HERSCHEL / PLANCK

Planck Cleanliness Control Plan

Product Code : 200000

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ENREGISTREMENT DES EVOLUTIONS / CHANGE RECORDS

ISSUE	DATE	§ : DESCRIPTION DES EVOLUTIONS § : CHANGE RECORD	REDACTEUR AUTHOR
01	15/06/2002	Initial Issue	M. Giordanengo
02	09/04/2004	Update of the document for the CDR PPLM : • Implementation of the witnesses for the hardware and the cleanroom (§ 10.2) • Detailed flow chart of the CQM according to the CQM AIT plan (§ 10.4)	M. Giordanengo
03	16/07/2004	Update of the document following the CDR PPLM RIDs for the CQM : • Text correction (§ 6, 9.1.6) • Hypotheses for mechanical tests (§ 9.1.1) • Witnesses for the CQM and the FM (§ 9.2.1) • FPU budget (hypothesis : § 9.4.1; CQM budget : § 9.4.3) • Hypotheses for the contamination redistribution in the optical cavity (§ 9.1.1) Update of the document for the FM contamination budget : • Integration of the new AIT inputs (§ 9.5) • Discussion on the PPLM cleaning efficiency and on the FPU cover (§ 11.3)	M. Giordanengo
04	27/02/2006	Update of the document for the PFM : • Precision of baked out constraints for AAS supplies (§ 8) • Update of the protection policy and the associated contamination (§ 10.1.1, 10.1.3.2 and 10.1.7.3) • CQM feedback for PPLM cleaning (§ 10.1.6) • Precision for the FM grooves witnesses (§ 10.2.1.2) • Integration of RFQM sequence (§ 10.5) • Integration of telescope sequence (§ 10.6) • Update of the PFM cleanliness flow chart (§ 10.7) • Update of the associated contamination budget (§ 11) • Update of the conclusions with discussion on particulate contamination budget (§ 12)	M. Giordanengo

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1. INTRODUCTION

This document presents the dispositions taken during the AIT sequence of Planck satellite to guarantee that the contamination level reached after the launch is compliant with the optical performances specifications. More over, it gives a detailed contamination synoptic that covers all the AIT sequences, from the beginning of the satellite integration to the delivery to Arianespace.
As it concerns AIT sequence, only the on ground contaminants, particulate and molecular, are studied. The other contaminants (NH_3, H_2O …) are taken into account in the flight analyses ([RD04]).

In § 11, PFM contamination budgets are calculated, considering the impact of the AIT sequence detailed in § 10.3. They are then compared to the needs.

This document is applicable to the CQM and the PFM.
Compared to the issue 2 of the document, the hypotheses have not been updated for the PFM.

2. DOCUMENTATION

2.1 Reference documents

[RD01] : ECSS-Q-70-01 : "Contamination and cleanliness control"

[RD02] : ESA PSS 01 204 : "Particulate contamination control in cleanrooms by particle fallout measurements "

[RD03] : ESA PSS 01 705 : "The detection of organic contamination of surfaces by infrared spectroscopy"

[RD04] : H-P-1-ASPI-AN-0269 :"Contamination Analysis"

[RD05] : H-P-1-ASPI-MN-1488 :"Cleanliness Team MoM N°7"

[RD06] : ASPI-02-PM/PT-0409 :"caractérisation du nettoyage de Nida Aluminium"

[RD07] : H-P-3-ASPI-TS-0051 :"Requirement specification for the Planck cryogenic facility"

[RD08] : ICU 623 : "Evaluation de la contamination moléculaire"

[RD09] :	ICU 625 :	" Evaluation de la contamination particulaire surfacique par compteur de particules en milieu liquide: METONE 211"
[RD10] :	ICU 626 :	" Evaluation de la contamination particulaire surfacique par microscope BHSM-NL "
[RD11] :	ICU 904 :	" Contrôle et suivi des salles à ambiance contrôlée "
[RD12] :	ICU 906 :	" Contrôle de pollution particulaire en lumière UV "
[RD13] :	IFCA 250.000 :	"Conditionnement des pièces spatiales"
[RD14] :	IFCA 291.000 :	"Nettoyage, emballage, déballage des pièces de types Classe 100"
[RD15] :	IFCA 341.000 :	"Procédure de travail en salle V01 Nord"
[RD16] :	IFCA 428.000 :	" travail en salle à empoussièrement contrôlé de cl 10000 et 100 000"
[RD17] :	REF-ASP-PN-93-F :	"salles propres à ambiance contrôlée"

2.2 Applicable documents

[AD01] : H-P-1-ASPI-SP-0035 :"Cleanliness requirements specifications"

[AD02] : H-P-3-ASP-PL-0668 :"Planck CQM AIT Plan"

3. ACRONYMS

AD	Applicable Document
AIT	Assembly, Integration and Test
CVCM	Collected Volatile Condensable Material
EOL	End Of Life
GSE	Ground Support Equipment
MLI	MultiLayer Insulation
NRB	Non-Conformance Review Board
PA	Product Assurance
PLM	PayLoad Module
PPM	Parts Per Million
QA	Quality Assurance

RD	Reference Document
RF	Radio Frequency
RML	Recovered Mass Loss
S/C	Spacecraft
SVM	Service Module
TBC	To Be Confirmed
TBD	To Be Defined

4. LIST OF SENSITIVE ELEMENTS

Planck sensitive elements (in term of contamination) are :

- the focal plane unit
- the reflectors
- the V-grooves low emissivity surfaces
- the V-grooves high emissivity surfaces
- the external side of the baffle
- the optical cavity.

5. AIT CONTAMINATION ALLOCATIONS

All the contamination allocations for the AIT sequence (till encapsulation) are given in [AD01].
They are applicable to the PFM :

element	particulate contamination allocation for S/C AIT till encapsulation
Focal plane unit	800 ppm
Primary and secondary reflectors	1400 ppm (telescope + spacecraft AIT)
Optical cavity	2400 ppm
External parts of the PPLM	1500 ppm
External surfaces of the SVM	3400 ppm

Table 5.1 : particulate contamination allocations for S/C AIT till encapsulation

element	molecular contamination allocation for S/C AIT till encapsulation
Focal plane unit	$3\ 10^{-7}$ g/cm^2
Primary and secondary reflectors	$6\ 10^{-7}$ g/cm^2 (telescope + spacecraft AIT)
Optical cavity	$7\ 10^{-7}$ g/cm^2 (telescope + spacecraft AIT)
External parts of the PPLM	$9\ 10^{-7}$ g/cm^2 (telescope + spacecraft AIT)
External surfaces of the SVM	$2\ 10^{-6}$ g/cm^2

Table 5.2 : molecular contamination allocations for S/C AIT till encapsulation

6. GENERAL RULES FOR PREVENTION OF CONTAMINATION

6.1 Design

The materials near the sensitive surfaces shall be compliant with the outgassing specifications (RML < 1% ; CVCM < 0.1%). This criterion is necessary but may not be sufficient. So, due to the potential outgassing that shall not affect the cleanliness level, a conditioning may be realised considering the needs coming from the cleanliness analyses.

Generally, the following kinds of materials will undergo a bake out :

- the materials that have a view factor with the optical surfaces
- the materials that are near the optical surfaces
- the materials that are in the optical cavity
- the materials that have a high mass and an important temperature difference with the optical surfaces.

The materials used for the sensitive elements shall not induce scraps . They must be inert with regards to the creation of particles.

The metal pieces shall not have pointed edges that could create particles during integration.

Open holes will be avoided.

6.2 Manufacturing

All items manufactured in non-clean conditions shall be subject to cleaning to the required cleanliness level and packaged for delivery to the classified clean area according to [RD14]. Such cleaning and packaging shall be supervised and certified by the PA Engineer.

For the lubrication during manufacturing, no oil with paraffin will be used. Oils cleanable with usual solvents will be preferred. After each operation, the pieces will be degreased.

The metal pieces shall not have barbs that could create particles during integration. This point has to be checked at their arrival.

6.3 Assembly and test

6.3.1 Clean rooms

The cleanliness of Assembly, Integration and tests areas must be compatible w.r.t. equipment/subsystem/system required cleanliness level.

Certification of the facilities in accordance with the cleanroom standards shall be done by the QA Department. PA shall also check the facilities compliance to project requirements and review the operating controls implemented in the facilities.

All hardware not pre-packaged must be cleaned before entering the controlled areas up to the required cleanliness levels.

Written operational guides are established to avoid contamination and degradation of the cleanrooms cleanliness level.
This guide shall deal with :

- rules to be applied
- cleanroom constraint and monitoring
- cleanroom cleaning
- garments
- personnel entrance …

All these requirements are included in the document [RD17].

The critical elements are protected most of the time during activities according to § 10. During exposure of these elements, the time duration shall be controlled and recorded.

For specific tests or facilities:

1. Acoustic and vibrations facilities
   - The responsible shall take measures to reduce or eliminate the contamination hazards by keeping the exposure time to the minimum, using additional enclosure, clean walls, clean tent...
   - The cleanliness constraints defined in the cleanliness control plan shall be integrated in the AIT plan and procedures shall be approved by the PA Engineer.

2. Thermal vacuum facilities

Just prior any application to hardware, it shall be demonstrated that the test facilities will not induce unacceptable contamination to the hardware. A blank test shall be performed to check this.

6.3.2 Personnel

The personnel have to respect the specifications of [RD17] and of [RD15].

All personnel working in clean areas shall receive training about the purpose and practice of clean area operations. Only those trained people shall be authorised for area access.
The clothes (cap, gloves, mask …) must be compatible with the 100000 or 10000 cleanroom.

Only personnel trained in precision cleaning process shall be involved in special hardware cleaning.

Any manipulation of flight hardware and the associated set of tools must be done with clean and lint-free gloves.

Personnel assignment and entry into a clean area shall be under the responsibility of the AIT manager.

For occasional visitors who might need to enter the clean room the right of access shall be given by the AIT manager. He has the responsibility for visitor briefing in compliance with cleanroom procedures.

6.3.3 GSE

For all GSE :

- a cleaning to meet the required cleanliness level has to be performed
- packaging has to be implemented before delivery to the classified clean area

according to [RD14] and [RD16].

The GSE submitted to the same constraints as the hardware shall meet the same requirements.

For uncleanable means, the cleanliness of manufacturing area must be compatible w.r.t. equipment/subsystem/system required cleanliness level. If not, covers shall be implemented not to contaminate the hardware.

Special attention has to be taken for GSE and means used under vacuum.

6.3.4 Cleaning process

The cleaning processes used to clean integration means (as screws, nuts, washers …) are defined in [RD13] and [RD14].

6.3.5 Harnesses

All manipulations that create particles after wiring are forbidden.

Interventions as soldering, splice, crimping, stripping … are not authorised in cleanroom. In case of need, specific procedures will be defined in the frame of NRB.

All the wiring activities will be done with a special care and will be treated individually.

6.4 Handling, packaging, transport

The packaging processes are defined in [RD13] and [RD14].

Handling of components and units shall be minimised and shall be controlled in accordance with the respective handling and safety procedures. A protection of sensitive elements and cleanliness volumes must be used as often as possible. Clean items shall be protected from contamination by proper preservation, packaging or storage prior to further handling as assembly and integration.

Packaging requirements shall be defined in written procedures. Their content shall be reviewed for contamination aspects by the PA Engineer. The requirements of ECSS-Q-70-01 § 6.5. shall be met by these procedures (packing materials shall not release corrosive vapours or containing corrosive constituents. The contamination level of the packed item shall not increase the specified cleanliness level...).

Transportation containers shall be designed such as the contamination of the components contained therein is not degraded. Consequently, materials used in the construction of the container shall not induce contamination. Entry of contamination from external sources shall not be possible. Purging gas system shall contain appropriate filtration.

Monitoring of contamination during transportation shall be carried out by the provision of particulate and molecular witnesses and visual inspection as a minimum. Cleaning procedures for the transport containers shall be developed and applied prior to use it for flight hardware.

6.5 Storage

The storage shall be performed:

- either in clean packaging (see [RD14])
- or in clean container.

In any case, the cleanliness conditions during storage have to meet the equipment/subsystem/system cleanliness requirements.

Cleanliness during storage shall be controlled with at least a pair of particulate and molecular witnesses and recorded.

6.6 Launch activities

The cleanliness during launch activities shall be compatible w.r.t. required cleanliness level.

A monitoring of cleanliness during these phases has to be implemented to control contamination. This monitoring consists in :

- registrating the exposure duration
- controlling the room area under UV light (TBC).

7. CLEANLINESS CONTROL

7.1 Method of control

7.1.1 Molecular control

The molecular contamination must be checked by I.R. spectrometry method according to [RD08]. This method is compatible with ESA PSS 01 705.

7.1.2 Particulate control

The particulate contamination can be controlled by 3 methods :

- counting the particles in a volume using a particle counter functioning on a light diffusion (MET ONE, HIAC-ROYCO) according to [RD11]
- the indirect method which consists in counting in the rinsing solvent the dust grains of different sizes, with the help of a microscope ([RD10]) or a liquid laser counter ([RD09]) which answers to the specifications listed in ESA PSS 01 204

- counting the contamination under UV light as described in [RD12].

7.2 Hardware monitoring

Monitoring of the hardware shall be performed during manufacturing (if necessary), AIT, transportation, storage... at equipment, subsystem or system level by the company responsible of the hardware, in compliance with cleanliness flow chart.

Due to contamination risks during handling and inability to clean some optical elements (which may cause performance degradation) monitoring by witnesses is recommended and wiping process shall be strictly limited.

At least one pair of molecular / particulate witnesses will be placed in the equipment (TBC), or subsystem or system near the sensitive elements. They can be useful either for specific activities (vibrations, etc...) or for cumulating the pollution until final measurements.

- They will be exposed in an environment representative of the sensitive elements one.
- All the measurements shall be recorded and sent to the QA Engineer.

The policy hold for Planck critical elements is :

- to protect them each time it's possible
- to clean them (in case of cleanable elements) in order to decrease their contamination level.

For each critical element, when no cleaning is scheduled any more, the contamination level will be followed using witnesses. Their types, positions and the frequency of controls are defined in § 10.2.

7.3 Cleanroom monitoring

The cleanroom shall respect the rules defined in [RD17].

Within an environmentally controlled area, only the equipment which is specifically needed for the work in progress shall be stored. Equipment to be used in a clean room shall be cleaned before entering the clean area. Special care shall be taken so that volatile materials (e.g. oil) are not stored or used near the equipment.

Prior to the entry of flight hardware into a clean area, the cleanliness of this area shall be checked.

7.4 Treatment of the non-conformance

Each non-conformance will be treated as specified in PA plan H-P-1-ASPI-PL-0055.

In a first step, no cleaning or decontamination are scheduled for the optical surfaces (reflectors and FPU) : it is considered as an exceptional case. In case of accidental contamination of these critical surfaces, dispositions will be taken according to NRB.

7.5 Documentation

The applicable documents for the usual information (cleaning processes, working procedures, bake out …) are listed in the § 2.2.

All the cleaning processes developed especially for Planck will be listed in the « Declared Process List ».

All the results concerning the cleanliness levels reached on the satellite will be gathered by the QA Engineer and checked with the Cleanliness Engineer.

At the end of the AIT phase, a summary of the cleanliness levels reached will be provided by the QA Engineer in the ADP.

8. SPECIFIC CLEANLINESS PROVISIONS AND ASSOCIATED MEASURES FOR PLANCK

This paragraph concerns all the thermal control equipments (as heaters, cables, MLI …) provided by Alcatel Alenia Space for the PPLM.

Before integration on the structure, all these elements will be baked out.

9. CLEANLINESS CONTROL PLAN FOR THE SUB-SYSTEMS

9.1 Cleanliness control plan

All the AAS cleanliness specifications will be applicable to the subcontractors.

Each subcontractor will answer to this specification by a cleanliness control plan. He must indicate the location of activities, the time exposure duration, the moment of protections, the moment of cleaning, the cleaning and preventive actions, the tests procedures (whether the test could have an effect on cleanliness level), the cleanliness flow chart, the cleanliness and inspection procedures.

The Prime Contractor has to check the conformance between the specifications and the specific provisions scheduled in the subcontractors Cleanliness Control Plans.

When this plan, after comments and negotiation, is in accordance with the specifications, it is approved by the Cleanliness Engineer and it becomes prior to the specifications.

9.2 Audit

- In case of non-conformance or repeated problems concerning the cleanliness level of a Subcontractor delivery, a cleanliness audit will be performed by PA Engineer, in order
  - ð to check the application of the Cleanliness Control Plan
  - ð to determine the potential lacuna of this plan
  - ð to determine the preventive and corrective necessary actions to reach the cleanliness specification.

- The Subcontractor shall conduct audits of his own and of his lower Subcontractors or Suppliers facilities, equipment, personnel, procedures, services and operations to check if this Cleanliness Control Plan is well applied.

- An audit can also be conducted to estimate the available means of a new supplier that has no space references.

It is recommended that the "cleanliness audits" are performed by a team of personnel trained with the cleanliness activities; Planck Cleanliness Engineer shall participate to such audits.

These audits shall be conducted early in the program to minimize the effects of the eventual corrective actions. The results of these audits shall be documented in a report and the follow-up of the required corrections must be performed by the concerned Contractor.

AAS and its Customer shall be invited to participate to such audits, and shall receive a copy of these reports.

9.3 Documentation

At delivery, each Subcontractor summarises the reached cleanliness levels.
This cleanliness report will be included in the End Item Data Package.

9.4 Contractors cleanliness control plan

All the subsystems for which AAS expects a cleanliness control plan are listed here after.

9.4.1 Cryostructure

9.4.2 Telescope

9.4.3 FPU

9.4.4 SVM

10. AIT/AIV SEQUENCE

10.1 Hypotheses

10.1.1 Contamination during AIT (except cryogenic tests)

All the AIT, except cryogenic tests, is done in Cannes, in a cleanroom 100000. The following expected contamination levels are given considering the standard particles size distribution MIL-STD-1246-B.

- 1 day in class 100000 : 225 ppm
- 1 year in class 100000 : 1.10^{-6} g/cm^2

These values correspond to 24 working hours. To take into account the real exposure time, if the material is protected during the non-working hours, a correction coefficient has to be applied.
The normal work corresponds to 8 working hours per day.

- If the hardware is protected otherwise, the coefficient to be applied on the number of days will be taken equal to 0.5 (and not 8/24 = 0.33) to keep a margin.
- If not, the coefficient is equal to 1.

According to the Cleanliness Team Report (see [RD05]), the assumptions are transport :

- Particulate : 25 ppm
- Molecular : 1.10^{-9} g/cm^2 /day (equivalent to contamination in cleanroom 100).

Based on the protection designed for the vibration tests, the cleanliness budget is done considering the following values during this test :

- Particulate : 12 ppm/day (equivalent to contamination in cleanroom 1000)
- Molecular : 2.7 10^{-10} g/cm^2 /day (10% of the contamination in cleanroom 100000).

Note 1 : due to accessibility constraints under the tent during the vibration sequence, this protection is not completely closed. This is the reason why the associated contamination is not supposed to be null.

Note 2 : Concerning the redistribution,

- For the CQM model, the mirrors or the FPU are not present during the test (see § 10.4.2), so the impact of redistribution has not to be considered
- For the FM model, the redistribution inside the optical cavity is considered in the “cleanliness end of life analysis” (H-P-1-ASPI-AN-0269) considering the ratio of the optical cavity inner surfaces.

10.1.2 Contamination during cryogenic tests

These tests take place in CSL in a cleanroom 10000. The following expected contamination levels are given considering the standard particles size distribution MIL-STD-1246-B.

- 1 day in class 10000 : 60 ppm
- 1 year in class 10000 : 1.10^{-6} g/cm^2

These values correspond to 24 working hours.
The spacecraft arrives in CSL with its protections. As long as they are not put away, the particulate and molecular contamination are not considered for the corresponding elements.

1 thermal vacuum test (according to the cleanliness working team – see [RD05]) :
- Particulate : 25 ppm
- Molecular : 1.10^{-9} g/cm^2 /day

This hypothesis is confirmed by the measures done on the CQM during the thermal vacuum test in CSL facilities (see environmental witnesses control reference CTLC-ASP-TR-3140. The values provided in this document are in accordance with the wipes done on the hardware and in the chamber and the CSL measures).

10.1.3 Protections

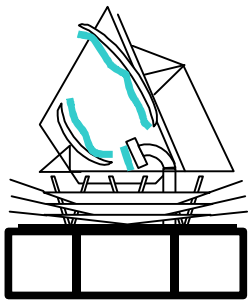
The protections only concern the PPLM : the SVM is not supposed to be protected.

During non-working periods, the PPLM is protected as far as possible. In that case, it is supposed that the particulate and the molecular contamination are null (see [RD05]).

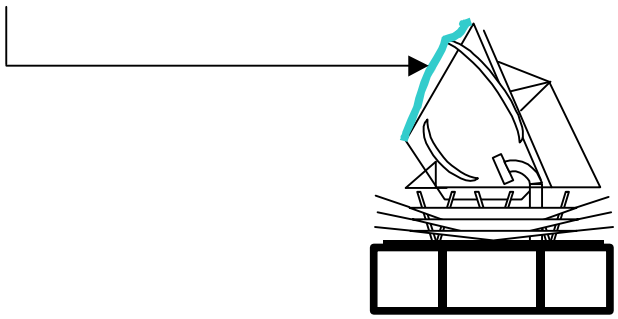
10.1.3.1 First protections policy

At the beginning of Planck cleanliness study, the following protections were defined :

- Protection 0 : no covers on the whole PPLM (including the optics)
- Protection 1 : covers on the 2 mirrors and the FPU

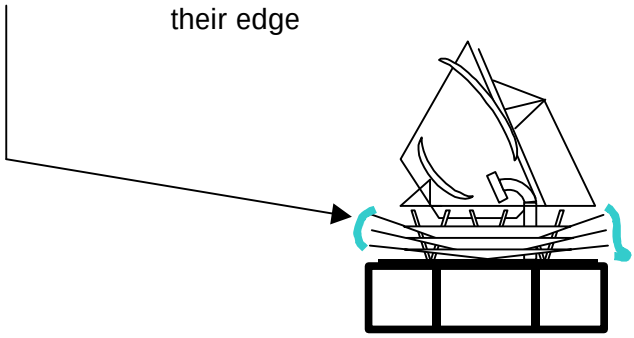


- Protection 2 : the optical cavity is covered with a film

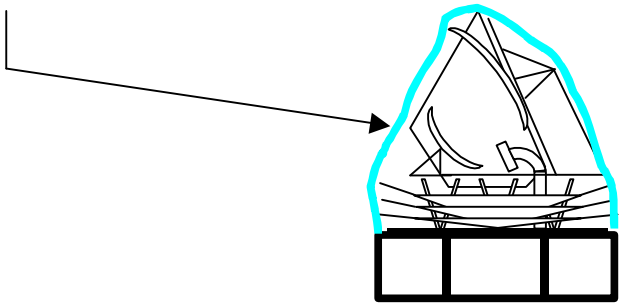


Note : this protection is linked on the PPLM baffle using velcros. The attachment points have overcome the thermal vacuum test (input check after the CQM thermal vacuum phase).

- Protection 3 : the upper and lower faces of the grooves are protected with a film on their edge



- Protection 4 : the whole PPLM is covered



10.1.3.2 protections design update

Based on experience on the acoustic model and thermal model, the following inputs have to be considered :

- FPU protection : once the baffle is mounting, the FPU access platform allows to mount/dismount the HFI protection. In this document, in a conservative way, it is supposed that the FPU is not reachable anymore once the baffle is mounting. So the FPU contamination follows the optical cavity ones. Considering the FPU orientation, only 10% of the optical cavity total particulate contamination is considered (and 100% for the molecular one).
- Mirrors protection : they can be removed with the baffle mounting; but they cannot be re-installed later in the sequence.

- The protection 4 can be used during integration phases, but not during specific tests.
- For the vibration test, considering the AAS facilities, a "box" is implemented during this test to limit the PPLM exposure duration.

The PFM detailed updated preventive measures for the different specific tests is described in § 10.1.7.3.

10.1.4 Cleanliness budget

For each critical subsystem in term of contamination, the duration of each phase is divided between :

- the periods without protection
- the periods with protection.

The total amount of exposed hours is then multiplied by the contamination per hour linked to the cleanroom class.

For the specific phases (thermal vacuum, mechanical tests and transports), the budget defined in § 10.1.1 and 10.1.2 is then added.

10.1.5 Hypotheses for the cleanings

The cleanings only concern the particulate contamination, as the molecular contamination has been shown as non critical (see budget in § 12.1).

The assembly really begins with the RAA mounting. For the earlier activities (WU preparation), the panels are supposed to be cleaned after their preparation, before their assembly. As it concerns plane surfaces, they are supposed to reach 300 ppm after this cleaning.
The electronics, the piping and the He tank are supposed to be integrated at 300 ppm - $2\ 10^{-7}$ g/cm^2. Concerning the harness, the cleaning is supposed to decrease the contamination down to 1000 ppm - 10^{-6} g/cm^2
Finally, cleanings on the mirrors guarantee a level of 300 ppm - $2\ 10^{-7}$ g/cm^2 .

If a cleaning is scheduled on the SVM, it is supposed that not all the surfaces are accessible (due to external elements such as antennas …). The final contamination level is calculated supposing that :

- 90 % of the surface reaches a level of 1000 ppm
- 10% of the surface keeps the initial level Ci.

So the final level is equal to : (Ci * 0.1) + (1000 * 0.9).

If a cleaning is scheduled on the PPLM, as it can concern non-plane surfaces, it is supposed that the particulate contamination can decrease down to 1000 ppm.
If this cleaning happens once the baffle is mounted, the optical cavity is not accessible anymore. So its particulate contamination is not improved by the cleaning.

10.1.6 feedback of the CQM cleaning

The CQM cleaning has been performed in CSL, before the thermal vacuum. During this sequence :

- the particulate contamination has been controlled before and after cleaning using UV light, on the open honey comb parts and the Miro parts
- a global check has been performed at the end of the cleaning phase to control the homogeneity of the cleaning on the PPLM.

This procedure has been lead successfully : the specific cleaning means provided for Planck allow to decrease the particulate contamination level on the different surfaces constituting the PPLM. All the results are presented in the test report TR-2480 (that referred to the procedure MM1-P25).

10.1.7 Preventive actions

10.1.7.1 Global preventive actions

During the assembly / integration, if no activities are scheduled on the PPLM, it is protected, whatever its integration status.

A cleaning of the PPLM is scheduled just before the baffle mounting : it corresponds to the last moment when the telescope is accessible. During this phase, the PPLM and the baffle are cleaned. It takes 2 days to install the baffle and close the optical cavity. So the optical cavity can be exposed 2 days to the environment 100 000 after its cleaning, before its protection.

In the AIT sequence, for the shrouds installation (or the shrouds removal) in CSL, the optical cavity cover can be put away very late (or put in very early) in the phase. So the optical cavity, the mirrors and the FPU are non-protected only one day during the shrouds installation or the shrouds removal.
This hypothesis is confirmed by the CQM sequence (protection put away in the chamber directly, and put in place at the end of the test in the chamber too).

10.1.7.2 Specific preventive actions for the CQM

The CQM will be used to qualify the PPLM cleaning procedures at S/C level. The implementation of this cleaning in the CQM flow chart depends on the expected contamination level, in order to be representative of the ones estimated on the PFM level before the S/C cleanings (se § 10.7).

The following cleanings are scheduled on the CQM :

- at the end of the acoustic test, once the model is dismounted, the different parts of the PPLM (telescope, baffle, grooves) will be cleaned separately. A level of 1000 ppm is expected on these elements. A cleaning will also be applied on the different panels of the SVM : as they are cleaned individually, a level of 1000 ppm is expected too.
- at the end of the cryo test, the external sides of the baffle and the grooves will be cleaned before the model dismounting. The dismounting allows to control the reached particulate level on the different parts of the grooves (extension and centre).

Concerning the cleanings, as for the PFM, a spacecraft cleaning is scheduled in Cannes before the transport to CSL. According to the CSL AIT activities duration, this cleaning guarantees a particulate contamination before the cryo test in accordance with the one expected for the PFM.

10.1.7.3 Specific preventive actions for the PFM

Three cleanings are scheduled on the whole spacecraft :

- one at the end of the assembly / integration phase
- one in CSL before the first thermal vacuum test
- one before encapsulation.

Telescope is integrated with protective covers on the reflectors. These protections can be removed once the baffle is mounted. As the first alignment phase can be done without using the mirrors active face, these protections are kept until the RF test. For this test, the mirrors protections have to be removed and can not be put again (accessibility problems with the baffle mounting – see § 10.1.3.2).

During the vibration test, the satellite is under a protection (see § 10.1.3.2). As this protection is not completely closed for accessibility constraints, the associated contamination hypotheses are provided in § 10.1.1.

For the acoustic test and the RF test, the optical cavity is :

- opened during the tests
- closed (using the protection 2) between 2 runs.

In the budget, half a day is considered with the optical cavity opened.

The MCI test is done with the protection 2 on the top of the baffle (negligible element in the S/C budget).

For the balancing, the hypothesis is that the optical cavity is opened during the runs, with :

- 1 run in cleanroom 100 000 (in normal work)
- 3 runs under vacuum (with 1 day margin in cleanroom 100 000) for the last balancing phase.

10.2 Control / witnesses

10.2.1 Witnesses on the hardware

The policy for the contamination control is defined as follows :

- step witnesses will be scheduled for the environmental tests and RF tests
- cumulative witnesses will be implemented to guarantee a contamination level at delivery.

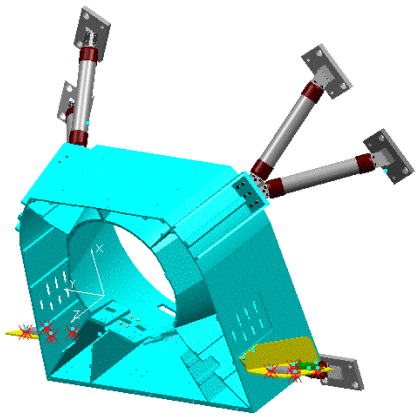
In the following description of the witnesses, the term “set” includes :

- 2 cumulative witnesses (1 molecular and 1 particulate)
- 2 step witnesses (1 molecular and 1 particulate).

10.2.1.1 Witnesses for the CQM

The following sets of witnesses will be implemented on the CQM :

- one set is positioned inside the optical cavity. It will be linked on the FPU (see next figure)

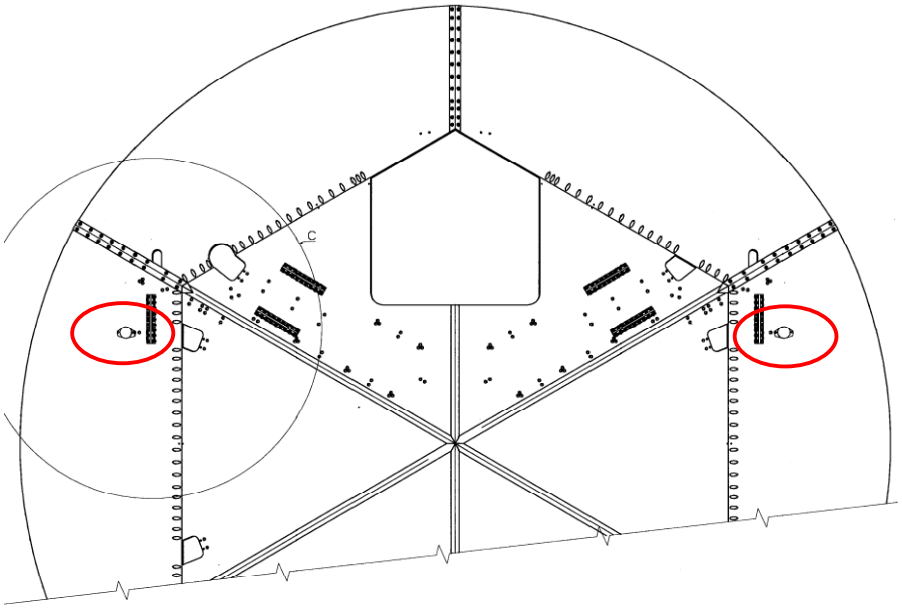


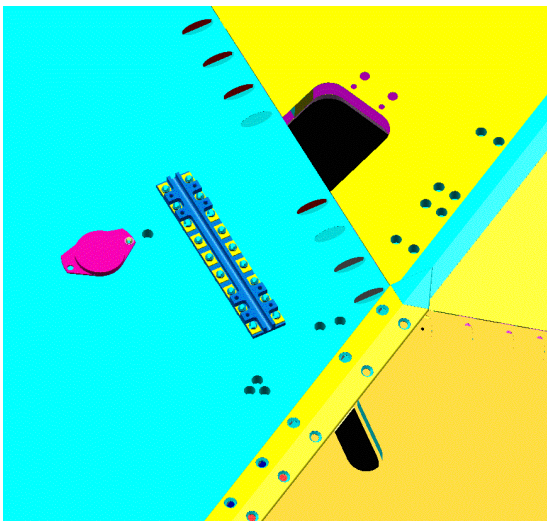
- one set is positioned on the upper face of the groove 2 extensions or the lower face of the groove 3.

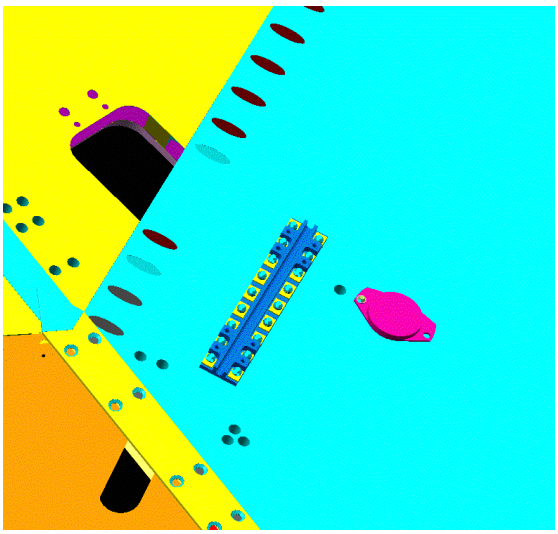
Molecular Cumulative and Step witnesses location on Cryo-Structure :

These 2 witnesses are directly attached with one screw each on the lower side of Groove 3 (-X face), definition of the link for 1 piece :

- 1 screw RSAT M4x10
- 1 Spring washer CuBe2, Dia int 4.2 mm, Dia ext 8 mm, thickness 0.4 mm
- 1 large washer, Dia int 4.25 mm, Dia ext 14 mm, thickness 0.8 mm



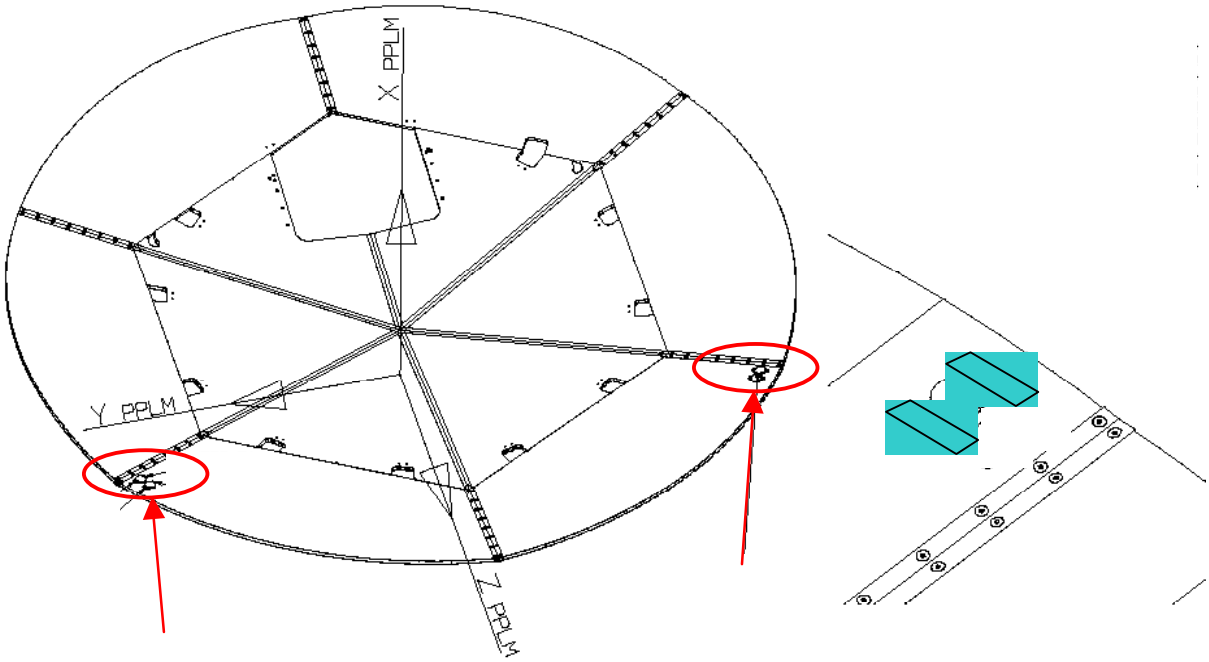




Particular Cumulative and Step witnesses location :

- For the particulate ones, this position opposite to the gravity is not the best one. So these witnesses will be stickled on the upper face of the groove 2. During the thermal vacuum itself, in order to avoid any risk of hardware damage, the witnesses will be moved and stickled on the GSE around the cryostructure (and not the grooves themselves). This policy is not the best one, but it is acceptable as it only concerns the particulate contamination (which is not the critical contamination expected during a TV test).

During integration or stocking phases : these 2 witnesses are attached with adhesive strips on the upper side of Groove 2 (+X face), Definition of the link : Kapton adhesive strips 8901.



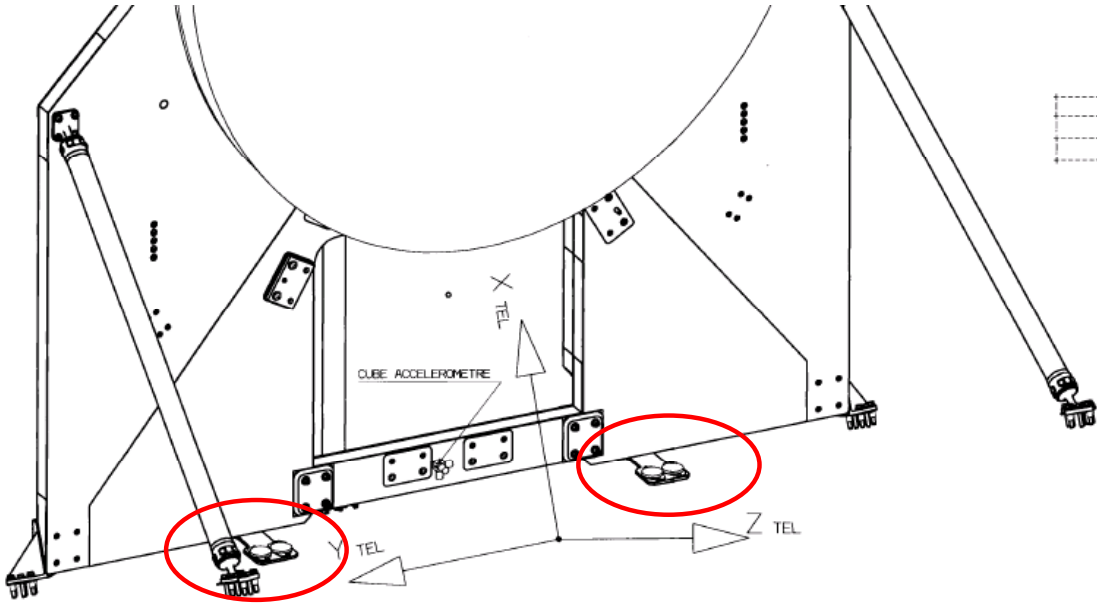
These sets are not designed to support all the mechanical tests (acoustic and vibration). This constraint is taken into account in the detailed CQM flow chart (see § 10.4).

10.2.1.2 Witnesses for the PFM

The following sets of witnesses will be implemented on the PFM :

- one set is positioned inside the optical cavity. It will be linked to the PR panel.

Particular and Molecular Cumulative and Step witnesses location in the optical cavity :
These 4 witnesses are attached on specific support plates. These 2 support plates are attached on free shurlock at the back of the PR Panel, bottom side (-X).
The attachment of these support plates is detailed in the FM model integration drawings.



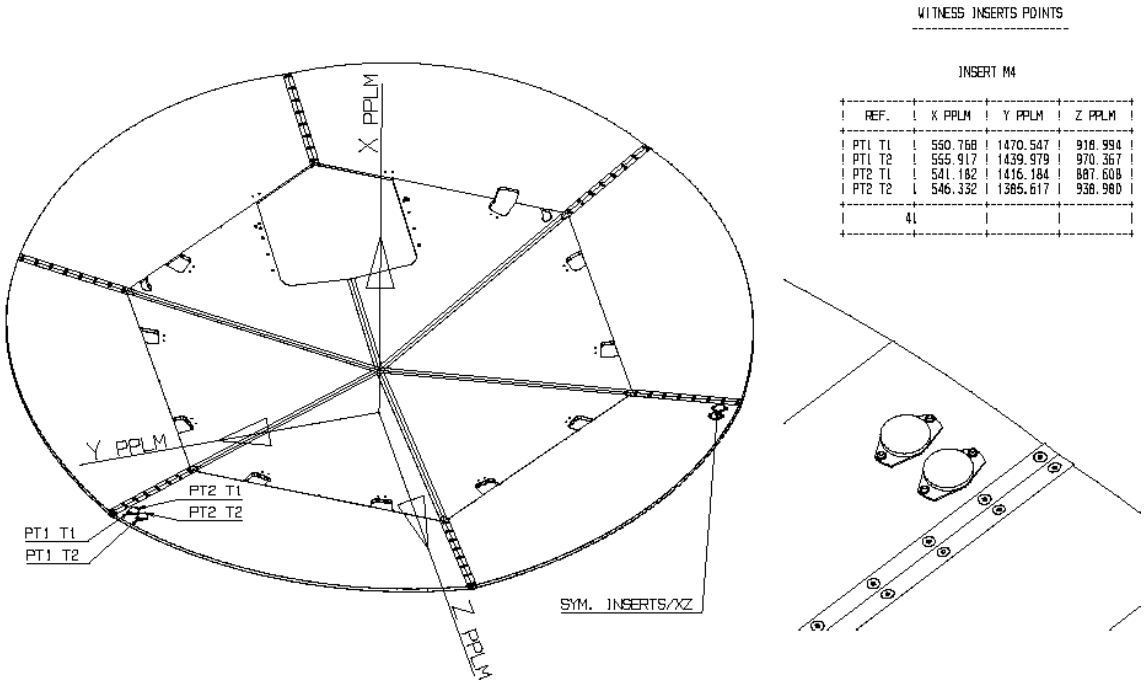
- one set is positioned on the upper face of the groove 2 extensions.

These sets will be designed in order to support all the environmental tests.

Particular and Molecular Cumulative and Step witnesses location on Cryo-Structure :

These 4 witnesses are directly attached with two screws each on the upper side of Groove 2 (+X face), definition of the link for 1 attachment point :

- 1 screw RSAT M4x10
- 1 Spring washer CuBe2, Dia int 4.2 mm, Dia ext 8 mm, thickness 0.4 mm
- 1 large washer, Dia int 4.25 mm, Dia ext 14 mm, thickness 0.8 mm



As long as the extension is not integrated, the witnesses will be put near the PPLM, to follow the parts already mounting on the flight hardware.

10.2.2 Control of the cleanroom

To guarantee the environment cleanliness level, the cleanroom chosen for Planck AIT activities will be controlled 2 months before the arrival of the hardware. More over, during the AIT activities :

- according to [RD17], the particulate contamination will be controlled at least once a week (continuously depending on the cleanroom). This control consists in an airborne particles counting (no Obscuration Factor calculation) : the counter is calibrated for particles sizes of 0.5 µm and 5 µm.
- additionally, 1 particulate witness will be put in the cleanroom, near the S/C, and analysed each month
- concerning the molecular contamination, it will be measured once per month (instead of once per trimester as precised in [RD17]). For this control, 1 molecular witness will be added in the cleanroom, near the AIT activities and will be analysed each month.

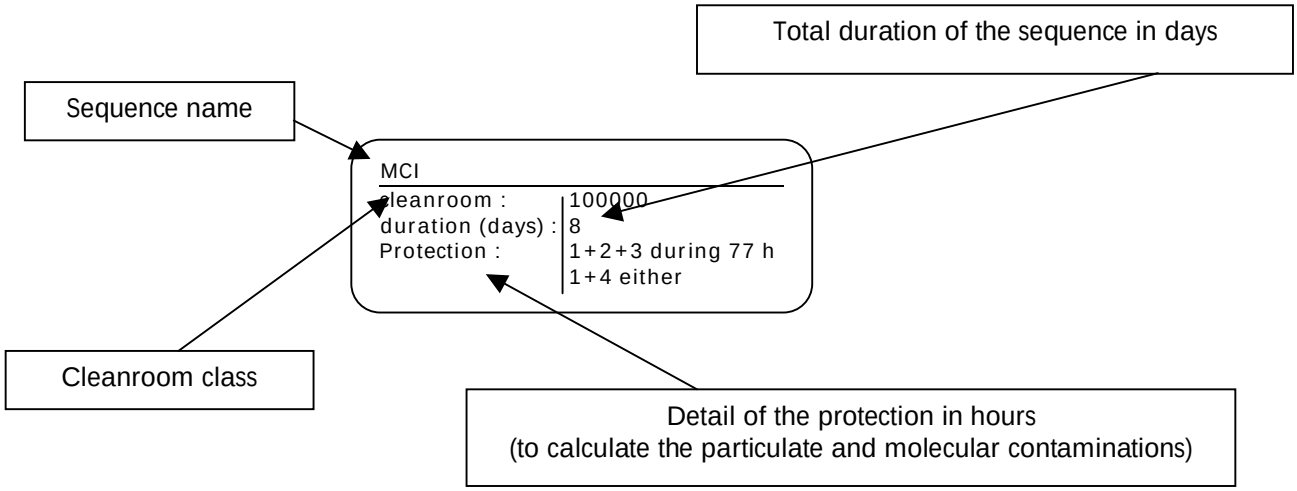
These cleanroom controls will be applied for the CQM and the PFM.

10.3 Flow chart description

10.3.1 Information available

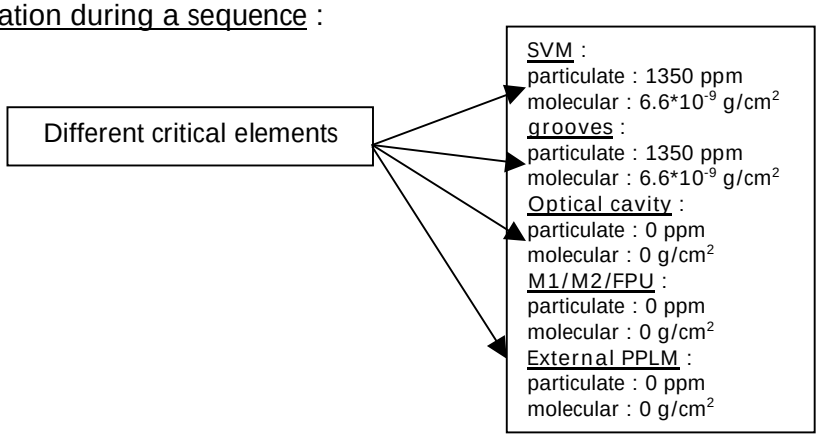
In the flow chart, the following information is given :

AIT sequence :



Nota : if there is no detail in « hours » for the protection, that means that it is kept during the whole phase duration (in days).

Contamination during a sequence :



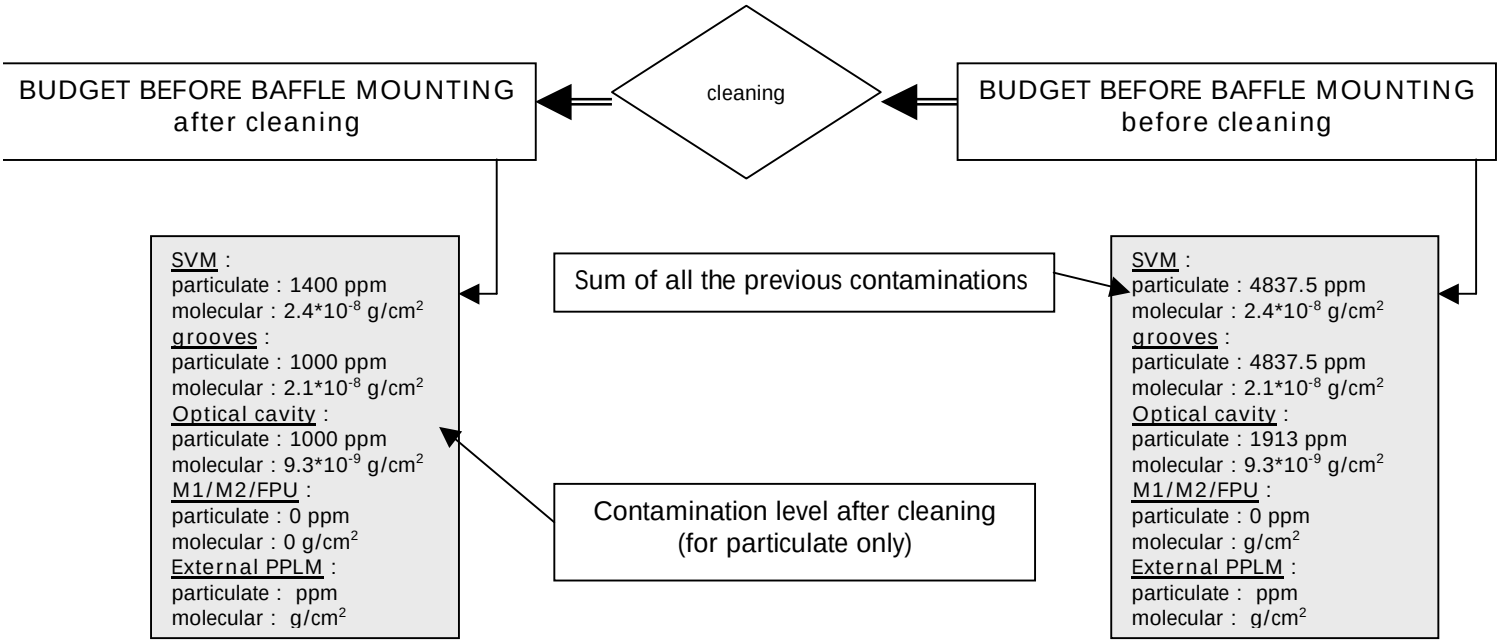
ð The particulate contamination is calculated as follows for a 100000 cleanroom :

$$(\text{number of exposed hours}) \times \frac{225 \text{ ppm}}{24}$$

ð The molecular contamination is calculated as follow for a 100000 cleanroom :

$$(\text{number of exposed hours}) \times \frac{1.10^{-6} \text{ g/cm}^2}{365 \times 24}$$

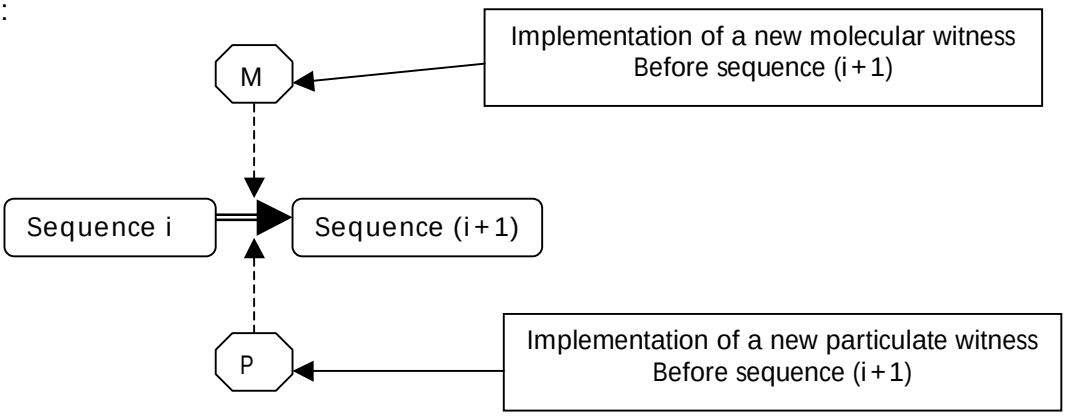
Total contamination before and after a cleaning :



Note 1 : the decrease of the particulate contamination after a cleaning is calculated as described in § 10.1.5.

Note 2 : for the S/C cleaning, the baffle is not dismounted. So it is supposed that, after the baffle mounting, the optical cavity is not cleanable because of accessibility problems (see § 10.1.5).

Witnesses :



Note : the witnesses are named

- M/P_{FPU} for the ones on the FPU (CQM model)
- M/P_{OPT} for the ones in the optical cavity (FM model)
- M/P_{VG} for the ones on the groove 2 extensions (see § 10.2.1).

10.4 Flow chart for the CQM

The aim of this model on a cleanliness point of view is essentially to validate :

- the cleaning procedures at satellite level
- the manipulation of the different protections that are scheduled.

The major objective of the CQM detailed contamination budget is to place the PPLM cleaning:

- before a dismounting in order to be able to measure the reached contamination level after cleaning
- at the more representative phase in terms levels expected for the FM (to apply the cleaning at a level equivalent to the one estimated on the PFM before cleaning).

These two constraints will allow to validate the cleaning procedures that will be applied on the PFM.

The detailed CQM flow chart is based on the document [AD02].

10.4.1 Definition of the groups for the CQM

In the flow chart, the contamination levels are calculated for the following « groups » :

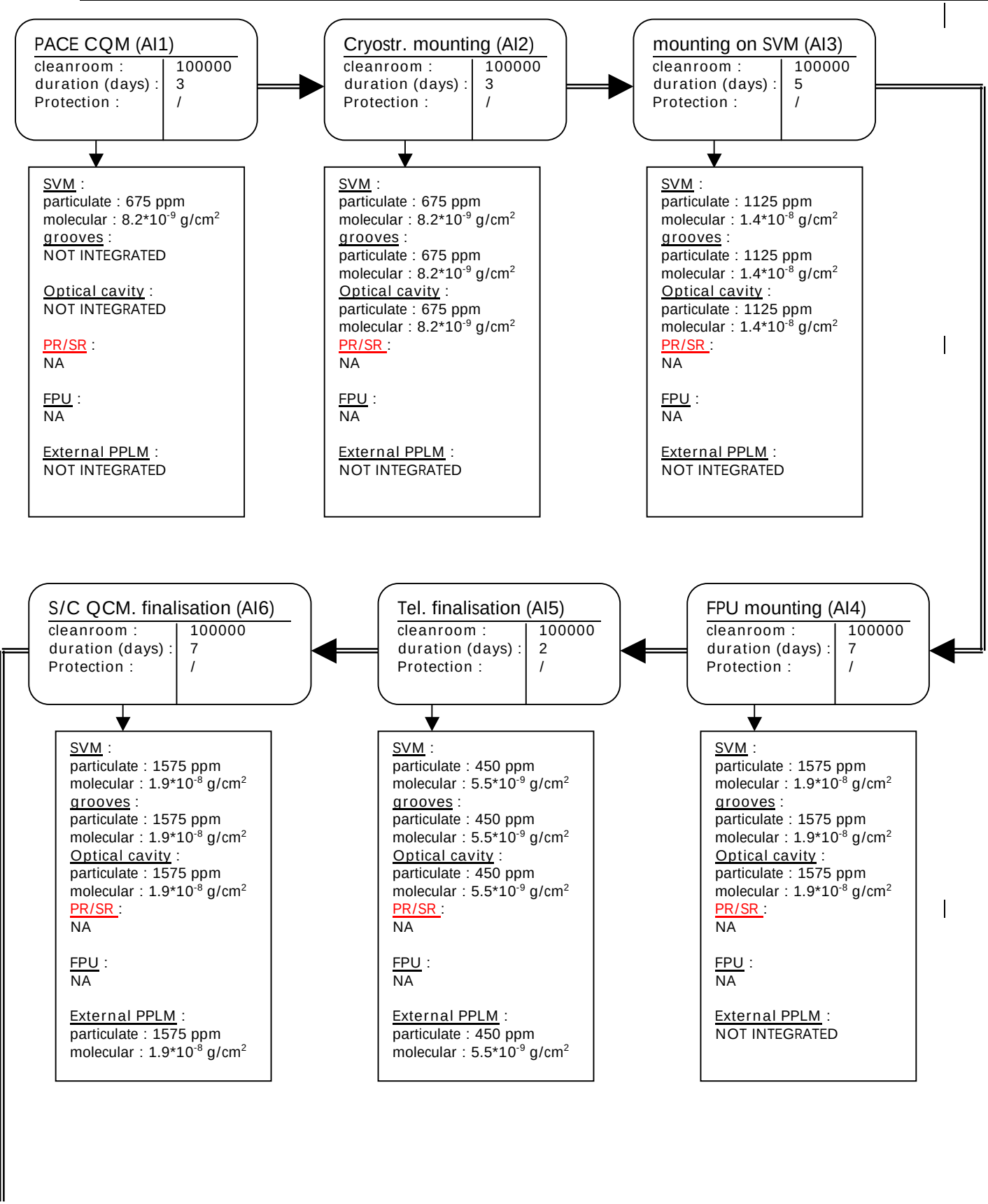
- grooves : it concerns the areas between the internal grooves
- optical cavity : it includes the telescope (structural parts) and the inner side of the baffle. As a cleaning of the telescope is scheduled before the baffle mounting, the contamination of the telescope and the inner side of the baffle can be considered as equal, even if they are not integrated at the same moment.
- PR/SR : they have the same policy for covers, so they are submitted to the same contamination
- FPU : detailed information of the FPU cover are TBC. In particular, this cover may protect only the horns, and its compatibility with the different activities scheduled on the FPU is not completely defined. So, for this first CQM budget, the FPU contamination level corresponds to the FPU parts without protection : the FPU is protected only once it is integrated in the telescope and the optical cavity is closed. This corresponds to a worst case. According to the FPU position (parallel to the gravity) only 10% of the particulate contamination is considered (and the total value for the molecular one).
- external PPLM : it concerns the external side of the baffle and the grooves extensions (as they are integrated rather at the same moment in the AIT sequences)
- SVM : it is not supposed to be protected (see § 10.1.3). More over, no distinction is done between the different panels, according to their integration in the AIT sequence : the contamination budget provided is a worst one.

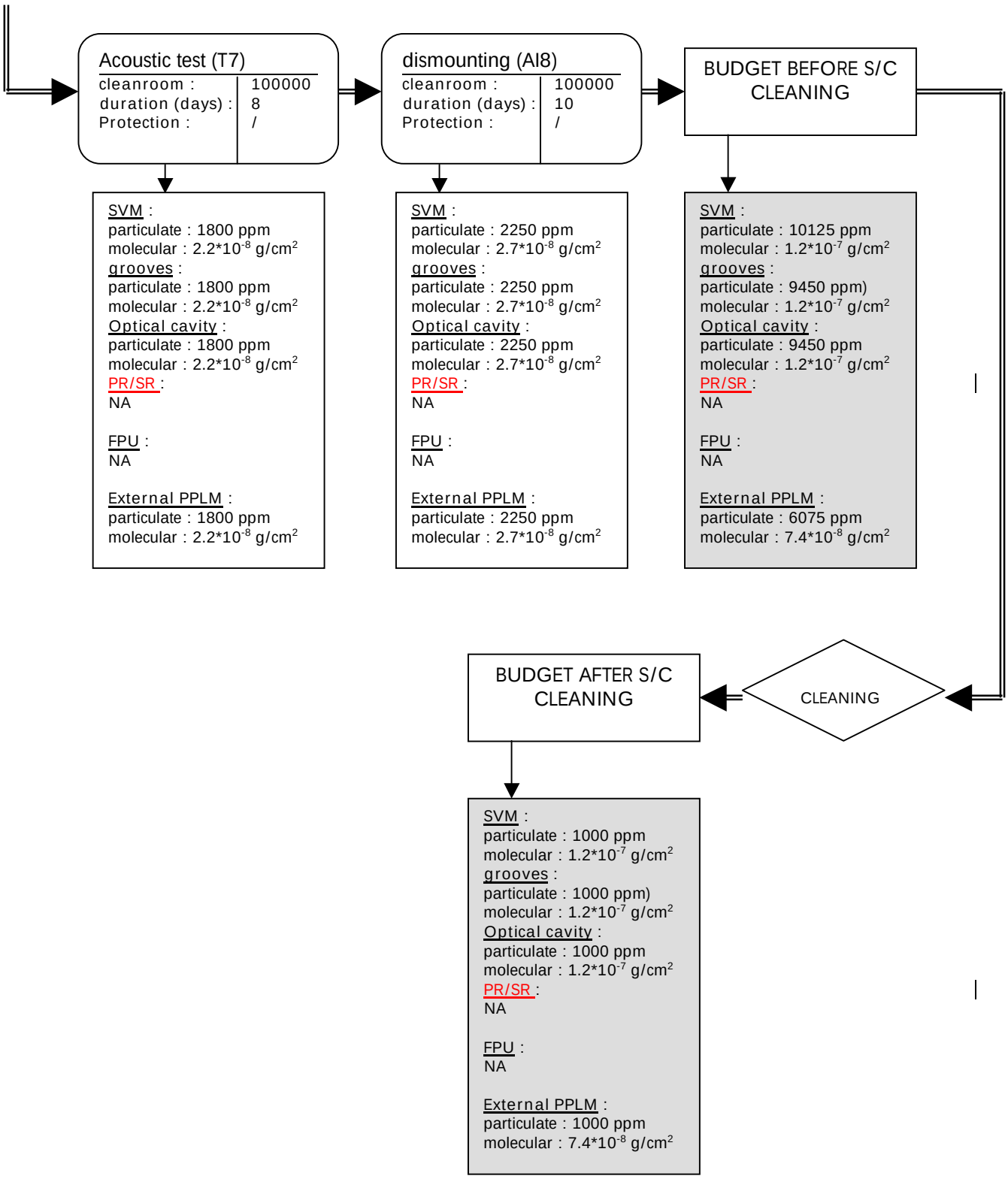
10.4.2 Acoustic test

For the acoustic test, no contamination budgets are done on the FPU or the mirrors, as they only consist in STM or dummies.

During this test, no specific protections or hardware witnesses are scheduled. Indeed :

- the CQM witnesses are not sized to support the mechanical test (see § 10.2.1.1)
- at the end of the acoustic test, the different parts of the model are dismounted and cleaned.





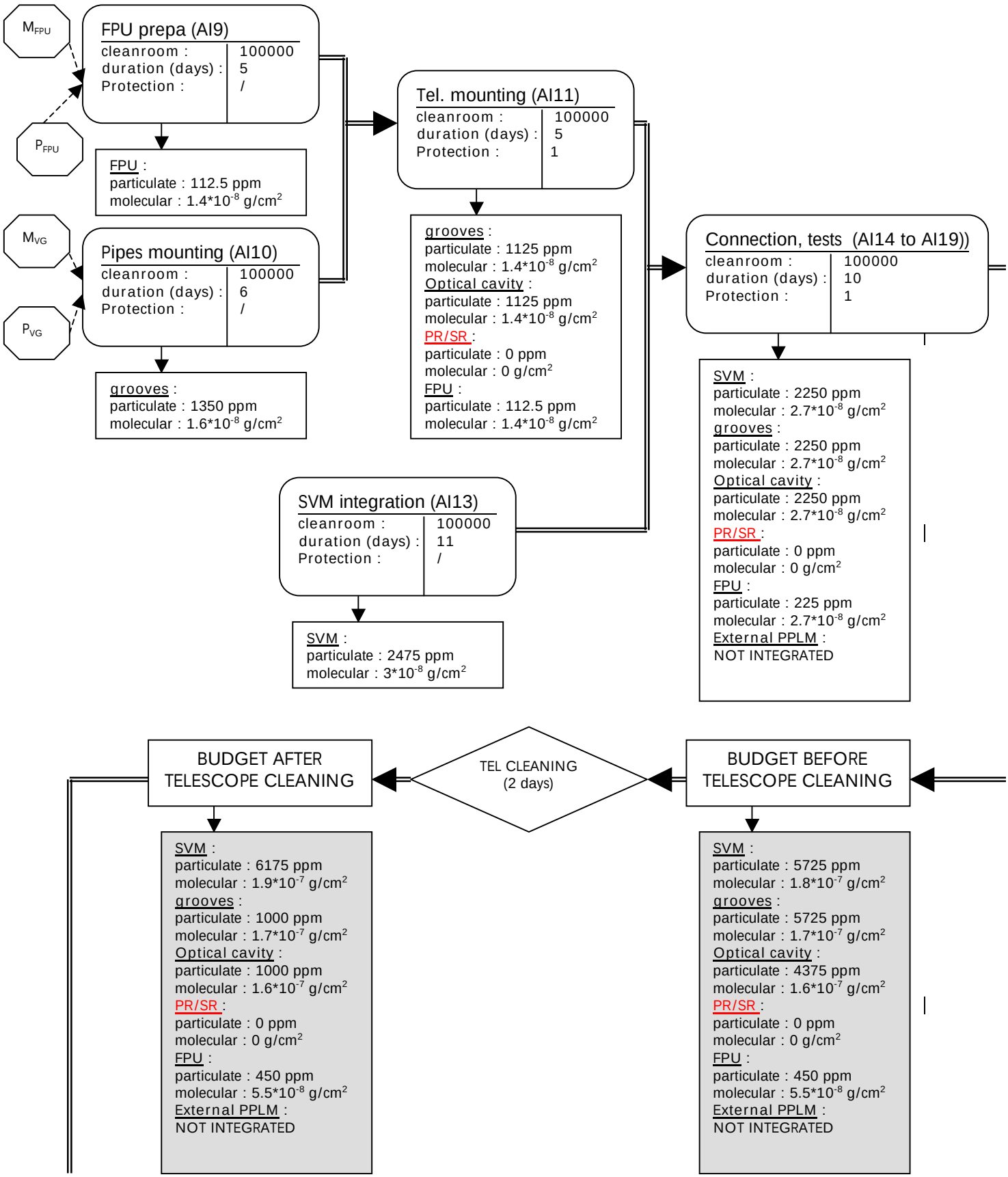
10.4.3 Cryo test

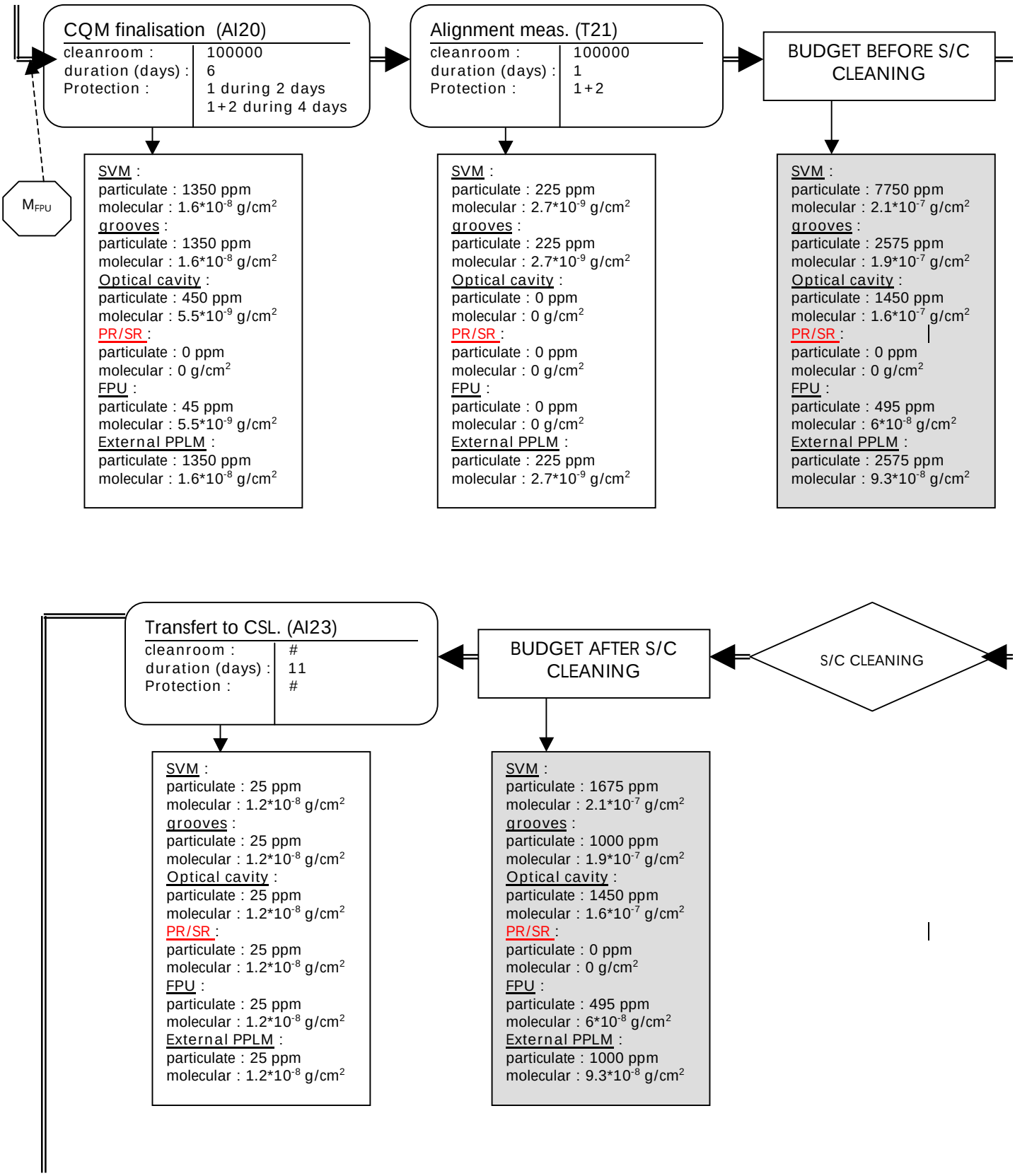
For the cryo test, the contamination witnesses listed in § 10.2.1.1 and some protections described in § 10.1.3 are implemented.

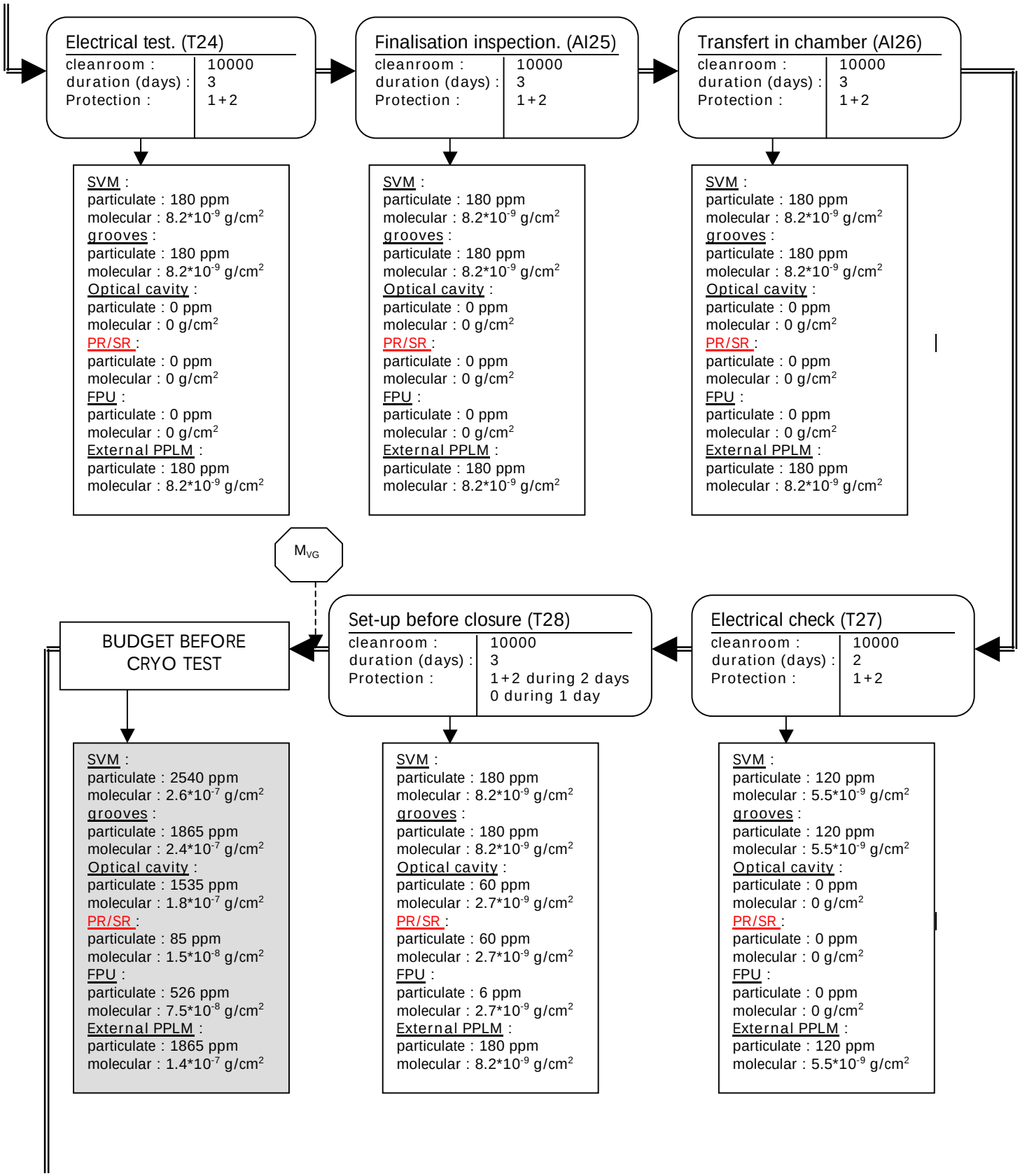
- The cumulative witnesses will be implemented from the beginning of the cryo test sequence to the end. Concerning the step witnesses, the change is defined in the flow chart.
- Concerning the witnesses that are implemented on the grooves extension, as this structural part is not integrated since the beginning of the activities, they will placed :
  - near the PPLM during the AIT sequences without the extension (precised position TBC)
  - on their scheduled position once the extensions are mounted on the CQM.

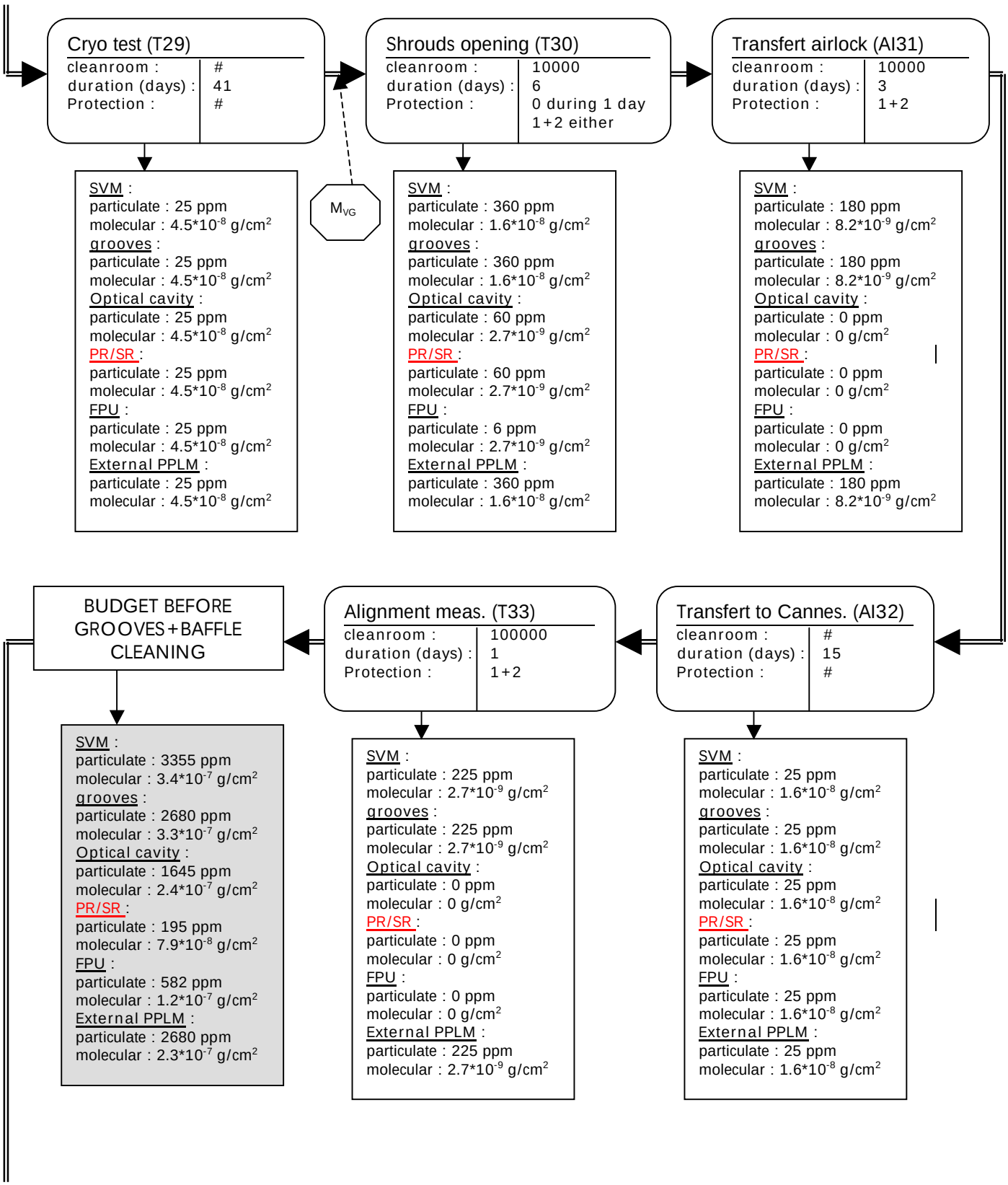
Concerning the activities :

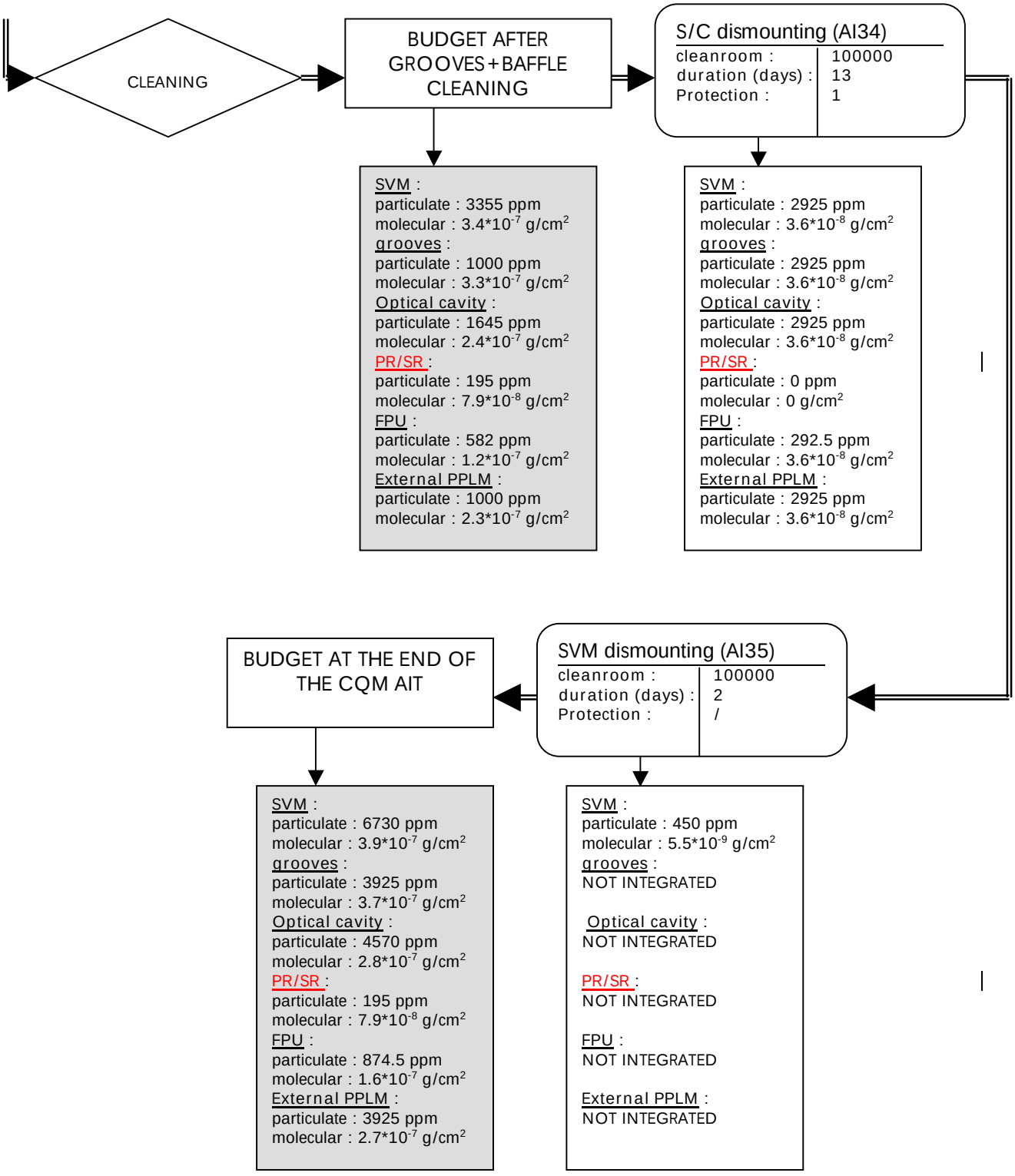
- AI9 and AI10 are made in parallel
- (AI10 + AI11), AI12 and AI13 are made in parallel
- for the set of activities from AI14 to AI19 (electronic integration, connection check …), that are made during the same period, the budget is done considering the sum of the AI14 and T16 durations (so 10 days)











10.5 Flow chart for RFQM

The RFQM is not critical in terms of contamination as the FM model. More over, no RFQM parts are integrated in the FM model.
The only concern is to be able to quantify the reflectors particulate contamination during the tests, contamination being a contributor in the RF budget. To answer this question, the following cleanliness policy is defined :

10.5.1 Contamination level at the beginning of the RFQM sequence

As the SR comes back from coating, its contamination corresponds to the one at AST delivery.
For the primary reflector, the different witnesses that have followed this model will be analysed to determine the initial PR contamination.

10.5.2 Contamination during RFQM test

The optical cavity witnesses will be implemented to follow the reflectors particulate contamination.

10.6 Flow chart for the FM telescope AIT

As targets are sticked on the reflectors optical face, it is necessary to make a particulate and molecular reflectors cleaning at the end of the telescope AIT. So no specific cleanliness control is necessary. At the end of the telescope AIT, the reflectors will be at the level guaranteed by the cleaning procedure. Based on the cleanliness specifications, these levels correspond to :

- 300 ppm
- 2 10^{-7} g/cm^2 .

For what concern the structure, a particulate cleaning is scheduled at the end of the telescope AIT, before PFM activities. According to § 10.1.5, the structure particulate contamination will be then equal to 1000 ppm. The only concern may be the molecular one, as no cleaning is done during the whole sequence.
To control the FM telescope structure contamination, the following witnesses are implemented:

- the cumulative particulate witness
- the cumulative molecular witness
- one molecular step witness. During the vacuum phases (telescope stabilisation or videogrammetric test), this step witness will be removed, covered and replaced by a new step one. After the vacuum sequence, the specific vacuum molecular witness will be analysed, and the first one will be reinstalled on the FM telescope.

In the budget, we consider a sequence of

- 134 days in cleanroom 100 000
- 20 days of vacuum (telescope stabilisation + videogrammetric test).

Based on the molecular contamination hypothesis (see § 10.1), this exposure induces a molecular contamination level of 3.9 10^{-7} g/cm^2 on the telescope structure.

Note : as the baffle will be stored for a long period, a set of witnesses will be placed with each part of the baffle, under the dedicated protections.

10.7 Flow chart for the PFM1 and PFM

10.7.1 Definition of the groups for the PFM1 and PFM

In the flow chart, the contamination levels are calculated for the following « groups » :

- grooves : it concerns the areas between the grooves. No distinction is done between the low emissivity and the high emissivity parts as they have the same protection policy
- optical cavity : it includes the telescope (structural parts) and the inner side of the baffle. As a cleaning of the telescope is scheduled before the baffle mounting, the contaminations of the telescope and the inner side of the baffle can be considered as equal, even if they are not integrated at the same moment.
- PR/SR : they have the same policy for covers, so they are submitted to the same contamination
- FPU : once the baffle is mounting, the FPU has not its protection anymore (conservative hypothesis, see § 10.1.3.2)
- external PPLM : it concerns the external side of the baffle and the upper part of the groove 3 extension
- SVM : it is not supposed to be protected (see § 10.1.3).

10.7.2 FM witnesses

In the flow chart, only the changes concerning the step witnesses are detailed. For what concerned the cumulative ones in the optical cavity and on the cryostructure (see § 10.2.1), they will be implemented on the hardware at the beginning of the AIT activities for these subsystems.

More over, each transport will be followed by container specific witnesses. As this measure concerns all the transport, it is not precised in the flow chart (in order to make the reading more easy).

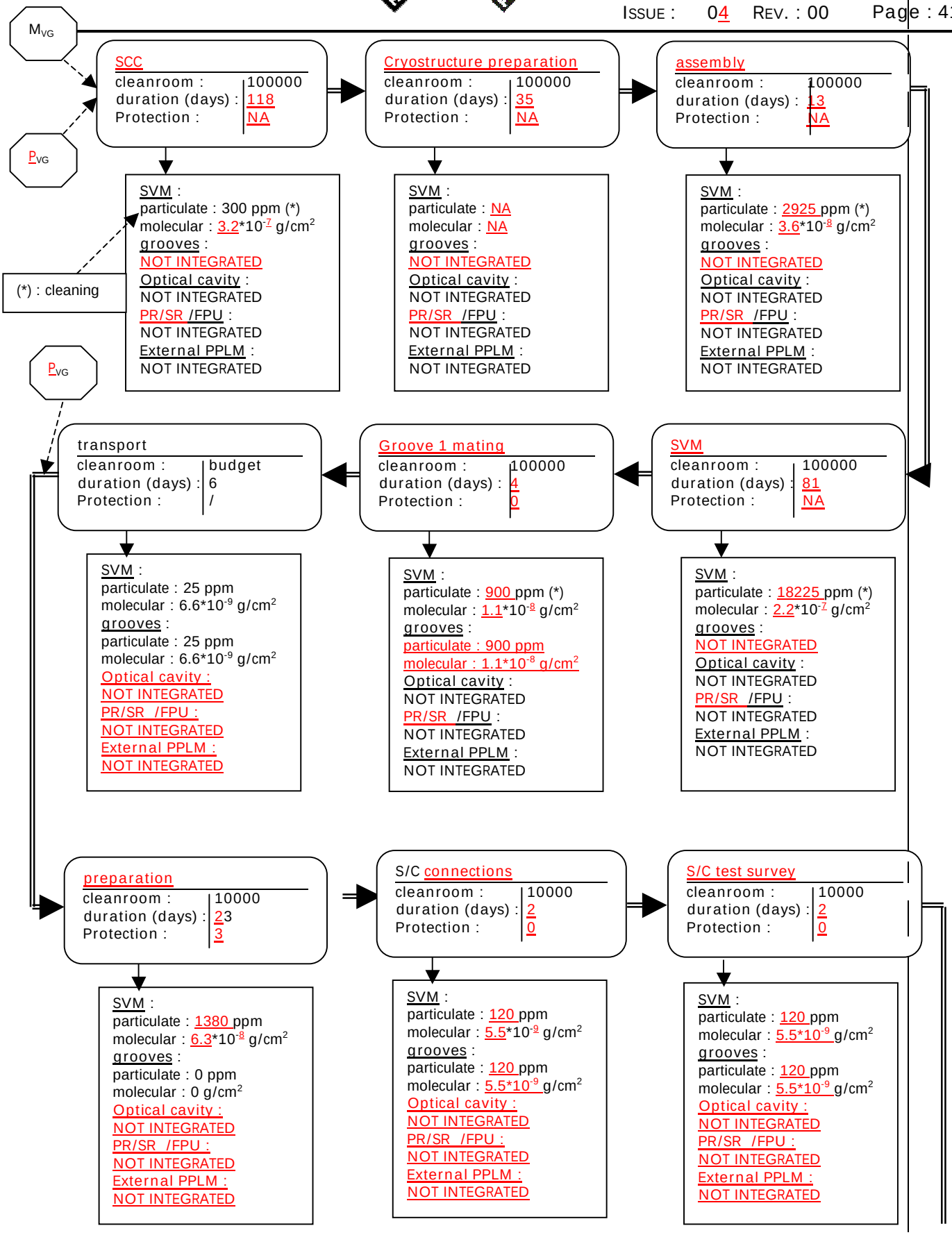
10.7.3 PFM1 sequence

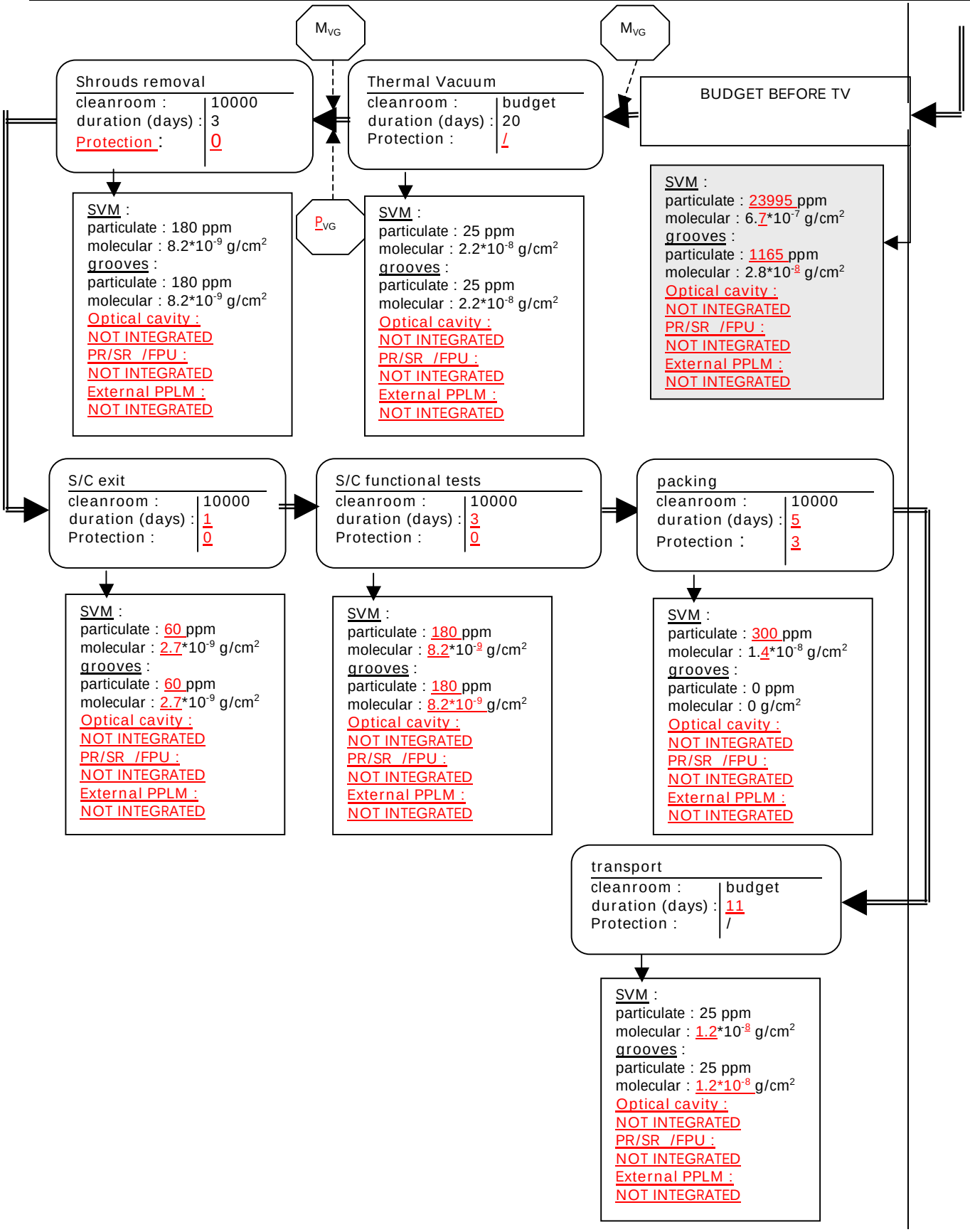
The PFM1 model includes :

- the 3 grooves
- the groove 3 extension.

The Miro parts are delivered with their protection film. This protection will be put away just before the thermal vacuum test in CSL.

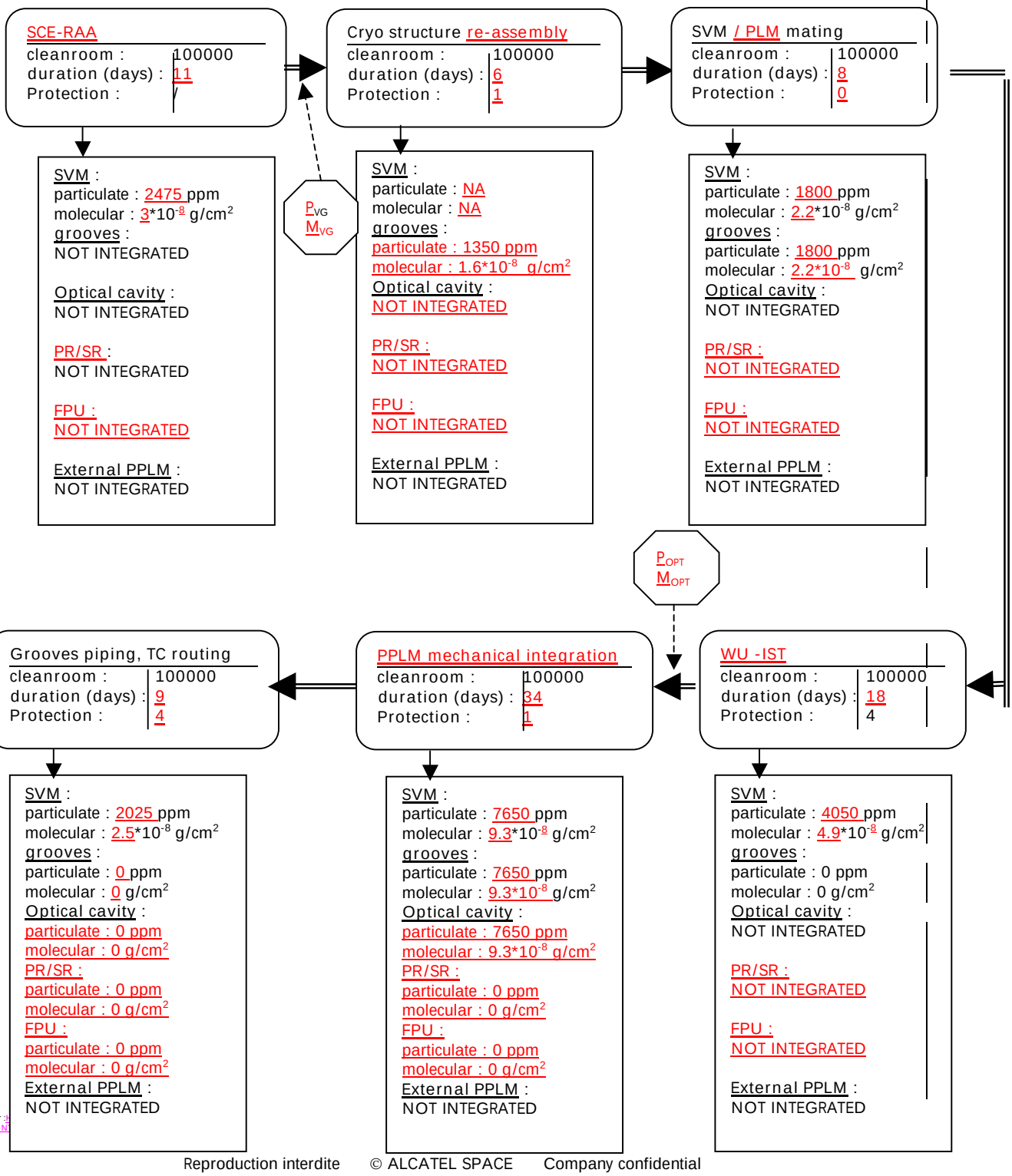
No cleanings are scheduled at the beginning of the PFM1 activities or before cryotest in CSL facilities. This is not critical as no performances are linked to contamination for this model.
At the end of the PFM1 sequence, the present elements of the cryostructure will be dismounted and will be submitted to a particulate cleaning before integration on the PFM.

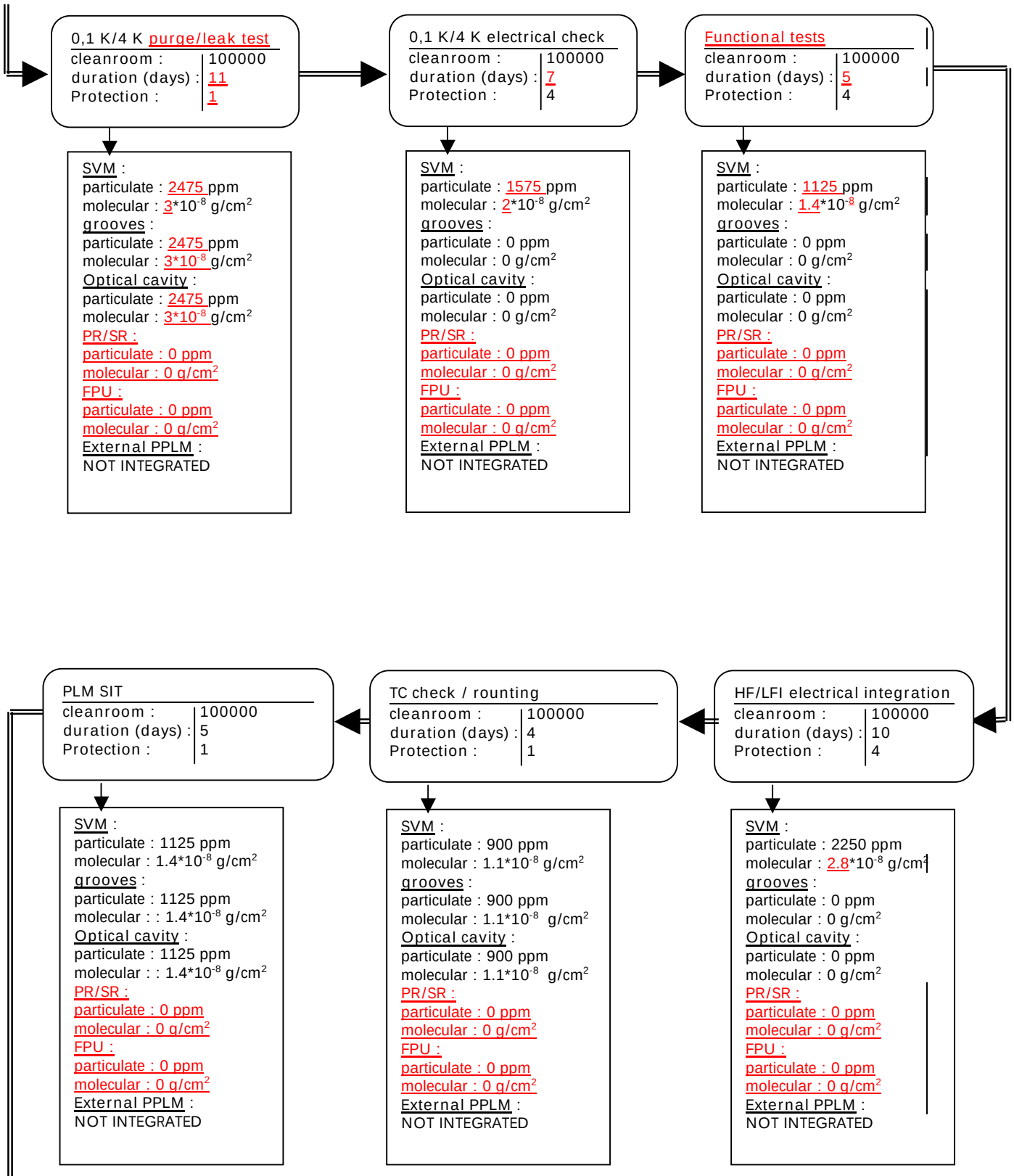


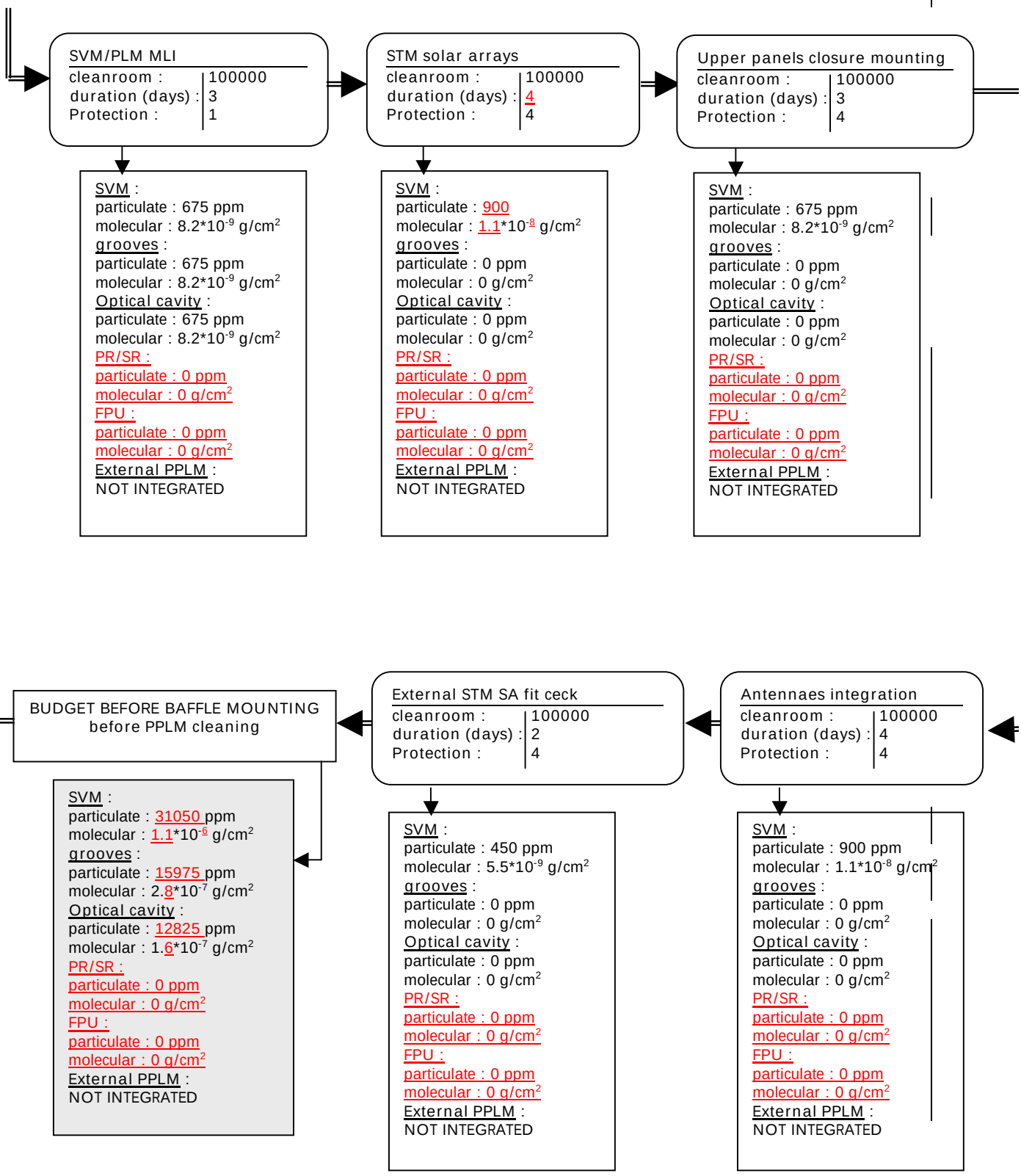


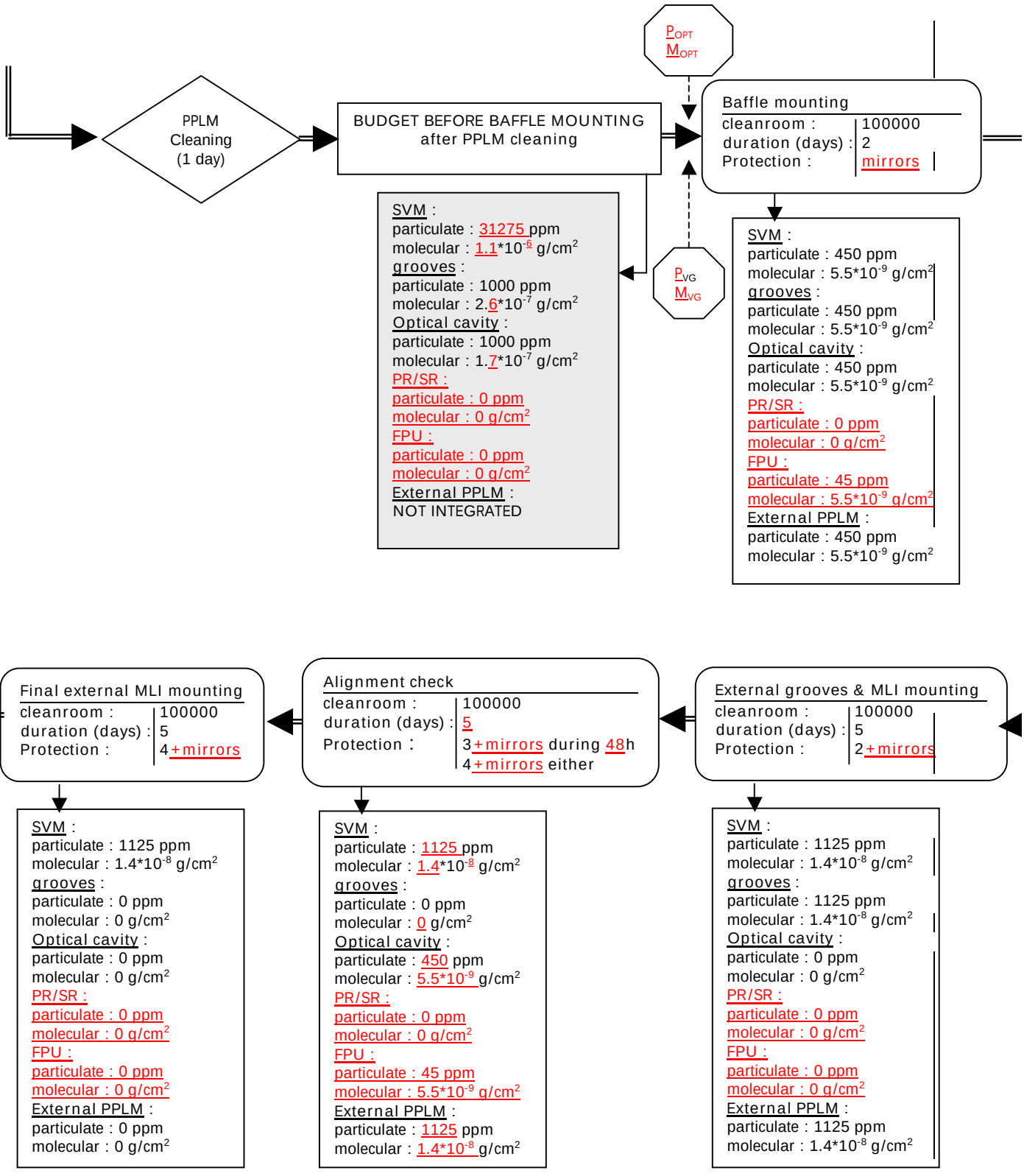
10.7.4 PFM Assembly / Integration

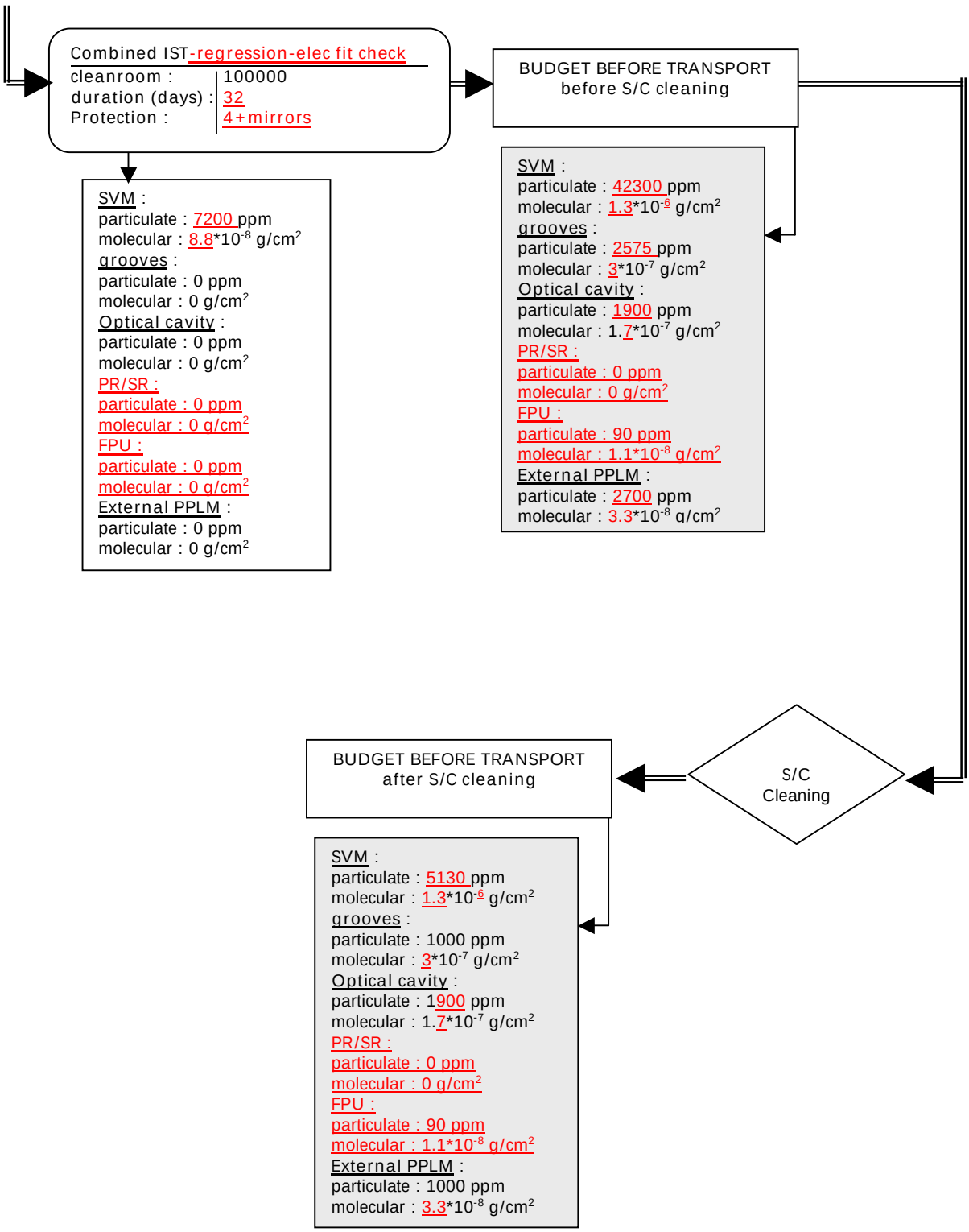
As precised in § 10.7.3, the elements constituting the PFM1 will be cleaned before starting PFM activities.
For what concerns the baffle, as it will have been stored for a long period, the specific witnesses will be analysed (see § 10.6). Additionally, a wipe will be done on each part to control the total molecular contamination.





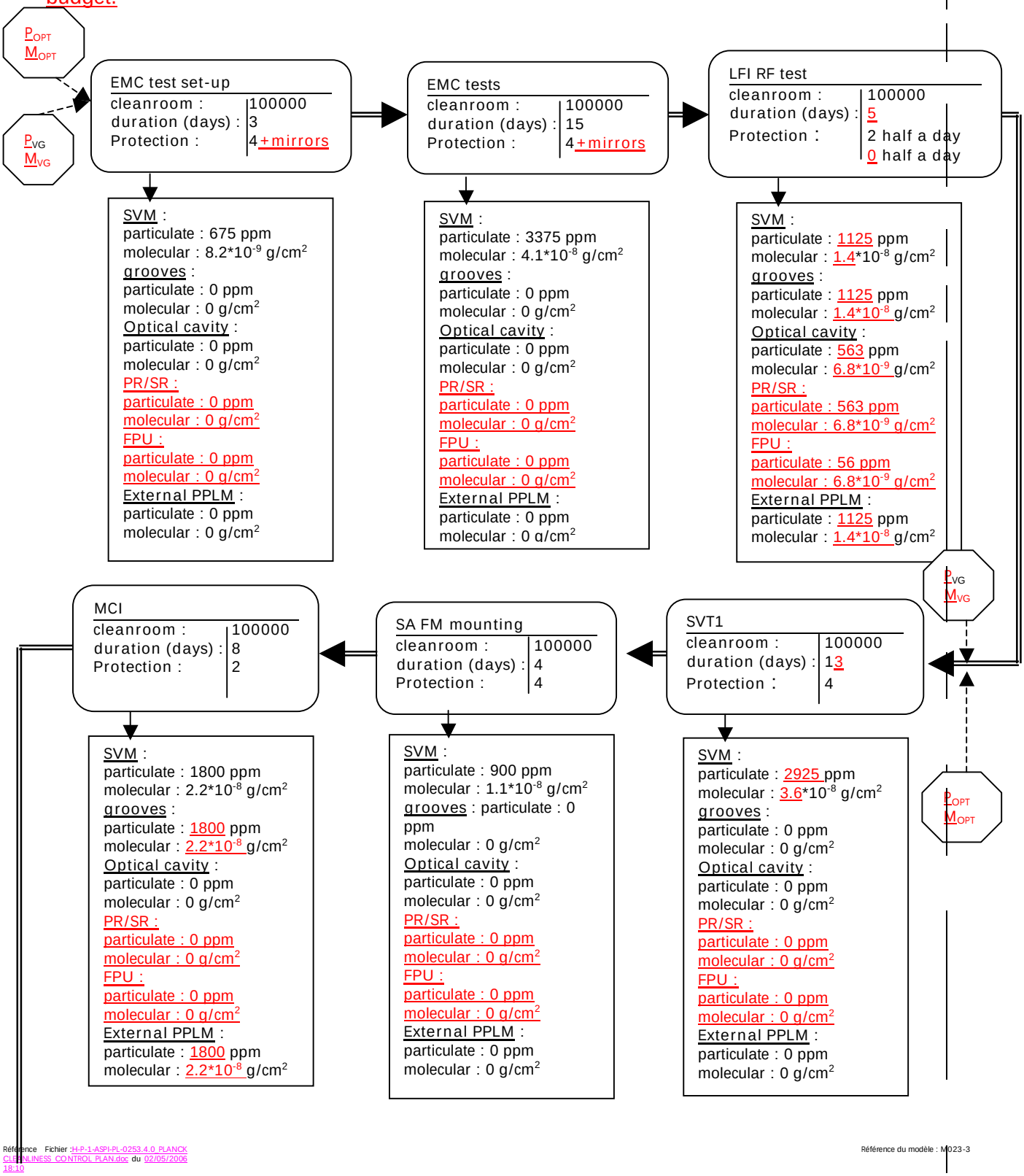


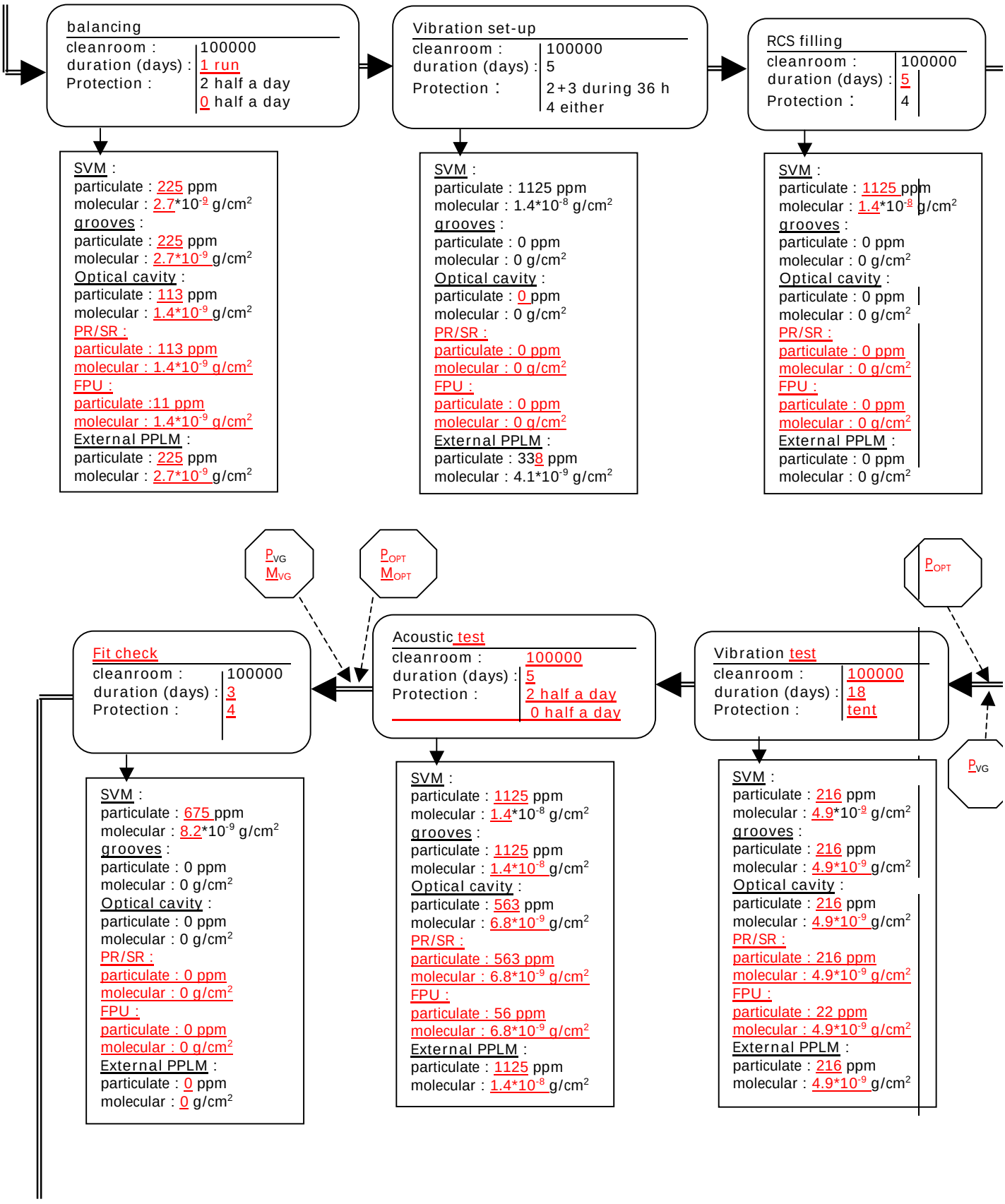


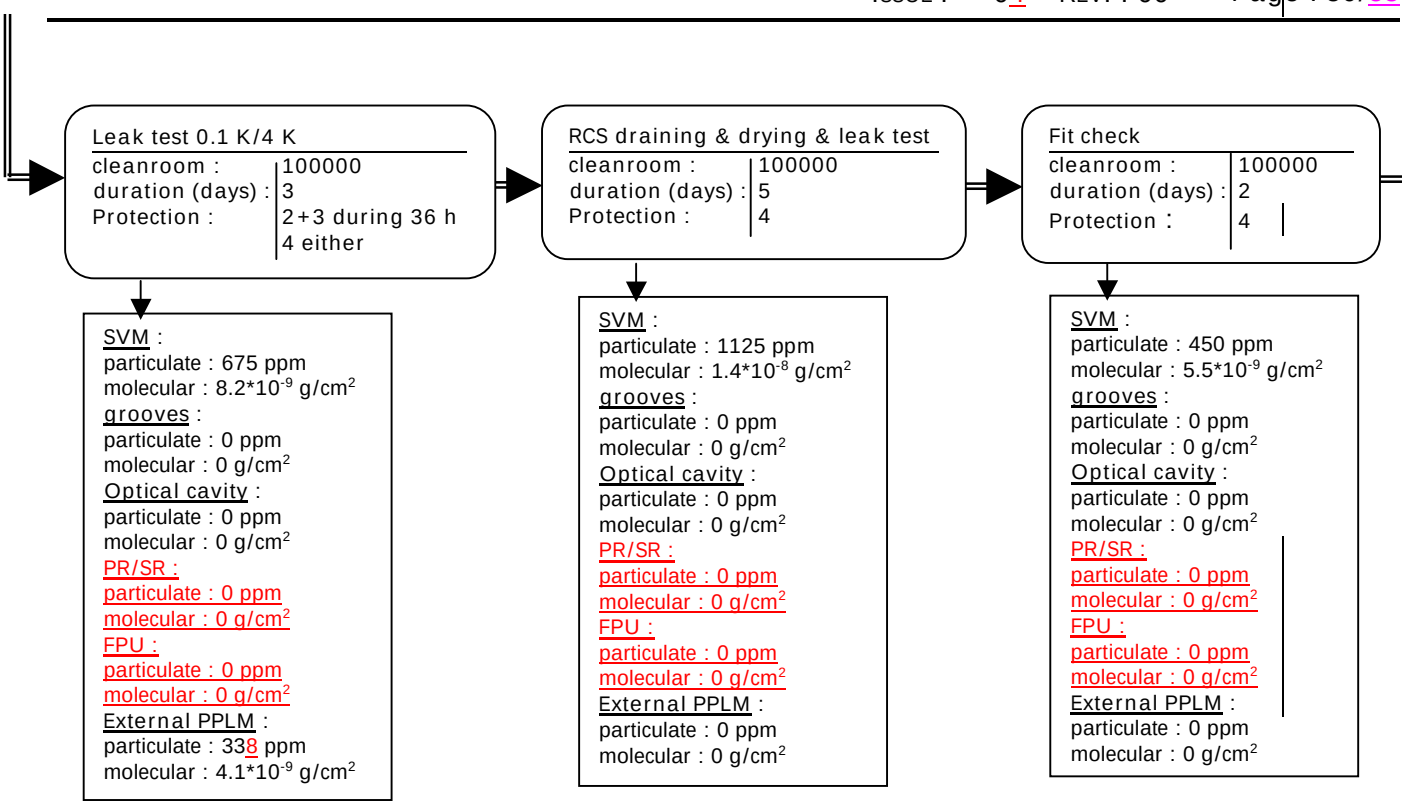


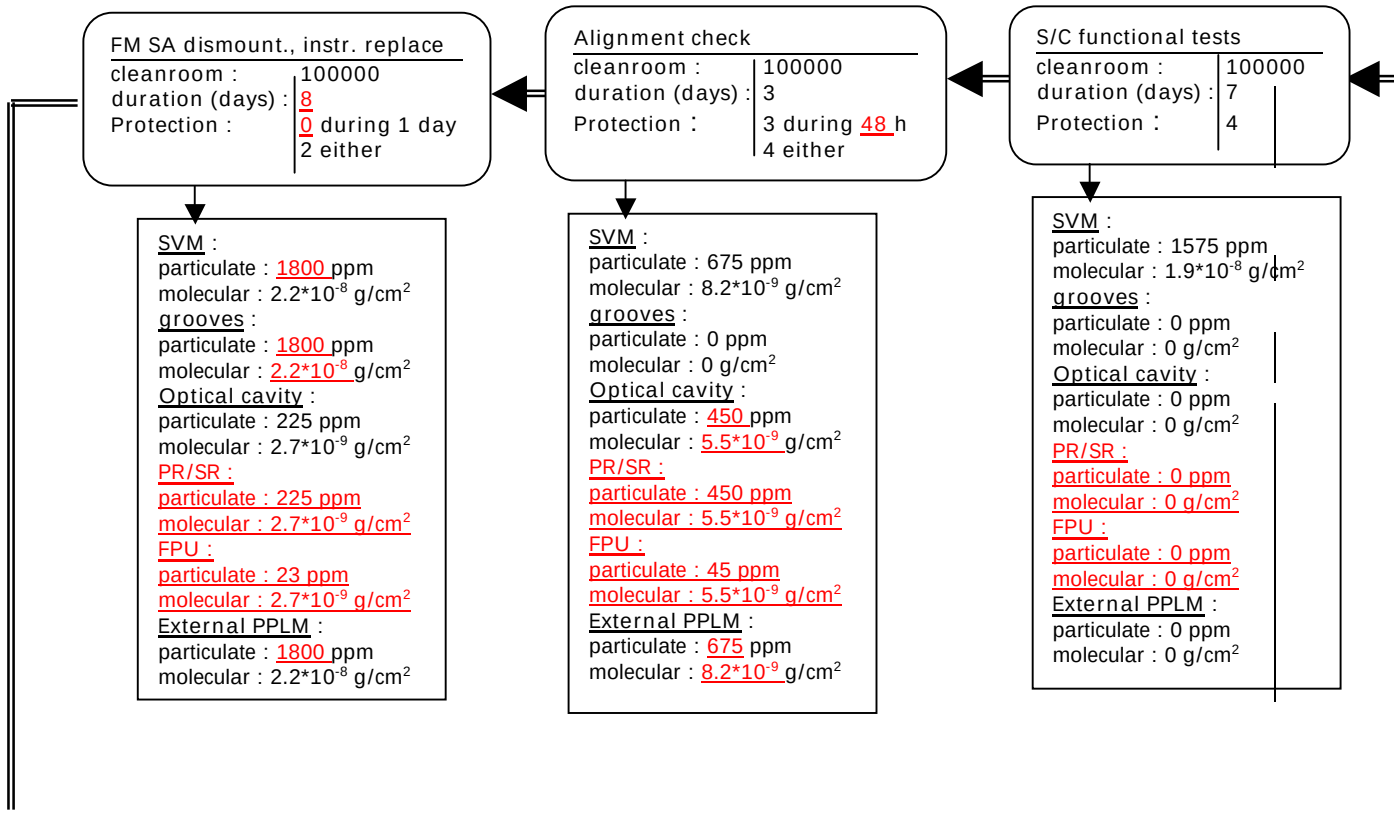
10.7.5 PFM System tests

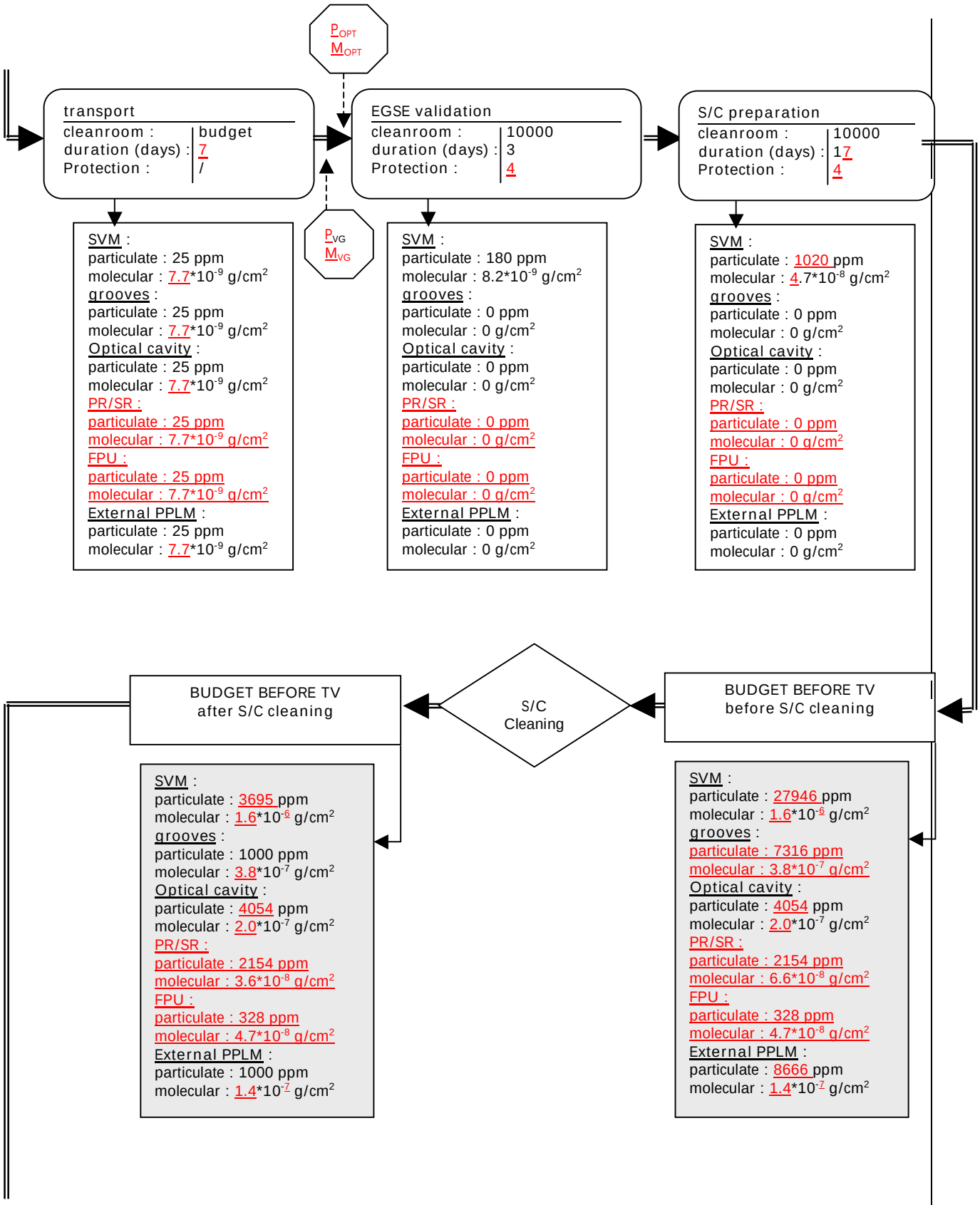
The chronology of the tests have to be confirmed, but the linking does not impact the global budget.

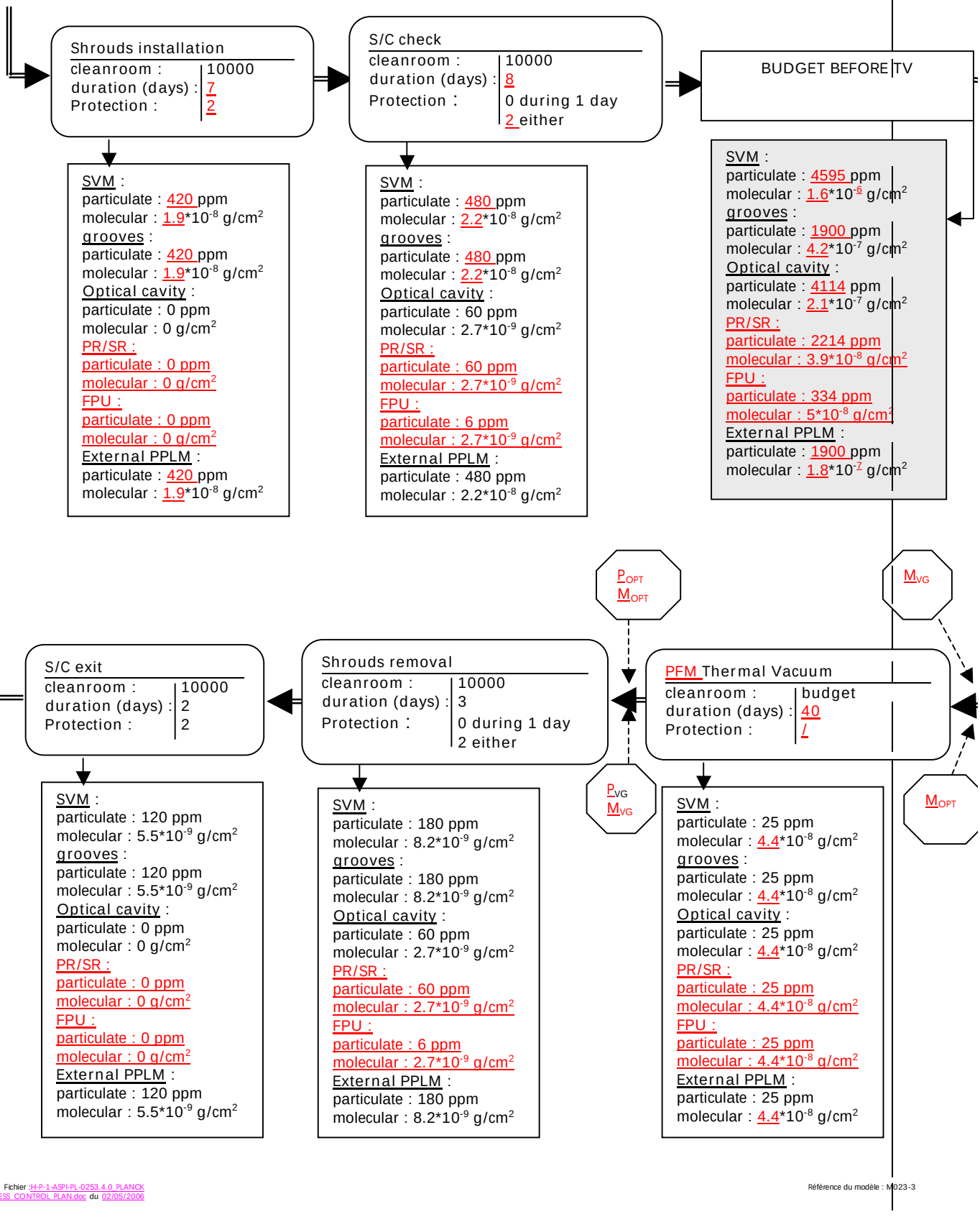


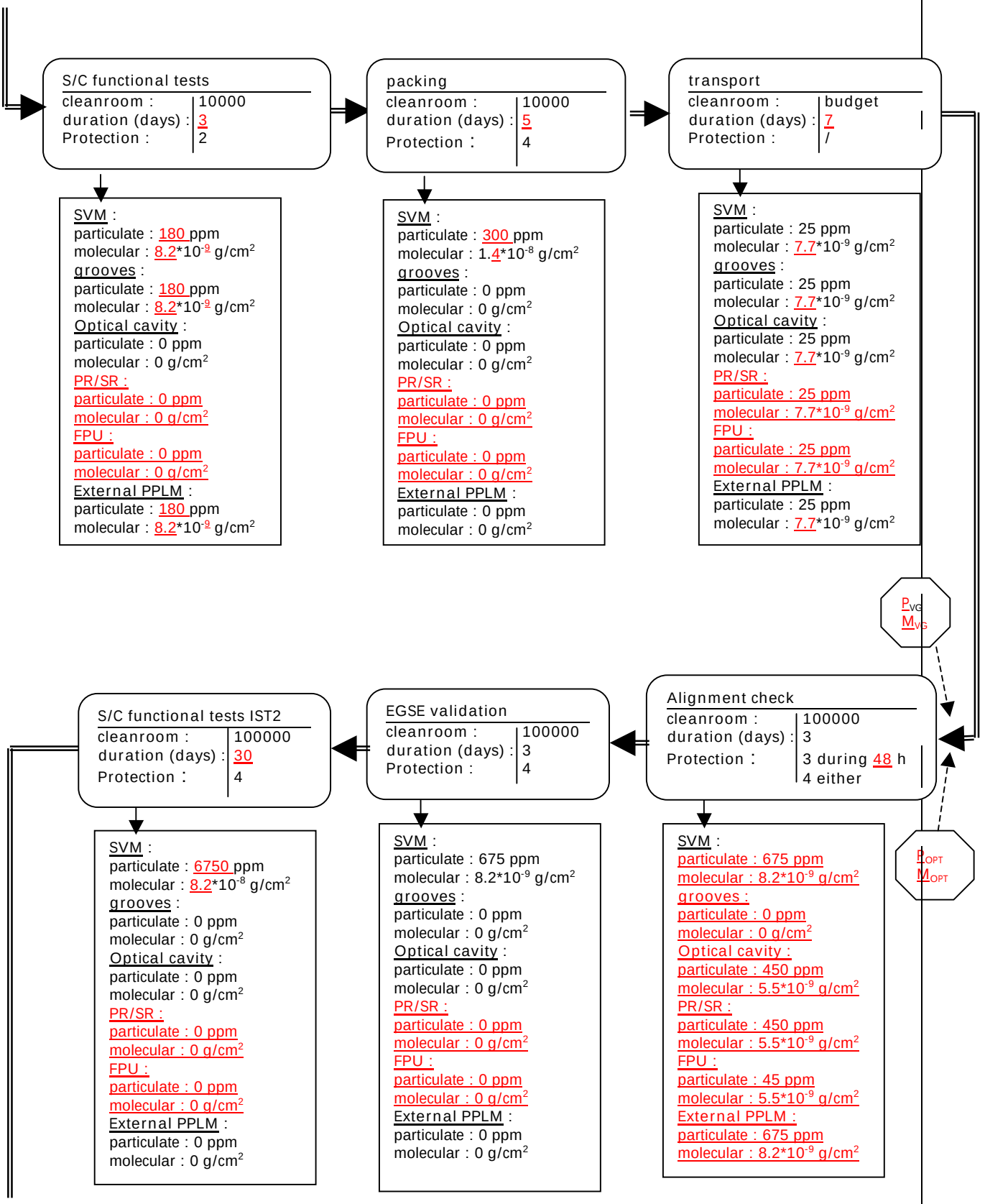


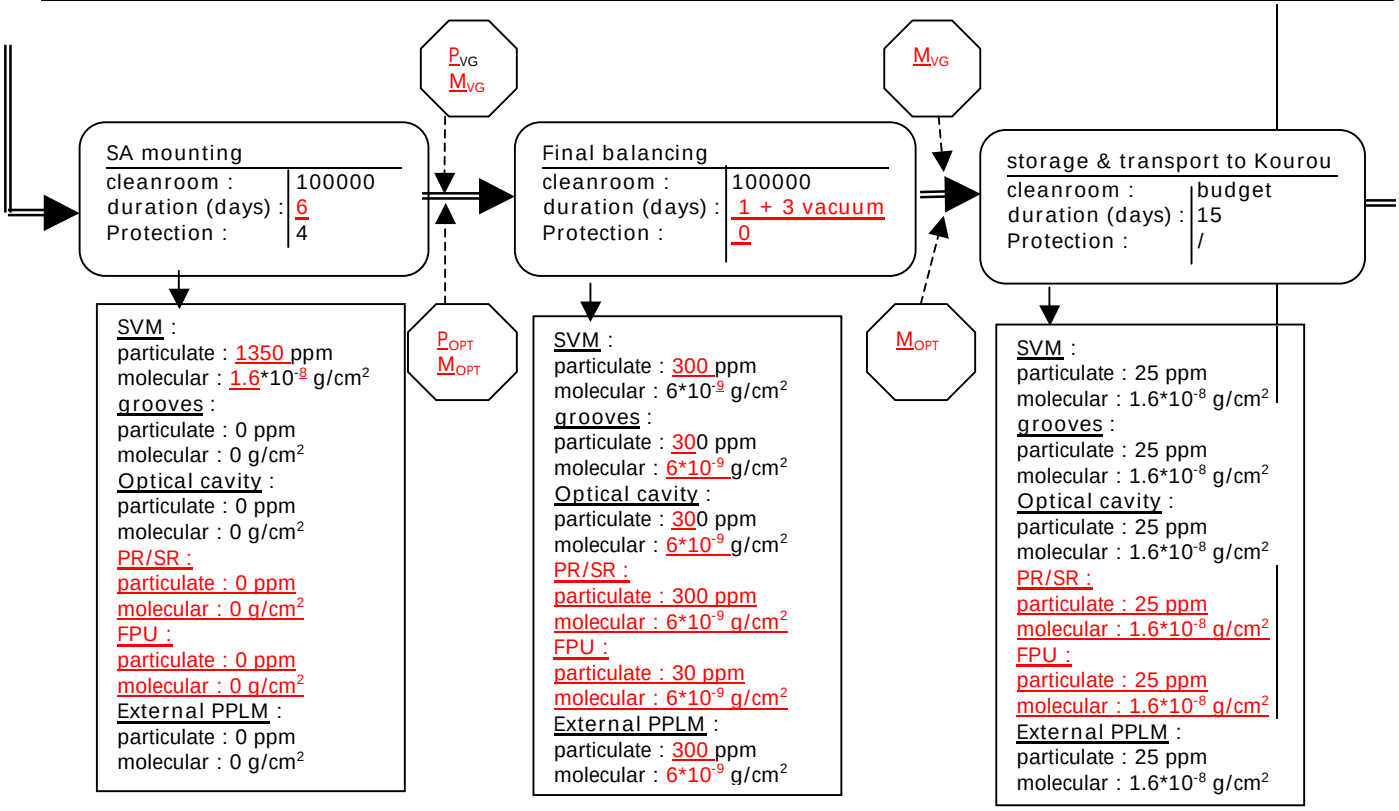


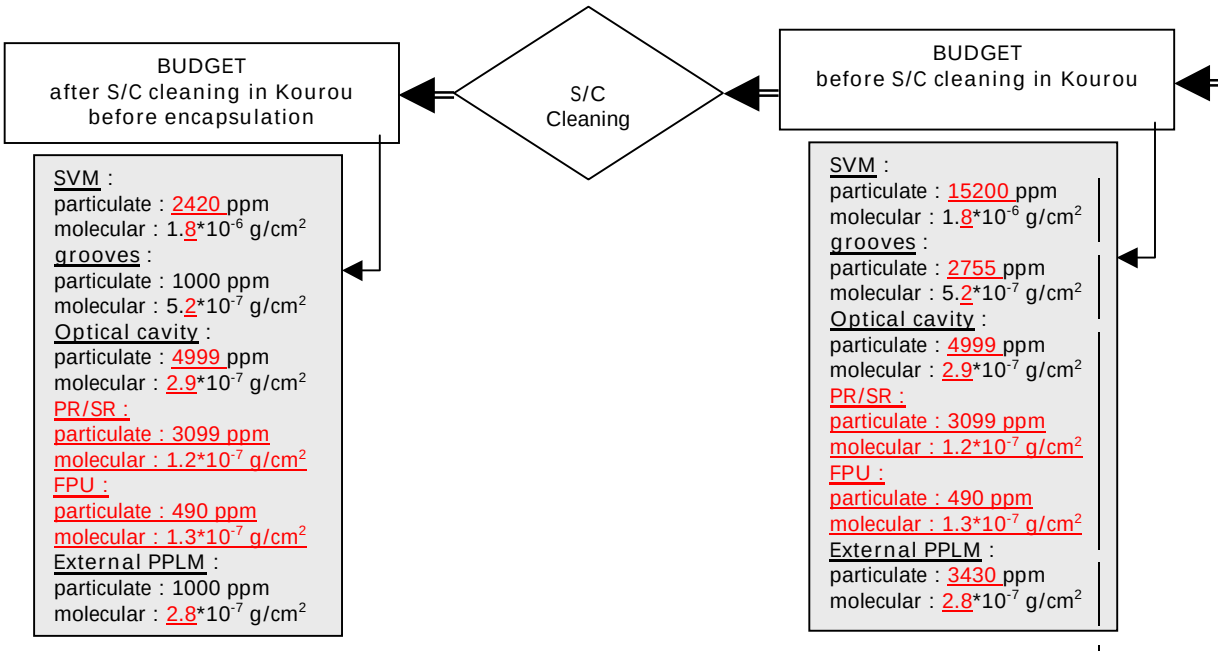












11. PFM BUDGET

The flow charts of § 10.6 and § 10.7 give the FM particulate and molecular contamination due to the AIT sequence, from the beginning of the integration up to the last cleaning in Kourou, before the launch campaign.
The results are summarised hereafter :

	FPU	mirrors	V-grooves	Optical cavity	Baffle outer side	SVM External surfaces
AIT sequence	490	3099	1000	4999	1000	2420
allocations	800	1400	1500	2400	1500	3400

Table 11.1 : particulate contamination due to the AIT sequence (ppm)

	FPU	mirrors	V-grooves	Optical cavity	Baffle outer side	SVM External surfaces
AIT sequence	$1.3\ 10^{-7}$	$1.2\ 10^{-7}$	$5.2\ 10^{-7}$	$6.8\ 10^{-7}$	$2.8\ 10^{-7}$	$1.8\ 10^{-6}$
allocations	$3\ 10^{-7}$	$6\ 10^{-7}$	$9\ 10^{-7}$	$7\ 10^{-7}$	$9\ 10^{-7}$	$2\ 10^{-6}$

Table 11.2 : molecular contamination due to the AIT sequence (g/cm^2)

12. CONCLUSION FOR THE PFM

12.1 Molecular contamination

The molecular contamination due to the AIT sequence on the whole spacecraft is within the needs, with margins.
In particular, the level before the thermal vacuum test induces no problem.

The global contribution of the CSL activities, taking into account the duration planned in § 10.7.5 and the hypotheses described in § 10.1.2, correspond to $3.3\ 10^{-7}$ g/cm^2. Concerning the specific phases with no protection on the whole spacecraft, and with the preventive action defined in § 10.1.7, the molecular contamination is around $3\ 10^{-8}$ g/cm^2 for the PFM thermal vacuum test.

12.2 Particulate contamination

According to the protection policy update (based on experience on hardware via the acoustic model and the CQM), the particulate allocations during the S/C AIT sequence seems not reachable in the optical cavity.
This protection policy comes from several discussions between system and AIT to reduce the particulate budget for system requirements, taking into account acoustic model / CQM inputs as accessibility problems, specific tests facilities constraints, designed protections …

12.3 Discussion on particulate budget

12.3.1 Inputs consideration

It has to be noticed that the presented budget is a conservative one, as :

- the impact of the primary mirror orientation is not considered
- the budget is done considering the standard values (225 ppm/day) without any analysis of Cannes facilities.

- For what concerns Cannes facilities, cleanroom witnesses placed around Planck as requested in this document show a mean value of 11 ppm/day (values based on 24 witnesses analysed from august 2004 to November 2005).
- Working constraints, as mask wearing while working on the PPLM, have been implemented during AIT to secure the particulate level.
- Integration and test experience shows that the alignment test (for which the optical cavity has to be opened) can be done with the baffle oriented towards the ground. This position is much more favourable in terms on contamination impact inside the optical cavity.

All these elements can hardly be translated in the budget, but they show that the hypothesis of daily contamination is very conservative.

If the budget is done :

- with 60 ppm/day (hypothesis still conservative based on the previous listed elements)
- without any hypotheses on the primary mirror orientation

the particulate contamination due to S/C AIT is equal to

	FPU	mirrors	Optical cavity
AIT sequence	218	1343	2283

Table 12.1 : particulate contamination due to the AIT sequence considering 60 ppm/day (ppm)

All the particulate levels are compliant with the requirements.

12.3.2 Impact of the S/C AIT particulate contamination on the EOL budget

As S/C AIT is only one contributor of the contamination level, the potential impact of the updated levels has to be studied in a global point of view. The effect in terms of EOL particulate contamination level, and so associated system performances, is presented in this paragraph.

As presented in the document [RD04], several contributors have to be considered in the EOL budget :

- level at AIT delivery (for uncleanable elements)
- FM telescope and S/C AIT
- redistribution
- launcher
- micrometeoroids

The associated EOL particulate budget is presented in the following table (only on the PPLM elements) :

	FPU	mirrors	V-grooves	Baffle inner side	Baffle outer side
delivery	300	300	3500	900	3500
FM AIT	490	3099	1000	4999	1000
Redistribution (1)	4855	4855	1000	4855	1000
Launcher (2)	7875	7875	4020	7875	4020
Micrometeoroids (3)	7885	7885	4030	7885	4030
EOL budget	7885	7885	4030	7885	4030
allocations	5000	5000	10000	10000	15000

Table 12.2 : update of the EOL particulate budget with 225 ppm/day for the S/C AIT sequence (ppm)

The S/C AIT exceeding induces a EOL out of specification on the mirrors and the FPU, and this level is acceptable at system level.

Note 1 : The redistribution inside the optical cavity is calculated on a surfaces ratio, base on the following inputs :

- baffle inner side : 8 m^2
- primary reflector : 2.4 m^2
- secondary reflector : 1.1 m^2
- FPU : 0.8 m^2 .

Note 2 : after S/C AIT, we consider, as presented in the document RD04 :

- 720 ppm for the launch preparation (12 days in cleanroom 10 000)
- 2300 ppm for the launcher specific contribution.

Note 3 : according to document AD01, micrometeorites represent 10 ppm

For sensitivity, the same budget has been done considering 60 ppm/day for the FM AIT sequence :

	FPU	mirrors	V-grooves	Baffle inner side	Baffle outer side
delivery	300		3500	900	3500
FM AIT	218	1343	1000	2283	1000
Redistribution (1)	2486	2486	1000	2486	1000
Launcher (2)	5506	5506	4020	5506	4020
Micrometeoroids (3)	5516	5516	4030	5516	4030
EOL budget	5516	5516	4030	5516	4030
allocations	5000	5000	10000	10000	15000

Table 12.3 : update of the EOL particulate budget with 60 ppm/day for the S/C AIT sequence (ppm)

The EOL out of specification on the mirrors and the FPU is marginal.

12.3.3 Conclusion for the particulate contamination

The estimated EOL budget presented in § 11 is out of specification for the elements inside the optical cavity.

- As precised in § 12.2, discussions have already been lead between system and AIT to improve as much as possible the S/C AIT particulate budget.
- Once these discussions have been closed, the new realistic reachable level has been analysed at system level, in terms of system performances (as straylight, mirrors self emission …). Conclusion is that this level is acceptable.
- More over, this budget is done with conservative hypotheses, without any consideration on preventive measures already implemented for AIT (as mask wearing …, see § 12.3.1).

The combination of this data show that the updated protection policy seems acceptable.
More over, based on AAS experience on previous program and on Planck CQM activities, the budget can be largely improved from values provided in § 11, to be around the budget presented in § 12.3.1. In that case, the EOL particulate contamination budget is lightly overpassed, and the calculated values are acceptable with regards to system performances.

Such conclusion validates the updated protection policy.

12.4 Discussion on hypotheses

This paragraph gives a sensitivity on the values found in § 10.7.3 to 10.7.5 according to the hypothesis that have been done.

The flow chart described in § 10.7.5 has been issued assuming that :

1. the cleaning of the PPLM (except the optics) can decrease its particulate contamination down to 1000 ppm

All the data concerning this input (results already available and activities to be performed) are presented in a specific technical note (ASP-04-OS/I/IA-53).
The CQM experience is described in § 10.1.6, that confirms this hypothesis.

2. As precised in § 10.1.3.2, a conservative hypothesis has been considered for the FPU protection once the baffle is mounting (no specific protection)

3. In the same way, the hypothesis for the RF test has been refined (no RF transparent film during the test) : see § 10.1.7.3.

4. for the shrouds installation or the shrouds removal, CSL can nearly perform all their activities with the optical cavity film. So it has to be put away only 1 day for each phase

The constraints of optical cavity accessibility has already been integrated in the Planck cryogenic facility requirements (see [RD07]). The verification of this request has been demonstrated during the CQM sequence (see § 10.1.7.1).

5. the budget on the mirrors and in the optical cavity is calculated without considering the geometry

This is a sizing hypothesis as : no surface is considered to be hidden, a vertical or an horizontal plane collect the same contaminants quantity.

END OF DOCUMENT