56E-05	1,19E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,88E-07	6,52E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	1,04E-08	6,21E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	1,80E-07	1,08E-06	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	2,17E-12	1,30E-11	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,32E-05	8,70E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	6,72E-09	4,65E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	20,1	4,24E-16	4,24E-16	4,24E-16
PAU	MLI	0,118	0,844	303,1	4,54E-05	7,58E-05	5,49E-06
Wave guide	CFRP	8,888	4,937	88,4	3,37E-06	2,73E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	6,39E-07	3,35E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	3,28E-07	1,30E-06	0
M1 support struts	NEXTEL	0,348	1,990	46,2	2,02E-07	4,91E-06	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	9,45E-08	1,26E-06	0
Baffle external side	NEXTEL	5,615	8,022	90,4	5,37E-08	5,05E-07	0
M2 support	CFRP	0,349	0,194	40,2	4,38E-07	2,63E-05	1,02E-09
M2 support struts	NEXTEL	0,032	0,184	40,2	7,01E-11	4,20E-09	0
M2 front side	NO OUTGASSING	0,000	0,957	40,2	2,42E-07	2,42E-07	2,42E-07
M2 rear side	KALU	0,134	0,957	40,2	9,76E-11	9,76E-11	9,76E-11
STM	MLI	0,047	0,334	311,1	2,98E-05	2,98E-05	2,98E-05
Sensor #1	MLI	0,005	0,033	311,1	6,84E-05	1,40E-04	0
Sensor #2	MLI	0,004	0,030	311,1	3,75E-05	1,48E-04	0
Sensor #3	MLI	0,005	0,033	311,1	2,82E-05	1,42E-04	0
Sensor #4	MLI	0,014	0,097	311,1	1,12E-04	5,19E-04	1,23E-07
BEU	MLI	0,130	0,465	301,1	4,66E-05	8,07E-05	3,21E-06
BEU Z306	Z306	0,006	0,058	301,1	5,17E-05	5,17E-05	5,17E-05
M1 front face	NO OUTGASSING	0,000	2,764	38,2	3,57E-07	1,33E-05	0
M1 rear face	KALU	0,387	2,764	38,2	1,38E-11	5,79E-10	0

TABLE 7.2-10 - PLANCK – OUTGASSING CONTAMINATION AFTER 21 MONTHS, OPERATIONAL CONDITIONS

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,46E-04	1,46E-04	1,46E-04
GS rear side	MLI	3,103	13,850	311,1	3,46E-05	3,46E-05	3,46E-05
SVM lateral	CFRP	75,124	9,763	311,1	4,05E-04	5,73E-04	1,97E-04
SVM upper	MLI	2,266	10,116	300,1	3,59E-05	8,48E-05	1,20E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0,00E+00	0,00E+00	0,00E+00
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,89E-07	6,54E-07	0,00E+00
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	1,04E-08	6,25E-08	0,00E+00
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	2,88E-06	1,73E-05	0,00E+00
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0,00E+00	0,00E+00	0,00E+00
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0,00E+00	0,00E+00	0,00E+00
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	2,17E-12	1,30E-11	0,00E+00
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,39E-05	8,74E-05	0,00E+00
Cadre	NEXTEL	0,191	1,094	46,2	9,62E-09	6,68E-08	0,00E+00
FPU (active side)	NO OUTGASSING	0,000	0,260	20,1	4,24E-16	4,24E-16	4,24E-16
PAU	MLI	0,118	0,844	303,1	4,54E-05	7,59E-05	5,48E-06
Wave guide	CFRP	8,888	4,937	88,4	4,75E-06	4,24E-05	0,00E+00
M1 support rear side	NEXTEL	0,545	3,112	46,2	9,27E-07	3,36E-05	0,00E+00
M1 support towards M1	KALU	0,349	3,112	46,2	3,56E-07	1,30E-06	0,00E+00
M1 support struts	NEXTEL	0,348	1,990	46,2	1,26E-06	3,66E-05	0,00E+00
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	7,92E-08	1,27E-06	0,00E+00
Baffle external side	NEXTEL	5,615	8,022	90,4	4,03E-07	5,73E-06	0,00E+00
M2 support	CFRP	0,349	0,194	40,2	4,42E-07	2,65E-05	1,01E-09
M2 support struts	NEXTEL	0,032	0,184	40,2	1,49E-13	6,43E-12	0,00E+00
M2 front side	NO OUTGASSING	0,000	0,957	40,2	2,42E-07	2,42E-07	2,42E-07
M2 rear side	KALU	0,134	0,957	40,2	3,33E-12	3,33E-12	3,33E-12
STM	MLI	0,047	0,334	311,1	2,04E-04	2,04E-04	2,04E-04
Sensor #1	MLI	0,005	0,033	311,1	8,31E-04	2,19E-03	0,00E+00
Sensor #2	MLI	0,004	0,030	311,1	5,38E-04	2,30E-03	0,00E+00
Sensor #3	MLI	0,005	0,033	311,1	3,83E-04	2,27E-03	0,00E+00
Sensor #4	MLI	0,014	0,097	311,1	1,75E-03	8,26E-03	1,97E-06
BEU	MLI	0,130	0,465	301,1	7,28E-05	1,89E-04	3,18E-06
BEU Z306	Z306	0,006	0,058	301,1	5,16E-05	5,16E-05	5,16E-05
M1 front face	NO OUTGASSING	0,000	2,764	38,2	5,06E-06	2,06E-04	0,00E+00
M1 rear face	KALU	0,387	2,764	38,2	1,38E-11	5,79E-10	0,00E+00

TABLE 7.2-11 - PLANCK – OUTGASSING CONTAMINATION AFTER 21 MONTHS, OP CONDITIONS WITH SVM INTERNAL MATERIALS

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,43E-04	1,43E-04	1,43E-04
GS rear side	MLI	3,103	13,850	311,1	2,24E-06	2,24E-06	2,24E-06
SVM lateral	Z306	0,957	9,763	311,1	3,30E-05	4,84E-05	2,11E-05
SVM upper	MLI	2,266	10,116	300,1	2,03E-05	3,58E-05	1,20E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,89E-07	6,55E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	1,04E-08	6,22E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	1,84E-07	1,10E-06	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	3,03E-12	1,82E-11	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,35E-05	8,90E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	6,77E-09	4,67E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	20,1	3,42E-13	3,42E-13	3,42E-13
PAU	MLI	0,118	0,844	303,1	4,58E-05	7,62E-05	6,68E-06
Wave guide	CFRP	8,888	4,937	88,4	4,23E-06	2,79E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	6,41E-07	3,35E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	4,57E-07	1,82E-06	1,15E-12
M1 support struts	NEXTEL	0,348	1,990	46,2	2,53E-07	6,85E-06	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	1,32E-07	1,76E-06	1,06E-12
Baffle external side	NEXTEL	5,615	8,022	90,4	5,50E-08	5,06E-07	0
M2 support	CFRP	0,349	0,194	40,2	4,40E-07	2,64E-05	1,45E-09
M2 support struts	NEXTEL	0,032	0,184	40,2	1,02E-10	6,00E-09	0
M2 front side	NO OUTGASSING	0,000	0,957	40,2	3,37E-07	3,37E-07	3,37E-07
M2 rear side	KALU	0,134	0,957	40,2	1,39E-10	1,39E-10	1,39E-10
STM	MLI	0,047	0,334	311,1	3,01E-05	3,01E-05	3,01E-05
Sensor #1	MLI	0,005	0,033	311,1	6,94E-05	1,42E-04	0
Sensor #2	MLI	0,004	0,030	311,1	3,81E-05	1,51E-04	0
Sensor #3	MLI	0,005	0,033	311,1	2,87E-05	1,45E-04	0
Sensor #4	MLI	0,014	0,097	311,1	1,14E-04	5,29E-04	1,25E-07
BEU	MLI	0,130	0,465	301,1	4,69E-05	8,10E-05	3,23E-06
BEU Z306	Z306	0,006	0,058	301,1	5,20E-05	5,20E-05	5,20E-05
M1 front face	NO OUTGASSING	0,000	2,764	38,2	3,63E-07	1,35E-05	0
M1 rear face	KALU	0,387	2,764	38,2	1,98E-11	8,29E-10	0

TABLE 7.2-12 - PLANCK – OUTGASSING CONTAMINATION AFTER 2.5 YEARS, OPERATIONAL CONDITIONS

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,46E-04	1,46E-04	1,46E-04
GS rear side	MLI	3,103	13,850	311,1	3,52E-05	3,52E-05	3,52E-05
SVM lateral	CFRP	75,124	9,763	311,1	4,12E-04	5,83E-04	2,01E-04
SVM upper	MLI	2,266	10,116	300,1	3,63E-05	8,59E-05	1,21E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,90E-07	6,56E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	1,04E-08	6,27E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	2,93E-06	1,76E-05	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	3,03E-12	1,82E-11	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,42E-05	8,94E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	9,71E-09	6,73E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	20,1	3,41E-13	3,41E-13	3,41E-13
PAU	MLI	0,118	0,844	303,1	4,57E-05	7,62E-05	6,66E-06
Wave guide	CFRP	8,888	4,937	88,4	5,64E-06	4,32E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	9,34E-07	3,37E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	4,85E-07	1,81E-06	1,15E-12
M1 support struts	NEXTEL	0,348	1,990	46,2	1,33E-06	3,73E-05	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	1,10E-07	1,76E-06	1,06E-12
Baffle external side	NEXTEL	5,615	8,022	90,4	4,10E-07	5,83E-06	0
M2 support	CFRP	0,349	0,194	40,2	4,44E-07	2,66E-05	1,44E-09
M2 support struts	NEXTEL	0,032	0,184	40,2	1,82E-12	8,24E-11	0
M2 front side	NO OUTGASSING	0,000	0,957	40,2	3,37E-07	3,37E-07	3,37E-07
M2 rear side	KALU	0,134	0,957	40,2	4,75E-12	4,75E-12	4,75E-12
STM	MLI	0,047	0,334	311,1	2,07E-04	2,07E-04	2,07E-04
Sensor #1	MLI	0,005	0,033	311,1	8,46E-04	2,23E-03	0
Sensor #2	MLI	0,004	0,030	311,1	5,47E-04	2,34E-03	0
Sensor #3	MLI	0,005	0,033	311,1	3,89E-04	2,31E-03	0
Sensor #4	MLI	0,014	0,097	311,1	1,78E-03	8,40E-03	2,00E-06
BEU	MLI	0,130	0,465	301,1	7,35E-05	1,92E-04	3,21E-06
BEU Z306	Z306	0,006	0,058	301,1	5,19E-05	5,19E-05	5,19E-05
M1 front face	NO OUTGASSING	0,000	2,764	38,2	5,15E-06	2,09E-04	0
M1 rear face	KALU	0,387	2,764	38,2	1,98E-11	8,29E-10	0

TABLE 7.2-13 - PLANCK – OUTGASSING CONTAMINATION AFTER 2.5 YEARS, OP CONDITIONS WITH SVM INTERNAL MATERIALS

7.2.3.1.3.4 Heating phase

An outgassing simulation was performed with ESABASE software, taking into consideration the telescope (M1, M2, FPU) heating during 2 weeks at 40°C, while the other parts of the Planck satellite stay at the operational temperatures.

The results of the simulation are available in tables N°7.2-14 and N°7.2-15. The contaminant evaporation can be estimated as presented in the paragraph 7.2.3.1.3.

The difference between the results obtained with the telescope heating phase and the results obtained for the operational conditions after 2 weeks are available in tables N°7.2-16 and N°7.2-17.

This heating phase induces a contamination amount increase (increase average value of 1.41 10^{-6} g/cm², 9.3 10^{-6} g/cm² maximum value) on the internal part of the baffle, due to the outgassing of the material implemented on the M1 and M2 rear sides. Others increases are noticed on the AOCS sensors.

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,43E-04	1,43E-04	1,43E-04
GS rear side	MLI	3,103	13,850	311,1	1,77E-06	1,77E-06	1,77E-06
SVM lateral	Z306	0,957	9,763	311,1	2,73E-05	4,02E-05	1,75E-05
SVM upper	MLI	2,266	10,116	300,1	1,89E-05	3,31E-05	1,11E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,73E-07	6,17E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	9,79E-09	5,87E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	1,45E-07	8,68E-07	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0,00E+00	0,00E+00	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0,00E+00	0,00E+00	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	5,03E-14	3,02E-13	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,13E-05	7,09E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	6,25E-09	4,38E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	313,1	0	0	0
PAU	MLI	0,118	0,844	303,1	4,26E-05	7,19E-05	2,45E-06
Wave guide	CFRP	8,888	4,937	88,4	1,38E-06	2,47E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	6,06E-07	3,17E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	3,14E-07	7,61E-06	0
M1 support struts	NEXTEL	0,348	1,990	46,2	6,30E-08	1,84E-06	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	1,41E-06	9,33E-06	0
Baffle external side	NEXTEL	5,615	8,022	90,4	4,60E-08	4,78E-07	0
M2 support	CFRP	0,349	0,194	40,2	1,01E-06	3,58E-05	8,41E-12
M2 support struts	NEXTEL	0,032	0,184	40,2	1,35E-06	4,28E-05	0
M2 front side	NO OUTGASSING	0,000	0,957	313,1	2,37E-05	2,37E-05	2,37E-05
M2 rear side	KALU	0,134	0,957	313,1	3,50E-06	3,50E-06	3,50E-06
STM	MLI	0,047	0,334	311,1	2,66E-05	2,66E-05	2,66E-05
Sensor #1	MLI	0,005	0,033	311,1	5,76E-05	1,13E-04	0
Sensor #2	MLI	0,004	0,030	311,1	3,07E-05	1,19E-04	0
Sensor #3	MLI	0,005	0,033	311,1	2,33E-05	1,14E-04	0
Sensor #4	MLI	0,014	0,097	311,1	9,00E-05	4,17E-04	9,86E-08
BEU	MLI	0,130	0,465	301,1	4,37E-05	7,65E-05	2,96E-06
BEU Z306	Z306	0,006	0,058	301,1	4,85E-05	4,85E-05	4,85E-05
M1 front face	NO OUTGASSING	0,000	2,764	313,1	2,45E-05	3,65E-05	1,22E-05
M1 rear face	KALU	0,387	2,764	313,1	7,43E-14	3,54E-12	0

TABLE 7.2-14 - PLANCK- OUTGASSING CONTAMINATION AFTER 2 WEEKS, HEATING PHASE

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,46E-04	1,46E-04	1,46E-04
GS rear side	MLI	3,103	13,850	311,1	3,06E-05	3,06E-05	3,06E-05
SVM lateral	CFRP	75,124	9,763	311,1	3,60E-04	5,09E-04	1,75E-04
SVM upper	MLI	2,266	10,116	300,1	3,29E-05	7,70E-05	1,14E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,74E-07	6,19E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	9,86E-09	5,91E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	2,55E-06	1,53E-05	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0,00E+00	0,00E+00	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0,00E+00	0,00E+00	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	5,03E-14	3,02E-13	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,19E-05	7,12E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	8,83E-09	6,18E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	313,1	0	0	0
PAU	MLI	0,118	0,844	303,1	4,25E-05	7,19E-05	2,43E-06
Wave guide	CFRP	8,888	4,937	88,4	2,61E-06	3,75E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	8,62E-07	3,18E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	3,41E-07	7,61E-06	0
M1 support struts	NEXTEL	0,348	1,990	46,2	1,00E-06	3,24E-05	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	1,42E-06	9,35E-06	0
Baffle external side	NEXTEL	5,615	8,022	90,4	3,56E-07	5,07E-06	0
M2 support	CFRP	0,349	0,194	40,2	1,01E-06	3,56E-05	8,36E-12
M2 support struts	NEXTEL	0,032	0,184	40,2	1,35E-06	4,27E-05	0
M2 front side	NO OUTGASSING	0,000	0,957	313,1	2,37E-05	2,37E-05	2,37E-05
M2 rear side	KALU	0,134	0,957	313,1	3,48E-06	3,48E-06	3,48E-06
STM	MLI	0,047	0,334	311,1	1,82E-04	1,82E-04	1,82E-04
Sensor #1	MLI	0,005	0,033	311,1	7,37E-04	1,94E-03	0
Sensor #2	MLI	0,004	0,030	311,1	4,76E-04	2,04E-03	0
Sensor #3	MLI	0,005	0,033	311,1	3,39E-04	2,01E-03	0
Sensor #4	MLI	0,014	0,097	311,1	1,55E-03	7,32E-03	1,74E-06
BEU	MLI	0,130	0,465	301,1	6,69E-05	1,70E-04	2,94E-06
BEU Z306	Z306	0,006	0,058	301,1	4,84E-05	4,84E-05	4,84E-05
M1 front face	NO OUTGASSING	0,000	2,764	313,1	2,87E-05	2,01E-04	1,22E-05
M1 rear face	KALU	0,387	2,764	313,1	7,45E-14	3,55E-12	0

TABLE 7.2-15 - PLANCK- OUTGASSING CONTAMINATION AFTER 2 WEEKS, HEATING PHASE WITH SVM INTERNAL MATERIALS

Element	Material	Mass (kg)	Surface (m²)	Delta Temperature (K)	Delta Average contamination (g/cm²)	Delta Maximum contamination (g/cm²)	Delta Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	0,0	1,00E-07	1,00E-07	1,00E-07
GS rear side	MLI	3,103	13,850	0,0	-1,00E-09	-1,00E-09	-1,00E-09
SVM lateral	Z306	0,957	9,763	0,0	2,50E-08	5,00E-08	1,00E-08
SVM upper	MLI	2,266	10,116	0,0	1,63E-08	2,00E-08	2,00E-08
Groove #1 +X	NO OUTGASSING	0,000	10,590	0,0	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	0,0	-2,33E-10	-5,00E-10	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	0,0	-1,83E-11	-1,10E-10	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	0,0	3,33E-11	2,00E-10	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	0,0	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	0,0	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	0,0	0	0	0
Cryo Struts	NEXTEL	0,278	1,589	0,0	2,49E-09	-8,00E-08	0
Cadre	NEXTEL	0,191	1,094	0,0	-1,86E-11	-1,30E-10	0
FPU (active side)	NO OUTGASSING	0,000	0,260	293,0	0	0	0
PAU	MLI	0,118	0,844	0,0	7,33E-09	0	4,00E-09
Wave guide	CFRP	8,888	4,937	0,0	2,13E-07	2,00E-08	0
M1 support rear side	NEXTEL	0,545	3,112	0,0	4,37E-09	-4,00E-08	0
M1 support towards M1	KALU	0,349	3,112	0,0	3,05E-07	7,55E-06	0
M1 support struts	NEXTEL	0,348	1,990	0,0	-5,31E-11	-1,00E-09	0
Baffle internal side	NO OUTGASSING	0,000	8,022	0,0	1,41E-06	9,30E-06	0
Baffle external side	NEXTEL	5,615	8,022	0,0	5,09E-11	-5,00E-10	0
M2 support	CFRP	0,349	0,194	0,0	5,97E-07	1,09E-05	1,20E-14
M2 support struts	NEXTEL	0,032	0,184	0,0	1,35E-06	4,28E-05	0
M2 front side	NO OUTGASSING	0,000	0,957	272,9	-5,60E-09	-5,60E-09	-5,60E-09
M2 rear side	KALU	0,134	0,957	272,9	-2,06E-12	-2,06E-12	-2,06E-12
STM	MLI	0,047	0,334	0,0	1,63E-08	1,63E-08	1,63E-08
Sensor #1	MLI	0,005	0,033	0,0	-2,01E-08	-1,00E-07	0
Sensor #2	MLI	0,004	0,030	0,0	-1,67E-09	0	0
Sensor #3	MLI	0,005	0,033	0,0	-2,05E-08	-1,00E-07	0
Sensor #4	MLI	0,014	0,097	0,0	1,17E-07	7,00E-07	0
BEU	MLI	0,130	0,465	0,0	3,00E-09	0	5,00E-09
BEU Z306	Z306	0,006	0,058	0,0	3,00E-08	3,00E-08	3,00E-08
M1 front face	NO OUTGASSING	0,000	2,764	274,9	-2,93E-07	-1,07E-05	0
M1 rear face	KALU	0,387	2,764	274,9	-1,13E-13	-4,72E-12	0

TABLE 7.2-16 - PLANCK- DELTA OUTGASSING CONTAMINATION AFTER 2 WEEKS BETWEEN HEATING AND NOMINAL PHASES

Element	Material	Mass (kg)	Surface (m²)	Delta Temperature (K)	Delta Average contamination (g/cm²)	Delta Maximum contamination (g/cm²)	Delta Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	0,0	-3,00E-07	-3,00E-07	-3,00E-07
GS rear side	MLI	3,103	13,850	0,0	-3,08E-06	-3,08E-06	-3,08E-06
SVM lateral	CFRP	75,124	9,763	0,0	-3,75E-05	-6,06E-05	-2,03E-05
SVM upper	MLI	2,266	10,116	0,0	-4,96E-07	-2,60E-07	0
Groove #1 +X	NO OUTGASSING	0,000	10,590	0,0	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	0,0	-1,33E-10	-2,00E-10	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	0,0	-1,00E-11	-6,00E-11	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	0,0	-3,13E-07	-1,88E-06	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	0,0	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	0,0	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	0,0	0	0	0
Cryo Struts	NEXTEL	0,278	1,589	0,0	-6,25E-08	-3,00E-08	0
Cadre	NEXTEL	0,191	1,094	0,0	-1,00E-11	-7,00E-11	0
FPU (active side)	NO OUTGASSING	0,000	0,260	293,0	0	0	0
PAU	MLI	0,118	0,844	0,0	2,00E-09	0	2,00E-09
Wave guide	CFRP	8,888	4,937	0,0	5,02E-08	-4,62E-06	0
M1 support rear side	NEXTEL	0,545	3,112	0,0	-2,16E-08	-2,00E-08	0
M1 support towards M1	KALU	0,349	3,112	0,0	3,02E-07	6,70E-06	0
M1 support struts	NEXTEL	0,348	1,990	0,0	-1,22E-07	-3,98E-06	0
Baffle internal side	NO OUTGASSING	0,000	8,022	0,0	1,43E-06	9,32E-06	0
Baffle external side	NEXTEL	5,615	8,022	0,0	-3,97E-08	-6,25E-07	0
M2 support	CFRP	0,349	0,194	0,0	5,94E-07	1,05E-05	7,00E-15
M2 support struts	NEXTEL	0,032	0,184	0,0	1,35E-06	4,27E-05	0
M2 front side	NO OUTGASSING	0,000	0,957	272,9	-5,61E-09	-5,61E-09	-5,61E-09
M2 rear side	KALU	0,134	0,957	272,9	-2,76E-14	-2,76E-14	-2,76E-14
STM	MLI	0,047	0,334	0,0	-2,02E-05	-2,02E-05	-2,02E-05
Sensor #1	MLI	0,005	0,033	0,0	-8,87E-05	-2,38E-04	0
Sensor #2	MLI	0,004	0,030	0,0	-5,81E-05	-2,50E-04	0
Sensor #3	MLI	0,005	0,033	0,0	-4,12E-05	-2,47E-04	0
Sensor #4	MLI	0,014	0,097	0,0	-1,89E-04	-8,93E-04	-2,14E-07
BEU	MLI	0,130	0,465	0,0	-3,04E-06	-1,52E-05	3,00E-09
BEU Z306	Z306	0,006	0,058	0,0	1,00E-08	1,00E-08	1,00E-08
M1 front face	NO OUTGASSING	0,000	2,764	274,9	-4,49E-06	-1,82E-04	0
M1 rear face	KALU	0,387	2,764	274,9	-1,13E-13	-4,72E-12	0

TABLE 7.2-17 - PLANCK- DELTA CONTAMINATION (2 WEEKS) BETWEEN HEATING AND NOMINAL PHASES WITH SVM INTERNAL MATERIALS

The contamination at the end of nominal lifetime (21months) can be estimated with the heating phase consideration by subtracting the results obtained for the 2 weeks simulations with nominal conditions on all the equipment and adding the results of the heating phase simulations on all the equipment.

This is not valid for the heated elements (M1, M2 and FPU) where no contamination is foreseen during the heating phase (see the evaporation rates for surfaces placed at 313,15K). In this case, the contamination at end of life is equal to the results at end of life without heating minus the results obtained after 2 weeks.

The results are presented in tables N°7.2-18 and 7.2-19.

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,43E-04	1,43E-04	1,43E-04
GS rear side	MLI	3,103	13,850	311,1	2,19E-06	2,19E-06	2,19E-06
SVM lateral	Z306	0,957	9,763	311,1	3,26E-05	4,78E-05	2,08E-05
SVM upper	MLI	2,266	10,116	300,1	2,02E-05	3,56E-05	1,20E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0,00E+00	0,00E+00	0,00E+00
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,88E-07	6,51E-07	0,00E+00
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	1,03E-08	6,20E-08	0,00E+00
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	1,80E-07	1,08E-06	0,00E+00
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	2,17E-12	1,30E-11	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,32E-05	8,69E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	6,70E-09	4,64E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	313,1	4,24E-16	4,24E-16	4,24E-16
PAU	MLI	0,118	0,844	303,1	4,54E-05	7,58E-05	5,50E-06
Wave guide	CFRP	8,888	4,937	88,4	3,58E-06	2,73E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	6,43E-07	3,34E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	6,33E-07	8,86E-06	0
M1 support struts	NEXTEL	0,348	1,990	46,2	2,02E-07	4,91E-06	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	1,50E-06	1,06E-05	0
Baffle external side	NEXTEL	5,615	8,022	90,4	5,38E-08	5,05E-07	0
M2 support	CFRP	0,349	0,194	40,2	1,03E-06	3,72E-05	1,02E-09
M2 support struts	NEXTEL	0,032	0,184	40,2	1,35E-06	4,28E-05	0,00E+00
M2 front side	NO OUTGASSING	0,000	0,957	313,1	2,36E-07	2,36E-07	2,36E-07
M2 rear side	KALU	0,134	0,957	313,1	9,55E-11	9,55E-11	9,55E-11
STM	MLI	0,047	0,334	311,1	2,98E-05	2,98E-05	2,98E-05
Sensor #1	MLI	0,005	0,033	311,1	6,83E-05	1,40E-04	0
Sensor #2	MLI	0,004	0,030	311,1	3,75E-05	1,48E-04	0
Sensor #3	MLI	0,005	0,033	311,1	2,82E-05	1,42E-04	0
Sensor #4	MLI	0,014	0,097	311,1	1,12E-04	5,20E-04	1,23E-07
BEU	MLI	0,130	0,465	301,1	4,66E-05	8,07E-05	3,21E-06
BEU Z306	Z306	0,006	0,058	301,1	5,17E-05	5,17E-05	5,17E-05
M1 front face	NO OUTGASSING	0,000	2,764	313,1	6,39E-08	2,53E-06	0
M1 rear face	KALU	0,387	2,764	313,1	1,37E-11	5,74E-10	0

TABLE 7.2-18 - PLANCK – OUTGASSING CONTAMINATION AFTER 21 MONTHS, WITH 2WEEKS HEATING PHASE

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
GS front side	RTVS	4,156	13,850	395,1	1,46E-04	1,46E-04	1,46E-04
GS rear side	MLI	3,103	13,850	311,1	3,46E-05	3,46E-05	3,46E-05
SVM lateral	CFRP	75,124	9,763	311,1	4,06E-04	5,74E-04	1,97E-04
SVM upper	MLI	2,266	10,116	300,1	3,59E-05	8,48E-05	1,20E-05
Groove #1 +X	NO OUTGASSING	0,000	10,590	117,2	0	0	0
Groove #1 -X	NO OUTGASSING	0,000	10,590	117,2	2,89E-07	6,53E-07	0
Groove #2 +X	NO OUTGASSING	0,000	10,098	83,2	1,04E-08	6,24E-08	0
Groove #2 -X	NO OUTGASSING	0,000	10,098	83,2	2,88E-06	1,73E-05	0
Groove #3 +X (Nextel)	NEXTEL	5,889	8,412	44,2	0	0	0
Groove #3 +X (Alu)	NO OUTGASSING	0,000	1,261	44,2	0	0	0
Groove #3 -X	NO OUTGASSING	0,000	8,060	44,2	2,17E-12	1,30E-11	0
Cryo Struts	NEXTEL	0,278	1,589	60,2	2,39E-05	8,73E-05	0
Cadre	NEXTEL	0,191	1,094	46,2	9,60E-09	6,67E-08	0
FPU (active side)	NO OUTGASSING	0,000	0,260	313,1	4,24E-16	4,24E-16	4,24E-16
PAU	MLI	0,118	0,844	303,1	4,54E-05	7,59E-05	5,48E-06
Wave guide	CFRP	8,888	4,937	88,4	4,96E-06	4,24E-05	0
M1 support rear side	NEXTEL	0,545	3,112	46,2	9,30E-07	3,36E-05	0
M1 support towards M1	KALU	0,349	3,112	46,2	6,61E-07	8,00E-06	0
M1 support struts	NEXTEL	0,348	1,990	46,2	1,25E-06	3,66E-05	0
Baffle internal side	NO OUTGASSING	0,000	8,022	90,4	1,50E-06	1,06E-05	0
Baffle external side	NEXTEL	5,615	8,022	90,4	4,02E-07	5,73E-06	0
M2 support	CFRP	0,349	0,194	40,2	1,04E-06	3,70E-05	1,01E-09
M2 support struts	NEXTEL	0,032	0,184	40,2	1,35E-06	4,27E-05	0
M2 front side	NO OUTGASSING	0,000	0,957	313,1	2,36E-07	2,36E-07	2,36E-07
M2 rear side	KALU	0,134	0,957	313,1	3,30E-12	3,30E-12	3,30E-12
STM	MLI	0,047	0,334	311,1	2,04E-04	2,04E-04	2,04E-04
Sensor #1	MLI	0,005	0,033	311,1	8,31E-04	2,19E-03	0
Sensor #2	MLI	0,004	0,030	311,1	5,38E-04	2,30E-03	0
Sensor #3	MLI	0,005	0,033	311,1	3,82E-04	2,27E-03	0
Sensor #4	MLI	0,014	0,097	311,1	1,75E-03	8,27E-03	1,97E-06
BEU	MLI	0,130	0,465	301,1	7,27E-05	1,89E-04	3,19E-06
BEU Z306	Z306	0,006	0,058	301,1	5,16E-05	5,16E-05	5,16E-05
M1 front face	NO OUTGASSING	0,000	2,764	313,1	5,78E-07	2,35E-05	0
M1 rear face	KALU	0,387	2,764	313,1	1,37E-11	5,74E-10	0

TABLE 7.2-19 - PLANCK – OUTGASSING CONTAMINATION AFTER 21 MONTHS, WITH 2WEEKS HEATING PHASE WITH SVM INTERNAL MATERIALS

7.2.3.1.4 Outgassing contamination increase assessment

The contamination increase assessment due to in orbit materials outgassing at the nominal end of life (21 months) is summarised in the tables N°7.2-20 and N°7.2-21. This budget considers the launch phase, the transient phase, the operational phase and if necessary the heating phase. The same budgets are available in the tables N°7.2-22 and 7.2-23 with the SVM internal materials considered.

(g/cm²)	Launch	Transient	Operationnal (21 months)	Total contamination
V-groove#1 +X	0	4,61E-08	0,00E+00	4,61E-08
V-groove #1-X	0	0,00E+00	2,88E-07	2,88E-07
V-groove #2 +X	0	5,55E-13	1,04E-08	1,04E-08
V-groove #2 -X	0	1,47E-05	1,80E-07	1,49E-05
V-groove #3 +X (Nextel part)	0	5,58E-09	0,00E+00	5,58E-09
V-groove #3 +X (Alu part)	0	1,41E-06	0,00E+00	1,41E-06
V-groove #3 -X	0	1,45E-05	2,17E-12	1,45E-05
Baffle internal part	0	5,47E-07	9,45E-08	6,41E-07
Baffle external part	0	5,95E-09	5,37E-08	5,97E-08
Primary mirror front	0	2,12E-07	3,57E-07	5,69E-07
Secondary mirror front	0	3,45E-07	2,42E-07	5,86E-07
FPU (active side)	0	5,05E-07	4,24E-16	5,05E-07

TABLE 7.2-20 - PLANCK- CONTAMINATION BUDGET DUE TO MATERIALS OUTGASING WITHOUT HEATING

(g/cm²)	Launch	Transient	Operationnal (21 months) + heating (2 weeks)	Total contamination
V-groove#1 +X	0	4,61E-08	0,00E+00	4,61E-08
V-groove #1-X	0	0,00E+00	2,88E-07	2,88E-07
V-groove #2 +X	0	5,55E-13	1,03E-08	1,03E-08
V-groove #2 -X	0	1,47E-05	1,80E-07	1,49E-05
V-groove #3 +X (Nextel part)	0	5,58E-09	0,00E+00	5,58E-09
V-groove #3 +X (Alu part)	0	1,41E-06	0,00E+00	1,41E-06
V-groove #3 -X	0	1,45E-05	2,17E-12	1,45E-05
Baffle internal part	0	5,47E-07	1,50E-06	2,05E-06
Baffle external part	0	5,95E-09	5,38E-08	5,97E-08
Primary mirror front	0	2,12E-07	6,39E-08	2,76E-07
Secondary mirror front	0	3,45E-07	2,36E-07	5,81E-07
FPU (active side)	0	5,05E-07	4,24E-16	5,05E-07

TABLE 7.2-21 - PLANCK- CONTAMINATION BUDGET DUE TO MATERIALS OUTGASING WITH HEATING

(g/cm²)	Launch	Transient	Operationnal (21 months)	Total contamination
V-groove#1 +X	0	4,61E-08	0,00E+00	4,61E-08
V-groove #1-X	0	0,00E+00	2,89E-07	2,89E-07
V-groove #2 +X	0	5,55E-13	1,04E-08	1,04E-08
V-groove #2 -X	0	1,47E-05	2,88E-06	1,76E-05
V-groove #3 +X (Nextel part)	0	5,58E-09	0,00E+00	5,58E-09
V-groove #3 +X (Alu part)	0	1,41E-06	0,00E+00	1,41E-06
V-groove #3 -X	0	1,45E-05	2,17E-12	1,45E-05
Baffle internal part	0	5,47E-07	7,92E-08	6,26E-07
Baffle external part	0	5,95E-09	4,03E-07	4,09E-07
Primary mirror front	0	2,12E-07	5,06E-06	5,27E-06
Secondary mirror front	0	3,45E-07	2,42E-07	5,86E-07
FPU (active side)	0	5,05E-07	4,24E-16	5,05E-07

TABLE 7.2-22 - PLANCK- CONTAMINATION BUDGET DUE TO MATERIALS OUTGASING WITHOUT HEATING (SVM INTERNAL MATERIALS HYPOTHESIS)

(g/cm²)	Launch	Transient	Operationnal (21 months) + heating (2 weeks)	Total contamination
V-groove#1 +X	0	4,61E-08	0,00E+00	4,61E-08
V-groove #1-X	0	0,00E+00	2,89E-07	2,89E-07
V-groove #2 +X	0	5,55E-13	1,04E-08	1,04E-08
V-groove #2 -X	0	1,47E-05	2,88E-06	1,76E-05
V-groove #3 +X (Nextel part)	0	5,58E-09	0,00E+00	5,58E-09
V-groove #3 +X (Alu part)	0	1,41E-06	0,00E+00	1,41E-06
V-groove #3 -X	0	1,45E-05	2,17E-12	1,45E-05
Baffle internal part	0	5,47E-07	1,50E-06	2,05E-06
Baffle external part	0	5,95E-09	4,02E-07	4,08E-07
Primary mirror front	0	2,12E-07	5,78E-07	7,89E-07
Secondary mirror front	0	3,45E-07	2,36E-07	5,81E-07
FPU (active side)	0	5,05E-07	4,24E-16	5,05E-07

TABLE 7.2-23 - PLANCK- CONTAMINATION BUDGET DUE TO MATERIALS OUTGASING WITH HEATING (SVM INTERNAL MATERIALS HYPOTHESIS)

7.2.3.1.5 Conclusion

The outgassing contamination summaries are available without heating phase in table N°7.2-24 and N°7.2.26 and with heating phase in table N°7.2-25 and N°7.2.27.

These summaries are worst cases ones due to the simulations strategy chosen (the different satellite phases are computed independently) and the materials are supposed to have not been baked out.

Contamination increase due to outgassing	Molecular (g/cm2)		
	H20	NH3	On ground contaminants
V-groove#1 +X	4,61E-08	N/A	N/A
V-groove #1-X	2,88E-07	N/A	N/A
V-groove #2 +X	1,04E-08	N/A	N/A
V-groove #2 -X	1,49E-05	N/A	N/A
V-groove #3 +X (Nextel part)	5,58E-09	N/A	N/A
V-groove #3 +X (Alu part)	1,41E-06	N/A	N/A
V-groove #3 -X	1,45E-05	N/A	N/A
Baffle internal part	6,41E-07	N/A	N/A
Baffle external part	5,97E-08	N/A	N/A
Primary mirror front	5,69E-07	N/A	N/A
Secondary mirror front	5,86E-07	N/A	N/A
FPU (active side)	5,05E-07	N/A	N/A

TABLE 7.2-24 - PLANCK- OUTGASSING CONTAMINATION ASSESSMENT WITHOUT HEATING

Contamination increase due to outgassing	Molecular (g/cm2)		
	H20	NH3	On ground contaminants
V-groove#1 +X	4,61E-08	N/A	N/A
V-groove #1-X	2,88E-07	N/A	N/A
V-groove #2 +X	1,03E-08	N/A	N/A
V-groove #2 -X	1,49E-05	N/A	N/A
V-groove #3 +X (Nextel part)	5,58E-09	N/A	N/A
V-groove #3 +X (Alu part)	1,41E-06	N/A	N/A
V-groove #3 -X	1,45E-05	N/A	N/A
Baffle internal part	2,05E-06	N/A	N/A
Baffle external part	5,97E-08	N/A	N/A
Primary mirror front	2,76E-07	N/A	N/A
Secondary mirror front	5,81E-07	N/A	N/A
FPU (active side)	5,05E-07	N/A	N/A

TABLE 7.2-25 - PLANCK- OUTGASSING CONTAMINATION ASSESSMENT WITH HEATING

Contamination increase due to outgassing	Molecular		
	(g/cm2)		
	H20	NH3	On ground contaminants
V-groove#1 +X	4,61E-08	N/A	N/A
V-groove #1-X	2,89E-07	N/A	N/A
V-groove #2 +X	1,04E-08	N/A	N/A
V-groove #2 -X	1,76E-05	N/A	N/A
V-groove #3 +X (Nextel part)	5,58E-09	N/A	N/A
V-groove #3 +X (Alu part)	1,41E-06	N/A	N/A
V-groove #3 -X	1,45E-05	N/A	N/A
Baffle internal part	6,26E-07	N/A	N/A
Baffle external part	4,09E-07	N/A	N/A
Primary mirror front	5,27E-06	N/A	N/A
Secondary mirror front	5,86E-07	N/A	N/A
FPU (active side)	5,05E-07	N/A	N/A

TABLE 7.2-26 - PLANCK- OUTGASSING CONTAMINATION ASSESSMENT WITHOUT HEATING (WITH SVM INTERNAL MATERIALS HYPOTHESIS)

Contamination increase due to outgassing	Molecular		
	(g/cm2)		
	H20	NH3	On ground contaminants
V-groove#1 +X	4,61E-08	N/A	N/A
V-groove #1-X	2,89E-07	N/A	N/A
V-groove #2 +X	1,04E-08	N/A	N/A
V-groove #2 -X	1,76E-05	N/A	N/A
V-groove #3 +X (Nextel part)	5,58E-09	N/A	N/A
V-groove #3 +X (Alu part)	1,41E-06	N/A	N/A
V-groove #3 -X	1,45E-05	N/A	N/A
Baffle internal part	2,05E-06	N/A	N/A
Baffle external part	4,08E-07	N/A	N/A
Primary mirror front	7,89E-07	N/A	N/A
Secondary mirror front	5,81E-07	N/A	N/A
FPU (active side)	5,05E-07	N/A	N/A

TABLE 7.2-27 - PLANCK- OUTGASSING CONTAMINATION ASSESSMENT WITH HEATING (WITH SVM INTERNAL MATERIALS HYPOTHESIS)

7.2.3.2 Thruster-plume

7.2.3.2.1 Hypotheses

The selected thrusters for the Planck satellite are 20 N and 1N hydrazine thrusters manufactured by ASTRIUM.

The plume composition of an hydrazine catalytic thruster is available in Table N° 7.2-28.

COMPONENT	FORMULA	PROPORTION
Ammonia	NH_3	34.31%
Nitrogen	N_2	57.86%
Hydrogen	H_2	6.22%
Water	H_2O	0.65%
Hydrazine	N_2H_4	0.46%
Aniline	$C_6H_5NH_2$	0.50%

TABLE 7.2-28 - PLANCK – MASSIC COMPOSITION OF AN HYDRAZINE CATALYTIC THRUSTER PLUME

The sticking temperatures of these plume components are presented in table 7.2-29.

COMPONENT	STICKING TEMPERATURE (K)
Ammonia	102
Nitrogen	26
Hydrogen	4
Water	159
Hydrazine	165
Aniline	190

TABLE 7.1-29 - PLANCK - STICKING TEMPERATURES OF THE PLUME COMPONENT

The table N°7.2-30 shows the thruster utilisation strategy used for the Planck satellite.

Manœuvre	Fuel mass	Thruster
Compensation for perigee velocity variation	9.6	(D1 + D2) or (F1 + F2) or (U1 + U2)
Removal of launcher dispersion	68	(D1 + D2) or (F1 + F2) or (U1 + U2)
Manœuvre on day 12 from perigee	6.7	(D1 + D2) or (F1 + F2) or (U1 + U2)
Mid course correction	5	(D1 + D2) or (F1 + F2) or (U1 + U2)
Orbit injection	275	F1 + F2
Orbit maintenance for mission lifetime	8.9	(D1 + D2) or (F1 + F2) or (U1 + U2)
Orbit maintenance due to attitude control	8.7	(D1 + D2) or (F1 + F2) or (U1 + U2)
Attitude control	16.7	A1 or B1

TABLE N°7.2-30 – PLANCK - THRUSTERS UTILISATION STRATEGY

To compute the worst case for the chemical thrusters contamination, the following scenario has to be used:

- 275 kg with 50% on F1 and 50% on F2
- 16.7 kg on the worst contaminating thruster A1 or B1
- 107 kg on the worst contaminating thrusters couple (D1,D2) or (F1,F2) or (U1,U2) with 50% consumption on each thruster.

The positions and the orientations of the Planck 1N and 20N thrusters are presented in table N°7.2-31 and in figure N°7.2-6 with respect to the conventions presented in figure N°7.2-4 and N°7.2-5.

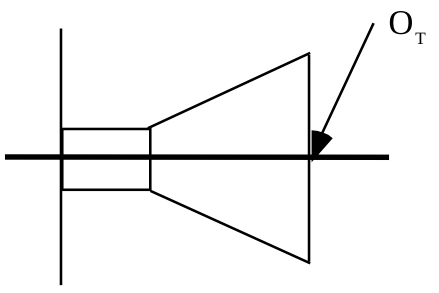


FIGURE 7.2-4 DEFINITION OF THE THRUSTER REFERENCE POINT

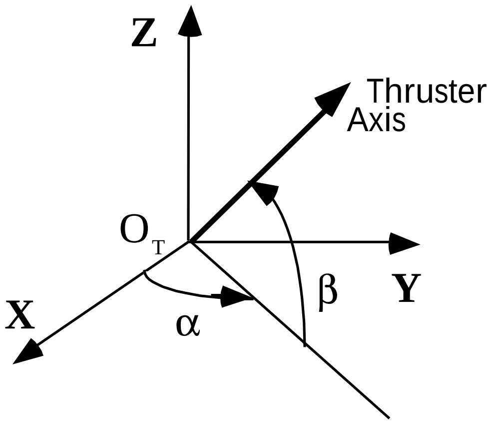


FIGURE 7.2- 5 DEFINITION OF THE THRUSTER ORIENTATION

Thruster		D1A	D2A	F1A	F2A	U1A	U2A	D1B	D2B	F1B	F2B	U1B	U2B	A1A	B1A	A1B	B1B
Coordinates of the thruster (mm)	XT	-117,9	-121,2	-101,6	-126,4	236,4	240,0	-117,9	-121,2	-106,7	-105,6	309,1	312,3	805,3	805,3	719,0	719,0
	YT	-574,9	575,9	-1704,1	886,8	1873,3	-1874,1	-664,9	665,9	-1618,7	800,7	1851,4	-1852,3	-784,8	-1768,7	-766,8	-1750,7
	ZT	1566,3	-1564,0	621,6	1616,5	-727,1	-723,0	1566,3	-1564,0	649,6	1600,3	-768,5	-764,0	1768,7	784,8	1750,7	766,8
Orientation (degrees)	α	179,55	179,55	-156,9	-156,9	48,9	-46,3	179,55	179,55	-156,7	-156,7	52,3	-49,7	-112,7	-112,7	-112,7	-112,7
	β	1,1	1,1	48,0	48,0	38,4	39,7	1,1	1,1	48,4	48,4	41,7	43,3	42,7	42,7	42,7	42,7

TABLE 7.2-31 - PLANCK THRUSTERS POSITIONS AND ORIENTATIONS

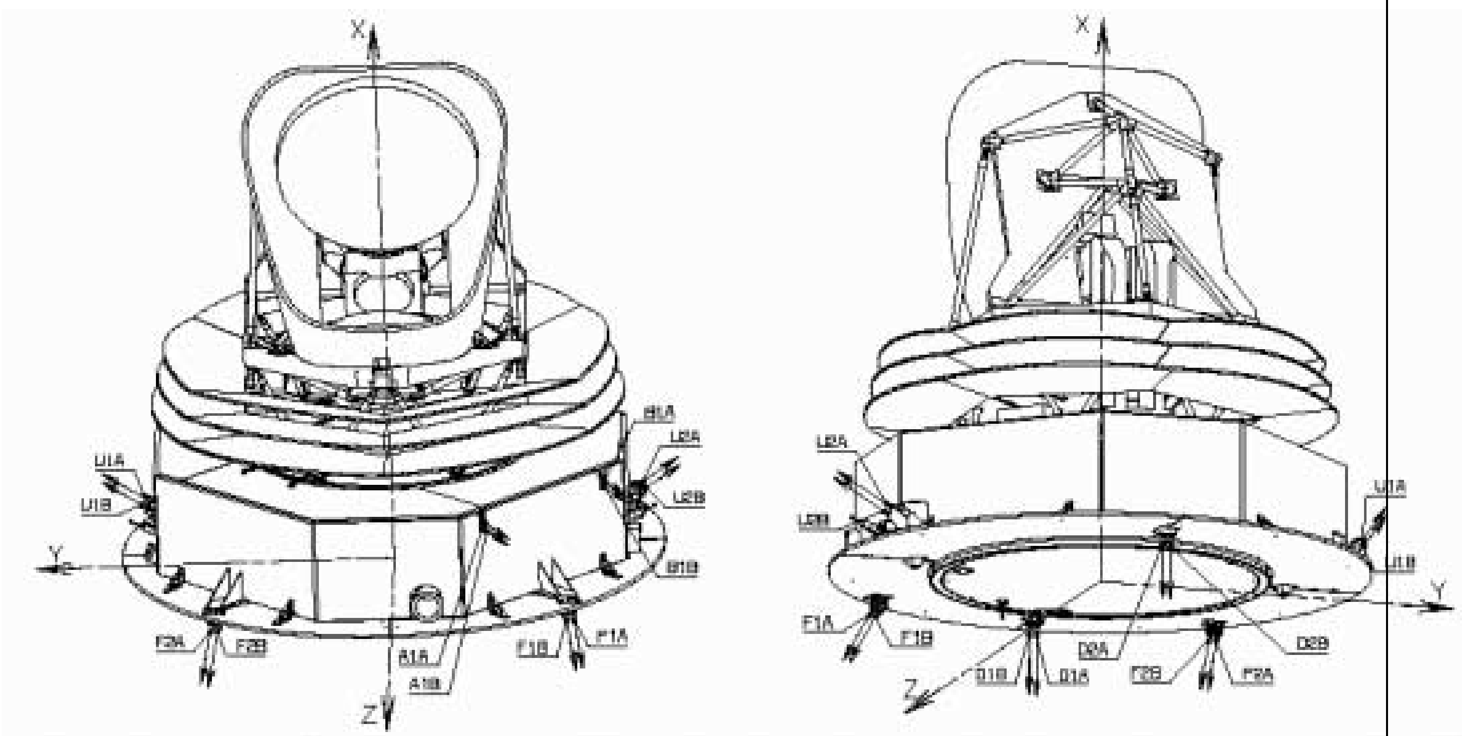


FIGURE N°7.2-6 - PLANCK THRUSTERS DEFINITION

The hydrazine 20 N thruster definition is available in [RD12]. Concerning the 1N hydrazine thruster please refer to [RD14].

The main characteristics of the 20N and 1N thrusters are recalled, for information, in table N° 7.2-32.

Thruster			1N	20N
Fuel	-	-	N2H4	N2H4
Chamber pressure	Pc	[Bar]	10	9.3
Chamber temperature	Tc	[K]	1156	1156
Molar mass	W	[g/mol]	13.689	13.689
Adiabatic coefficient	γ	[-]	1.358	1.358
Viscosity at T0	Bμo	[Poiseuille]	3.924E-5	3.899E-5
Exponent of the Sutherland law	ωv	[-]	0.73	0.698451
Prandtl number	Pr	[-]	0.4	0.4087
Throat radius	RSTAR	[m]	0.000425	0.0021
Convergence radius	RCURV1 (1)	[-]	1.788	2.14
Convergence angle	TTA1	[°]	55.	38
Divergence radius	RCURV2 (1)	[-]	2.146	2.14
Divergence angle	TTA2	[°]	15.	28.92
Exit radius	REXIT (1)	[-]	8.9412	7.7143
Exit distance	ZEXIT	[-]	30.2823	22.0952
Contour parameter for circle	IWALL	[-]	5	3
Exit angle	TTEXIT	[°]	-	5
Area ratio	Ae/A	[-]	79.94	59.51

Table 7.2-32 – 1N and 20N thrusters main characteristics

7.2.3.2.2 Analysis

The simulations of the contamination due to UPS activation are performed with the CONTAMINE software. This software was developed under CNES contract. It permits to simulate first, the contaminants propagation from the reaction chamber to the satellite surfaces, and second the interactions between the contaminants and the satellite surfaces (deposits and surfaces properties modifications).

This software is interfaced with PLUMFLOW, which was also developed under CNES contract. The PLUMFLOW software calculates the flow inside the chemical thrusters. It is constituted by 9 modules.

- ODE: calculates the chemical equilibrium inside the combustion chamber and inside the thruster divergent
- NAVIER: determines the flow characteristics in the thruster and in the near field region
- TPPLUME: calculates the flow in the continuous part of the jet
- SESJET: evaluates the flow gaseous characteristics, to have a first order of magnitude of the different quantities
- MATFLOW: calculates the streamlines resulting from NAVIER and TPPLUME, and extend them in the far field region
- TRAJET: permits a 2D flow characteristics visualization
- CEC: permits to gather or add contaminant species generated by the ODE module from PLUMFLOW in order to limit or modify the species to be taken into further computation
- MCLIP: computes the thruster flow field at the vicinity of the nozzle lip with a transient regime taking into account each specie from the stream. It permits a good modeling of the expansion of the limit layer in the thruster backflow.
- DROPLET: modelises the droplets or particles propagation in a thruster plume. It takes into account not only the droplets and particles from the chamber but also the droplets ejected at the thruster nozzle lip

The ODE calculations are performed in order to determine a reaction temperature for a given reactants by minimising the Gibbs free energy at a given pressure leading to a number of reaction products and associated gas mixture properties. In the real hydrazine decomposition, a reaction kinetic is involved with a fast exothermic decomposition of N2H4 into NH3 and H2, followed by a slower endothermic dissociation of NH3 in H2 and N2. The real exhaust gas composition depends on the catalytic bed (quality, thickness, material, grain size, …)and the catalytic bed load (specific mass flux). Typically molar fractions of 0.2 NH3, 0.27 N2 and 0.52 H2 are reached at the catalytic bed exit whereas the ODE analysis leads to mole fractions of 0.001 NH3, 0.333 N2 and 0.666 H2.

The reaction kinetics (rates of change) cannot be analysed with ODE, only the equilibrium state can be. However during the expansion of the gas mixture, frozen conditions might be assumed with a frozen gas composition in spite of temperature varying mixture properties. This is realistic because of the short time residence inside the nozzle due to the high velocity expansion.

In order to meet the real temperature inside the chamber, either the propellant reaction enthalpy can be adjusted, or the composition and chamber temperature might be set by others means and the given properties (chamber pressure and temperature, specific heat, dynamic viscosity, specific heat ratio, …) are given as inputs for the nozzle/plume flow via the NAVIER inputs namelist $GASPROP.

For this analysis the second solution was chosen. The gas properties retained for the simulations are presented in the table 7.2-32.

The CONTAMINE software is shared in 5 different modules, these modules are presented here after.

- PROPEC: computes the gaseous contaminants propagation which are ejected by the thrusters towards the satellite surfaces in a free molecular regime. It takes into account several contaminant species
- DROPEC: computes the droplets / particles propagation which are ejected towards the satellite surfaces
- PICS: integrates the gaseous contaminants and the particles / droplets ones on the satellite surfaces over the satellite lifetime
- SURFACE: evaluates the influence of the gaseous contaminants on the properties of the satellite surfaces

- DROPSURF: evaluates the influence of the droplets / particles contaminants on the properties of the satellite surfaces

For more details on the CONTAMINE software please refer to [RD13].

For the Planck simulations only the five main contributors (NH3, N2, H2O, N2H4 and H2) for contamination are investigated.

The SURFACE and DROPSURF modules do not work properly and for instance only the cumulative contamination is presented in the following tables.

All the thrusters strategies have been done. The worst case in term of contamination is found with the F1A, F2A and A1A thrusters combination.

The results are presented in table N°7.2-33.

Element	Contamination by	Contamination by	Contamination by	Contamination by	Contamination by
Groove1_X	0	0	0	NC	1,05E-18
Groove1_-X	0	1,92E-11	0	NC	2,94E-18
Groove2_X	0	0	0	NC	4,29E-08
Groove2_-X	0	0	0	NC	3,36E-17
Groove3_+X#1	0	0	0	NC	0
Groove3_+X#2	0	0	0	NC	0
Groove3_-X	0	0	7,37E-25	NC	0
Cryo_strut#1	0	0	0	NC	3,43E-21
Cryo_strut#2	0	0	0	NC	1,77E-21
Cryo_strut#3	0	0	0	NC	5,19E-21
Cryo_strut#4	0	0	0	NC	1,77E-20
Cryo_strut#5	0	0	0	NC	8,26E-21
Cryo_strut#6	0	0	0	NC	6,78E-21
Cryo_strut#7	0	0	0	NC	1,10E-20
Cryo_strut#8	0	0	0	NC	2,14E-21
Cryo_strut#9	0	0	0	NC	2,83E-21
Cryo_strut#10	0	0	0	NC	6,12E-22
Cryo_strut#11	0	0	0	NC	1,41E-21
Cryo_strut#12	0	0	0	NC	2,14E-21
FPU_active	**0**	**0**	**0**	**NC**	**0**
Baffle_ext	0	0	2,70E-23	NC	5,30E-16
M2_front	**0**	**0**	**0**	**NC**	**0**
M1_front	**0**	**0**	**0**	**NC**	**0**

TABLE 7.2-33 - PLANCK CHEMICAL THRUSTERS CONTAMINATION WORST CASE

7.2.3.2.3 Contamination increase assessment due to plume

The contamination increase assessment due to the plume is presented in the table N°7.2-34.

Contamination due to thruster plume	Molecular (g/cm2)				
	H2	H2O	N2	N2H4	NH3
FPU	-	-			-
M1	-	-			-
M2	-	-			-

TABLE 7.2-34- PLANCK TELESCOPE CONTAMINATION INCREASE ASSESSMENT DUE TO PLUME

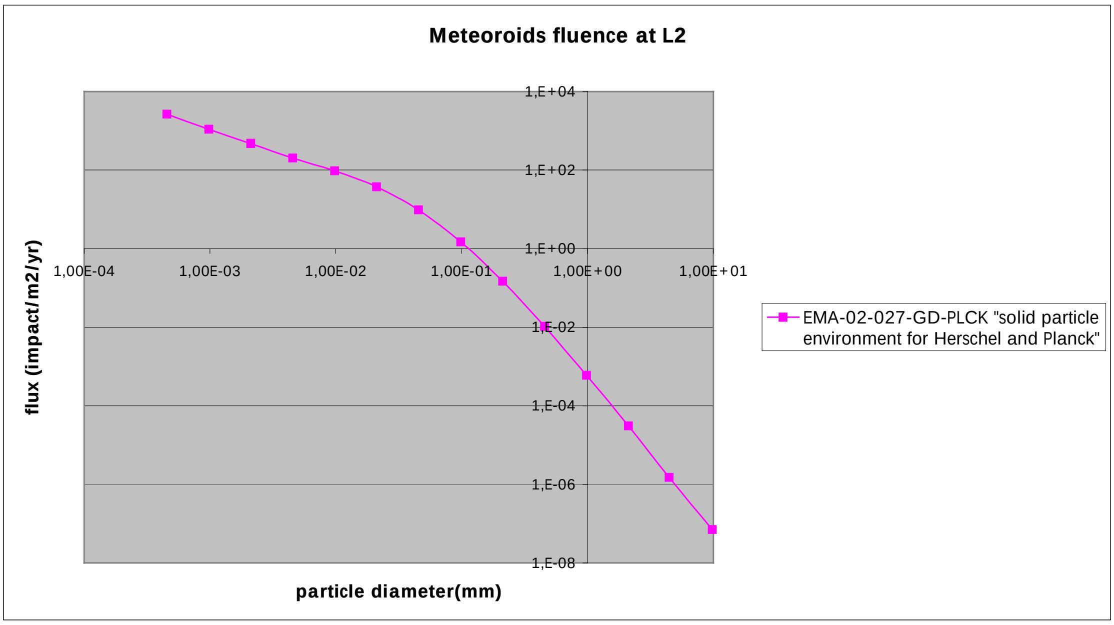
The plumes have no impact on Planck optical cavity contamination

7.2.3.3 Particulate redistribution

At the beginning of in-orbit life, the particulate contamination level on each element of a group is the same. This is due to the fact that the redistribution has already been taken into account during launch. No further redistribution can happen.

7.2.3.4 micrometeoroids

The distribution of micrometeoroids around L2 is the following (see [|RD16])



This means that the total particle surface which hits Planck telescope is:

$$impact\ surface = \frac{\pi * (Planck\ aperture\ diameter)^2}{4} * lifetime * \int_{particle\ size\ range} flux * \frac{\pi\phi^2}{4} d\phi$$

Taking into account the assumption (due to J. Mac Donnel in 1979 and used in the frame of ISO programme(cf [RD1]) that the pit diameter is 4 times the micrometeoroid diameter, we have the following obscuration factor:

$$OF_{eq} = \frac{4 * (impact\ surface)^2}{Planck\ aperture\ surface} = 4 * lifetime * \int_{particle\ size\ range} flux * \frac{\pi\phi^2}{4} d\phi$$

this leads to a total of 1.5ppm whatever the surface.

The fact that no surface "sees" a complete hemisphere has been neglected.

8. BUDGETS

8.1 Herschel

g/cm2	Molecular telescope		inside cryostat	LOU windows		references
	M1	**M2**		external	internal	
On ground contaminants						
delivery	2,00E-07	2,00E-07	3,00E-06	1,00E-07	1,00E-07	Spec Tel (SCI-PT-RS-04671, Iss 5) / instruments at delivery /optical windows spec: HP-2-ASED-PS-0033
AIT	8,70E-08	8,70E-08	5,00E-08	1,46E-06	1,46E-06	Clean team Annex 2-2
Launch	4,00E-07	4,00E-07	-	4,00E-07	0,00E+00	ARIANE value for 2 weeks
budget	**6,87E-07**	**6,87E-07**	**3,05E-06**	**1,96E-06**	**1,56E-06**	
EoL Needs	1,00E-06	1,00E-06	-	-	-	Cleanliness EOL Needs H-P-1-ASPI-TN-0197
NH3						
In-orbit	**0,00E+00**	**6,59E-10**	**0,00E+00**	**0,00E+00**	**0,00E+00**	§7.1.3.2.3
EoL Needs	1,00E-06	1,00E-06	-	-	-	Cleanliness EOL Needs H-P-1-ASPI-TN-0197
H20						
On ground outgassing	-	-	2,20E-06	-	2,20E-06	Clean team Annex 2-2
water permeation	-	-	2,00E-06	-	0,00E+00	HP-2-ASED-TN-0034 issue 2
In-orbit outgassing	6,31E-07	6,99E-07	3,41E-08	4,95E-05	3,41E-08	§7.1.3.1
Thruster plume	0,00E+00	1,03E-11	0,00E+00	1,53E-12	0,00E+00	§7.1.3.2
budget	**6,31E-07**	**6,99E-07**	**4,23E-06**	**4,95E-05**	**2,23E-06**	
EoL Needs	1,50E-06	1,50E-06	-	-	-	Cleanliness EOL Needs H-P-1-ASPI-TN-0197
N2						
Thruster plume	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	§7.1.3.2.3
Total	**1,32E-06**	**1,39E-06**	**7,28E-06**	**5,15E-05**	**3,79E-06**	
EoL Needs	3,50E-06	3,50E-06	6,00E-06	8,50E-06	8,50E-06	Cleanliness EOL Needs H-P-1-ASPI-TN-0197

particulate

ppm	telescope		inside cryostat	LOU windows		references
	M1	**M2**		external	internal	
delivery	300	300	300	300,00	300,00	Spec Tel (SCI-PT-RS-04671, Iss 5)/ instruments at delivery /other subsystems specs
AIT	1600	1600	75	2060,00	2060,00	Clean team Annex 2-1
Launch (Enc to sep)	2300	2300	0	2300,00		H-PLM PM#15 and SCI-PT-19395
in-orbit	0,7	0,7	5,7	0,70		§7.1.3.3 and §7.1.3.4
budget	**4200**	**4200**	**380,7**	**4660,70**	**2360,00**	
EoL Needs	4300	4650	1200	1200,00	1200,00	H-P-1-ASPI-TN-0197

The molecular contamination budget build for Herschel shows that, thanks to the decontamination phase, the needs are fulfilled, except

-for the FPU, where the air permeation has to be reduced in order to fulfil the instruments needs.

- for the LOU windows, the external surface is contaminated with water, due to outgassing, both transient and operational phases.

The particulate contamination budget shows compliance on the mirrors , but, on the LOU surfaces HIFI needs are exceeded, due to launcher fairing and AIT.

On the windows, the critical performance is the transmission at 1.9THz, sizing case.

- The total obscuration factor is 4660 + 2360 = 7020ppm i.e. 0.7% . According to SRON-U/HIFI/TN/2002-002, it induces 3.4% transmission loss.
- The total molecular contaminant thickness is 0.55µm, giving, as per SRON-U/HIFI/TN/2000-002, 0.8% transmission loss.

Finally the total transmission loss is 3.4+0.8=4.2%, still below the 5% transmission loss allocated by Astrium in the window transmission budget.

The major unknown is the particulate contamination by the fairing during launch, where a 2300ppm allocation has been taken, according to [RD15]

The margins which appear with regards to the end of life needs are redistributed among the several steps of spacecraft life in the cleanliness requirements specification [RD8]

8.2 Planck

Molecular

g/cm2	Groove 1		Groove 2		Groove 3		Baffle		optical cavity			references
	+X	-X	+X	-X	+X	-X	internal	external	PR	SR	FPU	
other contaminants												
delivery	1,00E-06	1,00E-06	1,00E-06	1,00E-06	1,00E-06	1,00E-06	5,00E-07	1,00E-06				Planck cryo structure specification
tel delivery									5,00E-07	5,00E-07	3,00E-06	Planck telescope specification
End of AIT	3,90E-07	3,90E-07	3,90E-07	3,90E-07	3,90E-07	3,90E-07	2,10E-07	3,60E-07	1,40E-07	1,40E-07	1,40E-07	Cleanliness Control Plan
Launch	4,00E-07	4,00E-07	4,00E-07	4,00E-07	4,00E-07	4,00E-07	4,00E-07	4,00E-07	4,00E-07	4,00E-07	4,00E-07	ARIANE
budget	**1,79E-06**	1,79E-06	**1,79E-06**	1,79E-06	**1,79E-06**	1,79E-06	**1,11E-06**	**1,76E-06**	**1,04E-06**	**1,04E-06**	**3,54E-06**	
EOL needs	1,30E-04	1,30E-04	1,30E-04	1,30E-04	1,30E-04	1,30E-04	1,00E-05	3,00E-05	-	-	-	Cleanliness EOL Needs H-P-1-ASPI-TN-0197
H2O												
Trans. + Opera.	4,61E-08	2,89E-07	1,04E-08	1,76E-05	1,41E-06	1,45E-05	6,26E-07	4,09E-07	5,27E-06	5,86E-07	5,05E-07	§7.2.3.1.5
Plume	0	1,92E-11	0	0,00E+00	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	§7.2.3.2.2
budget	**4,61E-08**	**2,89E-07**	**1,04E-08**	**1,76E-05**	**1,41E-06**	**1,45E-05**	**6,26E-07**	**4,09E-07**	**5,27E-06**	**5,86E-07**	**5,05E-07**	
EOL Needs	1,00E-04	1,00E-04	1,50E-04	1,50E-04	1,00E-04	1,00E-04	2,00E-04	3,00E-05	-	-	-	Cleanliness EOL Needs H-P-1-ASPI-TN-0197
NH3												
Plume	1,05E-18	2,94E-18	4,29E-08	3,36E-17	0	0,00E+00	0,00E+00	5,30E-16	0,00E+00	0,00E+00	0,00E+00	§7.2.3.2.2
EOL Needs	1,40E-05	1,40E-05	1,40E-05	1,40E-05	1,00E-04	1,00E-04	5,60E-05	1,50E-05	-	-	-	Cleanliness EOL Needs H-P-1-ASPI-TN-0197
N2												
Plume	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	§7.2.3.2.2
TOTAL	**1,84E-06**	**2,08E-06**	**1,84E-06**	**1,94E-05**	**3,20E-06**	**1,63E-05**	**1,74E-06**	**2,17E-06**	**6,31E-06**	**1,63E-06**	**4,05E-06**	
Instruments EOL Needs									4,00E-06	4,00E-06	7,00E-06	Cleanliness EOL Needs H-P-1-ASPI-TN-0197

Particulate

ppm	Groove 1		Groove 2		Groove 3		Baffle		optical cavity			references
	+X	-X	+X	-X	+X	-X	internal	external	PR	SR	FPU	
Livraison	3500		3500		3500		900	3500			300	Planck cryo structure specification
Livrason tel									900	900		Planck telescope specification
End of AIT	1000		1000		1000		2205	1000	530	530	530	Cleanliness Control Plan
Bef encapsulation	1000		1000		1000		1895	1000	1895	1895	1895	Cleanliness team conclusions
Launch	2300		2300		2300		2300	2300	2300	2300	2300	H-PLM PM#15 and SCI-PT-19395
budget	**3300**		**3300**		**3300**		**4195**	**3300**	**4195**	**4195**	**4195**	
EOL Need	10000		10000		10000		10000	15000	5000	5000	5000	Cleanliness EOL Needs H-P-1-ASPI-TN-0197
Instruments EOL Needs									5000	5000	5000	Cleanliness EOL Needs H-P-1-ASPI-TN-0197

The contamination budgets built for Planck show that the needs are fulfilled <u>without decontamination phase in-orbit</u>. The total molecular contamination on the Primary reflector is just above the requirements. However, what is important is the total telescope emissivity increase, and so only the sum of the contamination on SR and PR is significant. PR+SR contamination = 6.3^{e}-6+1.7^{e}-6=8^{e}-6, which just equals the 8^{e}-6 total maximum contaminant thickness required.

The major unknown is the particulate contamination by the fairing during launch, where a 2300ppm allocation has been taken, according to [RD15]

The margins which appear with regards to the end of life needs are redistributed among the several steps of spacecraft life in the cleanliness requirements specification [RD8]