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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 environment updated	
3.1	26/04/04	Cleanliness needs have been updated, according to SRS 3.2 Windows Contamination during Herschel AIT has been updated to account for protections LOU mirror contamination budget is built LOU windows and mirror discussion of contamination meetings with HIFI (ref H-P-ASP-MN-4736 dated 07/04/04) Updated permeation through CVV seals considered Orientation of Herschel sensitive surfaces during AIT is considered The following items are not covered by this issue -indirect migration path of water molecules -LOU as outgassing source	P. Martin
4.0	1/07/2004	H-P System CDR General update for to be in line with the modules -materials -cleanliness control plans	H-P Team

ISSUE	DATE	§ : DESCRIPTION DES EVOLUTIONS § : CHANGE RECORD	REDACTEUR AUTHOR
		more specifically on Herschel: -update/correction of spacecraft temperature - indirect migration path of water molecules - LOU as outgassing source for the windows is considered - outgassing of the SVM onto the star-tracker is quantified (see annex) on Planck, the decontamination of PR, SR and FPU is now favored	

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 3/2

[AD2] " Planck telescope optical and RF system specification "
H-P-3-ASP-SP-0274 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 2/0

[RD3] “Herschel Contamination Control Plan

HP-2-ASED-PL-0023

[RD4] “Planck Cleanliness Control Plan

H-P-1-ASPI-PL-0253 issue 3/0

[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 7/0

[RD10] LOU windows assembly procurement specification

HP-2-ASED-PS-0033 Issue 3/0

[RD11] Permeation through CVV seals

HP-2-ASED-TN-0034 Issue 3

[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

[RD17] LOU optical system

MPIfR/HIFI/DD/2001-001 issue 1.0

[RD18] H-PLM cleanliness budgets

H-P-ASP-LT-4790 dated 19/04/04

[RD19] Herschel Transmission analysis

H-P-2-ASPI-TN-0344 issue 3/0

[RD20] Cleanliness and contamination control plan for Herschel/Planck autonomous Star Tracker Units

H-P-4-GAF-PL-0003 issue 2/0

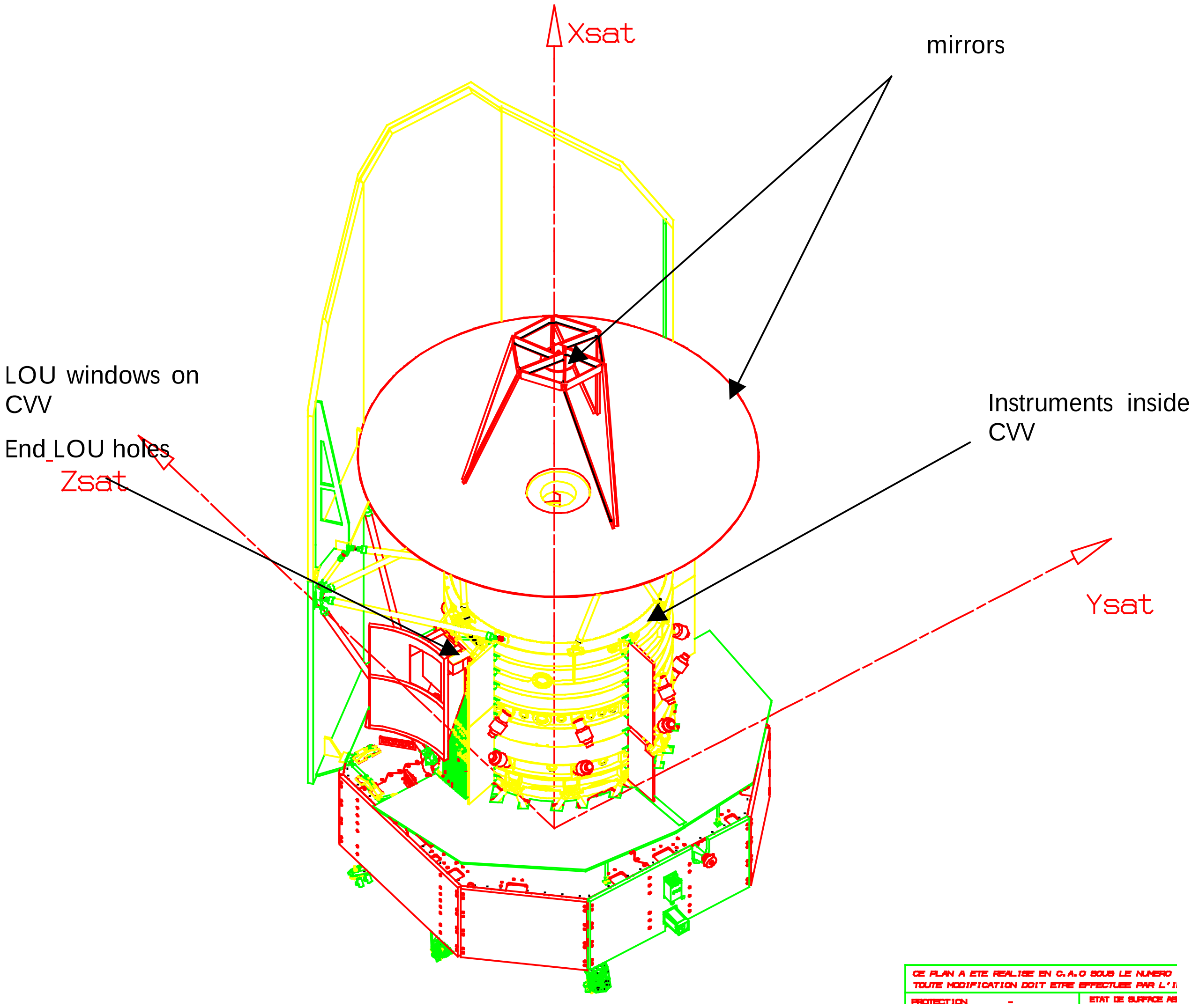
4. ABBREVIATION/ACRONYMS

CVV	Cryo-Vacuum Vessel
EOL	End Of Life
HP	Herschel-Planck
IR	Infrared
LOU	Local Oscillator Unit
LOA	Local Oscillator Assembly
N/A	Not Applicable
NC	Not Calculated
PA	Product Assurance
PLM	Payload Module
Ppm	Part Per Million
S/C	Spacecraft
SRS	System Requirements Specification
TBC	To Be Confirmed
TBD	To Be Defined
AOCS	Attitude and Orbit Control System
TLM	Total Mass Loss
CVCM	Collected Volatile and Condensable Materials

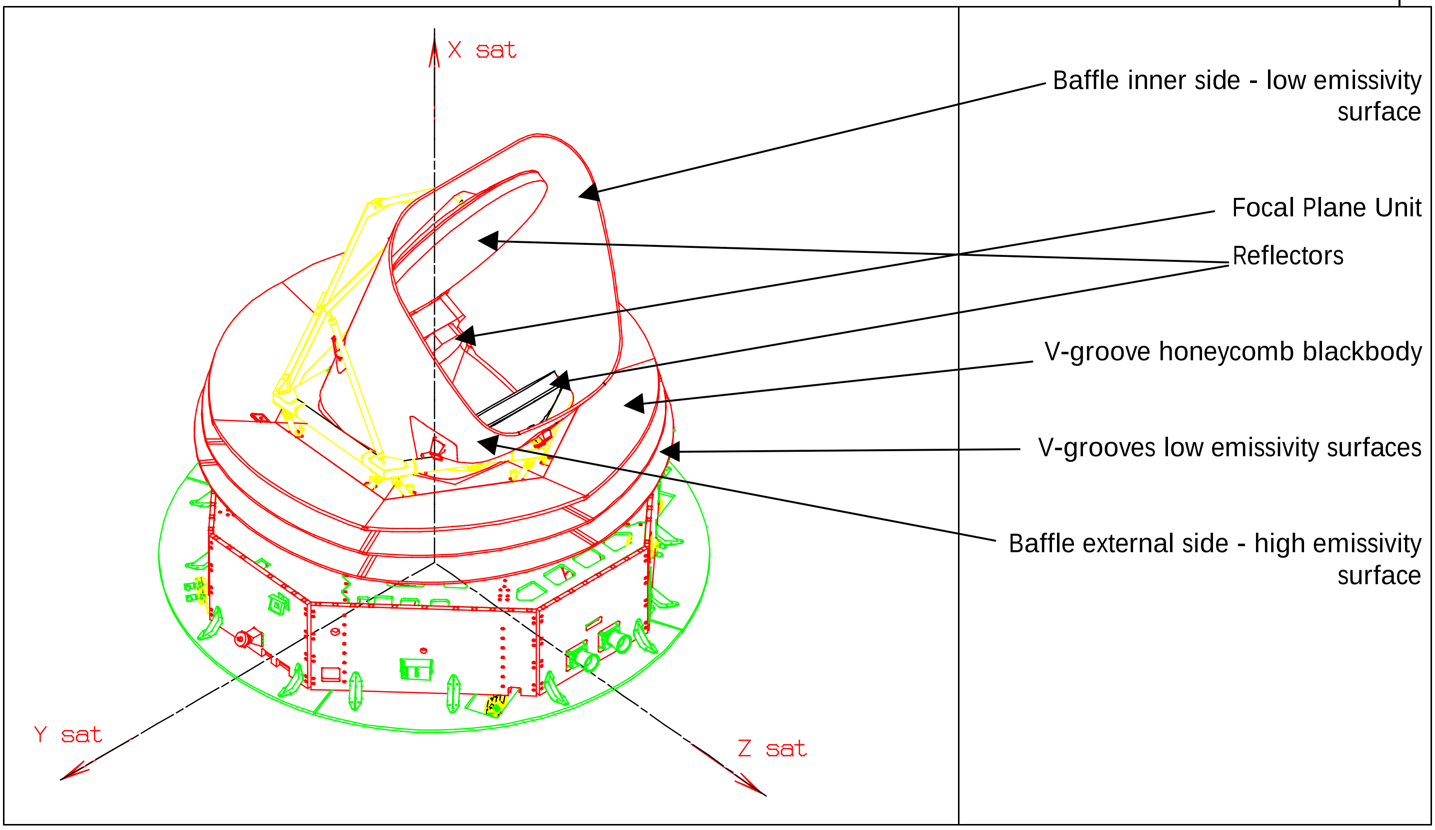
5. GEOMETRY AND CRITICAL ELEMENTS

This section describes the geometry and 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]) and to the System Requirement specification ([AD1]), 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.

6.1 Herschel

EOL cleanliness level needs	Molecular (g/cm^2)			Particulate (ppm)
	H_20	NH_3	On ground contaminants	
Telescope M1	$4\ 10^{-6}$			4500(*)
Telescope M2	$4\ 10^{-6}$			4500(*)
Instruments FPU (outside)	$6\ 10^{-6}$			1200
HIFI LOU CVV windows	$6\ 10^{-6}$			1200
LOU first mirror	$6\ 10^{-6}$ (TBC)			1200 (TBC)

(*) average level for M1 and M2

6.2 Planck

EOL cleanliness level needs	Molecular (g/cm^2)			Particulate (ppm)
	H_2O	NH_3	On ground contaminants	

From instruments (system needs are not driving):

Focal Plane Unit	6 10^{-6}	5000
Telescope PR	4 10^{-6}	5000
Telescope SR	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}	2200
M2	0	0	2.87 10^{-7}	395(**)
FPU and optical bench	37 10^{-7} (*)	0	31 10^{-7}	500
LOU window (Internal and external)	0	0	6 10^{-7}	300
Spacecraft	0	0	27 10^{-7}	2500

(*) this includes:

-permeation

as per [RD11], water permeation on the FPU's follows the rule 3.10-6/1500*cryogenic operation of CVV). The expected Herschel AIT duration are less than 600days, leading to 12 10-7g/cm2

-CVV internal outgassing

->25 10-7 g/cm2

(**) M2 particulate contamination during AIT is derived from M1 contamination divided by 20, to account for M2 looking toward –X (cf. [RD18])

7.1.2 Cleanliness degradation due to launch preparation

We expect a maximum duration of 8 days in class 10 000, leading to:

- 2.4 10-8 g/cm2 molecular contamination
- 480ppm particulate for M1, (horizontal, toward +X)
- 48ppm particulate on LOU windows , (vertical)
- 24ppm particulate for M2, (horizontal, toward -X)

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

The specified hypothesis for the launcher contribution (from the encapsulation to the separation) are (cf. [AD1]) 2300 ppm

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	$3\ 10^{-7}$	4980
M2	0	0	$3\ 10^{-7}$	2720
FPU and optical bench	$37\ 10^{-7}$	0	$31\ 10^{-7}$	275
LOU window (internal	0	0	$6\ 10^{-7}$	300
LOU window (external)	0	0	$6\ 10^{-7}$	2650
Spacecraft	0	0	$27\ 10^{-7}$	5300

7.1.4 In-orbit contamination

7.1.4.1 Outgassing

7.1.4.1.1 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 degrades the mission performances.

7.1.4.1.2 Hypotheses and modelisation

7.1.4.1.2.1 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)

7.1.4.1.2.2 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

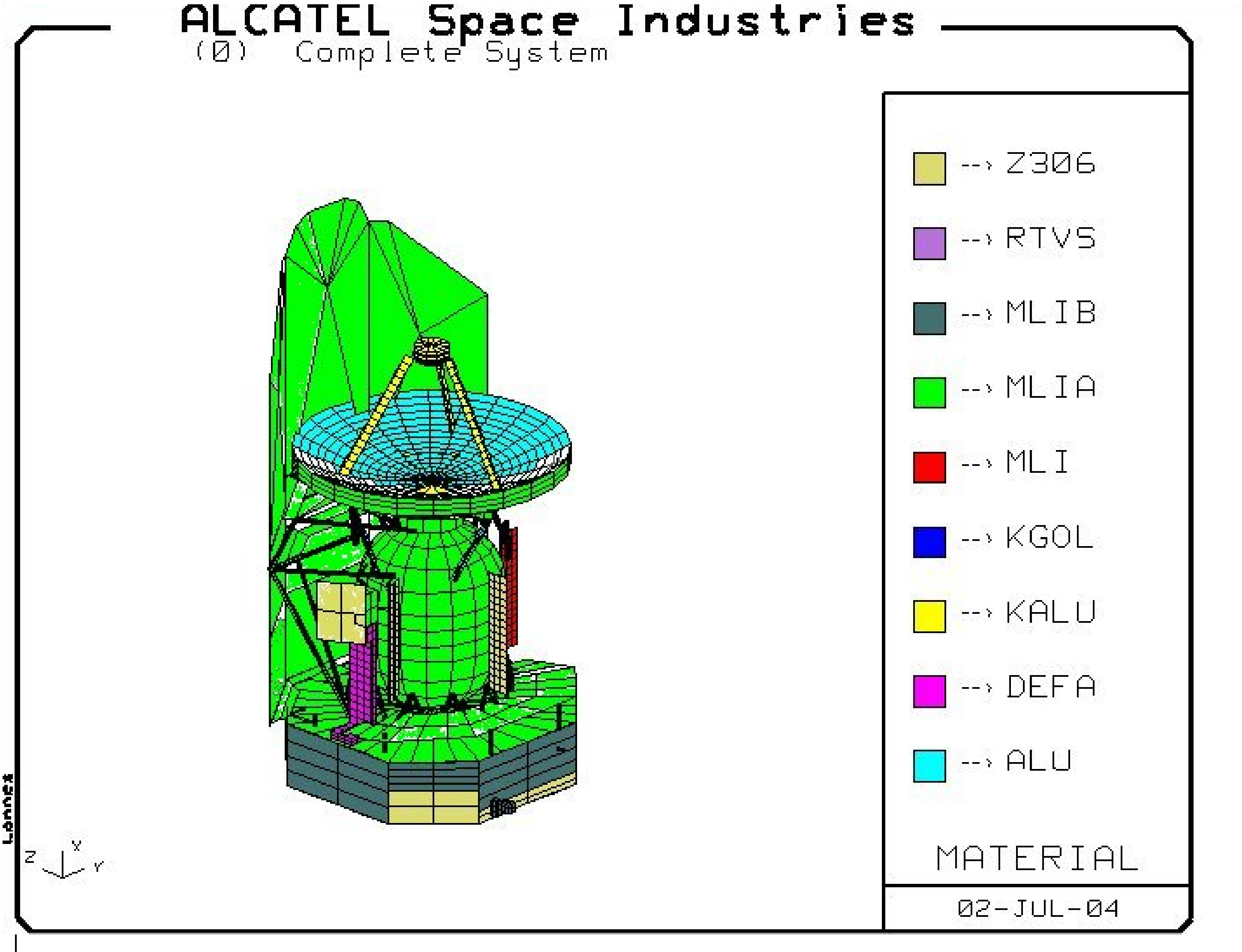


FIGURE 7.1-1- HERSCHEL- OUTGASSING MODEL

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
SVM upper face	MLI Alu	1.4	250	SVM
SVM lower face	MLI black	1.4	140	SVM
SVM lateral panels	MLI black	1.3	140	SVM
SVM Panel Radiators	Z 307	1.3	60	SVM
VMC camera	MLI black	1.4	140	SVM
SAS (+Z/-Z)	MLI black	1.4	140	SVM
TTC (+Z/-Z) LGA	MLI black	1.4	140	SVM
SREM	MLI black	1.4	140	SVM
MGA	MLI black	1.4	140	SVM
CVV external surface	Aluminium, MLI on +Z, black anodised on -Z side	1.4	410	PLM
CVV radiators	MLI	1.4	410	PLM
CVV struts (PLM-SVM I/F struts)	GFRP wrapped in aluminised MLI	(CFRP) 2,05 (MLI) 1,4	(CFRP) 1800 (MLI) 170	PLM
LOU WG	Metal No Outgassing		N/A	
LOU radiator	Z306	1.3	75	Instrument
LOU	Z306 on -Y sides MLI on others sides	1,3 1,4	75 410	Instrument
LOU struts	GFRP wrapped in aluminised MLI	1.4	170	PLM
SVM shield	MLI ALU	1,4	360	PLM
SVM shield struts	GFRP wrapped in aluminised MLI	(GFRP) 2,05 (MLIA) 1,4	(GFRP) 1000 (MLIA) 170	PLM
Struts sun shield, I/F to SVM	CFRP wrapped in aluminised MLI	(CFRP)1,68 (MLIA) 1,4	(CFRP) 4000 (MLIA) 100	PLM
Struts sun shield, all others	GFRP wrapped in aluminised MLI	(CFRP) 2,05 (MLIA) 1,4	(GFRP) 4800 (MLIA) 360	PLM
Sun shield stiffners	CFRP sandwich +Aluminised MLI internal side	(MLI) 1,4	160	PLM
Sun shade external side	CFRP sandwich + OSR stuck by RTV S691	(glue) 1,42	(Glue) 210	PLM
Sun shade internal side	CFRP sandwich +Aluminised MLI internal side	(MLI) 1,4	350	PLM
Sun shield external side	CFRP sandwich + solar cells stuck by RTV S691	(glue) 1,42	(Glue) 150	PLM
Sun shield internal side	CFRP sandwich +Aluminised MLI internal side	(MLI) 1,4	350	PLM
M1 support struts	ALU	1,4	80	PLM
M1 active side	Aluminised kapton	N/A	N/A	Telescope
M1 lateral side	Aluminised kapton	1.4	25	Telescope
M1 rear side	Aluminised kapton	1.4	75	Telescope
M2 support struts	Aluminised kapton	1.4	50	Telescope
M2 upper cylinder (+X)	Aluminised kapton	1.4	50	Telescope
M2 lower cylinder (-X)	SiC (or Alu)	N/A	N/A	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)
Alu NIDA panel	Glue BSL312L	5
Internal black paint	Z306	2
Central tube (Nominal + Reinforcement)	CFRP M18/M40 J	31.25
Cone adhesive skin-core	Glue BSL 319L	3.94
Cone Adhesive	Hysol EA 9321	0.69
Adhesive	Hysol EA 9309	0.036
Shear panels (Nominal + Reinforcement)	CFRP M18/G969	10.84
Shear panels adhesive skin-core	Glue BSL 312 L	1.06
Shear panels adhesive core-core	FM 410	0.85
Upper closure panels (nominal + reinforcements)	CFRP M18/G801	13.96
Upper closure panels adhesive skin-core	Glue BSL 312L	1.57
Upper closure panels adhesive core-core	FM 410	1.94
Lower closure panels (nominal + reinforcements)	CFRP M18/G801	11.5
Lower closure panels adhesive skin-core	Glue BSL 312L	1.37
Lower closure panels adhesive core-core	FM 410	1.76
Sub PF skins	CFRP M18/G810	5
Sub PF adhesive	Glue BSL 312L	1.2
Thermal closing skins	CFRP M18/G810	5
Thermal closing adhesive	Glue BSL 312L	1.2
Propellant tanks supports	CFRP M18/M55J	1.24
Miscellaneous	Hysol EA 9321	0.39
Miscellaneous	Scotchweld EC 2216	0.4
Glue insert for potting	Stycast 1090/°	10
Internal MLI (8 m2 tanks + 4 m2 panels)	MLI	2

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

The following table shows the RFD coming from lower levels which have been considered at the time of the analysis

Equipment	RFD Reference	Material	Mass (g)	Mass for the analysis (g)	Remark
EPC	H-P-342000-ETCA-RD-0003	Z306	< 10	10	
EPC	H-P-342000-ETCA-RD-0012	EC 2216 Ink Label	10 0,5 1	10 0 0	 Negligible Negligible
PCDU	H-P-361000-ETCA-RD-016	Z306	10-100	100	
PCDU	H-P-361000-ETCA-RD-017	EC 2216 Ink Epoxy glass laminate Label	10-100 1-10 10-100 1-10	100 0 0 0	 Negligible Considered covered by EC2216 Negligible
CDMU+ACC	HP-300000-SES-RD-0005	Z306			2600 cm2

		EC 2216 Label	80	80 0	30 cm2
NED	HP-2-AAE-RD-0003				Low masses < 5g Low temperature Considered not critical
Battery	HP4-AEA-RD-0006	Araldite 420	10	10	
Battery	HP4-AEA-RD-0007	Sheldahl G401100	20	20	
Battery	HP4-AEA-RD-0008	Sheldahl G401100 VDA	10	10	
Battery	HP4-AEA-RD-0009	Stycast 4952	10	10	
STR	H-P-4-GAF-RD-0014	EC 2216 Aeroglaze L300 + primer	1 0,2	1 0	Negligible
RFDN	HP-343000-AEO-RD-0001	EC 2216 Electrodag 504 Z306 Kapton Epoxy patch	10 5 140 (H) 169 (P) 0,3 5	10 5 169 0 0	Negligible Considered covered by EC2216
X-Band transponder	H-P-341000-AEO-RD-0005	Epiphen ER 825 A EC 2216 Z306 Kapton Enamelled Wire	5 21 16 4 10	5 21 16 0 0	Negligible, covered by internal MLI Negligible, TML almost in spec (1,03 %)

From this table, the materials with significant mass are the Z306 and the EC2216 for which the total mass is 311 and 323 g respectively. This is covered by the internal SVM materials shown in Table 7.1-2.

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

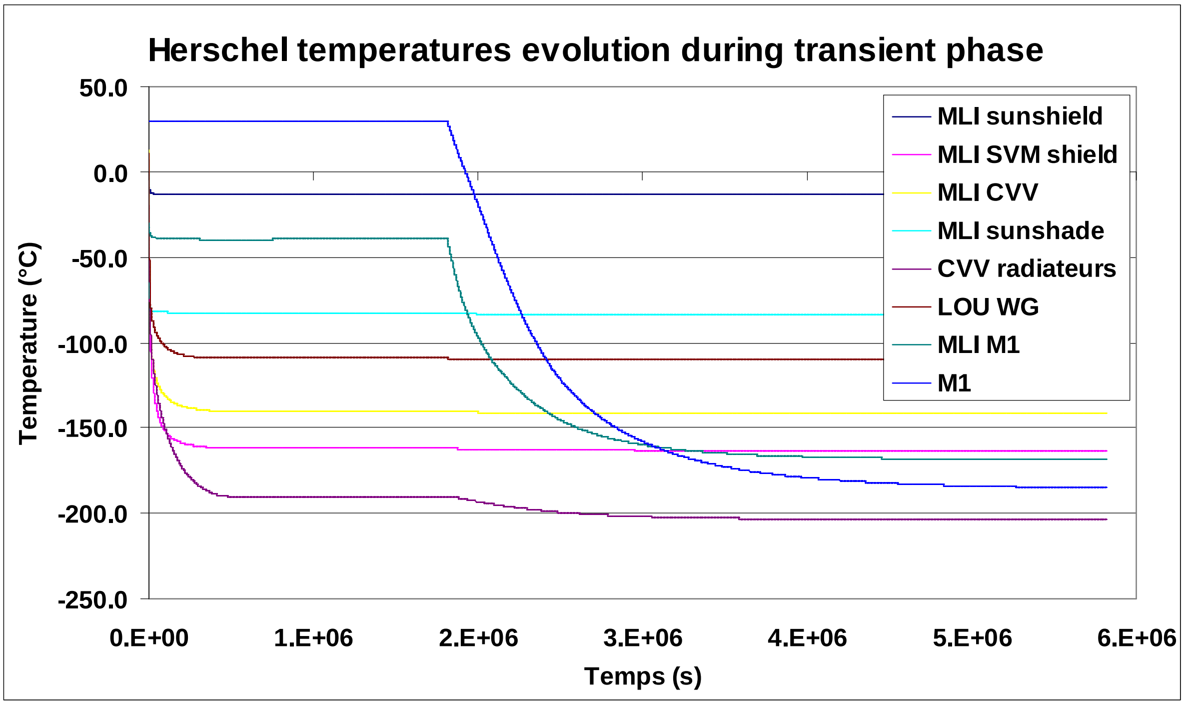


FIGURE 7.1-2- Herschel temperatures evolution during transient phase

The surface temperatures chosen for the simulations are those of the thermal hot case. This case corresponds to a hot SVM and a 'hot' HPLM.

CDR SVM TCS hot case (pitch 30°)

Element		Temperature (K)
HERSCHEL SVM	SVM upper	314.395
	SVM lower	317.155
	SVM lateral panel +Z	428.1
	SVM lateral panel +Y+Z	380.1
	SVM lateral panel +Y	155.7
	SVM lateral panel +Y-Z	122.0
	SVM radiator panel +Y/-Z	313.9
	SVM lateral panel -Z	167.6
	SVM Radiator panel -Z	313.6
	SVM lateral panel -Y-Z	119.8
	SVM radiator panel -Y/-Z	305.1
	SVM lateral panel -Y	146.1
	SVM lateral panel -Y+Z	392.4
	VMC	330.02
	SAS (-Z)	284.58
	SAS (+Z)	325.65
	MGA (+Z)	406.42
	LGA (-Z)	266.96
	LGA (+Z)	375.58
	AAD	343.18
	STR support (radiator)	291.63
	STR 1 box	298.25
	STR 1 baffle	242.87
	STR 2 box	289.15
	STR 2 baffle	238.61

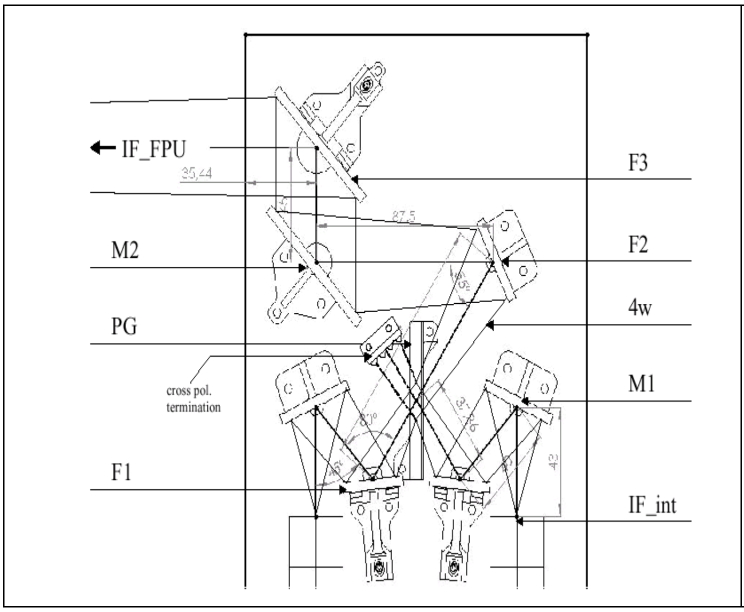
CDR PLM hot case (pitch 0°)

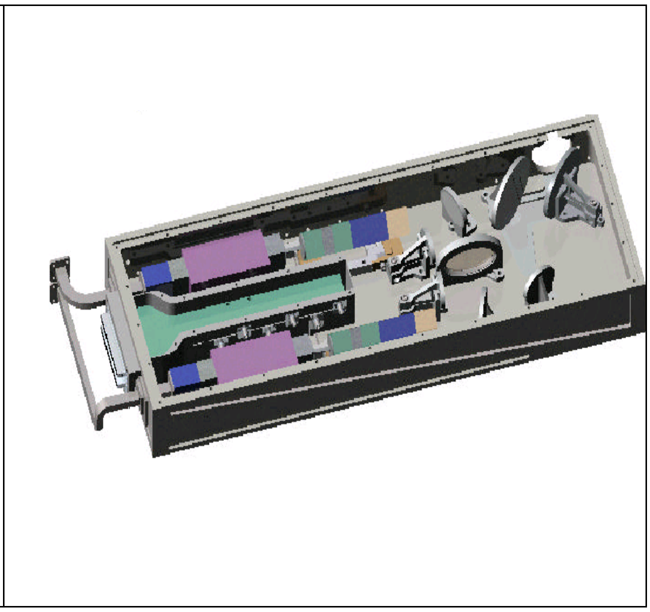
Element		Temperature (K) [min - max]
HERSCHEL PLM	CVV radiator (on CVV)	68.8
	CVV radiator nose -Z	68.4
	CVV radiator ear +Y	68.9
	CVV radiator ear -Y	69.6
	CVV radiators MLI	[63,8 - 141,5]
	CVV MLI	[72,7 - 165,9]
	CVV LOU windows	70.37
	CVV struts	[104,2 - 232,4]
	LOU WG	[136,07 - 265,29]
	LOU radiator	[123,7 - 136,9]
	LOU	138.2
	LOU struts	[68,8 - 138,2]
	SVM shield	[132,31 - 138,27]
	SVM shield struts	[132,31 - 293]
	Sunshade external side	[258,42 - 278,07]
	Sunshade internal side (MLI)	[181,68 - 202,11]
	Sunshade struts	[68,8 - 278,07]
	Sunshield external side	[374,46 - 396,22]
	Sunshield internal side (MLI)	[252,89 - 270,29]
	Sunshield struts (I/F CVV)	[68,8 - 396,22]
	Sunshield struts (I/F SVM)	[293 - 396,22]
	M1 active side	87.86
	M1 rear side	[69 - 133,5]
	M2	87.5
	M2 supporting structure	87.54

TABLE 7.1-3- HERSCHEL- SURFACES TEMPERATURES

The LOU mirrors are inside the LOA's. In order to account for the shielding of the LOU housing, the principle is the following:

1. to consider that the LOU hole cleanliness is the same than the LOU windows. This is valid because:
   -the AIT protection of the LOA's holes and the windows are identical
   -the outgassed water ice trapped by the foil (see §7.1.4.1.2.4.1) is a worst case representation of what occurs on the windows and on the LOU holes, because the contamination levels seen by both sides of the LOU are summed up.
2. To compute the view factor between a LOA hole and a LOU mirror. The geometry is taken from [RD17].





The computed view factor is 0.13

3. This view factor is then applied to all the common steps seen by the window and the LOU, i.e. all the contributors after delivery

7.1.4.1.2.3 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 M18	Cyanate composite	VBQC 3794
Aluminised MLI	Mylar DA foil	VBQC 3141
Z306	Z306	VBQC 3148
Z307	Z306	VBQC 3148
MLI	Kapton	VBQC 3193/2
MLI black	ASP Black Kapton	VBQC 3798
Stycast 1090/9	Stycast 1090/9	VBQC 3520
Glue BSL 312L/319L	FM 73U	VBQC 3613
DC 93500	rtv s691	VBQC 3624
RTV S691	rtv s691	VBQC 3624
GFRP	Cyanate composite	VBQC 3794
Aluminised kapton	Mylar DA foil	VBQC 3141
Stycast 1090/9	Stycast 1090/9	VBQC 3520
Glue FM 410	FM 73U	VBQC 3613

TABLE 7.1-4 - HERSCHEL- OUTGASSING MATERIALS CONVERSION

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

7.1.4.1.2.4 Herschel outgassing simulations

Various phases are distinguished and analysed 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)

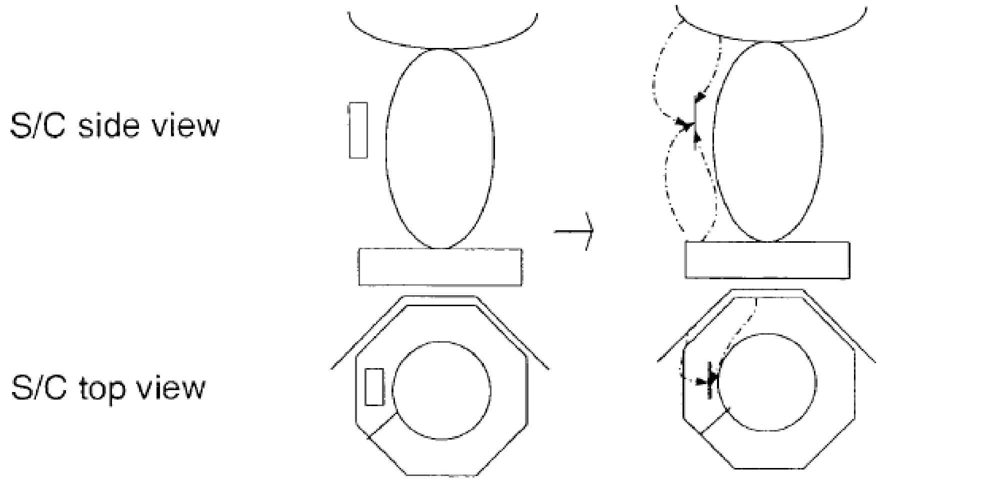
The simulations were performed twice, once with only the external configuration materials taken into account and the second one with the consideration of the outgassing materials inside the hot SVM.

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.

7.1.4.1.2.4.1 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, CVV). In addition, the external contribution of the LOU has been introduced: MLI on the LOU base plate in front of the CVV and LOU support struts. 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 fictitious 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.



Model for transient analysis

The sum, on both surfaces (+/-Y), of contamination is computed. The sensitive surface, representing both the LOU baseplate and the LOU windows, is a cold trap on which the molecules stick for ever. One reflection on hot surfaces (for example the sunshade) is also taken into account by considering that all the contamination deposed on hot surfaces are reflected and can therefore impinged the LOU windows.

Two contributors are not considered in the analysis:

- Several reflections (more than one) on hot surfaces but theirs contributions are negligible compared to the direct flux and the first reflection;
- The inner part of the LOU as contamination source. The external contribution (MLI in front of the CVV, on the LOU baseplate and the LOU struts) is taken into account.

First the result of this analysis gives a molecular contamination of the LOU test surface during the transient phase due to direct flux only second, contamination of the LOU test surface during the transient phase due to reflection only and third, by taking into account the both.

LOU Windows contamination level after 3 weeks due to direct outgassing element and reflection on elements			
Elements seen by the LOU windows	LOU windows contamination level after 3 weeks in transient phase (g/m²)	Average LOU windows contamination level due to reflection (g/cm²)	Average Total contamination level on the LOU windows (direct + reflections) (g/cm²)
MLI sunshield	2.02E-06	1.82E-05	2.02E-05
MLI sunshade	1.16E-08	0.00E+00	1.16E-08
MLI SVM top	1.60E-09	0.00E+00	1.60E-09
M1	0.00E+00	0.00E+00	0.00E+00
M2	0.00E+00	0.00E+00	0.00E+00
CVV radiators	1.25E-10	0.00E+00	1.25E-10
LOU WG	0.00E+00	0.00E+00	0.00E+00
MLI SVM shield	5.90E-14	0.00E+00	5.90E-14
MLI M1	1.54E-06	2.22E-05	2.38E-05
MLI CVV	2.12E-06	0.00E+00	2.12E-06
LOU Struts MLI	3.18E-09	0.00E+00	3.18E-09
LOU +Y MLI Side	9.74E-09	0.00E+00	9.74E-09
Total:	5.71E-06	4.04E-05	4.61E-05

TABLE 7.1.5: LOU test surface contamination levels due to direct flux and reflection after the heating phase (i.e.3 weeks).

Each line shows the contribution of the considered element on the LOU windows contamination level (due to the transient phase, due to the reflection phenomenon or the both for the last column) except for the last line, which represents the sum of all of element contributions.

The result of this analysis gives a molecular contamination (in a worse case approach) of the LOU test surface during the transient phase of 4.61 E-5 g/cm² in average.

7.1.4.1.2.4.2 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 § 7.1.4.1.2.2).

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 the 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 (which is the main contributor). The re-evaporation is estimated with the equation determining the vaporisation rate of a water splash under vacuum conditions.

$$\frac{dW}{dt} = 4{,}36.10^{-3} * P_s * A * S_1 * \sqrt{\frac{M}{T_s}}$$ (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)

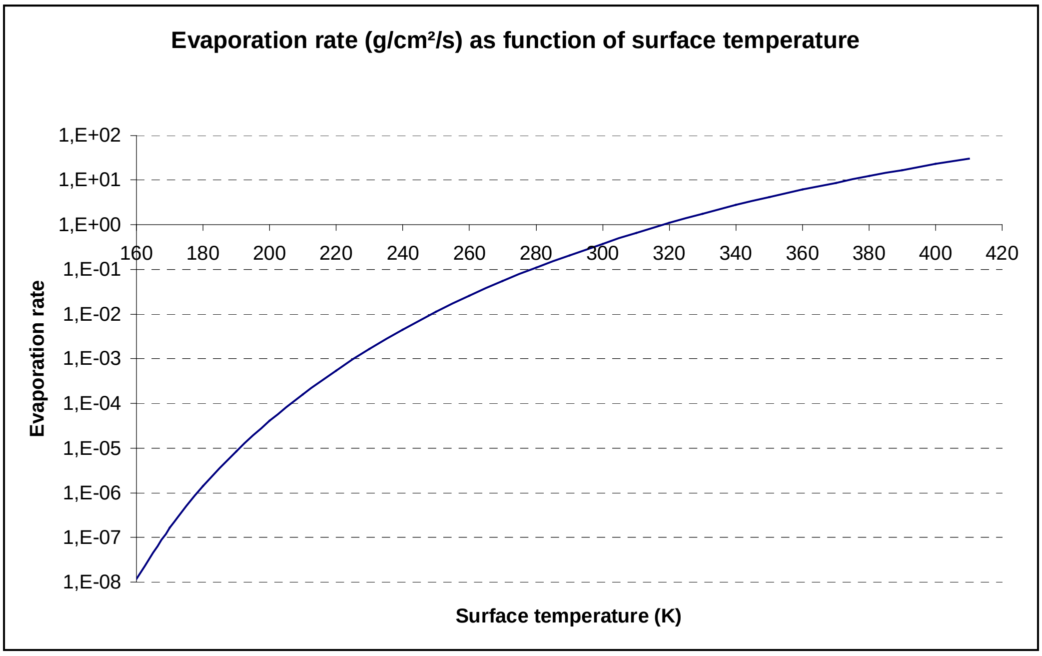
A: surface area

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.

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLIB	1.847	8.551	260.0	7.00E-05	2.21E-04	7.93E-08
SVM Panel radiators	Z306	0.105	1.223	310.9	9.70E-06	1.93E-05	8.28E-07
SVM upper panel	MLIA	3.894	10.116	314.4	6.49E-05	1.01E-04	4.16E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.22E-04	1.22E-04	1.22E-04
VMC Camera	MLIB	0.008	0.035	330.0	8.98E-05	2.19E-04	1.72E-06
SAS #1 +Z	MLIB	0.024	0.112	325.6	6.93E-05	1.68E-04	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.6	2.21E-05	7.10E-05	0.00E+00
TTC #1	MLIB	0.008	0.039	375.6	1.14E-04	5.85E-04	0.00E+00
TTC #2	MLIB	0.008	0.039	266.9	3.03E-05	8.23E-05	0.00E+00
SREM	MLIB	0.021	0.097	167.0	2.91E-05	8.94E-05	0.00E+00
MGA	MLIB	0.009	0.041	406.4	1.38E-04	3.00E-04	8.47E-05
AAD	MLIB	0.008	0.035	343.2	4.85E-04	1.09E-03	1.62E-04
CVV external surface	MLIA	10.906	17.313	165.9	2.01E-05	6.26E-05	0.00E+00
CVV radiators	MLI	1.372	3.026	141.5	2.69E-06	2.44E-05	0.00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	232.4	1.18E-05	8.49E-05	2.80E-12
LOU WG	NO OUTGASSING	0.000	1.994	136.0	1.88E-05	6.92E-05	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	3.70E-06	1.62E-05	7.61E-08
SVM shield -X	KGOL	0.545	4.952	138.0	2.02E-05	5.63E-05	9.98E-07
SVM shield struts	MLIA	0.148	0.568	293.0	4.15E-05	2.70E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.2	4.68E-06	1.33E-05	2.92E-09
LOU radiator	Z306	0.110	1.000	136.9	1.09E-05	2.18E-05	1.78E-10
LOU +Y face	MLIA	0.090	0.157	138.2	1.29E-06	1.29E-06	1.29E-06
LOU struts	MLIA	0.021	0.082	138.2	1.71E-05	2.57E-04	0.00E+00
Sun shield struts	MLIA	1.004	3.861	270.3	3.87E-05	1.78E-04	0.00E+00
Sun shade internal	MLIA	7.859	14.554	202.1	2.31E-05	6.97E-05	3.94E-07
Sun shade external	RTVS	3.347	14.554	278.1	1.16E-06	8.24E-06	0.00E+00
Sun Shield internal	MLIA	5.760	10.665	270.1	2.13E-04	2.60E-04	1.23E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.30E-05	8.12E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.1	5.06E-05	1.29E-04	5.71E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.1	5.05E-05	1.01E-04	2.13E-05
M1 support struts	ALU	0.157	1.275	79.0	6.77E-06	4.81E-05	0.00E+00
M1 frame	MLIA	0.976	1.775	79.0	7.74E-06	3.95E-05	0.00E+00
M1 active side	NO OUTGASSING	0.000	10.380	87.9	1.64E-07	2.20E-07	1.08E-07
M1 lateral side 1	MLIA	0.192	5.052	87.9	1.14E-05	4.44E-05	0.00E+00
M1 lower surface	KALU	1.571	6.892	133.0	5.78E-06	2.31E-05	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	122.0	1.21E-05	2.21E-05	0.00E+00
M2 support	KALU	0.122	1.584	87.9	8.20E-08	5.05E-07	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	6.68E-09	1.39E-08	1.57E-09
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	9.00E-09	2.67E-08	0.00E+00

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

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75.124	9.763	276.1	4.15E-04	1.29E-03	9.92E-08
SVM upper panel	MLIA	3.894	10.116	314.0	6.96E-05	1.24E-04	4.19E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.35E-04	2.17E-04	7.50E-05
VMC Camera	MLIB	0.008	0.035	330.1	2.91E-04	5.93E-04	1.01E-05
SAS #1 +Z	MLIB	0.024	0.112	326.0	2.03E-04	1.15E-03	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.0	2.99E-05	1.10E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.0	6.66E-04	5.04E-03	0.00E+00
TTC #2	MLIB	0.008	0.039	266.0	3.56E-04	1.25E-03	0.00E+00
SREM	MLIB	0.021	0.097	167.0	3.01E-05	1.50E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.0	8.26E-04	1.29E-03	8.59E-06
AAD	MLIB	0.008	0.035	343.0	2.78E-03	1.08E-02	6.72E-04
CVV external surface	MLIA	10.906	17.313	165.9	1.89E-05	4.38E-05	0.00E+00
CVV radiators	MLI	1.372	3.026	141.0	1.20E-05	1.52E-04	2.95E-11
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	233.0	1.18E-05	6.80E-05	8.97E-08
LOU WG	NO OUTGASSING	0.000	0.098	136.0	2.17E-05	1.12E-04	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	2.11E-06	8.70E-06	3.47E-09
SVM shield -X	KGOL	0.545	4.952	138.0	1.90E-05	5.64E-05	9.61E-07
SVM shield struts	MLIA	0.148	0.568	293.0	3.81E-05	3.49E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.0	1.82E-05	7.48E-05	2.18E-09
LOU radiator	Z306	0.110	1.000	138.0	4.69E-06	9.38E-06	1.56E-10
LOU +Y face	MLIA	0.090	0.157	138.0	8.17E-08	8.17E-08	8.17E-08
LOU struts	MLIA	0.021	0.082	139.0	4.93E-06	2.49E-05	5.66E-11
Sun shield struts	MLIA	1.004	3.861	270.0	3.46E-05	2.17E-04	4.20E-14
Sun Shade internal	MLIA	7.859	14.554	202.1	4.48E-06	3.74E-05	0.00E+00
Sun shade external	RTVS	3.347	14.554	278.1	3.59E-05	2.49E-04	0.00E+00
Sun shield internal	MLIA	5.760	10.665	270.1	2.11E-04	2.59E-04	1.25E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.22E-05	7.85E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.0	5.62E-05	1.23E-04	2.88E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.0	4.89E-05	1.18E-04	2.66E-05
M1 support struts	ALU	0.157	1.275	79.0	4.70E-06	2.99E-05	9.57E-12
M1 frame	MLIA	0.976	1.775	79.0	8.72E-06	4.83E-05	0.00E+00
M1 active side	NO OUTGASSING	0.000	10.380	88.0	5.52E-08	1.01E-07	9.55E-09
M1 lateral side 1	MLIA	0.192	5.052	79.0	8.44E-06	3.20E-05	0.00E+00
M1 lower surface	KALU	1.571	6.892	133.0	5.10E-06	2.04E-05	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	122.0	7.11E-06	1.40E-05	0.00E+00
M2 support	KALU	0.122	1.584	79.0	9.69E-08	4.59E-07	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	3.21E-09	8.80E-09	9.65E-11
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	7.91E-09	2.35E-08	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/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLIB	1.847	8.551	260.0	8.25E-05	2.27E-04	6.92E-07
SVM Panel radiators	Z306	0.105	1.223	310.9	3.21E-05	4.93E-05	2.03E-05
SVM upper panel	MLIA	3.894	10.116	314.4	7.10E-05	1.09E-04	4.70E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.29E-04	1.29E-04	1.29E-04
VMC Camera	MLIB	0.008	0.035	330.0	9.38E-05	2.30E-04	1.81E-06
SAS #1 +Z	MLIB	0.024	0.112	325.6	7.20E-05	1.73E-04	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.6	4.81E-05	1.39E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.6	1.17E-04	5.97E-04	0.00E+00
TTC #2	MLIB	0.008	0.039	266.9	3.83E-05	8.46E-05	0.00E+00
SREM	MLIB	0.021	0.097	167.0	1.35E-04	5.88E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.4	1.42E-04	3.08E-04	8.78E-05
AAD	MLIB	0.008	0.035	343.2	4.97E-04	1.12E-03	1.66E-04
CVV external surface	MLIA	10.906	17.313	165.9	2.87E-05	6.49E-05	7.66E-11
CVV radiators	MLI	1.372	3.026	141.5	1.31E-05	1.22E-04	4.02E-14
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	232.4	1.87E-05	1.00E-04	1.19E-10
LOU WG	NO OUTGASSING	0.000	1.994	136.0	2.05E-05	7.83E-05	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	8.58E-06	3.33E-05	1.64E-07
SVM shield -X	KGOL	0.545	4.952	138.0	2.23E-05	6.20E-05	1.09E-06
SVM shield struts	MLIA	0.148	0.568	293.0	4.66E-05	2.86E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.2	5.53E-06	1.73E-05	1.29E-08
LOU radiator	Z306	0.110	1.000	136.9	1.15E-05	2.29E-05	1.10E-08
LOU +Y face	MLIA	0.090	0.157	138.2	1.33E-06	1.33E-06	1.33E-06
LOU struts	MLIA	0.021	0.082	138.2	1.76E-05	2.61E-04	0.00E+00
Sun shield struts	MLIA	1.004	3.861	270.3	4.31E-05	1.80E-04	6.06E-11
Sun shade internal	MLIA	7.859	14.554	202.1	9.00E-05	1.62E-04	1.78E-05
Sun shade external	RTVS	3.347	14.554	278.1	1.35E-05	4.59E-05	0.00E+00
Sun Shield internal	MLIA	5.760	10.665	270.1	2.18E-04	2.66E-04	1.27E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.37E-05	8.23E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.1	5.71E-05	1.32E-04	6.01E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.1	5.28E-05	1.06E-04	2.26E-05
M1 support struts	ALU	0.157	1.275	79.0	7.85E-06	4.84E-05	7.35E-13
M1 frame	MLIA	0.976	1.775	79.0	1.01E-05	4.79E-05	2.16E-14
M1 active side	NO OUTGASSING	0.000	10.380	87.9	4.61E-06	4.86E-06	4.37E-06
M1 lateral side 1	MLIA	0.192	5.052	87.9	2.09E-05	5.17E-05	3.41E-12
M1 lower surface	KALU	1.571	6.892	133.0	7.17E-06	2.87E-05	2.72E-16
M1 lateral side 2	KALU	0.267	7.018	122.0	1.29E-05	2.41E-05	1.05E-12
M2 support	KALU	0.122	1.584	87.9	3.69E-06	2.28E-05	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	2.37E-07	6.27E-07	2.39E-08
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	4.52E-08	1.22E-07	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/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75.124	9.763	276.1	4.45E-04	1.30E-03	4.11E-06
SVM upper panel	MLIA	3.894	10.116	314.0	7.64E-05	1.33E-04	4.63E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.42E-04	2.28E-04	7.90E-05
VMC Camera	MLIB	0.008	0.035	330.1	2.96E-04	5.97E-04	1.07E-05
SAS #1 +Z	MLIB	0.024	0.112	326.0	2.43E-04	1.16E-03	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.0	7.87E-05	1.76E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.0	6.67E-04	5.04E-03	0.00E+00
TTC #2	MLIB	0.008	0.039	266.0	3.67E-04	1.25E-03	0.00E+00
SREM	MLIB	0.021	0.097	167.0	7.91E-05	2.11E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.0	8.26E-04	1.29E-03	8.97E-06
AAD	MLIB	0.008	0.035	343.0	2.78E-03	1.08E-02	6.75E-04
CVV external surface	MLIA	10.906	17.313	165.9	2.74E-05	5.09E-05	8.27E-11
CVV radiators	MLI	1.372	3.026	141.0	3.21E-05	1.90E-04	1.81E-09
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	233.0	1.95E-05	8.09E-05	1.76E-06
LOU WG	NO OUTGASSING	0.000	0.098	136.0	2.34E-05	1.22E-04	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	8.17E-06	2.67E-05	5.85E-08
SVM shield -X	KGOL	0.545	4.952	138.0	2.25E-05	6.23E-05	1.03E-06
SVM shield struts	MLIA	0.148	0.568	293.0	4.33E-05	3.70E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.0	1.92E-05	7.55E-05	2.90E-08
LOU radiator	Z306	0.110	1.000	138.0	4.93E-06	9.85E-06	9.64E-09
LOU +Y face	MLIA	0.090	0.157	138.0	8.61E-08	8.61E-08	8.61E-08
LOU struts	MLIA	0.021	0.082	139.0	5.02E-06	2.53E-05	3.53E-09
Sun shield struts	MLIA	1.004	3.861	270.0	3.98E-05	2.20E-04	1.77E-11
Sun Shade internal	MLIA	7.859	14.554	202.1	3.49E-05	1.63E-04	0.00E+00
Sun shade external	RTVS	3.347	14.554	278.1	8.26E-05	2.53E-04	0.00E+00
Sun shield internal	MLIA	5.760	10.665	270.1	2.16E-04	2.65E-04	1.30E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.29E-05	7.96E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.0	6.10E-05	1.30E-04	3.03E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.0	5.11E-05	1.25E-04	2.78E-05
M1 support struts	ALU	0.157	1.275	79.0	7.24E-06	3.91E-05	5.82E-10
M1 frame	MLIA	0.976	1.775	79.0	1.46E-05	8.37E-05	0.00E+00
M1 active side	NO OUTGASSING	0.000	10.380	88.0	2.43E-06	4.43E-06	4.31E-07
M1 lateral side 1	MLIA	0.192	5.052	79.0	1.81E-05	3.90E-05	3.56E-12
M1 lower surface	KALU	1.571	6.892	133.0	6.84E-06	2.74E-05	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	122.0	8.48E-06	1.58E-05	9.75E-13
M2 support	KALU	0.122	1.584	79.0	4.37E-06	2.07E-05	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	1.43E-07	3.97E-07	9.81E-11
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	3.15E-08	8.27E-08	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/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLIB	1.847	8.551	260.0	8.56E-05	2.27E-04	1.12E-06
SVM Panel radiators	Z306	0.105	1.223	310.9	3.91E-05	5.68E-05	2.83E-05
SVM upper panel	MLIA	3.894	10.116	314.4	7.15E-05	1.10E-04	4.75E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.29E-04	1.29E-04	1.29E-04
VMC Camera	MLIB	0.008	0.035	330.0	9.43E-05	2.31E-04	1.82E-06
SAS #1 +Z	MLIB	0.024	0.112	325.6	7.23E-05	1.74E-04	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.6	5.30E-05	1.51E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.6	1.17E-04	5.97E-04	0.00E+00
TTC #2	MLIB	0.008	0.039	266.9	3.96E-05	8.46E-05	0.00E+00
SREM	MLIB	0.021	0.097	167.0	1.57E-04	7.06E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.4	1.42E-04	3.09E-04	8.80E-05
AAD	MLIB	0.008	0.035	343.2	4.97E-04	1.12E-03	1.66E-04
CVV external surface	MLIA	10.906	17.313	165.9	3.11E-05	7.13E-05	1.32E-10
CVV radiators	MLI	1.372	3.026	141.5	1.62E-05	1.54E-04	6.81E-14
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	232.4	1.94E-05	1.02E-04	1.30E-10
LOU WG	NO OUTGASSING	0.000	1.994	136.0	2.06E-05	7.89E-05	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	9.67E-06	3.79E-05	1.72E-07
SVM shield -X	KGOL	0.545	4.952	138.0	2.25E-05	6.24E-05	1.10E-06
SVM shield struts	MLIA	0.148	0.568	293.0	4.70E-05	2.86E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.2	5.87E-06	1.90E-05	2.02E-08
LOU radiator	Z306	0.110	1.000	136.9	1.16E-05	2.32E-05	1.88E-08
LOU +Y face	MLIA	0.090	0.157	138.2	1.34E-06	1.34E-06	1.34E-06
LOU struts	MLIA	0.021	0.082	138.2	1.77E-05	2.62E-04	0.00E+00
Sun shield struts	MLIA	1.004	3.861	270.3	4.47E-05	1.81E-04	1.04E-10
Sun shade internal	MLIA	7.859	14.554	202.1	1.14E-04	2.02E-04	2.52E-05
Sun shade external	RTVS	3.347	14.554	278.1	1.86E-05	6.47E-05	0.00E+00
Sun Shield internal	MLIA	5.760	10.665	270.1	2.19E-04	2.68E-04	1.27E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.37E-05	8.24E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.1	5.95E-05	1.33E-04	6.12E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.1	5.29E-05	1.06E-04	2.27E-05
M1 support struts	ALU	0.157	1.275	79.0	8.21E-06	4.85E-05	1.23E-12
M1 frame	MLIA	0.976	1.775	79.0	1.11E-05	5.35E-05	4.11E-14
M1 active side	NO OUTGASSING	0.000	10.380	87.9	6.49E-06	6.86E-06	6.11E-06
M1 lateral side 1	MLIA	0.192	5.052	87.9	2.48E-05	5.47E-05	5.71E-12
M1 lower surface	KALU	1.571	6.892	133.0	7.71E-06	3.09E-05	4.54E-16
M1 lateral side 2	KALU	0.267	7.018	122.0	1.33E-05	2.49E-05	1.88E-12
M2 support	KALU	0.122	1.584	87.9	5.23E-06	3.22E-05	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	3.33E-07	8.85E-07	3.09E-08
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	6.03E-08	1.62E-07	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/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75.124	9.763	276.1	4.56E-04	1.30E-03	6.91E-06
SVM upper panel	MLIA	3.894	10.116	314.0	7.70E-05	1.33E-04	4.66E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.43E-04	2.29E-04	7.94E-05
VMC Camera	MLIB	0.008	0.035	330.1	2.96E-04	5.97E-04	1.07E-05
SAS #1 +Z	MLIB	0.024	0.112	326.0	2.53E-04	1.16E-03	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.0	9.18E-05	1.96E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.0	6.67E-04	5.04E-03	0.00E+00
TTC #2	MLIB	0.008	0.039	266.0	3.70E-04	1.25E-03	0.00E+00
SREM	MLIB	0.021	0.097	167.0	9.36E-05	2.28E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.0	8.26E-04	1.29E-03	9.00E-06
AAD	MLIB	0.008	0.035	343.0	2.78E-03	1.08E-02	6.75E-04
CVV external surface	MLIA	10.906	17.313	165.9	2.98E-05	5.17E-05	1.43E-10
CVV radiators	MLI	1.372	3.026	141.0	3.79E-05	2.49E-04	3.10E-09
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	233.0	2.03E-05	8.24E-05	1.91E-06
LOU WG	NO OUTGASSING	0.000	0.098	136.0	2.35E-05	1.22E-04	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	9.70E-06	3.18E-05	6.35E-08
SVM shield -X	KGOL	0.545	4.952	138.0	2.35E-05	6.28E-05	1.04E-06
SVM shield struts	MLIA	0.148	0.568	293.0	4.37E-05	3.71E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.0	1.96E-05	7.56E-05	4.57E-08
LOU radiator	Z306	0.110	1.000	138.0	4.96E-06	9.91E-06	1.65E-08
LOU +Y face	MLIA	0.090	0.157	138.0	8.84E-08	8.84E-08	8.84E-08
LOU struts	MLIA	0.021	0.082	139.0	5.04E-06	2.54E-05	5.45E-09
Sun shield struts	MLIA	1.004	3.861	270.0	4.18E-05	2.20E-04	3.05E-11
Sun Shade internal	MLIA	7.859	14.554	202.1	4.66E-05	2.06E-04	0.00E+00
Sun shade external	RTVS	3.347	14.554	278.1	9.87E-05	2.54E-04	0.00E+00
Sun shield internal	MLIA	5.760	10.665	270.1	2.17E-04	2.66E-04	1.31E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.29E-05	7.97E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.0	6.28E-05	1.33E-04	3.08E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.0	5.13E-05	1.26E-04	2.79E-05
M1 support struts	ALU	0.157	1.275	79.0	7.77E-06	4.20E-05	9.97E-10
M1 frame	MLIA	0.976	1.775	79.0	1.70E-05	1.14E-04	1.62E-14
M1 active side	NO OUTGASSING	0.000	10.380	88.0	3.43E-06	6.25E-06	6.08E-07
M1 lateral side 1	MLIA	0.192	5.052	79.0	2.22E-05	4.19E-05	5.96E-12
M1 lower surface	KALU	1.571	6.892	133.0	7.50E-06	3.00E-05	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	122.0	8.99E-06	1.63E-05	1.80E-12
M2 support	KALU	0.122	1.584	79.0	6.17E-06	2.92E-05	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	2.02E-07	5.60E-07	9.83E-11
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	4.14E-08	1.08E-07	0.00E+00

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

The differences observed between simulations performed without considering the internal SVM materials and with consideration of the internal SVM materials are due the numerical method.

Indeed, the ray –tracing method used by the ESABASE software adapts the ray number in function of elements which have the bigger amount of the outgassing materials.

A test has been done by multiply the number of rays and no significant difference has been observed onto sensitive surfaces such as M1 and M2 mirrors. The SVM internal materials have no influence on the M1 and M2 mirror contamination levels.

7.1.4.1.2.4.3 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 except for the mirrors which are considered as clean after the heating phase. 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 7.1.4.1.2.4.2).

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

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (g/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLIB	1.847	8.551	260.0	7.00E-05	2.21E-04	8.14E-08
SVM Panel radiators	Z306	0.105	1.223	310.9	9.70E-06	1.93E-05	8.28E-07
SVM upper panel	MLIA	3.894	10.116	314.4	6.51E-05	1.01E-04	4.16E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.22E-04	1.22E-04	1.22E-04
VMC Camera	MLIB	0.008	0.035	330.0	8.98E-05	2.19E-04	1.70E-06
SAS #1 +Z	MLIB	0.024	0.112	325.6	6.93E-05	1.68E-04	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.6	2.21E-05	7.11E-05	0.00E+00
TTC #1	MLIB	0.008	0.039	375.6	1.14E-04	5.85E-04	0.00E+00
TTC #2	MLIB	0.008	0.039	266.9	3.03E-05	8.22E-05	0.00E+00
SREM	MLIB	0.021	0.097	167.0	2.91E-05	8.94E-05	0.00E+00
MGA	MLIB	0.009	0.041	406.4	1.38E-04	3.00E-04	8.47E-05
AAD	MLIB	0.008	0.035	343.2	4.85E-04	1.09E-03	1.62E-04
CVV external surface	MLIA	10.906	17.313	165.9	2.43E-05	6.31E-05	9.50E-09
CVV radiators	MLI	1.372	3.026	141.5	2.97E-06	2.47E-05	0.00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	232.4	1.18E-05	8.48E-05	2.78E-12
LOU WG	NO OUTGASSING	0.000	1.994	136.0	1.88E-05	6.92E-05	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	3.86E-06	1.65E-05	4.62E-07
SVM shield -X	KGOL	0.545	4.952	138.0	1.99E-05	5.63E-05	9.94E-07
SVM shield struts	MLIA	0.148	0.568	293.0	4.15E-05	2.70E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.2	4.97E-06	1.47E-05	2.73E-09
LOU radiator	Z306	0.110	1.000	136.9	1.10E-05	2.19E-05	5.59E-10
LOU +Y face	MLIA	0.090	0.157	138.2	3.62E-06	3.62E-06	3.62E-06
LOU struts	MLIA	0.021	0.082	138.2	1.71E-05	2.57E-04	0.00E+00
Sun shield struts	MLIA	1.004	3.861	270.3	3.96E-05	1.78E-04	3.25E-08
Sun shade internal	MLIA	7.859	14.554	202.1	2.52E-05	7.58E-05	8.36E-07
Sun shade external	RTVS	3.347	14.554	278.1	1.16E-06	8.24E-06	0.00E+00
Sun Shield internal	MLIA	5.760	10.665	270.1	2.15E-04	2.61E-04	1.24E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.30E-05	8.12E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.1	5.35E-05	1.30E-04	5.67E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.1	5.05E-05	1.01E-04	2.13E-05
M1 support struts	ALU	0.157	1.275	79.0	4.52E-05	1.92E-04	3.72E-09
M1 frame	MLIA	0.976	1.775	79.0	2.96E-05	9.80E-05	3.86E-06
M1 active side	NO OUTGASSING	0.000	10.380	313.0	8.90E-07	1.67E-06	1.11E-07
M1 lateral side 1	MLIA	0.192	5.052	313.0	6.58E-06	1.71E-05	5.75E-08
M1 lower surface	KALU	1.571	6.892	313.0	1.60E-05	3.89E-05	5.97E-09
M1 lateral side 2	KALU	0.267	7.018	313.0	3.59E-05	5.45E-05	7.65E-06
M2 support	KALU	0.122	1.584	313.0	3.32E-06	1.31E-05	9.53E-11
M2 upper cylinder	KALU	0.042	0.549	313.0	3.92E-06	7.92E-06	1.90E-09
M2 lower cylinder	NO OUTGASSING	0.000	0.314	313.0	4.34E-06	1.11E-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/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75.124	9.763	276.1	4.15E-04	1.29E-03	1.00E-07
SVM upper panel	MLIA	3.894	10.116	314.0	6.97E-05	1.25E-04	4.20E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.35E-04	2.17E-04	7.49E-05
VMC Camera	MLIB	0.008	0.035	330.1	2.90E-04	5.93E-04	1.01E-05
SAS #1 +Z	MLIB	0.024	0.112	326.0	2.03E-04	1.15E-03	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.0	2.99E-05	1.10E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.0	6.66E-04	5.04E-03	0.00E+00
TTC #2	MLIB	0.008	0.039	266.0	3.56E-04	1.25E-03	0.00E+00
SREM	MLIB	0.021	0.097	167.0	3.00E-05	1.50E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.0	8.26E-04	1.29E-03	8.57E-06
AAD	MLIB	0.008	0.035	343.0	2.77E-03	1.08E-02	6.72E-04
CVV external surface	MLIA	10.906	17.313	165.9	2.23E-05	4.38E-05	1.52E-06
CVV radiators	MLI	1.372	3.026	141.0	1.21E-05	1.51E-04	1.81E-10
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	233.0	1.18E-05	6.80E-05	8.98E-08
LOU WG	NO OUTGASSING	0.000	0.098	136.0	2.17E-05	1.13E-04	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	2.66E-06	8.95E-06	3.46E-09
SVM shield -X	KGOL	0.545	4.952	138.0	1.88E-05	5.65E-05	9.57E-07
SVM shield struts	MLIA	0.148	0.568	293.0	3.81E-05	3.49E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.0	1.96E-05	7.60E-05	2.17E-09
LOU radiator	Z306	0.110	1.000	138.0	4.86E-06	9.72E-06	1.56E-10
LOU +Y face	MLIA	0.090	0.157	138.0	8.17E-08	8.17E-08	8.17E-08
LOU struts	MLIA	0.021	0.082	139.0	5.45E-06	3.58E-05	3.17E-10
Sun shield struts	MLIA	1.004	3.861	270.0	3.55E-05	2.17E-04	6.69E-09
Sun Shade internal	MLIA	7.859	14.554	202.1	4.48E-06	3.75E-05	0.00E+00
Sun shade external	RTVS	3.347	14.554	278.1	3.64E-05	2.51E-04	0.00E+00
Sun shield internal	MLIA	5.760	10.665	270.1	2.13E-04	2.63E-04	1.26E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.22E-05	7.85E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.0	5.87E-05	1.25E-04	2.87E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.0	4.90E-05	1.19E-04	2.65E-05
M1 support struts	ALU	0.157	1.275	79.0	3.54E-05	1.07E-04	5.70E-10
M1 frame	MLIA	0.976	1.775	313.0	3.52E-05	1.27E-04	1.27E-05
M1 active side	NO OUTGASSING	0.000	10.380	313.0	5.80E-07	1.15E-06	9.51E-09
M1 lateral side 1	MLIA	0.192	5.052	313.0	6.33E-06	1.84E-05	2.82E-08
M1 lower surface	KALU	1.571	6.892	313.0	1.47E-05	3.57E-05	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	313.0	3.05E-05	4.78E-05	8.12E-06
M2 support	KALU	0.122	1.584	313.0	4.98E-06	2.18E-05	5.76E-07
M2 upper cylinder	KALU	0.042	0.549	313.0	4.63E-06	7.63E-06	1.15E-06
M2 lower cylinder	NO OUTGASSING	0.000	0.314	313.0	2.42E-06	5.66E-06	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	MLIB	1.847	8.551	260.0	260.0	0.0	3.35E-07	3.35E-08	1.00E-07	2.07E-09
SVM Panel radiators	Z306	0.105	1.223	310.9	310.9	0.0	5.50E-08	5.50E-09	2.00E-08	5.00E-10
SVM upper panel	MLIA	3.894	10.116	314.4	314.4	0.0	1.36E-06	1.36E-07	2.00E-07	3.00E-08
SVM lower panel	MLIB	2.185	10.116	317.1	317.1	0.0	1.50E-07	1.50E-08	1.50E-08	1.50E-08
VMC Camera	MLIB	0.008	0.035	330.0	330.0	0.0	-3.00E-08	-3.00E-09	1.00E-07	-1.80E-08
SAS #1 +Z	MLIB	0.024	0.112	325.6	325.6	0.0	-3.32E-07	-3.32E-08	0.00E+00	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.6	284.6	0.0	-3.33E-08	-3.33E-09	5.00E-08	0.00E+00
TTC #1	MLIB	0.008	0.039	375.6	375.6	0.0	-3.33E-08	-3.33E-09	3.00E-07	0.00E+00
TTC #2	MLIB	0.008	0.039	266.9	266.9	0.0	-2.26E-07	-2.26E-08	-5.00E-08	0.00E+00
SREM	MLIB	0.021	0.097	167.0	167.0	0.0	-2.67E-07	-2.67E-08	-3.00E-08	0.00E+00
MGA	MLIB	0.009	0.041	406.4	406.4	0.0	-8.67E-07	-8.67E-08	-1.00E-07	-1.00E-08
AAD	MLIB	0.008	0.035	343.2	343.2	0.0	3.33E-06	3.33E-07	1.00E-06	0.00E+00
CVV external surface	MLIA	10.906	17.313	165.9	165.9	0.0	4.14E-05	4.14E-06	5.60E-07	9.50E-09
CVV radiators	MLI	1.372	3.026	141.5	141.5	0.0	2.77E-06	2.77E-07	2.30E-07	0.00E+00
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	232.4	232.4	0.0	-3.42E-08	-3.42E-09	-5.00E-08	-1.70E-14
LOU WG	NO OUTGASSING	0.000	1.994	136.0	136.0	0.0	-7.03E-08	-7.03E-09	-2.00E-08	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	138.0	0.0	1.60E-06	1.60E-07	2.80E-07	3.86E-07
SVM shield -X	KGOL	0.545	4.952	138.0	138.0	0.0	-2.39E-06	-2.39E-07	-5.00E-08	-4.10E-09
SVM shield struts	MLIA	0.148	0.568	293.0	293.0	0.0	6.55E-08	6.55E-09	2.00E-07	0.00E+00
LOU	MLIA	0.217	0.508	138.2	138.2	0.0	2.87E-06	2.87E-07	1.42E-06	-1.84E-10
LOU radiator	Z306	0.110	1.000	136.9	136.9	0.0	8.02E-07	8.02E-08	1.60E-07	3.81E-10
LOU +Y face	MLIA	0.090	0.157	138.2	138.2	0.0	2.32E-05	2.32E-06	2.32E-06	2.32E-06
LOU struts	MLIA	0.021	0.082	138.2	138.2	0.0	3.50E-07	3.50E-08	2.00E-07	0.00E+00
Sun shield struts	MLIA	1.004	3.861	270.3	270.3	0.0	8.42E-06	8.42E-07	3.00E-07	3.25E-08
Sun shade internal	MLIA	7.859	14.554	202.1	202.1	0.0	2.08E-05	2.08E-06	6.10E-06	4.42E-07
Sun shade external	RTVS	3.347	14.554	278.1	278.1	0.0	-1.00E-08	-1.00E-09	1.00E-09	0.00E+00
Sun Shield internal	MLIA	5.760	10.665	270.1	270.1	0.0	1.87E-05	1.87E-06	1.70E-06	9.00E-07
Sun shield external	RTVS	2.453	10.665	396.1	396.1	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.1	278.1	0.0	2.87E-05	2.87E-06	5.00E-07	-3.80E-09
Sun Shield lower struts	MLIA	0.041	0.074	278.1	278.1	0.0	-2.67E-07	-2.67E-08	0.00E+00	-3.00E-08
M1 support struts	ALU	0.157	1.275	79.0	79.0	0.0	3.85E-04	3.85E-05	1.44E-04	3.72E-09
M1 frame	MLIA	0.976	1.775	79.0	79.0	0.0	2.19E-04	2.19E-05	5.85E-05	3.86E-06
M1 active side	NO OUTGASSING	0.000	10.380	313.0	87.9	225.1	-1.64E-06	-1.64E-07	-2.20E-07	-1.08E-07
M1 lateral side 1	MLIA	0.192	5.052	313.0	87.9	225.1	-1.14E-04	-1.14E-05	-4.44E-05	0.00E+00
M1 lower surface	KALU	1.571	6.892	313.0	133.0	180.0	-5.78E-05	-5.78E-06	-2.31E-05	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	313.0	122.0	191.0	-1.21E-04	-1.21E-05	-2.21E-05	0.00E+00
M2 support	KALU	0.122	1.584	313.0	87.9	225.1	-8.20E-07	-8.20E-08	-5.05E-07	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	313.0	87.0	226.0	-6.68E-08	-6.68E-09	-1.39E-08	-1.57E-09
M2 lower cylinder	NO OUTGASSING	0.000	0.314	313.0	87.0	226.0	-9.00E-08	-9.00E-09	-2.67E-08	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 (kg/m²)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75.124	9.763	276.1	276.1	0.0	1.07E-06	1.07E-07	0.00E+00	8.90E-10
SVM upper panel	MLIA	3.894	10.116	314.0	314.0	0.0	1.67E-06	1.67E-07	4.00E-07	1.00E-08
SVM lower panel	MLIB	2.185	10.116	317.1	317.1	0.0	-2.50E-08	-2.50E-09	1.00E-07	-5.00E-08
VMC Camera	MLIB	0.008	0.035	330.1	330.1	0.0	-8.33E-07	-8.33E-08	-2.00E-07	0.00E+00
SAS #1 +Z	MLIB	0.024	0.112	326.0	326.0	0.0	5.00E-08	5.00E-09	0.00E+00	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.0	284.0	0.0	5.00E-08	5.00E-09	0.00E+00	0.00E+00
TTC #1	MLIB	0.008	0.039	375.0	375.0	0.0	-6.67E-08	-6.67E-09	1.00E-06	0.00E+00
TTC #2	MLIB	0.008	0.039	266.0	266.0	0.0	1.36E-07	1.36E-08	0.00E+00	0.00E+00
SREM	MLIB	0.021	0.097	167.0	167.0	0.0	-1.73E-07	-1.73E-08	-1.00E-07	0.00E+00
MGA	MLIB	0.009	0.041	406.0	406.0	0.0	-3.39E-06	-3.39E-07	0.00E+00	-1.60E-08
AAD	MLIB	0.008	0.035	343.0	343.0	0.0	-2.03E-05	-2.03E-06	-1.00E-05	-4.00E-07
CVV external surface	MLIA	10.906	17.313	165.9	165.9	0.0	3.39E-05	3.39E-06	-1.00E-08	1.52E-06
CVV radiators	MLI	1.372	3.026	141.0	141.0	0.0	1.69E-06	1.69E-07	-1.00E-06	1.51E-10
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	233.0	233.0	0.0	1.14E-08	1.14E-09	0.00E+00	6.00E-11
LOU WG	NO OUTGASSING	0.000	0.098	136.0	136.0	0.0	2.29E-07	2.29E-08	1.00E-07	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	138.0	0.0	5.50E-06	5.50E-07	2.43E-07	-1.10E-11
SVM shield -X	KGOL	0.545	4.952	138.0	138.0	0.0	-1.70E-06	-1.70E-07	6.00E-08	-3.70E-09
SVM shield struts	MLIA	0.148	0.568	293.0	293.0	0.0	6.82E-08	6.82E-09	2.00E-07	0.00E+00
LOU	MLIA	0.217	0.508	138.0	138.0	0.0	1.38E-05	1.38E-06	1.21E-06	-1.20E-11
LOU radiator	Z306	0.110	1.000	138.0	138.0	0.0	1.70E-06	1.70E-07	3.41E-07	0.00E+00
LOU +Y face	MLIA	0.090	0.157	138.0	138.0	0.0	-3.00E-10	-3.00E-11	-3.00E-11	-3.00E-11
LOU struts	MLIA	0.021	0.082	139.0	139.0	0.0	5.25E-06	5.25E-07	1.09E-05	2.61E-10
Sun shield struts	MLIA	1.004	3.861	270.0	270.0	0.0	9.08E-06	9.08E-07	2.00E-07	6.69E-09
Sun Shade internal	MLIA	7.859	14.554	202.1	202.1	0.0	2.15E-08	2.15E-09	1.00E-08	0.00E+00
Sun shade external	RTVS	3.347	14.554	278.1	278.1	0.0	5.46E-06	5.46E-07	1.10E-06	0.00E+00
Sun shield internal	MLIA	5.760	10.665	270.1	270.1	0.0	1.87E-05	1.87E-06	3.50E-06	1.00E-06
Sun shield external	RTVS	2.453	10.665	396.1	396.1	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.0	278.0	0.0	2.56E-05	2.56E-06	2.10E-06	-1.00E-09
Sun Shield lower struts	MLIA	0.041	0.074	278.0	278.0	0.0	7.89E-07	7.89E-08	9.00E-07	-3.00E-08
M1 support struts	ALU	0.157	1.275	79.0	79.0	0.0	3.07E-04	3.07E-05	7.74E-05	5.60E-10
M1 frame	MLIA	0.976	1.775	313.0	79.0	234.0	2.65E-04	2.65E-05	7.87E-05	1.27E-05
M1 active side	NO OUTGASSING	0.000	10.380	313.0	88.0	225.0	-5.52E-07	-5.52E-08	-1.01E-07	-9.55E-09
M1 lateral side 1	MLIA	0.192	5.052	313.0	79.0	234.0	-8.44E-05	-8.44E-06	-3.20E-05	0.00E+00
M1 lower surface	KALU	1.571	6.892	313.0	133.0	180.0	-5.10E-05	-5.10E-06	-2.04E-05	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	313.0	122.0	191.0	-7.11E-05	-7.11E-06	-1.40E-05	0.00E+00
M2 support	KALU	0.122	1.584	313.0	79.0	234.0	-9.69E-07	-9.69E-08	-4.59E-07	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	313.0	87.0	226.0	-3.21E-08	-3.21E-09	-8.80E-09	-9.65E-11
M2 lower cylinder	NO OUTGASSING	0.000	0.314	313.0	87.0	226.0	-7.91E-08	-7.91E-09	-2.35E-08	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 (kg/m²)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	MLIB	1.847	8.551	260.0	8.25E-04	8.25E-05	2.27E-04	6.94E-07
SVM Panel radiators	Z306	0.105	1.223	310.9	3.21E-04	3.21E-05	4.93E-05	2.03E-05
SVM upper panel	MLIA	3.894	10.116	314.4	7.11E-04	7.11E-05	1.09E-04	4.71E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.29E-03	1.29E-04	1.29E-04	1.29E-04
VMC Camera	MLIB	0.008	0.035	330.0	9.38E-04	9.38E-05	2.30E-04	1.79E-06
SAS #1 +Z	MLIB	0.024	0.112	325.6	7.20E-04	7.20E-05	1.73E-04	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.6	4.81E-04	4.81E-05	1.39E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.6	1.17E-03	1.17E-04	5.97E-04	0.00E+00
TTC #2	MLIB	0.008	0.039	266.9	3.83E-04	3.83E-05	8.45E-05	0.00E+00
SREM	MLIB	0.021	0.097	167.0	1.35E-03	1.35E-04	5.88E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.4	1.42E-03	1.42E-04	3.08E-04	8.78E-05
AAD	MLIB	0.008	0.035	343.2	4.98E-03	4.98E-04	1.12E-03	1.66E-04
CVV external surface	MLIA	10.906	17.313	165.9	3.29E-04	3.29E-05	6.55E-05	9.58E-09
CVV radiators	MLI	1.372	3.026	141.5	1.33E-04	1.33E-05	1.23E-04	4.02E-14
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	232.4	1.87E-04	1.87E-05	1.00E-04	1.19E-10
LOU WG	NO OUTGASSING	0.000	1.994	136.0	2.05E-04	2.05E-05	7.82E-05	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	8.74E-05	8.74E-06	3.36E-05	5.51E-07
SVM shield -X	KGOL	0.545	4.952	138.0	2.21E-04	2.21E-05	6.20E-05	1.09E-06
SVM shield struts	MLIA	0.148	0.568	293.0	4.66E-04	4.66E-05	2.86E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.2	5.81E-05	5.81E-06	1.88E-05	1.28E-08
LOU radiator	Z306	0.110	1.000	136.9	1.15E-04	1.15E-05	2.31E-05	1.14E-08
LOU +Y face	MLIA	0.090	0.157	138.2	3.65E-05	3.65E-06	3.65E-06	3.65E-06
LOU struts	MLIA	0.021	0.082	138.2	1.76E-04	1.76E-05	2.62E-04	0.00E+00
Sun shield struts	MLIA	1.004	3.861	270.3	4.40E-04	4.40E-05	1.81E-04	3.26E-08
Sun shade internal	MLIA	7.859	14.554	202.1	9.21E-04	9.21E-05	1.68E-04	1.82E-05
Sun shade external	RTVS	3.347	14.554	278.1	1.35E-04	1.35E-05	4.59E-05	0.00E+00
Sun Shield internal	MLIA	5.760	10.665	270.1	2.20E-03	2.20E-04	2.68E-04	1.28E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.37E-04	5.37E-05	8.23E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.1	6.00E-04	6.00E-05	1.33E-04	5.97E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.1	5.27E-04	5.27E-05	1.06E-04	2.26E-05
M1 support struts	ALU	0.157	1.275	79.0	4.63E-04	4.63E-05	1.92E-04	3.72E-09
M1 frame	MLIA	0.976	1.775	79.0	3.20E-04	3.20E-05	1.06E-04	3.86E-06
M1 active side	NO OUTGASSING	0.000	10.380	87.9	4.45E-05	4.45E-06	4.64E-06	4.26E-06
M1 lateral side 1	MLIA	0.192	5.052	87.9	9.50E-05	9.50E-06	7.32E-06	3.41E-12
M1 lower surface	KALU	1.571	6.892	133.0	1.40E-05	1.40E-06	5.58E-06	2.72E-16
M1 lateral side 2	KALU	0.267	7.018	122.0	8.57E-06	8.57E-07	2.01E-06	1.05E-12
M2 support	KALU	0.122	1.584	87.9	3.61E-05	3.61E-06	2.23E-05	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	2.30E-06	2.30E-07	6.13E-07	2.24E-08
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	3.62E-07	3.62E-08	9.52E-08	0.00E+00

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

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (kg/m²)	Average contamination (g/cm²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
SVM lateral panels	CFRP	75.124	9.763	276.1	4.45E-03	4.45E-04	1.30E-03	4.11E-06
SVM upper panel	MLIA	3.894	10.116	314.0	7.65E-04	7.65E-05	1.33E-04	4.63E-05
SVM lower panel	MLIB	2.185	10.116	317.1	1.42E-03	1.42E-04	2.28E-04	7.89E-05
VMC Camera	MLIB	0.008	0.035	330.1	2.95E-03	2.95E-04	5.97E-04	1.07E-05
SAS #1 +Z	MLIB	0.024	0.112	326.0	2.43E-03	2.43E-04	1.16E-03	0.00E+00
SAS #2 -Z	MLIB	0.024	0.112	284.0	7.87E-04	7.87E-05	1.76E-04	0.00E+00
TTC #1	MLIB	0.008	0.039	375.0	6.67E-03	6.67E-04	5.04E-03	0.00E+00
TTC #2	MLIB	0.008	0.039	266.0	3.67E-03	3.67E-04	1.25E-03	0.00E+00
SREM	MLIB	0.021	0.097	167.0	7.91E-04	7.91E-05	2.11E-04	0.00E+00
MGA	MLIB	0.009	0.041	406.0	8.26E-03	8.26E-04	1.29E-03	8.95E-06
AAD	MLIB	0.008	0.035	343.0	2.77E-02	2.77E-03	1.08E-02	6.74E-04
CVV external surface	MLIA	10.906	17.313	165.9	3.08E-04	3.08E-05	5.09E-05	1.52E-06
CVV radiators	MLI	1.372	3.026	141.0	3.22E-04	3.22E-05	1.89E-04	1.96E-09
CVV struts (PLM-SVM I/F struts)	MLIA	0.649	2.494	233.0	1.95E-04	1.95E-05	8.09E-05	1.76E-06
LOU WG	NO OUTGASSING	0.000	0.098	136.0	2.34E-04	2.34E-05	1.22E-04	0.00E+00
SVM shield +X	MLIA	2.723	4.952	138.0	8.72E-05	8.72E-06	2.69E-05	5.85E-08
SVM shield -X	KGOL	0.545	4.952	138.0	2.23E-04	2.23E-05	6.24E-05	1.03E-06
SVM shield struts	MLIA	0.148	0.568	293.0	4.33E-04	4.33E-05	3.70E-04	0.00E+00
LOU	MLIA	0.217	0.508	138.0	2.06E-04	2.06E-05	7.67E-05	2.90E-08
LOU radiator	Z306	0.110	1.000	138.0	5.10E-05	5.10E-06	1.02E-05	9.64E-09
LOU +Y face	MLIA	0.090	0.157	138.0	8.61E-07	8.61E-08	8.61E-08	8.61E-08
LOU struts	MLIA	0.021	0.082	139.0	5.55E-05	5.55E-06	3.62E-05	3.79E-09
Sun shield struts	MLIA	1.004	3.861	270.0	4.07E-04	4.07E-05	2.20E-04	6.71E-09
Sun Shade internal	MLIA	7.859	14.554	202.1	3.49E-04	3.49E-05	1.63E-04	0.00E+00
Sun shade external	RTVS	3.347	14.554	278.1	8.31E-04	8.31E-05	2.54E-04	0.00E+00
Sun shield internal	MLIA	5.760	10.665	270.1	2.18E-03	2.18E-04	2.68E-04	1.31E-04
Sun shield external	RTVS	2.453	10.665	396.1	5.29E-04	5.29E-05	7.96E-05	0.00E+00
Sun shield Stiffners (int +ext)	MLIA	4.949	8.999	278.0	6.36E-04	6.36E-05	1.32E-04	3.02E-07
Sun Shield lower struts	MLIA	0.041	0.074	278.0	5.12E-04	5.12E-05	1.26E-04	2.78E-05
M1 support struts	ALU	0.157	1.275	79.0	3.79E-04	3.79E-05	1.16E-04	1.14E-09
M1 frame	MLIA	0.976	1.775	79.0	4.11E-04	4.11E-05	1.62E-04	1.27E-05
M1 active side	NO OUTGASSING	0.000	10.380	88.0	2.95E-05	2.95E-06	5.48E-06	4.30E-07
M1 lateral side 1	MLIA	0.192	5.052	79.0	1.60E-04	1.60E-05	2.54E-05	2.82E-08
M1 lower surface	KALU	1.571	6.892	133.0	1.74E-05	1.74E-06	6.95E-06	0.00E+00
M1 lateral side 2	KALU	0.267	7.018	122.0	1.37E-05	1.37E-06	1.82E-06	9.75E-13
M2 support	KALU	0.122	1.584	79.0	4.28E-05	4.28E-06	2.02E-05	0.00E+00
M2 upper cylinder	KALU	0.042	0.549	87.0	1.40E-06	1.40E-07	3.88E-07	1.58E-12
M2 lower cylinder	NO OUTGASSING	0.000	0.314	87.0	2.36E-07	2.36E-08	5.93E-08	0.00E+00

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

7.1.4.1.3 Outgassing contamination increase assessment

- Without considering the multireflection phenomenon:

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	4.86E-06	N/A	N/A
M2	1.22E-07	N/A	N/A
LOU Windows	1.33E-06	N/A	N/A
LOU mirrors	1.73E-07	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	4.64E-06	N/A	N/A
M2	9.52E-08	N/A	N/A
LOU Windows	5.75E-06	N/A	N/A
LOU mirrors	7.48E-07	N/A	N/A

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

- With consideration of the multireflection phenomenon:

In order to take into account more precisely the contamination physical phenomenon, the multireflexions of contamination on surfaces have been consider only on the sensitive surfaces as mirrors and LOU windows.

By taking into consideration also one reflection (the more important w.r.t. the others) in addition to 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 increased. Details of the reflection contribution are summarised table N°7.1-18, N°7.1-19 for LOU windows and M1 & M2 mirrors respectively and global results with heating consideration (total evaporation of the materials deposit on M1 and M2 during the first 3 weeks) are summarised in the N°7.1-20.

LOU Windows contamination level after 3.5 years due to direct outgassing element and reflection on elements				
Elements seen by the LOU windows	LOU windows contamination level after 3 weeks in transient phase (g/cm²)	Maximum LOU windows contamination level after 3.5 years in operational + transient phase (g/cm²)	Average LOU windows contamination level due to reflection (g/cm²)	Average Total contamination level on the LOU windows (direct + reflections) (g/cm²)
MLI sunshield	2.02E-06	-	1.82E-05	-
MLI sunshade	1.16E-08	-	0.00E+00	-
MLI SVM top	1.60E-09	-	0.00E+00	-
M1	0.00E+00	-	0.00E+00	-
M2	0.00E+00	-	0.00E+00	-
CVV radiators	1.25E-10	-	0.00E+00	-
LOU WG	0.00E+00	-	0.00E+00	-
MLI SVM shield	5.90E-14	-	0.00E+00	-
MLI M1	1.54E-06	-	2.22E-05	-
MLI CVV	2.12E-06	-	0.00E+00	-
LOU Struts MLI	3.18E-09	-	0.00E+00	-
LOU +Y MLI Side	9.74E-09	-	0.00E+00	-
Total:	5.71E-06	5.74E-06	4.05E-05	5.19E-05

TABLE 7.1.18: LOU test surface contamination levels due to direct flux and reflection for the operational phase and at the nominal end of life (3.5 years).

M1 & M2 mirrors contamination level after 3.5 years due to direct outgassing element and reflection on elements			
Element	Direct contamination level after 3.5 years in operational + transient phase (g/cm²)	Average contamination level due to reflection (g/cm²)	Average Total contamination level (direct + reflections) (g/cm²)
M1 Active side	4.64E-06	6.48E-06	1.11E-05
M2 Lower cylinder	9.52E-08	0.00E+00	9.52E-08

TABLE 7.1.19: M1 & M2 contamination levels due to direct flux and reflection for the operational phase and at the nominal end of life (3.5 years).

Contamination increase due to outgassing	Molecular (g/cm^2)		
	H_20	NH_3	On ground contaminants
M1	1.11E-05	N/A	N/A
M2	9.52E-08	N/A	N/A
LOU Windows	5.19E-05	N/A	N/A
LOU mirrors	6.75E-06	N/A	N/A

TABLE 7.1-20 - HERSCHEL- CONTAMINATION INCREASE DUE TO MATERIALS OUTGASSING WITH HEATING PHASE and ONE REFLEXION CONSIDERED.

7.1.4.1.4 Conclusion

The decontamination phase consists in heating the telescope during 3 weeks at a temperature of 40°C. The decontamination phase has two protective effects:

1. To Prevent the mirrors to be contaminated at the beginning of the flight, when the rest of the spacecraft outgasses
2. To bake out the heated materials (mainly the hexapods MLI) of the telescope, and thus to lower the TML at the beginning of the operationnal phase

The first phenomena is considered in the model, but only protects the telescope (M1) from 5 10-7 g/cm2. The second phenomena is not considered yet in the analysis (nor in the budgets) and is expected to protect the telescope (M1) from around 1.5 10-6g/cm2

According to first point, the contamination budget due to this phase is presented in table 7.1-21.

Contamination increase due to outgassing	Molecular (g/cm^2)		
	H_20	NH_3	On ground contaminants
M1	1.11E-05	N/A	N/A
M2	9.52E-08	N/A	N/A
LOU Windows	5.19E-05	N/A	N/A
LOU mirrors	6.75E-06	N/A	N/A

TABLE 7.1-21 - HERSCHEL- BASELINE CONTAMINATION INCREASE DUE TO MATERIALS OUTGASING WITH HEATING PHASE

The M1 contamination is mainly due to the sunshade long term outgassing.

The contamination level seen by the FPU can be assessed by considering the level seen by M1 (1.1e-05 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 § 7.1.4.2.2), which gives a contamination level of 5.4 10^{-7} g/cm2 of water on the FPU at EOL.

LOU windows contamination is mainly dominated by the indirect molecules migrations, coming from the hidden part of the sunshield and CVV, reflected on the visible part of the hot sunshield, and coming on the LOU windows.

7.1.4.2 Thruster-plume

7.1.4.2.1 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.

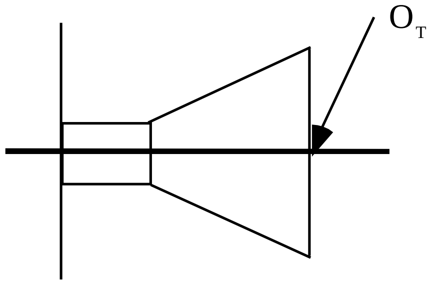


FIGURE 7.1-2 DEFINITION OF THE THRUSTER REFERENCE POINT

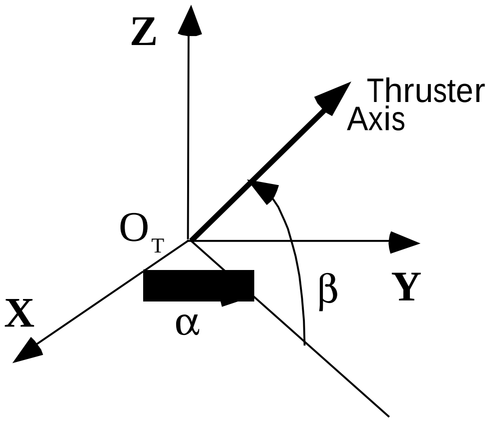


FIGURE 7.1- 3 DEFINITION OF THE THRUSTER ORIENTATION

Thruster		A1A	A2A	C1A	C2A	C3A	C4A	A1B	A2B	C1B	C2B	C3B	C4B
Coordinates of the thruster (mm)	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
	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
	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 (degrees)	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
	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

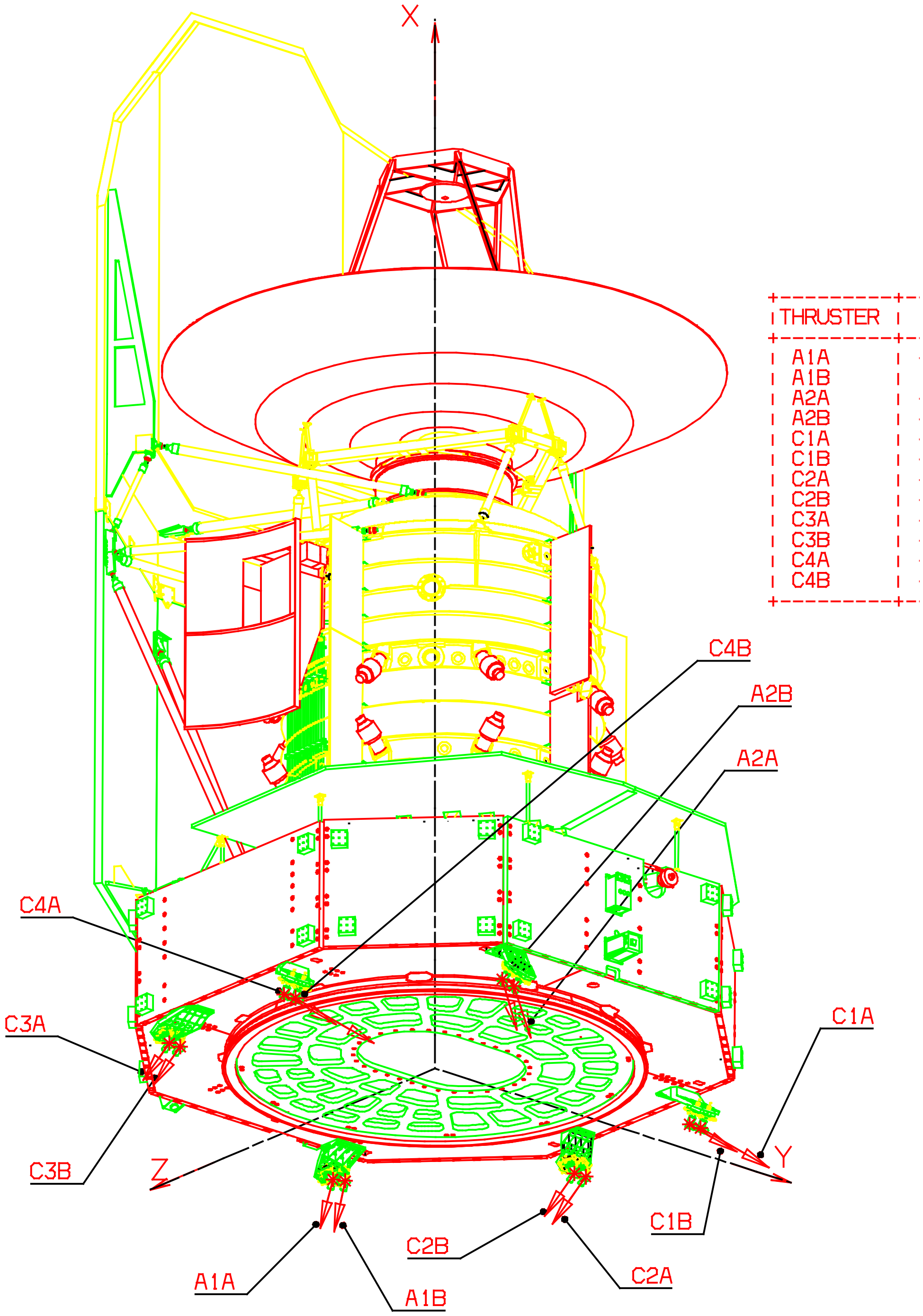


FIGURE N°7.1-4 HERSCHEL THRUSTERS DEFINITION

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	-	-	N2H4
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

7.1.4.2.2 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

Ä PICS: integrates the gaseous contaminants and the particles / droplets ones on the satellite surfaces over the satellite lifetime

Ä SURFACE: evaluates the influence of the gaseous contaminants on the properties of the satellite surfaces

Ä 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 H2O (g/cm²)	Contamination by N2 (g/cm²)	Contamination by N2H4 (g/cm²)	Contamination by NH3 (g/cm²)
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

7.1.4.2.3 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)				
	H2	H2O	N2	N2H4	NH3
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.

7.1.4.3 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.

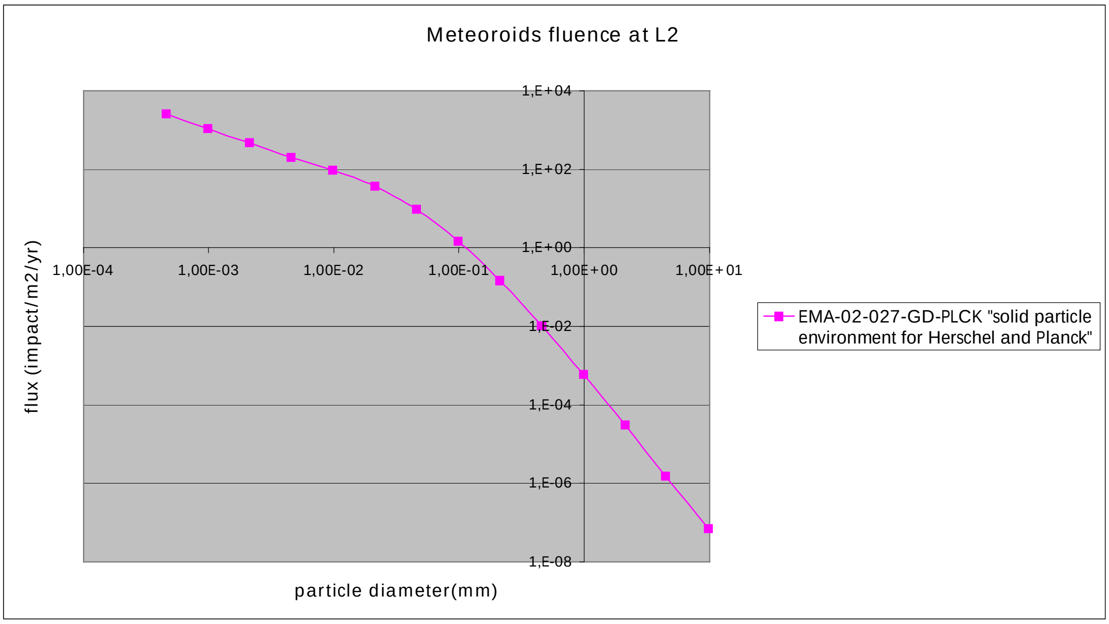
With an average particle diameter of 20µm, and a cryostat aperture of around 290mm diameter, this leads to an increase of the cryostat particulate contamination of:

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

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.

7.1.4.4 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	$31.4\ 10^{-7}$			880
Telescope PR	$6.4\ 10^{-7}$			1480
Telescope SR	$6.4\ 10^{-7}$			1480
Groove 1 (low emissivity surfaces)	0	0	$1.52\ 10^{-6}$	1000
Groove 2	0	0	$1.52\ 10^{-6}$	1000
Groove 3	0	0	$1.52\ 10^{-6}$	1000
Groove 3 and baffle external side (high emissivity surfaces)	0	0	$1.52\ 10^{-6}$	1000
Baffle (internal side)	0	0	$7.7\ 10^{-7}$	2255
spacecraft	0	0	$2\ 10^{-6}$	2495

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	$3.14\ 10^{-6}$			1945
Telescope PR	$6.4\ 10^{-7}$			1945
Telescope SR	$6.4\ 10^{-7}$			1945
Groove 1 (low emissivity surfaces)	0	0	$1.52\ 10^{-6}$	1000
Groove 2	0	0	$1.52\ 10^{-6}$	1000
Groove 3	0	0	$1.52\ 10^{-6}$	1000
Groove 3 and baffle external side (high emissivity surfaces)	0	0	$1.52\ 10^{-6}$	1000
Baffle (internal side)	0	0	$7.7\ 10^{-7}$	1945
spacecraft	0	0	$2\ 10^{-6}$	2495

7.2.2 Cleanliness degradation due to launch preparation

We expected a maximum duration of 12 days in class 10 000, leading to

3.6 10-8 g/cm2 molecular contamination

720ppm particulate

on the sensitive surfaces

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

FOR THE LAUNCHER CONTRIBUTION (FROM THE ENCAPSULATION TO THE SEPARATION), THE SPECIFIED CONTRIBUTION IS 2300 PPM

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	3.6 10^{-6}			4965
Telescope PR	1.1 10^{-6}			4965
Telescope SR	1.1 10^{-6}			4965
Groove 1 (low emissivity surfaces)	0	0	1.55 10^{-6}	4020
Groove 2	0	0	1.55 10^{-6}	4020
Groove 3	0	0	1.55 10^{-6}	4020
Groove 3 and baffle external side (high emissivity surfaces)	0	0	1.55 10^{-6}	4020
Baffle (internal side)	0	0	1.1 10^{-6}	4965
spacecraft	0	0	2 10^{-6}	5150

7.2.4 In-orbit contamination

7.2.4.1 Outgassing

7.2.4.1.1 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.

7.2.4.1.2 Hypotheses and modelisation

7.2.4.1.2.1 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 §7.1.4.1.2.1 of this document).

7.2.4.1.2.2 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.

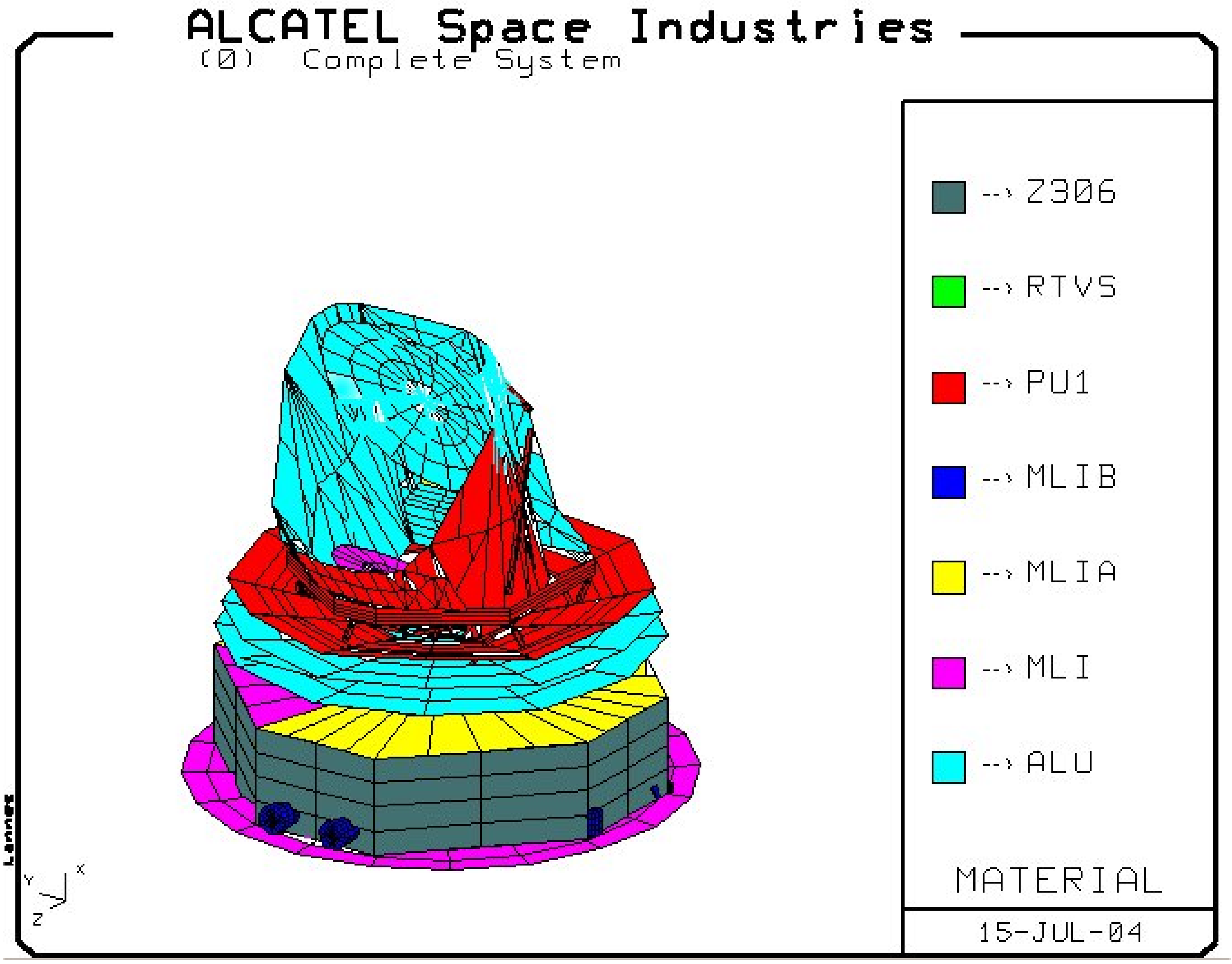


FIGURE 7.2-1 - PLANCK- OUTGASSING MODEL

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

Element	Material	Thickness (µm)	Density (g/cm3)
Solar array active side	RTVS	150	1.42
Solar array rear side	MLI Alu	250	1.4
SVM lateral panels	Z307 black paint	60	1.3
SVM upper panel	MLI Alu	250	1.4
STR Module 1&2	MLI Black	140	1.4
Sensors	MLI Black	140	1.4
BEU	MLI + Z306 on -Z side	250, paint 60	1.4
PAU	MLI + Z306 on outer sides	250, paint 60	1.4
Cryogenic struts	GFRP (R-Glass fiber, Epoxy Resin) black painted with PUK	paint 300	paint 1,4
Groove N°1 +X	Polished aluminium	N/A	N/A
Groove N°1 -X	Polished aluminium	N/A	N/A
Groove N°2 +X	Polished aluminium	N/A	N/A
Groove N°2 -X	Polished aluminium	N/A	N/A
Groove N°3 +X	aluminium for the internal baffle part, and open NIDA black painted (with PUK) for the external baffle part	paint 70	paint 1,4
Groove N°3 -X	Polished aluminium	N/A	N/A
Frame	M55J/Cyanate ester black painted with PUK	paint 70	paint 1,4
FPU	Aluminium	N/A	N/A
Wave guides	SS and copper	N/A	N/A
Struts supporting M1	M55J-Epoxy (48 mm length/ thickness 1,15 mm) black painted with PUK	paint 125	paint 1,4
M1 support panel internal side	Polished aluminium	N/A	N/A
M1 support panel external side	Open NIDA (hyp: surface * 4) Black painted (PUK)	paint 125	paint 1,4
Baffle internal side	Polished aluminium	N/A	N/A
Baffle external side	Open NIDA (hyp: surface * 4) Black painted (PUK)	paint 125	paint 1,4
M2 support	CFRP M55J/Cyanate ester 954-3 black painted with PUK	250	1.4
Struts supporting M2	CFRP M55J/Cyanate ester 954-3 black painted with PUK	250	1.4
M2 active side	Aluminium	N/A	N/A
M2 rear side	MLI	220	1.4
M1 active side	Aluminium	N/A	N/A
M1 rear side	MLI	220	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
Alu NIDA panel	Glue BSL 312L	5
Internal black paint	Paint Z306	2
Central tube (Nominal + Reinforcement)	CFRP M18/M40 J	36.48
Cone adhesive skin-core	Glue BSL 319L	2.63
Cone Adhesive	Hysol EA 9321	0.63
Adhesive	Hysol EA 9309	0.122
Shear panels (Nominal + Reinforcement)	CFRP M18/G969	11.44
Shear panels adhesive skin-core	Glue BSL 312L	1.12
Shear panels adhesive core-core	FM 410	0.88
Upper closure panels (nominal + reinforcements)	CFRP M18/G801	10.69
Upper closure panels adhesive skin-core	BSL 312L	2.81
Upper closure panels adhesive core-core	FM410	1.69
Lower closure panels (nominal + reinforcements)	CFRP M18/G801	8.41
Lower closure panels adhesive skin-core	Glue BSL 312L	2.73
Lower closure panels adhesive core-core	FM410	1.7
Sub PF skins	CFRP	16.5
Sub PF adhesive	Glue BSL 312L	1
Propellant tanks supports	CFRP M18/M55J	1.86
Helium tanks supports	CFRP M18/M55J	0.88
Miscellaneous	Hysol EA 9321	0.473
Miscellaneous	Scotchweld EC 2216	0.4
Glue insert for potting	Stycast 1090/°	10
Internal MLI (10 m2 tanks + 4 m2 panels)	MLI	2.3

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

The same RFD's from lower level have been considered for Planck as for Herschel (see section 7.1.4.1.2.2) and are also covered by SVM internal material of Table 7.2-2.

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

- Ø the launch phase
- Ø the transient phase
- Ø 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.

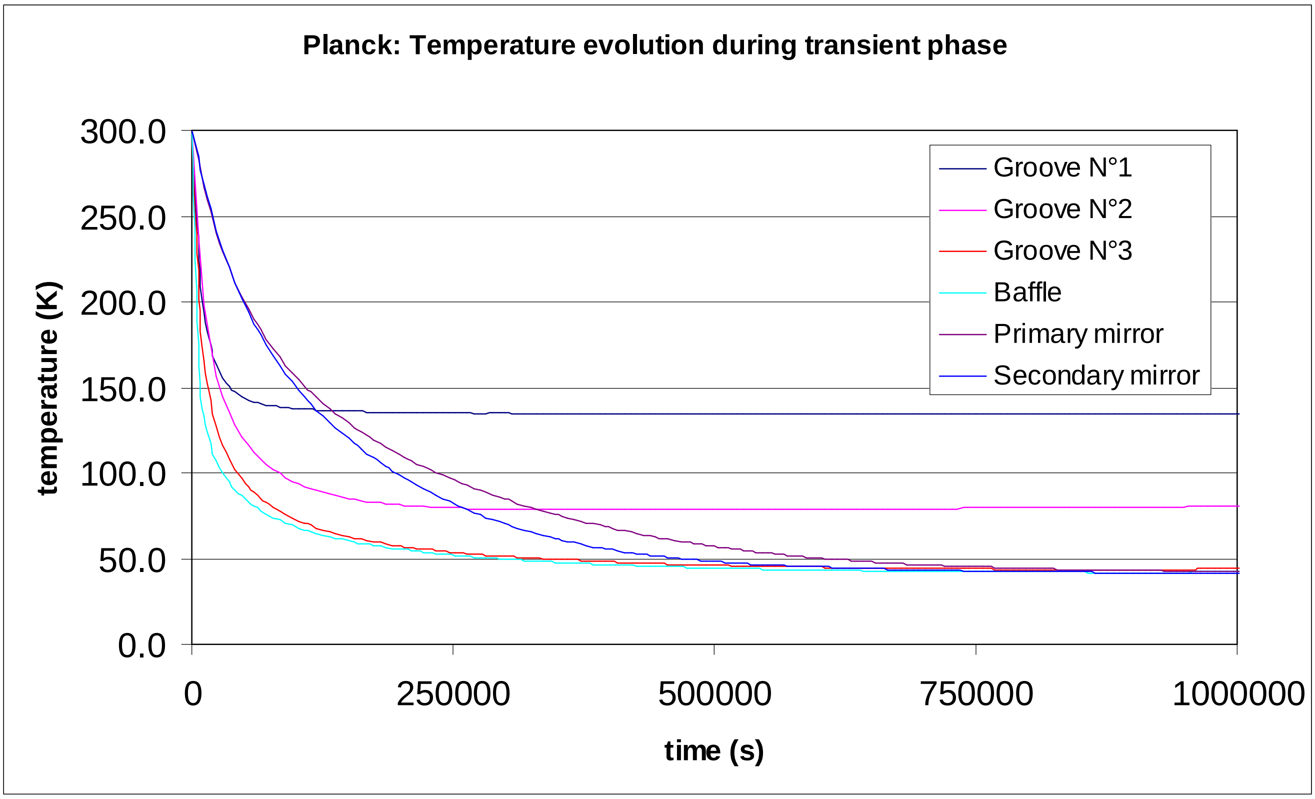


FIGURE 7.2-2 - PLANCK – TEMPERATURE EVOLUTION DURING THE TRANSIENT PHASE

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

Element	Temperature Nominal case (K)	Temperature decontamination (heating phase) case (K)
GS front side	399	399
GS rear side	312	312
SVM lateral	281	281
SVM upper	303	303
Groove #1 +X	129	115
Groove #1 -X	129	115
Groove #2 +X	80	77
Groove #2 -X	80	77
Groove #3 +X (Nextel)	45	68
Groove #3 +X (Alu)	45	68
Groove #3 -X	45	68
Cryo Struts	45-300	68-300
Cadre	42	69
FPU (active side)	0.1-20	86
PAU	312.7	312.7
PAU radiator	266.6	266.6
Wave guide	20-300	86-300
M1 support rear side	42	297
M1 support towards M1	42	297
M1 support struts	42	42
Baffle internal side	44	69
Baffle external side	44	69
M2 support	42	309
M2 support struts	42	309
M2 front side	42	309
M2 rear side	42	309
STM	281	281
Sensor #1	281	281
Sensor #2	281	281
Sensor #3	281	281
Sensor #4	281	281
BEU lateral -Y	309.8	309.8
BEU central	304.1	304.1
BEU lateral +Y	310.4	310.4
BEU radiator	281.3	281.3
M1 front face	42	297
M1 rear face	42	297

TABLE 7.2-3 - PLANCK- OPERATIONAL TEMPERATURES

7.2.4.1.2.3 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
CFRP G969 M18 (0,8mm)	Cyanate composite	VBQC 3794
CFRP G801 M18	Cyanate composite	VBQC 3794
CFRP M55J M18	Cyanate composite	VBQC 3794
Aluminised MLI	Mylar DA foil	VBQC 3141
PUK	PU1	VBQC 3512
MLI	Kapton	VBQC 3193/2
MLI black	Black Kapton	VBQC 3479
RTV S691	rtv s691	VBQC 3624
Glue BSL 312L	FM 73U	VBQC 3613
Glue BSL 319L	FM 73U	VBQC 3613
DC 93500	DC 93500	VBQC 3809
GFRP	Cyanate composite	VBQC 3794
GFRP WG	Cyanate composite	VBQC 3794
Z306	Z306	VBQC 3148
Aluminised kapton	Mylar DA foil	VBQC 3141
Z307	Z306	VBQC 3148
Polished Aluminium	ALU	N/A
Aluminium	ALU	N/A

TABLE 7.2-4 - PLANCK- OUTGASSING MATERIALS CONVERSION

7.2.4.1.3 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).

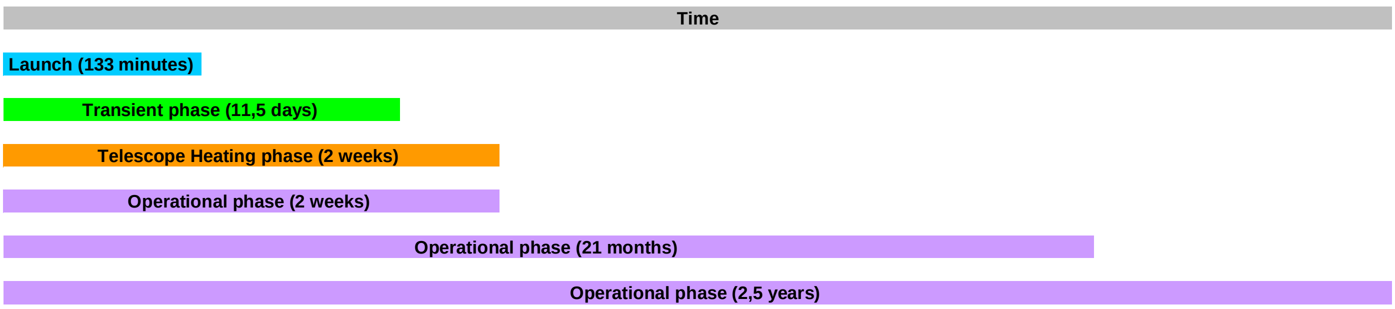


FIGURE 7.2-3 - PLANCK OUTGASSING SIMULATIONS STRATEGY

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)

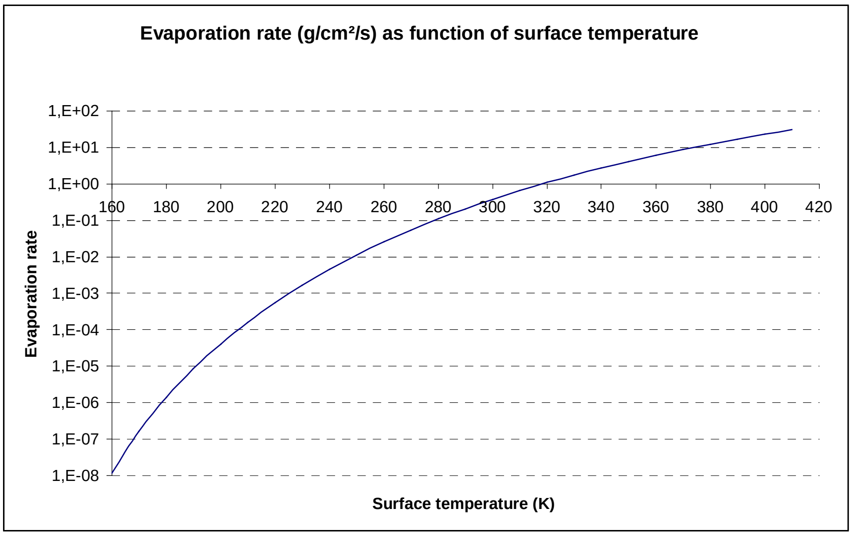
A: surface area

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.

7.2.4.1.3.1 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	3.187	13.850	293.0	7.87E-08	7.87E-08	7.87E-08
GS rear side	MLI	5.334	13.850	293.0	1.89E-06	1.89E-06	1.89E-06
SVM lateral	Z306	0.762	9.763	293.0	1.31E-05	3.41E-05	5.29E-06
SVM upper	MLIA	3.745	10.116	293.0	8.13E-06	2.82E-05	1.89E-06
Groove #1 +X	NO OUTGASSING	0.000	10.590	293.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	293.0	7.26E-07	1.14E-06	3.97E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	293.0	1.59E-07	9.52E-07	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	293.0	8.93E-08	5.36E-07	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	293.0	5.24E-11	6.05E-11	4.47E-11
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	293.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	293.0	9.93E-05	1.01E-04	9.77E-05
Cryo Struts	PU1	0.731	1.589	293.0	5.12E-05	2.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	293.0	1.30E-06	6.44E-06	1.41E-09
FPU (active side)	NO OUTGASSING	0.000	0.260	293.0	3.66E-08	3.66E-08	3.66E-08
PAU	MLIA	0.325	0.844	293.0	8.29E-05	2.16E-04	6.37E-07
Wave guide	NO OUTGASSING	0.000	4.937	293.0	5.65E-06	2.45E-05	0.00E+00
M1 support rear side	PU1	0.545	3.112	293.0	2.25E-06	5.73E-06	1.32E-08
M1 support towards M1	NO OUTGASSING	0.000	3.112	293.0	2.46E-05	7.49E-05	9.39E-06
M1 support struts	PU1	0.348	1.990	293.0	6.81E-06	3.77E-05	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	293.0	6.37E-05	1.34E-04	2.84E-07
Baffle external side	PU1	5.615	8.022	293.0	3.94E-07	2.02E-06	0.00E+00
M2 support	PU1	0.076	0.194	293.0	2.38E-06	7.66E-06	3.27E-09
M2 support struts	PU1	0.072	0.184	293.0	9.69E-06	3.56E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	293.0	1.03E-04	1.03E-04	1.03E-04
M2 rear side	MLI	0.326	0.957	293.0	1.81E-06	1.81E-06	1.81E-06
STM 1	MLIB	0.070	0.334	293.0	1.69E-05	2.39E-05	8.81E-06
STM 2	MLIB	0.070	0.334	293.0	1.34E-05	2.05E-05	1.67E-07
Sensor #1	MLIB	0.007	0.033	293.0	4.82E-05	2.25E-04	0.00E+00
Sensor #2	MLIB	0.006	0.030	293.0	4.71E-05	1.56E-04	0.00E+00
Sensor #3	MLIB	0.007	0.033	293.0	3.98E-05	9.17E-05	1.12E-08
Sensor #4	MLIB	0.020	0.097	293.0	1.57E-05	4.50E-05	0.00E+00
BEU	MLIA	0.179	0.465	293.0	4.79E-05	1.03E-04	4.07E-08
BEU Z306	Z306	0.005	0.058	293.0	5.93E-05	5.93E-05	5.93E-05
M1 front face	NO OUTGASSING	0.000	2.764	293.0	1.10E-04	2.14E-04	2.42E-10
M1 rear face	MLI	0.940	2.764	293.0	0.00E+00	0.00E+00	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	3.187	13.850	293.1	1.13E-07	1.13E-07	1.13E-07
GS rear side	MLI	5.334	13.850	293.1	1.25E-05	1.25E-05	1.25E-05
SVM lateral	CFRP	75.124	9.763	293.1	1.39E-05	3.46E-05	6.28E-06
SVM upper	MLIA	3.745	10.116	293.1	8.20E-06	2.83E-05	1.98E-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	7.26E-07	1.14E-06	3.97E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	293.1	1.59E-07	9.54E-07	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	293.1	9.80E-08	5.88E-07	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	293.1	6.05E-11	6.98E-11	5.15E-11
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	9.93E-05	1.01E-04	9.77E-05
Cryo Struts	PU1	0.731	1.589	293.1	5.12E-05	2.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	293.1	1.30E-06	6.46E-06	1.41E-09
FPU (active side)	NO OUTGASSING	0.000	0.260	293.1	4.11E-08	4.11E-08	4.11E-08
PAU	MLIA	0.325	0.844	293.1	8.30E-05	2.16E-04	6.38E-07
Wave guide	NO OUTGASSING	0.000	4.937	293.1	5.67E-06	2.45E-05	0.00E+00
M1 support rear side	PU1	0.545	3.112	293.1	2.27E-06	5.74E-06	1.11E-08
M1 support towards M1	NO OUTGASSING	0.000	3.112	293.1	2.46E-05	7.49E-05	9.39E-06
M1 support struts	PU1	0.348	1.990	293.1	6.82E-06	3.77E-05	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	293.1	6.37E-05	1.34E-04	2.92E-07
Baffle external side	PU1	5.615	8.022	293.1	4.04E-07	2.02E-06	0.00E+00
M2 support	PU1	0.076	0.194	293.1	2.39E-06	7.67E-06	3.27E-09
M2 support struts	PU1	0.072	0.184	293.1	9.70E-06	3.56E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	293.1	1.03E-04	1.03E-04	1.03E-04
M2 rear side	MLI	0.326	0.957	293.1	1.83E-06	1.83E-06	1.83E-06
STM 1	MLIB	0.070	0.334	293.1	4.06E-05	9.50E-05	8.81E-06
STM 2	MLIB	0.070	0.288	293.1	4.19E-05	1.03E-04	1.54E-06
Sensor #1	MLIB	0.007	0.033	293.1	1.63E-04	4.90E-04	0.00E+00
Sensor #2	MLIB	0.006	0.030	293.1	2.31E-04	6.07E-04	0.00E+00
Sensor #3	MLIB	0.007	0.033	293.1	2.14E-04	4.90E-04	1.29E-08
Sensor #4	MLIB	0.020	0.097	293.1	1.05E-04	2.37E-04	0.00E+00
BEU	MLIA	0.179	0.465	293.1	4.81E-05	1.03E-04	4.68E-08
BEU Z306	Z306	0.005	0.058	293.1	5.93E-05	5.93E-05	5.93E-05
M1 front face	NO OUTGASSING	0.000	2.764	293.1	1.11E-04	2.14E-04	2.42E-10
M1 rear face	MLI	0.940	2.764	293.1	0.00E+00	0.00E+00	0.00E+00

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

7.2.4.1.3.2 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	6.00E-07	6.00E-08
Groove #1 -x	0.00E+00	0.00E+00
Groove #2+x	5.10E-09	5.10E-10
Groove #2-x	1.91E-04	1.91E-05
Groove #3 +x (PUK)	6.31E-05	6.31E-06
Groove #3 +x (Alu)	2.27E-04	2.27E-05
Groove #3-x	2.29E-04	2.29E-05
Baffle : internal	1.88E-05	1.88E-06
Baffle : external	6.07E-05	6.07E-06
M1 PM front	2.66E-06	2.66E-07
M1 PM rear	4.77E-08	4.77E-09
M2 SM front	7.23E-06	7.23E-07
M2 SM rear	3.59E-05	3.59E-06
FPU (active side)	1.46E-05	1.46E-06

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

7.2.4.1.3.3 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 7.2.4.1.3.

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 5.4 10^{-7} g/cm² except with SVM internal materials hypothesis where contamination on M1 reaches 3.3 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	3.187	13.850	399.0	1.18E-04	1.18E-04	1.18E-04
GS rear side	MLI	5.334	13.850	312.0	1.44E-06	1.44E-06	1.44E-06
SVM lateral	Z306	0.762	9.763	281.0	5.75E-05	1.05E-04	3.66E-05
SVM upper	MLIA	3.745	10.116	303.0	5.74E-05	1.17E-04	2.54E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.39E-07	1.03E-06	2.58E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	4.66E-07	2.80E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	2.84E-07	1.70E-06	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	0.00E+00	0.00E+00	0.00E+00
Cryo Struts	PU1	0.731	1.589	300.0	5.20E-05	3.51E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.08E-08	2.15E-07	0.00E+00
FPU (active side)	NO OUTGASSING	0.000	0.260	20.0	1.25E-09	1.25E-09	1.25E-09
PAU	MLIA	0.325	0.844	312.0	1.82E-04	4.14E-04	4.21E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.07E-05	2.09E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	3.81E-06	1.89E-04	0.00E+00
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	2.51E-07	4.96E-06	0.00E+00
M1 support struts	PU1	0.348	1.990	42.0	1.42E-06	5.32E-05	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	1.07E-07	1.38E-06	0.00E+00
Baffle external side	PU1	5.615	8.022	44.0	4.33E-07	3.28E-06	0.00E+00
M2 support	PU1	0.076	0.194	42.0	6.78E-06	2.53E-05	0.00E+00
M2 support struts	PU1	0.072	0.184	42.0	1.39E-07	8.33E-07	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	42.0	1.06E-06	1.06E-06	1.06E-06
M2 rear side	MLI	0.326	0.957	42.0	1.50E-06	1.50E-06	1.50E-06
STM 1	MLIB	0.070	0.334	281.0	1.38E-04	3.32E-04	1.40E-05
STM 2	MLIB	0.07	0.334	281.0	2.27E-04	5.59E-04	1.72E-05
Sensor #1	MLIB	0.007	0.033	281.0	4.62E-05	1.99E-04	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	5.64E-05	1.79E-04	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	5.00E-05	1.41E-04	1.56E-08
Sensor #4	MLIB	0.020	0.097	281.0	8.86E-05	3.44E-04	0.00E+00
BEU	MLIA	0.179	0.465	309.0	6.95E-05	1.25E-04	9.65E-06
BEU Z306	Z306	0.005	0.058	301.0	7.57E-05	7.57E-05	7.57E-05
M1 front face	NO OUTGASSING	0.000	2.764	42.0	1.95E-07	6.98E-06	0.00E+00
M1 rear face	MLI	0.940	2.764	42.0	0.00E+00	0.00E+00	0.00E+00

TABLE 7.2-8 - PLANCK – OUTGASSING CONTAMINATION AFTER 2 WEEKS, 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	3.187	13.850	399.0	1.20E-04	1.20E-04	1.20E-04
GS rear side	MLI	5.334	13.850	312.0	2.27E-05	2.27E-05	2.27E-05
SVM lateral	CFRP	75.124	9.763	281.0	3.50E-04	5.28E-04	2.49E-04
SVM upper	MLIA	3.745	10.116	303.0	6.91E-05	1.51E-04	2.57E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.39E-07	1.03E-06	2.58E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	4.66E-07	2.80E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	2.23E-06	1.34E-05	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	0.00E+00	0.00E+00	0.00E+00
Cryo Struts	PU1	0.731	1.589	300.0	5.24E-05	3.51E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.29E-08	2.30E-07	0.00E+00
FPU (active side)	NO OUTGASSING	0.000	0.260	20.0	1.25E-09	1.25E-09	1.25E-09
PAU	MLIA	0.325	0.844	312.0	1.83E-04	4.14E-04	4.21E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.14E-05	2.09E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	3.92E-06	1.89E-04	0.00E+00
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	2.67E-07	4.96E-06	0.00E+00
M1 support struts	PU1	0.348	1.990	42.0	2.17E-06	5.32E-05	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	9.87E-08	1.38E-06	0.00E+00
Baffle external side	PU1	5.615	8.022	44.0	6.48E-07	3.65E-06	0.00E+00
M2 support	PU1	0.076	0.194	42.0	6.78E-06	2.53E-05	0.00E+00
M2 support struts	PU1	0.072	0.184	42.0	1.39E-07	8.33E-07	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	42.0	1.06E-06	1.06E-06	1.06E-06
M2 rear side	MLI	0.326	0.957	42.0	1.50E-06	1.50E-06	1.50E-06
STM 1	MLIB	0.070	0.334	281.0	2.69E-04	4.62E-04	1.40E-05
STM 2	MLIB	0.070	0.334	281.0	4.87E-04	5.67E-04	3.36E-04
Sensor #1	MLIB	0.007	0.033	281.0	3.73E-04	1.30E-03	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	6.11E-04	1.66E-03	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	5.35E-04	1.29E-03	1.56E-08
Sensor #4	MLIB	0.020	0.097	281.0	1.39E-03	6.73E-03	0.00E+00
BEU	MLIA	0.179	0.465	309.0	8.68E-05	1.45E-04	9.65E-06
BEU Z306	Z306	0.005	0.058	301.0	7.57E-05	7.57E-05	7.57E-05
M1 front face	NO OUTGASSING	0.000	2.764	42.0	2.29E-06	1.32E-04	0.00E+00
M1 rear face	MLI	0.940	2.764	42.0	0.00E+00	0.00E+00	0.00E+00

TABLE 7.2-9 - PLANCK – OUTGASSING CONTAMINATION AFTER 2 WEEKS, 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	3.187	13.850	399.0	1.18E-04	1.18E-04	1.18E-04
GS rear side	MLI	5.334	13.850	312.0	1.59E-06	1.59E-06	1.59E-06
SVM lateral	Z306	0.762	9.763	281.0	6.01E-05	1.09E-04	3.84E-05
SVM upper	MLIA	3.745	10.116	303.0	6.52E-05	1.24E-04	3.01E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.64E-07	1.07E-06	2.71E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	1.10E-06	6.60E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	5.71E-07	3.43E-06	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	1.61E-15	1.85E-15	1.38E-15
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	1.28E-11	1.30E-11	1.26E-11
Cryo Struts	PU1	0.731	1.589	300.0	6.10E-05	3.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.14E-08	2.17E-07	2.83E-16
FPU (active side)	NO OUTGASSING	0.000	0.260	20.0	3.18E-09	3.18E-09	3.18E-09
PAU	MLIA	0.325	0.844	312.0	1.96E-04	4.25E-04	6.70E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.24E-05	2.30E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	4.36E-06	1.91E-04	1.11E-14
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	6.37E-07	1.26E-05	8.86E-13
M1 support struts	PU1	0.348	1.990	42.0	3.52E-06	1.35E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	2.85E-07	3.50E-06	1.69E-12
Baffle external side	PU1	5.615	8.022	44.0	9.10E-07	7.84E-06	0.00E+00
M2 support	PU1	0.076	0.194	42.0	1.64E-05	6.43E-05	6.63E-16
M2 support struts	PU1	0.072	0.184	42.0	3.69E-07	2.16E-06	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	42.0	2.89E-06	2.89E-06	2.89E-06
M2 rear side	MLI	0.326	0.957	42.0	3.84E-06	3.84E-06	3.84E-06
STM 1	MLIB	0.070	0.334	281.0	1.41E-04	3.36E-04	1.41E-05
STM 2	MLIB	0.07	0.334	281.0	2.31E-04	5.65E-04	1.94E-05
Sensor #1	MLIB	0.007	0.033	281.0	4.94E-05	2.06E-04	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	6.09E-05	1.86E-04	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	5.35E-05	1.42E-04	1.62E-08
Sensor #4	MLIB	0.020	0.097	281.0	9.80E-05	3.88E-04	0.00E+00
BEU	MLIA	0.179	0.465	309.0	7.79E-05	1.31E-04	1.02E-05
BEU Z306	Z306	0.005	0.058	301.0	7.94E-05	7.94E-05	7.94E-05
M1 front face	NO OUTGASSING	0.000	2.764	42.0	4.37E-07	8.10E-06	4.78E-17
M1 rear face	MLI	0.940	2.764	42.0	0.00E+00	0.00E+00	0.00E+00

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	3.187	13.850	399.0	1.21E-04	1.21E-04	1.21E-04
GS rear side	MLI	5.334	13.850	312.0	2.92E-05	2.92E-05	2.92E-05
SVM lateral	CFRP	75.124	9.763	281.0	4.39E-04	6.57E-04	3.09E-04
SVM upper	MLIA	3.745	10.116	303.0	8.04E-05	1.69E-04	3.01E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.64E-07	1.07E-06	2.71E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	1.10E-06	6.60E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	3.10E-06	1.86E-05	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	1.61E-15	1.85E-15	1.38E-15
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	1.28E-11	1.30E-11	1.26E-11
Cryo Struts	PU1	0.731	1.589	300.0	6.14E-05	3.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.41E-08	2.36E-07	2.83E-16
FPU (active side)	NO OUTGASSING	0.000	0.260	20.0	3.18E-09	3.18E-09	3.18E-09
PAU	MLIA	0.325	0.844	312.0	1.96E-04	4.25E-04	6.70E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.33E-05	2.30E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	4.51E-06	1.91E-04	1.11E-14
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	6.58E-07	1.26E-05	8.86E-13
M1 support struts	PU1	0.348	1.990	42.0	4.50E-06	1.35E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	2.65E-07	3.50E-06	1.69E-12
Baffle external side	PU1	5.615	8.022	44.0	1.19E-06	8.00E-06	0.00E+00
M2 support	PU1	0.076	0.194	42.0	1.63E-05	6.43E-05	6.63E-16
M2 support struts	PU1	0.072	0.184	42.0	3.68E-07	2.16E-06	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	42.0	2.89E-06	2.89E-06	2.89E-06
M2 rear side	MLI	0.326	0.957	42.0	3.84E-06	3.84E-06	3.84E-06
STM 1	MLIB	0.070	0.334	281.0	3.11E-04	5.82E-04	1.41E-05
STM 2	MLIB	0.070	0.334	281.0	5.69E-04	7.10E-04	4.33E-04
Sensor #1	MLIB	0.007	0.033	281.0	4.73E-04	1.68E-03	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	7.80E-04	2.14E-03	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	6.83E-04	1.67E-03	1.62E-08
Sensor #4	MLIB	0.020	0.097	281.0	1.79E-03	8.68E-03	0.00E+00
BEU	MLIA	0.179	0.465	309.0	1.00E-04	1.74E-04	1.02E-05
BEU Z306	Z306	0.005	0.058	301.0	7.94E-05	7.94E-05	7.94E-05
M1 front face	NO OUTGASSING	0.000	2.764	42.0	3.15E-06	1.70E-04	4.78E-17
M1 rear face	MLI	0.940	2.764	42.0	0.00E+00	0.00E+00	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	3.187	13.850	399.0	1.18E-04	1.18E-04	1.18E-04
GS rear side	MLI	5.334	13.850	312.0	1.63E-06	1.63E-06	1.63E-06
SVM lateral	Z306	0.762	9.763	281.0	6.07E-05	1.10E-04	3.88E-05
SVM upper	MLIA	3.745	10.116	303.0	6.59E-05	1.25E-04	3.04E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.66E-07	1.07E-06	2.72E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	1.15E-06	6.90E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	5.96E-07	3.58E-06	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	2.58E-15	2.96E-15	2.21E-15
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	2.05E-11	2.08E-11	2.01E-11
Cryo Struts	PU1	0.731	1.589	300.0	6.17E-05	3.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.14E-08	2.18E-07	5.66E-16
FPU (active side)	NO OUTGASSING	0.000	0.260	20.0	3.34E-09	3.34E-09	3.34E-09
PAU	MLIA	0.325	0.844	312.0	1.96E-04	4.25E-04	6.90E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.25E-05	2.32E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	4.41E-06	1.91E-04	2.22E-14
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	6.69E-07	1.32E-05	1.77E-12
M1 support struts	PU1	0.348	1.990	42.0	3.69E-06	1.42E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	3.05E-07	3.68E-06	2.96E-12
Baffle external side	PU1	5.615	8.022	44.0	9.48E-07	8.21E-06	0.00E+00
M2 support	PU1	0.076	0.194	42.0	1.71E-05	6.74E-05	1.33E-15
M2 support struts	PU1	0.072	0.184	42.0	3.92E-07	2.28E-06	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	42.0	3.10E-06	3.10E-06	3.10E-06
M2 rear side	MLI	0.326	0.957	42.0	4.04E-06	4.04E-06	4.04E-06
STM 1	MLIB	0.070	0.334	281.0	1.41E-04	3.37E-04	1.41E-05
STM 2	MLIB	0.07	0.334	281.0	2.32E-04	5.66E-04	5.66E-04
Sensor #1	MLIB	0.007	0.033	281.0	4.99E-05	2.06E-04	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	6.17E-05	1.87E-04	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	5.42E-05	1.42E-04	1.62E-08
Sensor #4	MLIB	0.020	0.097	281.0	9.99E-05	3.97E-04	0.00E+00
BEU	MLIA	0.179	0.465	309.0	7.87E-05	1.31E-04	1.03E-05
BEU Z306	Z306	0.005	0.058	301.0	7.98E-05	7.98E-05	7.98E-05
M1 front face	NO OUTGASSING	0.000	2.764	42.0	5.37E-07	8.40E-06	9.57E-17
M1 rear face	MLI	0.940	2.764	42.0	0.00E+00	0.00E+00	0.00E+00

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	3.187	13.850	399.0	1.21E-04	1.21E-04	1.21E-04
GS rear side	MLI	5.334	13.850	312.0	2.94E-05	2.94E-05	2.94E-05
SVM lateral	CFRP	75.124	9.763	281.0	4.42E-04	6.62E-04	3.11E-04
SVM upper	MLIA	3.745	10.116	303.0	8.11E-05	1.69E-04	3.05E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.66E-07	1.07E-06	2.72E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	1.15E-06	6.90E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	3.15E-06	1.89E-05	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	2.58E-15	2.96E-15	2.21E-15
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	2.05E-11	2.08E-11	2.01E-11
Cryo Struts	PU1	0.731	1.589	300.0	6.22E-05	3.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.42E-08	2.37E-07	5.66E-16
FPU (active side)	NO OUTGASSING	0.000	0.260	20.0	3.34E-09	3.34E-09	3.34E-09
PAU	MLIA	0.325	0.844	312.0	1.96E-04	4.25E-04	6.90E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.34E-05	2.32E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	4.56E-06	1.91E-04	2.22E-14
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	6.90E-07	1.32E-05	1.77E-12
M1 support struts	PU1	0.348	1.990	42.0	4.67E-06	1.42E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	2.83E-07	3.68E-06	2.96E-12
Baffle external side	PU1	5.615	8.022	44.0	1.23E-06	8.37E-06	0.00E+00
M2 support	PU1	0.076	0.194	42.0	1.71E-05	6.74E-05	1.33E-15
M2 support struts	PU1	0.072	0.184	42.0	3.92E-07	2.28E-06	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	42.0	3.10E-06	3.10E-06	3.10E-06
M2 rear side	MLI	0.326	0.957	42.0	4.04E-06	4.04E-06	4.04E-06
STM 1	MLIB	0.070	0.334	281.0	3.12E-04	5.87E-04	1.41E-05
STM 2	MLIB	0.070	0.334	281.0	5.73E-04	7.15E-04	4.37E-04
Sensor #1	MLIB	0.007	0.033	281.0	4.77E-04	1.69E-03	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	7.87E-04	2.16E-03	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	6.88E-04	1.68E-03	1.62E-08
Sensor #4	MLIB	0.020	0.097	281.0	1.80E-03	8.75E-03	0.00E+00
BEU	MLIA	0.179	0.465	309.0	1.01E-04	1.76E-04	1.03E-05
BEU Z306	Z306	0.005	0.058	301.0	7.98E-05	7.98E-05	7.98E-05
M1 front face	NO OUTGASSING	0.000	2.764	42.0	3.27E-06	1.71E-04	9.57E-17
M1 rear face	MLI	0.940	2.764	42.0	0.00E+00	0.00E+00	0.00E+00

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

7.2.4.1.3.4 Heating phase

An outgassing simulation was performed with ESABASE software, taking into consideration the telescope (M1, M2, FPU… see table n° 7.2.3 for a complete heat case hypothesis) 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 7.2.4.1.3.

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 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 (m^2)	Temperature (K)	Average contamination (g/cm^2)	Maximum contamination (g/cm^2)	Minimum contamination (g/cm^2)
GS front side	RTVS	3.187	13.850	399.0	1.18E-04	1.18E-04	1.18E-04
GS rear side	MLI	5.334	13.850	312.0	1.44E-06	1.44E-06	1.44E-06
SVM lateral	Z306	0.762	9.763	281.0	5.76E-05	1.05E-04	3.66E-05
SVM upper	MLIA	3.745	10.116	303.0	5.74E-05	1.17E-04	2.54E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	115.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	115.0	6.39E-07	1.03E-06	2.58E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	77.0	4.66E-07	2.80E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	77.0	2.84E-07	1.70E-06	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	68.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	68.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	68.0	0.00E+00	0.00E+00	0.00E+00
Cryo Struts	PU1	0.731	1.589	300.0	5.27E-05	3.51E-04	0.00E+00
Cadre	PU1	0.233	1.094	69.0	3.08E-08	2.15E-07	0.00E+00
FPU (active side)	NO OUTGASSING	0.000	0.260	86.0	5.08E-09	5.08E-09	5.08E-09
PAU	MLIA	0.325	0.844	312.0	1.82E-04	4.14E-04	4.21E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.55E-05	2.09E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	297.0	1.84E-05	1.89E-04	0.00E+00
M1 support towards M1	NO OUTGASSING	0.000	3.112	297.0	5.45E-05	9.46E-05	2.10E-05
M1 support struts	PU1	0.348	1.990	42.0	1.59E-05	1.09E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	69.0	1.51E-05	1.39E-04	0.00E+00
Baffle external side	PU1	5.615	8.022	69.0	7.14E-07	4.15E-06	0.00E+00
M2 support	PU1	0.076	0.194	309.0	1.48E-05	3.66E-05	1.14E-08
M2 support struts	PU1	0.072	0.184	309.0	3.41E-05	9.33E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	313.0	2.14E-04	2.14E-04	2.14E-04
M2 rear side	MLI	0.326	0.957	313.0	4.96E-05	4.96E-05	4.96E-05
STM 1	MLIB	0.070	0.334	281.0	1.38E-04	3.32E-04	1.40E-05
STM 2	MLIB	0.070	0.334	281.0	2.27E-04	5.59E-04	1.72E-05
Sensor #1	MLIB	0.007	0.033	281.0	4.62E-05	1.99E-04	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	5.64E-05	1.79E-04	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	4.99E-05	1.40E-04	1.56E-08
Sensor #4	MLIB	0.020	0.097	281.0	8.86E-05	3.44E-04	0.00E+00
BEU	MLIA	0.179	0.465	309.0	6.95E-05	1.25E-04	9.66E-06
BEU Z306	Z306	0.005	0.058	301.0	7.57E-05	7.57E-05	7.57E-05
M1 front face	NO OUTGASSING	0.000	2.764	313.0	2.32E-04	4.52E-04	0.00E+00
M1 rear face	MLI	0.940	2.764	313.0	0.00E+00	0.00E+00	0.00E+00

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	3.187	13.850	399.0	1.20E-04	1.20E-04	1.20E-04
GS rear side	MLI	5.334	13.850	312.0	2.27E-05	2.27E-05	2.27E-05
SVM lateral	CFRP	75.124	9.763	281.0	3.50E-04	5.28E-04	2.50E-04
SVM upper	MLIA	3.745	10.116	303.0	6.91E-05	1.51E-04	2.57E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	115.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	115.0	6.39E-07	1.03E-06	2.58E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	77.0	4.66E-07	2.80E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	77.0	2.23E-06	1.34E-05	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	68.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	68.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	68.0	0.00E+00	0.00E+00	0.00E+00
Cryo Struts	PU1	0.731	1.589	300.0	5.30E-05	3.51E-04	0.00E+00
Cadre	PU1	0.233	1.094	69.0	3.29E-08	2.29E-07	0.00E+00
FPU (active side)	NO OUTGASSING	0.000	0.260	86.0	5.08E-09	5.08E-09	5.08E-09
PAU	MLIA	0.325	0.844	312.0	1.82E-04	4.14E-04	4.22E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.62E-05	2.09E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	297.0	1.84E-05	1.89E-04	0.00E+00
M1 support towards M1	NO OUTGASSING	0.000	3.112	297.0	5.45E-05	9.46E-05	2.10E-05
M1 support struts	PU1	0.348	1.990	42.0	1.67E-05	1.09E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	69.0	1.52E-05	1.39E-04	0.00E+00
Baffle external side	PU1	5.615	8.022	69.0	9.30E-07	5.81E-06	0.00E+00
M2 support	PU1	0.076	0.194	309.0	1.48E-05	3.66E-05	1.14E-08
M2 support struts	PU1	0.072	0.184	309.0	3.41E-05	9.33E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	313.0	2.14E-04	2.14E-04	2.14E-04
M2 rear side	MLI	0.326	0.957	313.0	4.97E-05	4.97E-05	4.97E-05
STM 1	MLIB	0.070	0.334	281.0	2.69E-04	4.62E-04	1.40E-05
STM 2	MLIB	0.070	0.334	281.0	4.88E-04	5.67E-04	3.36E-04
Sensor #1	MLIB	0.007	0.033	281.0	3.73E-04	1.30E-03	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	6.11E-04	1.66E-03	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	5.35E-04	1.29E-03	1.56E-08
Sensor #4	MLIB	0.020	0.097	281.0	1.39E-03	6.74E-03	0.00E+00
BEU	MLIA	0.179	0.465	309.0	8.68E-05	1.45E-04	9.66E-06
BEU Z306	Z306	0.005	0.058	301.0	7.57E-05	7.57E-05	7.57E-05
M1 front face	NO OUTGASSING	0.000	2.764	313.0	2.34E-04	4.52E-04	0.00E+00
M1 rear face	MLI	0.940	2.764	313.0	0.00E+00	0.00E+00	0.00E+00

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	3.187	13.850	0.0	1.00E-07	1.00E-07	1.00E-07
GS rear side	MLI	5.334	13.850	0.0	0.00E+00	0.00E+00	0.00E+00
SVM lateral	Z306	0.762	9.763	0.0	2.00E-08	0.00E+00	1.00E-08
SVM upper	MLIA	3.745	10.116	0.0	4.38E-08	1.00E-07	1.00E-08
Groove #1 +X	NO OUTGASSING	0.000	10.590	-14.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	-14.0	-2.83E-10	0.00E+00	-1.00E-10
Groove #2 +X	NO OUTGASSING	0.000	10.098	-3.0	0.00E+00	0.00E+00	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	-3.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	23.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	23.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	23.0	0.00E+00	0.00E+00	0.00E+00
Cryo Struts	PU1	0.731	1.589	0.0	6.65E-07	-1.00E-07	0.00E+00
Cadre	PU1	0.233	1.094	27.0	-4.29E-11	-3.00E-10	0.00E+00
FPU (active side)	NO OUTGASSING	0.000	0.260	66.0	-1.25E-09	-1.25E-09	-1.25E-09
PAU	MLIA	0.325	0.844	0.0	-1.63E-08	-1.00E-07	2.00E-09
Wave guide	NO OUTGASSING	0.000	4.937	0.0	4.77E-06	1.00E-07	0.00E+00
M1 support rear side	PU1	0.545	3.112	255.0	1.45E-05	-2.00E-07	0.00E+00
M1 support towards M1	NO OUTGASSING	0.000	3.112	255.0	5.43E-05	8.96E-05	2.10E-05
M1 support struts	PU1	0.348	1.990	0.0	1.45E-05	5.54E-05	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	25.0	1.50E-05	1.37E-04	0.00E+00
Baffle external side	PU1	5.615	8.022	25.0	2.82E-07	8.68E-07	0.00E+00
M2 support	PU1	0.076	0.194	267.0	7.99E-06	1.13E-05	1.14E-08
M2 support struts	PU1	0.072	0.184	267.0	3.40E-05	9.24E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	271.0	-1.06E-06	-1.06E-06	-1.06E-06
M2 rear side	MLI	0.326	0.957	271.0	-1.50E-06	-1.50E-06	-1.50E-06
STM 1	MLIB	0.070	0.334	0.0	3.67E-08	1.00E-07	-1.00E-08
STM 2	MLIB	0.070	0.334	0.0	6.67E-08	2.00E-07	0.00E+00
Sensor #1	MLIB	0.007	0.033	0.0	-1.63E-08	-1.00E-07	0.00E+00
Sensor #2	MLIB	0.006	0.030	0.0	1.67E-09	0.00E+00	0.00E+00
Sensor #3	MLIB	0.007	0.033	0.0	-1.92E-08	-1.00E-07	0.00E+00
Sensor #4	MLIB	0.020	0.097	0.0	5.17E-08	3.00E-07	0.00E+00
BEU	MLIA	0.179	0.465	0.0	7.20E-09	0.00E+00	6.00E-09
BEU Z306	Z306	0.005	0.058	0.0	1.00E-08	1.00E-08	1.00E-08
M1 front face	NO OUTGASSING	0.000	2.764	271.0	-1.95E-07	-6.98E-06	0.00E+00
M1 rear face	MLI	0.940	2.764	271.0	0.00E+00	0.00E+00	0.00E+00

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	3.187	13.850	0.0	1.00E-07	1.00E-07	1.00E-07
GS rear side	MLI	5.334	13.850	0.0	0.00E+00	0.00E+00	0.00E+00
SVM lateral	CFRP	75.124	9.763	0.0	1.75E-07	3.00E-07	1.00E-07
SVM upper	MLIA	3.745	10.116	0.0	4.63E-08	1.00E-07	1.00E-08
Groove #1 +X	NO OUTGASSING	0.000	10.590	-14.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	-14.0	-3.17E-10	0.00E+00	-2.00E-10
Groove #2 +X	NO OUTGASSING	0.000	10.098	-3.0	0.00E+00	0.00E+00	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	-3.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	23.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	23.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	23.0	0.00E+00	0.00E+00	0.00E+00
Cryo Struts	PU1	0.731	1.589	0.0	6.64E-07	-1.00E-07	0.00E+00
Cadre	PU1	0.233	1.094	27.0	-5.71E-11	-4.00E-10	0.00E+00
FPU (active side)	NO OUTGASSING	0.000	0.260	66.0	-1.25E-09	-1.25E-09	-1.25E-09
PAU	MLIA	0.325	0.844	0.0	-1.63E-08	-1.00E-07	2.00E-09
Wave guide	NO OUTGASSING	0.000	4.937	0.0	4.77E-06	0.00E+00	0.00E+00
M1 support rear side	PU1	0.545	3.112	255.0	1.45E-05	-2.00E-07	0.00E+00
M1 support towards M1	NO OUTGASSING	0.000	3.112	255.0	5.43E-05	8.96E-05	2.10E-05
M1 support struts	PU1	0.348	1.990	0.0	1.45E-05	5.55E-05	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	25.0	1.51E-05	1.37E-04	0.00E+00
Baffle external side	PU1	5.615	8.022	25.0	2.82E-07	2.17E-06	0.00E+00
M2 support	PU1	0.076	0.194	267.0	8.00E-06	1.13E-05	1.14E-08
M2 support struts	PU1	0.072	0.184	267.0	3.40E-05	9.24E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	271.0	-1.06E-06	-1.06E-06	-1.06E-06
M2 rear side	MLI	0.326	0.957	271.0	-1.50E-06	-1.50E-06	-1.50E-06
STM 1	MLIB	0.070	0.334	0.0	3.00E-08	0.00E+00	-1.00E-08
STM 2	MLIB	0.070	0.334	0.0	1.33E-07	2.00E-07	0.00E+00
Sensor #1	MLIB	0.007	0.033	0.0	-1.49E-08	0.00E+00	0.00E+00
Sensor #2	MLIB	0.006	0.030	0.0	-1.67E-08	0.00E+00	0.00E+00
Sensor #3	MLIB	0.007	0.033	0.0	-6.67E-10	0.00E+00	0.00E+00
Sensor #4	MLIB	0.020	0.097	0.0	8.17E-07	5.00E-06	0.00E+00
BEU	MLIA	0.179	0.465	0.0	5.40E-09	0.00E+00	7.00E-09
BEU Z306	Z306	0.005	0.058	0.0	0.00E+00	0.00E+00	0.00E+00
M1 front face	NO OUTGASSING	0.000	2.764	271.0	-2.29E-06	-1.32E-04	0.00E+00
M1 rear face	MLI	0.940	2.764	271.0	0.00E+00	0.00E+00	0.00E+00

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 (PR, SR and FPU …see table n°7.2.3) where no contamination is foreseen during the heating phase (see the evaporation rates for surfaces placed at 313 K). 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 transient phase is not taken into account after the heating phase because at the end of this one, a lot of materials are already outgassed and the transient phase contribution to the contamination level can be considered as negligible.

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	3.187	13.850	399.0	1.18E-04	1.18E-04	1.18E-04
GS rear side	MLI	5.334	13.850	312.0	1.59E-06	1.59E-06	1.59E-06
SVM lateral	Z306	0.762	9.763	281.0	6.02E-05	1.09E-04	3.84E-05
SVM upper	MLIA	3.745	10.116	303.0	6.53E-05	1.24E-04	3.01E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.63E-07	1.07E-06	2.71E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	1.10E-06	6.60E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	5.71E-07	3.43E-06	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	1.61E-15	1.85E-15	1.38E-15
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	1.28E-11	1.30E-11	1.26E-11
Cryo Struts	PU1	0.731	1.589	300.0	6.16E-05	3.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.13E-08	2.17E-07	2.83E-16
FPU (active side)	NO OUTGASSING	0.000	0.260	86.0	1.93E-09	1.93E-09	1.93E-09
PAU	MLIA	0.325	0.844	312.0	1.96E-04	4.25E-04	6.70E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.71E-05	2.31E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	1.89E-05	1.91E-04	1.11E-14
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	5.49E-05	1.02E-04	2.10E-05
M1 support struts	PU1	0.348	1.990	42.0	1.80E-05	1.91E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	1.53E-05	1.41E-04	1.69E-12
Baffle external side	PU1	5.615	8.022	44.0	1.19E-06	8.71E-06	0.00E+00
M2 support	PU1	0.076	0.194	42.0	2.43E-05	7.55E-05	1.14E-08
M2 support struts	PU1	0.072	0.184	42.0	3.43E-05	9.46E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	313.0	1.83E-06	1.83E-06	1.83E-06
M2 rear side	MLI	0.326	0.957	313.0	2.34E-06	2.34E-06	2.34E-06
STM 1	MLIB	0.070	0.334	281.0	1.41E-04	3.36E-04	1.41E-05
STM 2	MLIB	0.070	0.334	281.0	2.31E-04	5.65E-04	1.94E-05
Sensor #1	MLIB	0.007	0.033	281.0	4.94E-05	2.06E-04	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	6.09E-05	1.86E-04	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	5.35E-05	1.42E-04	1.62E-08
Sensor #4	MLIB	0.020	0.097	281.0	9.80E-05	3.88E-04	0.00E+00
BEU	MLIA	0.179	0.465	309.0	7.80E-05	1.31E-04	1.02E-05
BEU Z306	Z306	0.005	0.058	301.0	7.94E-05	7.94E-05	7.94E-05
M1 front face	NO OUTGASSING	0.000	2.764	313.0	2.42E-07	1.11E-06	4.78E-17
M1 rear face	MLI	0.940	2.764	313.0	0.00E+00	0.00E+00	0.00E+00

TABLE 7.2-18 - PLANCK – OUTGASSING CONTAMINATION AFTER 21 MONTHS, WITH 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	3.187	13.850	399.0	1.21E-04	1.21E-04	1.21E-04
GS rear side	MLI	5.334	13.850	312.0	2.92E-05	2.92E-05	2.92E-05
SVM lateral	CFRP	75.124	9.763	281.0	4.39E-04	6.57E-04	3.09E-04
SVM upper	MLIA	3.745	10.116	303.0	8.04E-05	1.69E-04	3.01E-05
Groove #1 +X	NO OUTGASSING	0.000	10.590	129.0	0.00E+00	0.00E+00	0.00E+00
Groove #1 -X	NO OUTGASSING	0.000	10.590	129.0	6.63E-07	1.07E-06	2.71E-07
Groove #2 +X	NO OUTGASSING	0.000	10.098	80.0	1.10E-06	6.60E-06	0.00E+00
Groove #2 -X	NO OUTGASSING	0.000	10.098	80.0	3.10E-06	1.86E-05	0.00E+00
Groove #3 +X (PUK)	PU1	5.889	8.412	45.0	1.61E-15	1.85E-15	1.38E-15
Groove #3 +X (Alu)	NO OUTGASSING	0.000	1.261	45.0	0.00E+00	0.00E+00	0.00E+00
Groove #3 -X	NO OUTGASSING	0.000	8.060	45.0	1.28E-11	1.30E-11	1.26E-11
Cryo Struts	PU1	0.731	1.589	300.0	6.21E-05	3.60E-04	0.00E+00
Cadre	PU1	0.233	1.094	42.0	3.40E-08	2.36E-07	2.83E-16
FPU (active side)	NO OUTGASSING	0.000	0.260	86.0	1.93E-09	1.93E-09	1.93E-09
PAU	MLIA	0.325	0.844	312.0	1.96E-04	4.25E-04	6.71E-06
Wave guide	NO OUTGASSING	0.000	4.937	300.0	1.81E-05	2.30E-04	0.00E+00
M1 support rear side	PU1	0.545	3.112	42.0	1.90E-05	1.90E-04	1.11E-14
M1 support towards M1	NO OUTGASSING	0.000	3.112	42.0	5.49E-05	1.02E-04	2.10E-05
M1 support struts	PU1	0.348	1.990	42.0	1.90E-05	1.91E-04	0.00E+00
Baffle internal side	NO OUTGASSING	0.000	8.022	44.0	1.54E-05	1.41E-04	1.69E-12
Baffle external side	PU1	5.615	8.022	44.0	1.47E-06	1.02E-05	0.00E+00
M2 support	PU1	0.076	0.194	42.0	2.43E-05	7.55E-05	1.14E-08
M2 support struts	PU1	0.072	0.184	42.0	3.43E-05	9.46E-05	0.00E+00
M2 front side	NO OUTGASSING	0.000	0.957	313.0	1.83E-06	1.83E-06	1.83E-06
M2 rear side	MLI	0.326	0.957	313.0	2.34E-06	2.34E-06	2.34E-06
STM 1	MLIB	0.070	0.334	281.0	3.11E-04	5.82E-04	1.41E-05
STM 2	MLIB	0.070	0.334	281.0	5.69E-04	7.10E-04	4.33E-04
Sensor #1	MLIB	0.007	0.033	281.0	4.73E-04	1.68E-03	0.00E+00
Sensor #2	MLIB	0.006	0.030	281.0	7.80E-04	2.14E-03	0.00E+00
Sensor #3	MLIB	0.007	0.033	281.0	6.83E-04	1.67E-03	1.62E-08
Sensor #4	MLIB	0.020	0.097	281.0	1.79E-03	8.68E-03	0.00E+00
BEU	MLIA	0.179	0.465	309.0	1.00E-04	1.74E-04	1.02E-05
BEU Z306	Z306	0.005	0.058	301.0	7.94E-05	7.94E-05	7.94E-05
M1 front face	NO OUTGASSING	0.000	2.764	313.0	8.64E-07	3.82E-05	4.78E-17
M1 rear face	MLI	0.940	2.764	313.0	0.00E+00	0.00E+00	0.00E+00

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

7.2.4.1.4 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	6.00E-08	0.00E+00	6.00E-08
V-groove #1-X	0	0.00E+00	6.64E-07	6.64E-07
V-groove #2 +X	0	5.10E-10	1.10E-06	1.10E-06
V-groove #2 -X	0	1.91E-05	5.71E-07	1.96E-05
V-groove #3 +X (Painted part)	0	6.31E-06	1.61E-15	6.31E-06
V-groove #3 +X (Alu part)	0	2.27E-05	0.00E+00	2.27E-05
V-groove #3 -X	0	2.29E-05	1.28E-11	2.29E-05
Baffle internal part	0	1.88E-06	2.85E-07	2.16E-06
Baffle external part	0	6.07E-06	9.10E-07	6.98E-06
Primary mirror front	0	2.66E-07	4.37E-07	7.02E-07
Secondary mirror front	0	7.23E-07	2.89E-06	3.61E-06
FPU (active side)	0	1.46E-06	3.18E-09	1.46E-06

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	0.00E+00	0.00E+00	0.00E+00
V-groove #1-X	0	0.00E+00	6.63E-07	6.63E-07
V-groove #2 +X	0	0.00E+00	1.10E-06	1.10E-06
V-groove #2 -X	0	0.00E+00	5.71E-07	5.71E-07
V-groove #3 +X (Painted part)	0	0.00E+00	1.61E-15	1.61E-15
V-groove #3 +X (Alu part)	0	0.00E+00	0.00E+00	0.00E+00
V-groove #3 -X	0	0.00E+00	1.28E-11	1.28E-11
Baffle internal part	0	0.00E+00	1.53E-05	1.53E-05
Baffle external part	0	0.00E+00	1.19E-06	1.19E-06
Primary mirror front	0	0.00E+00	2.42E-07	2.42E-07
Secondary mirror front	0	0.00E+00	1.83E-06	1.83E-06
FPU (active side)	0	0.00E+00	1.93E-09	1.93E-09

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	6.00E-08	0.00E+00	6.00E-08
V-groove #1-X	0	0.00E+00	6.64E-07	6.64E-07
V-groove #2 +X	0	5.10E-10	1.10E-06	1.10E-06
V-groove #2 -X	0	1.91E-05	3.10E-06	2.22E-05
V-groove #3 +X (Painted part)	0	6.31E-06	1.61E-15	6.31E-06
V-groove #3 +X (Alu part)	0	2.27E-05	0.00E+00	2.27E-05
V-groove #3 -X	0	2.29E-05	1.28E-11	2.29E-05
Baffle internal part	0	1.88E-06	2.65E-07	2.14E-06
Baffle external part	0	6.07E-06	1.19E-06	7.26E-06
Primary mirror front	0	2.66E-07	3.15E-06	3.41E-06
Secondary mirror front	0	7.23E-07	2.89E-06	3.61E-06
FPU (active side)	0	1.46E-06	3.18E-09	1.46E-06

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	0.00E+00	0.00E+00	0.00E+00
V-groove #1-X	0	0.00E+00	6.63E-07	6.63E-07
V-groove #2 +X	0	0.00E+00	1.10E-06	1.10E-06
V-groove #2 -X	0	0.00E+00	3.10E-06	3.10E-06
V-groove #3 +X (Painted part)	0	0.00E+00	1.61E-15	1.61E-15
V-groove #3 +X (Alu part)	0	0.00E+00	0.00E+00	0.00E+00
V-groove #3 -X	0	0.00E+00	1.28E-11	1.28E-11
Baffle internal part	0	0.00E+00	1.54E-05	1.54E-05
Baffle external part	0	0.00E+00	1.47E-06	1.47E-06
Primary mirror front	0	0.00E+00	8.64E-07	8.64E-07
Secondary mirror front	0	0.00E+00	1.83E-06	1.83E-06
FPU (active side)	0	0.00E+00	1.93E-09	1.93E-09

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

Heating of the reflectors and FPU has clearly the anticipated effect of “cleaning” all the PLM, (especially PR and FPU), except the baffle internal part, which is contaminated by the heated components.

7.2.4.1.5 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	6.00E-08	N/A	N/A
V-groove #1-X	6.64E-07	N/A	N/A
V-groove #2 +X	1.10E-06	N/A	N/A
V-groove #2 -X	1.96E-05	N/A	N/A
V-groove #3 +X (Painted part)	6.31E-06	N/A	N/A
V-groove #3 +X (Alu part)	2.27E-05	N/A	N/A
V-groove #3 -X	2.29E-05	N/A	N/A
Baffle internal part	2.16E-06	N/A	N/A
Baffle external part	6.98E-06	N/A	N/A
Primary mirror front	7.02E-07	N/A	N/A
Secondary mirror front	3.61E-06	N/A	N/A
FPU (active side)	1.46E-06	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	0.00E+00	N/A	N/A
V-groove #1-X	6.63E-07	N/A	N/A
V-groove #2 +X	1.10E-06	N/A	N/A
V-groove #2 -X	5.71E-07	N/A	N/A
V-groove #3 +X (Painted part)	1.61E-15	N/A	N/A
V-groove #3 +X (Alu part)	0.00E+00	N/A	N/A
V-groove #3 -X	1.28E-11	N/A	N/A
Baffle internal part	1.53E-05	N/A	N/A
Baffle external part	1.19E-06	N/A	N/A
Primary mirror front	2.42E-07	N/A	N/A
Secondary mirror front	1.83E-06	N/A	N/A
FPU (active side)	1.93E-09	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	6.00E-08	N/A	N/A
V-groove #1-X	6.64E-07	N/A	N/A
V-groove #2 +X	1.10E-06	N/A	N/A
V-groove #2 -X	2.22E-05	N/A	N/A
V-groove #3 +X (Painted part)	6.31E-06	N/A	N/A
V-groove #3 +X (Alu part)	2.27E-05	N/A	N/A
V-groove #3 -X	2.29E-05	N/A	N/A
Baffle internal part	2.14E-06	N/A	N/A
Baffle external part	7.26E-06	N/A	N/A
Primary mirror front	3.41E-06	N/A	N/A
Secondary mirror front	3.61E-06	N/A	N/A
FPU (active side)	1.46E-06	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	0.00E+00	N/A	N/A
V-groove #1-X	6.63E-07	N/A	N/A
V-groove #2 +X	1.10E-06	N/A	N/A
V-groove #2 -X	3.10E-06	N/A	N/A
V-groove #3 +X (Painted part)	1.61E-15	N/A	N/A
V-groove #3 +X (Alu part)	0.00E+00	N/A	N/A
V-groove #3 -X	1.28E-11	N/A	N/A
Baffle internal part	1.54E-05	N/A	N/A
Baffle external part	1.47E-06	N/A	N/A
Primary mirror front	8.64E-07	N/A	N/A
Secondary mirror front	1.83E-06	N/A	N/A
FPU (active side)	1.93E-09	N/A	N/A

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

7.2.4.2 Thruster-plume

7.2.4.2.1 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	NH3	34.31%
Nitrogen	N2	57.86%
Hydrogen	H2	6.22%
Water	H2O	0.65%
Hydrazine	N2H4	0.46%
Aniline	C6H5NH2	0.50%

TABLE 7.2-28 - 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.

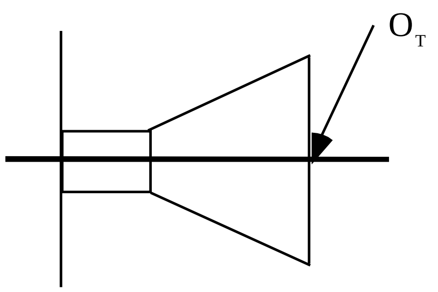


FIGURE 7.2-4 DEFINITION OF THE THRUSTER REFERENCE POINT

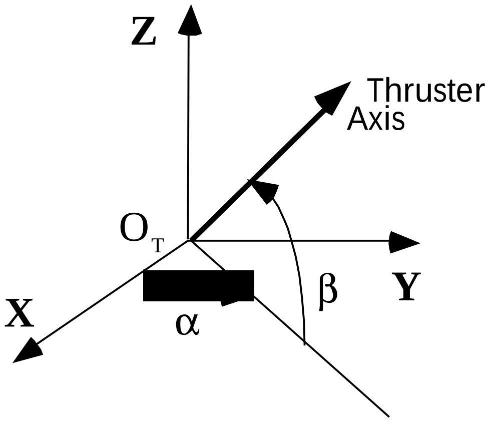


FIGURE 7.2- 5 DEFINITION OF THE THRUSTER ORIENTATION

Thruster		D1A	D2A	F1A	F2A	U1A	U2A	D1B	D2B	F1B	F2B	U1B	U2B	A1A	B1A	A1B	B1B
Coordinates	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
of the thruster	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
(mm)	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	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
(degrees)	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

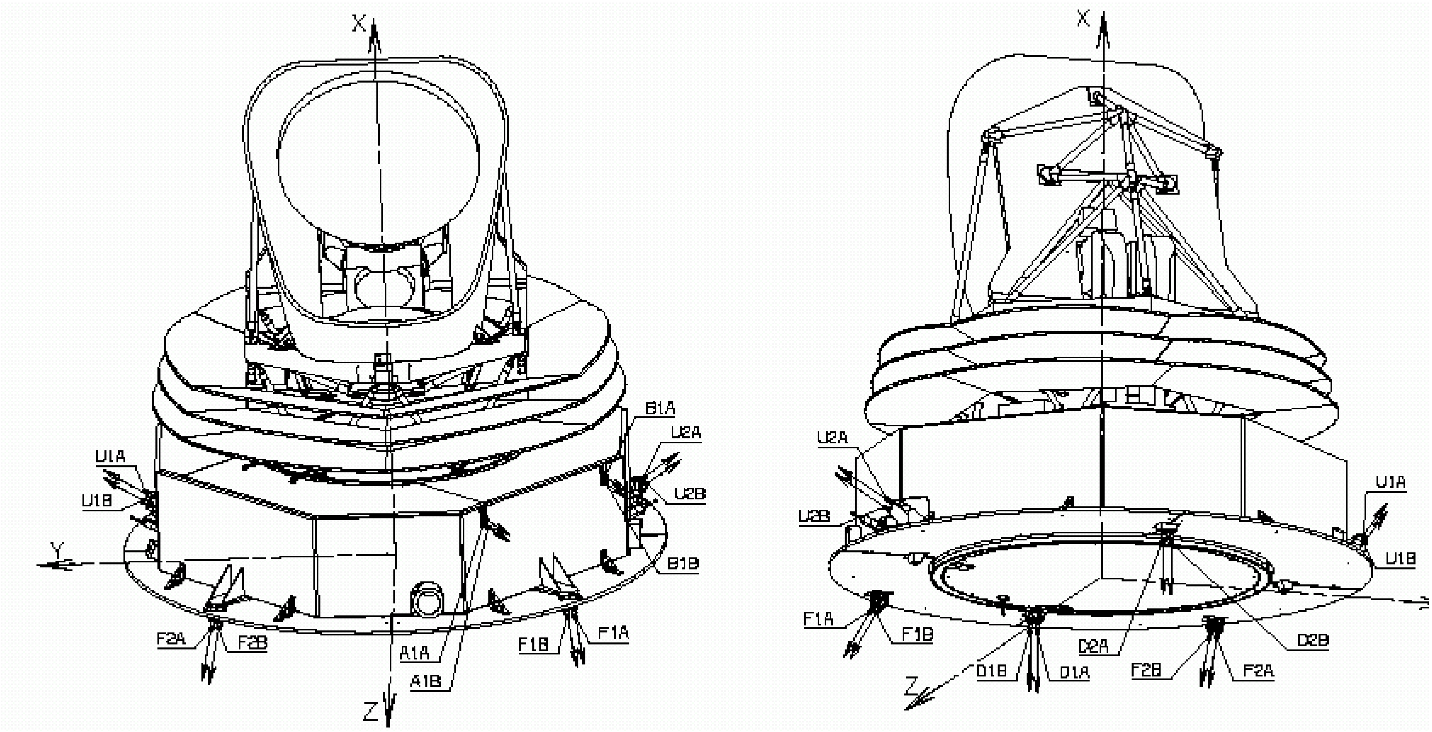


FIGURE N°7.2-6 - PLANCK THRUSTERS DEFINITION

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

7.2.4.2.2 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.

Ä 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 H2 (g/cm²)	Contamination by H2O (g/cm²)	Contamination by N2 (g/cm²)	Contamination by N2H4 (g/cm²)	Contamination by NH3 (g/cm²)
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

7.2.4.2.3 Contamination increase assessment due to plume

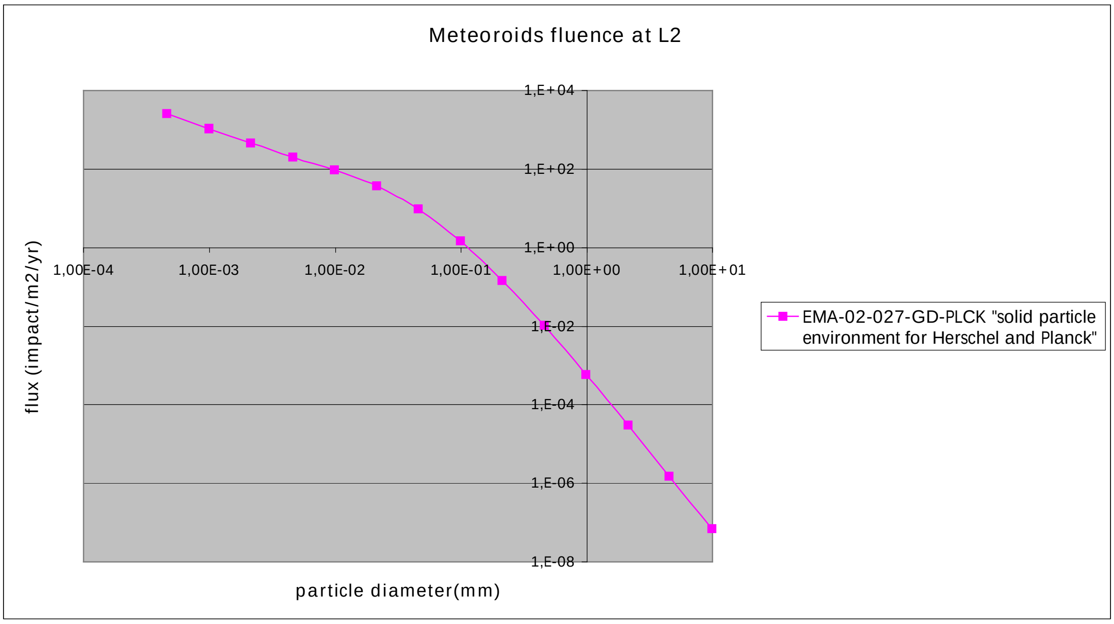
The contamination increase assessment due to the plume is completely negligible .

7.2.4.3 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.

7.2.4.4 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

Molecular

g/cm2	telescope		inside cryostat	LOU windows external	internal	LOU mirror	references
	M1	M2					
On ground contaminants							
delivery	2,00E-07	2,00E-07	4,00E-06	2,00E-07	2,00E-07	4,00E-06	Spec Tel (SCI-PT-RS-04671, Iss 7) / instruments at delivery /optical windows spec: HP-2-ASED-PS-0033
AIT	4,00E-07	4,00E-07	1,00E-07	4,00E-07	4,00E-07	5,20E-08	ASED cleanliness control plan
launch preparation	2,40E-08	2,40E-08	-	2,40E-08		3,12E-09	8 days in class 10 000 as per POC
ascent	-	-	-	-	-	-	
budget	6,24E-07	6,24E-07	4,10E-06	6,24E-07	6,00E-07	4,06E-06	
NH3							
In-orbit	0,00E+00	6,59E-10	0,00E+00	0,00E+00	0,00E+00		Contamination analysis H-P-1-ASPI-TN-0269 Issue 4
H20							
water permeation	-	-	1,20E-06	-	-		HP-2-ASED-TN-0034 issue 3
on-ground outgassing	-	-	2,50E-06	-	-	-	ASED cleanliness control plan
In-orbit outgassing	1,10E-05	9,52E-08	5,40E-07	5,20E-05	5,40E-07	6,76E-06	Contamination analysis H-P-1-ASPI-TN-0269 Issue 4
Thruster plume	0,00E+00	1,03E-11	0,00E+00	1,53E-12	0,00E+00	1,99E-13	Contamination analysis H-P-1-ASPI-TN-0269 Issue 4
budget	1,10E-05	9,52E-08	4,24E-06	5,20E-05	5,40E-07	6,76E-06	
Total	1,16E-05	7,20E-07	8,34E-06	5,262E-05	1,14E-06	1,08E-05	
EoL Needs	4,00E-06	4,00E-06	6,00E-06	6,00E-06	6,00E-06	6,00E-06	SRS 3.2

particulate

ppm	telescope		inside cryostat	LOU windows external	internal	LOU mirror	references
	M1	M2					
delivery	300	300	300	100,00	100,00	300,00	Spec Tel (SCI-PT-RS-04671, Iss 5)/ instruments at delivery /other subsystems specs
AIT	1900	95	200	200,00	200,00	26,00	latest ASED budgets
launch preparation	480	24		48		6,24	8 days in class 10 000 as per POC
ascent	2300	2300	0	2300,00		299,00	SRS 3.2
in-orbit	0,7	0,7	5,7	0,70		-	Contamination analysis H-P-1-ASPI-TN-0269 Issue 4
budget	4980,7	2719,7	505,7	2648,70	300,00	631,24	
EoL Needs	4500	4500	1200	1200,00	1200,00	1200,00	SRS 3.2

The molecular contamination budget build for Herschel shows that, despite the decontamination phase, some of the needs are exceeded.

The dominating effect is the water outgassing during operational lifetime. More precisely:

- On M1, the sunshade slow outgassing is contaminating M1 all along Herschel lifetime. However, in terms of transmission, the impact is negligible and should be acceptable for ESA/instruments (see [RD19])
- On the external part of the LOU windows, the indirect migration of water (from the hidden parts of the CVV and sunshield, via the visible part of the sunshield, impinging on the LOU windows) is the dominating contamination source. A dedicated analysis (see [RD19]) shows that the impact in terms of transmission is compliant with margins with HIFI transmission requirements
- On the LOU mirror, the need is slightly exceeded (same phenomenon as for the windows). Due to the lower level and the lower sensitivity of icing on the mirror, this should also be acceptable for ESA/HIFI
- On the FPUs, the CVV internal outgassing and the air permeation are responsible for the non-compliance

The particulate contamination budget shows compliance on the mirrors (average value of M1 + M2 is 3820ppm, below the max 4500ppm required), but, on the LOU surfaces HIFI needs are exceeded, due to launcher fairing. Here also, the impact in terms of transmission should however be acceptable for HIFI (see RD19).

8.2 Planck

8.2.1 Without decontamination phase

g/cm2	Groove 1		Groove 2		Groove 3		Baffle		optical cavity		
	+X	-X	+X	-X	+X	-X	internal	external	PR	SR	FPU
other contantminants											
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			
tel delivery									5,00E-07	5,00E-07	3,00E-06
End of AIT	5,20E-07	5,20E-07	5,20E-07	5,20E-07	5,20E-07	5,20E-07	2,70E-07	1,00E-06	1,40E-07	1,40E-07	1,40E-07
launch preparation	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08
ascent	-	-	-	-	-	-	-	-	-	-	-
budget	1,56E-06	1,56E-06	1,56E-06	1,56E-06	1,56E-06	1,56E-06	8,06E-07	2,04E-06	6,76E-07	6,76E-07	3,18E-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	-	-	-
H2O											
Trans. + Opera.	6E-08	6,64E-07	1,10E-06	2,22E-05	6,31E-06	2,29E-05	2,14E-06	7,26E-06	3,41E-06	3,61E-06	1,46E-06
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
budget	6,00E-08	6,64E-07	1,10E-06	2,22E-05	6,31E-06	2,29E-05	2,14E-06	7,26E-06	3,41E-06	3,61E-06	1,46E-06
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	-	-	-
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
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	-	-	-
TOTAL	1,62E-06	2,22E-06	2,70E-06	2,38E-05	7,87E-06	2,45E-05	2,95E-06	9,30E-06	4,09E-06	4,29E-06	4,64E-06
Instruments EOL Needs									4,00E-06	4,00E-06	6,00E-06

The contamination budgets built for Planck show that the needs are almost fulfilled without decontamination phase in-orbit.

Particulate

ppm	Groove 1		Groove 2		Groove 3		Baffle		optical cavity		
	+X	-X	+X	-X	+X	-X	internal	external	PR	SR	FPU
Livraison	3500		3500		3500		900	3500			300
Livrason tel									900	900	
End of AIT	1000		1000		1000		2255	1000	580	580	580
Bef encapsulation	1000		1000		1000		1945	1000	1945	1945	1945
launch preparation	720		720		720		720	720	720	720	720
Launch	2300		2300		2300		2300	2300	2300	2300	2300
budget	4020		4020		4020		4965	4020	4965	4965	4965
EOL Need	10000		10000		10000		10000	15000	5000	5000	5000
Instruments EOL Needs									5000	5000	5000

All the needs are fulfilled, although the optical cavity is just at the acceptable limit, mainly because of the launcher contribution

8.2.2 with decontamination phase

Molecular

g/cm2	Groove 1		Groove 2		Groove 3		Baffle		optical cavity		
	+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			
tel delivery									5,00E-07	5,00E-07	3,00E-06
End of AIT	5,20E-07	5,20E-07	5,20E-07	5,20E-07	5,20E-07	5,20E-07	2,70E-07	1,00E-06	1,40E-07	1,40E-07	1,40E-07
launch preparation	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08	3,60E-08
ascent	-	-	-	-	-	-	-	-	-	-	-
budget	1,56E-06	1,56E-06	1,56E-06	1,56E-06	1,56E-06	1,56E-06	8,06E-07	2,04E-06	6,76E-07	6,76E-07	3,18E-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	-	-	-
H2O											
Trans. + Opera.	0	6,63E-07	1,10E-06	3,10E-06	0	0,00E+00	1,54E-05	1,47E-06	8,70E-07	1,83E-06	2,00E-09
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
budget	0,00E+00	6,63E-07	1,10E-06	3,10E-06	0,00E+00	0,00E+00	1,54E-05	1,47E-06	8,70E-07	1,83E-06	2,00E-09
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	-	-	-
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
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	-	-	-
TOTAL	1,56E-06	2,22E-06	2,70E-06	4,66E-06	1,56E-06	1,56E-06	1,62E-05	3,51E-06	1,55E-06	2,51E-06	3,18E-06
Instruments EOL Needs									4,00E-06	4,00E-06	6,00E-06

Thanks to the decontamination phase, all the needs are fulfilled.

Particulate

ppm	Groove 1		Groove 2		Groove 3		Baffle		optical cavity		
	+X	-X	+X	-X	+X	-X	internal	external	PR	SR	FPU
Livraison	3500		3500		3500		900	3500			300
Livrason tel									900	900	
End of AIT	1000		1000		1000		2255	1000	580	580	580
Bef encapsulation	1000		1000		1000		1945	1000	1945	1945	1945
launch preparation	720		720		720		720	720	720	720	720
Launch	2300		2300		2300		2300	2300	2300	2300	2300
budget	4020		4020		4020		4965	4020	4965	4965	4965
EOL Need	10000		10000		10000		10000	15000	5000	5000	5000
Instruments EOL Needs									5000	5000	5000

All the needs are fulfilled, although the optical cavity is just at the acceptable limit, mainly because of the launcher contribution

APPENDICES : Contamination on the Star Tracker module

I. Contamination on the STR module.

The aim of this study is to quantify the contamination on the STR lenses due to the entire environment of the STR module. Neither the contribution of the internal baffle material of the Star Trackers, nor the multi-reflection contamination phenomenon induced by the internal baffle of the Star Tracker on lenses have been taken into account on this study.

On the one hand the contribution of the internal baffle paint Electrodag 501on lens's contamination have already been studied in the document [RD20], and on the other hand the multi reflection phenomenon have been neglected because the cold case lens's temperature (10°C) is higher than the hot case internal baffle's temperature (-25°C) and in this way no contamination coming from the internal baffle might deposit on the lenses.

The following inputs have been considered :

I.1. Geometrical inputs

The Esabase geometrical model is available in the figure hereafter :

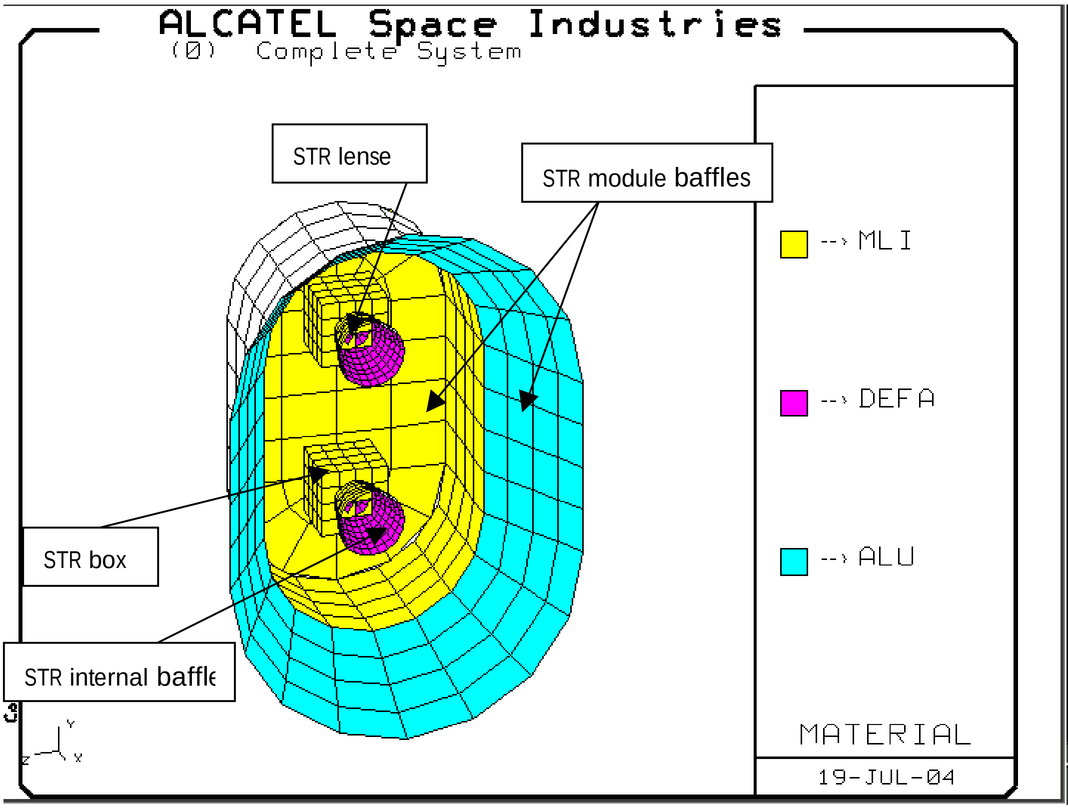


Figure 1: HERSCHEL – STR module – Outgassing model

I.2. Material implementation

The material implementation is presented in the table hereafter :

Element	Material	Density (g/cm3)	Thickness (10E-6m)
STR Box	MLI	1,4	140
STR Baffle internal	No Outgassing	N/A	N/A
STR Baffle external	MLI	1,4	140
STR lense	No Outgassing	N/A	N/A
Baffle around STR	MLI	1,4	140
Secondary baffle	Aluminium	1,4	140
Closure Panle SVM	MLI	1,4	140

Table 1 :STR module material implantation

Note : The goal of this particular study is to lay emphasis on the contribution of the platform to the contamination on the STR lenses. That is the reason why the internal baffle of the STR have been considered as no outgassing and the contribution of the black paint (Electrodag 501) on the internal baffle have not been taken into consideration.

I.3. Thermal inputs

The surface's temperatures chosen for the simulation are those of the thermal hot case for the parts of the module considered as outgassing (MLI surfaces for example). A thermal cold case have been taken into account for the STR lenses which are considered as sensible to contamination. A half part of the external baffle have been considered as "hot" (part being oriented towards sun) whereas the other half part have been considered as "cold" (part towards space).

These temperatures are presented in the table hereafter :

Element	Temperature (°K)
STR Box	283,0
STR Baffle internal	248,0
STR Baffle external	287,0
STR lense	283,0
Baffle around STR SUN	298,0
Baffle around STR Shadow	268,0
Secondary baffle Sun	303,0
Secondary baffle Shadow	268,0
Closure Panle SVM	303,0

Table 2 : Surfaces temperatures

I.4. Results

The simulation results are presented in the tables hereafter for two nominal configurations 3 weeks and 3,5 years.

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (kg/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
STR1 Box	MLI	0,005	0,023	283,0	1,90E-04	2,66E-04	9,47E-08
STR1 Baffle internal	NO OUTGASSING	0,000	0,051	248,0	2,31E-06	2,33E-06	2,30E-06
STR1 Baffle external	MLI	0,011	0,051	287,6	2,24E-04	2,25E-04	2,24E-04
STR1 lense	NO OUTGASSING	0,000	0,007	283,0	4,82E-08	4,82E-08	4,82E-08
STR2 Box	MLI	0,029	0,135	283,0	1,90E-04	2,75E-04	1,07E-07
STR2 Baffle internal	NO OUTGASSING	0,000	0,051	248,0	1,71E-06	2,09E-06	1,32E-06
STR2 Baffle external	MLI	0,011	0,051	283,0	2,25E-04	2,27E-04	2,23E-04
STR2 lense	NO OUTGASSING	0,000	0,007	283,0	1,02E-07	1,02E-07	1,02E-07
Baffle around STR Sun	MLI	0,165	0,764	298,0	2,04E-04	2,43E-04	1,65E-04
Baffle around STR Shadow	MLI	0,071	0,329	268,0	2,05E-04	2,34E-04	1,85E-04
Secondary baffle Sun	ALU	0,119	0,551	303,0	4,07E-05	5,49E-05	2,74E-05
Secondary baffle shadow	ALU	0,067	0,309	268,0	4,05E-05	5,21E-05	2,92E-05

Table 3: HERSCHEL STR module : Outgassing contamination after 3 weeks

Element	Material	Mass (kg)	Surface (m²)	Temperature (K)	Average contamination (kg/m²)	Maximum contamination (g/cm²)	Minimum contamination (g/cm²)
STR1 Box	MLI	0,005	0,023	283,0	1,84E-04	2,57E-04	9,32E-08
STR1 Baffle internal	NO OUTGASSING	0,000	0,051	496,0	2,29E-06	2,30E-06	2,28E-06
STR1 Baffle external	MLI	0,011	0,051	287,6	2,18E-04	2,18E-04	2,17E-04
STR1 lense	NO OUTGASSING	0,000	0,007	283,0	4,72E-08	4,72E-08	4,72E-08
STR2 Box	MLI	0,029	0,135	283,0	1,87E-04	2,72E-04	1,05E-07
STR2 Baffle internal	NO OUTGASSING	0,000	0,051	248,0	1,70E-06	2,07E-06	1,32E-06
STR2 Baffle external	MLI	0,011	0,051	283,0	2,21E-04	2,24E-04	2,19E-04
STR2 lense	NO OUTGASSING	0,000	0,007	283,0	1,00E-07	1,00E-07	1,00E-07
Baffle around STR Sun	MLI	0,165	0,764	298,0	2,01E-04	2,39E-04	1,62E-04
Baffle around STR Shadow	MLI	0,071	0,329	268,0	1,99E-04	2,27E-04	1,80E-04
Secondary baffle Sun	ALU	0,119	0,551	303,0	4,00E-05	5,39E-05	2,69E-05
Secondary baffle shadow	ALU	0,067	0,309	268,0	3,97E-05	5,10E-05	2,86E-05

Table 4: HERSCHEL STR module : Outgassing contamination after 3,5 years

The contaminant level on the STR lenses represent the hole quantity of contaminant incident on the surfaces during the time of simulation. In order to quantify the real quantity of contamination frozen on the lenses at the EOL, the CVCM have to be considered.

In this case the preponderant outagasing material is MLI and the temperature of the sensitive surface (STR lenses) is 10°C. In this condition the CVCM is near by zero. Nevertheless a worst case CVCM value of 0.01% have been considered.

The total mass deposit on the Star tracker lenses is done by the following formula :

$$\text{Total\_mass\_deposit} = \frac{CVCM}{TML} * \text{Incident\_contamination}$$

With : TML = 1.5% (TML of MLI at 30°C after 3,5 years)

CVCM = 0.01% (worst case for the CVCM of MLI at –25°C after 3.5 years)

The final results are presented in the table hereafter :

Element	Total incident contamination 3,5 years (g/cm²)	Total deposit contamination 3,5 years (g/cm²)
STR 1 lense	4,82E-08	3,21E-10
STR 2 lense	1,02E-07	6,78E-10

We can notice that the deposit contamination EOL due to STR module parts is very low with refer to the budget allocation of 3.10E-7 g/cm² (maximal contamination acceptance on the lenses at EOL) defined in [RD20].

Conclusion

As regard to the contamination there is no major impact of the STR module parts outgassing on the STR lenses.