**SUBJECT**: FIRST System Optimisation Study - Phase 1 Final Meeting

**PLACE**: ESTEC

| Participants | Organ. | Distribution |
|---|---|---|
| M. Cornut | ALCATEL/Cannes | FV, MA, PE, GP |
| P. Rideau | ALCATEL/Cannes | |
| J.J. Juillet | ALCATEL/Cannes | |
| J. Schupp | DSS | MASTER |
| A. Hauser | DSS | |
| K. Moritz | DSS | |
| B. Mossbacher | DSS | |
| H. Aarts | HIFI | |
| D. Beintema | HIFI | |
| R. Katterloher | PACS | |
| B. Collaudin | ESTEC | |
| B. Guillaume | ESTEC | |
| T. Passvogel | ESTEC | |

| AGREEMENTS STATEMENTS | ACTION |
|---|---|
| 1) Presentation of the results of phase 1 activities:<br>– Alcatel hand-out<br>– DSS hand-out | |
| DSS will provide the telescope temperature for each case presented in p9 of the hand-out | AI01<br>DSS |
| DSS will analyse the sensitivity of the HeII tank thermal balance to the CVV T° (say 50K) | AI02<br>DSS |

| AGREEMENTS STATEMENTS | ACTION |
| --- | --- |
| HeII tank MLI improvement is questionned (at least to reach -30% conduction). An alternative could be a low E coating with no MLI (impact on ground test TBChecked).<br><br>Shield 1 heat load balance.<br>DSS will consider to implement an improvement in the thermal anchoring concept for the instrument harness, such as thermalisation of brass wires to shield 2 or any other solution which could improve the shield 1 balance and decrease the lifetime sensitivity to the quality of the harness thermalisation.<br><br><u>Conclusion</u><br>For the next phase of the study the configuration as proposed by Alcatel in the | |

| AGREEMENTS STATEMENTS | ACTION |
|---|---|
| conclusion of the hand-out (+ 2 separate sun-shade/sun shield) is agreed by all parties<br>In addition, the need for an active cooling of the cavity will be reviewed by DSS<br>Mechanical model :<br>DSS will provide an updated model before or latest 20/04/00<br>Thermal model : 14/4/00<br><br>Note: Related to the helium mass flow DSS will try to obtain from Linde a rationale for the limitations and evaluation of potential solutions (phase separator, vent line, nozzle ...)<br><br>Next progress meeting 18/05/00 at Cannes | |

esa

FIRST/Planck Project

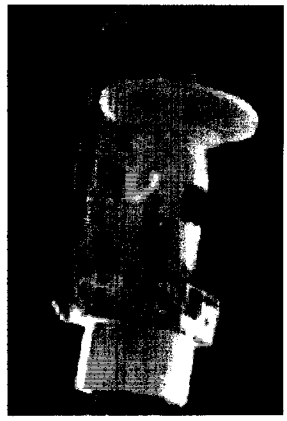
# Action Item Initiation Sheet

Title: FIRST System Optimisation Study - Phase 1 Final Meeting

Place: ESTEC

Date : 31/03/2000
Ref : SCI-PT/FSCP-07617
Page : 1 of 4

| Ordinal Action Number | Title and Description | Due Date | Originator | | Actionee | | Completion | |
|---|---|---|---|---|---|---|---|---|
| | | | Firm | Person | Firm | Person | Date | By Document No. |
| # 1 | DSS to provide telescope temperature for cases presented in p9 of handout | | ESTEC | TP | DSS | J. Schupp | | |
| # 2 | DSS to analyse sensitivity of He II tank thermal balance to CVV Temp. (e.g. 50 K) | | ESTEC | TP | DSS | J. Schupp. | | |



**FIRST System Optimisation Study**

## Phase 1 – Identification of Ways of Reduction Parasitic Loads

Consolidation and/or update, when necessary, of the present baseline configuration will serve as a basis for comparison of the potential improvements.

After the completion of these necessary steps, the following items shall be taken into account in the trade-off study in order to optimise the cryostat:

- Review of the thermal heat loads to the cryostat and the corresponding heat load budgets and the mechanisms of heat load transfer to the Helium II tank

- Impact on the in-orbit lifetime of the cryostat by the reducing:
  - the external temperature of the
  - the heat loads coming from the sunshield/sunshade and external units like LOU/BAU/STR. Potential benefits of using Orbital Disconnect Systems (ODS) struts shall be investigated.
  - the temperature of the FIRST telescope down to 60K
  - the heat loads coming from the SVM

- Adaptation of the instrument cooling architecture and instrument cooling stage and impact of having only one instrument operating at a time. These 2 points shall be considered in the thermal analysis.

- Assessment of system aspects of resizing the cryostat including, but not limited to:
  - Change of the system configuration (size)
  - Sunshield and solar array configuration and size
  - System mechanical design optimisation and simplification
  - System budgets updates
  - Conceptual layout of an optimised (mechanical/thermal) SVM

The contractor shall then recommend a solution, which shall be detailed in the course of the phase 2. Its technical justification shall be presented taking into account the impacts in terms of lifetime, feasibility, technical and cost improvements.

# FIRST System Optimization Study

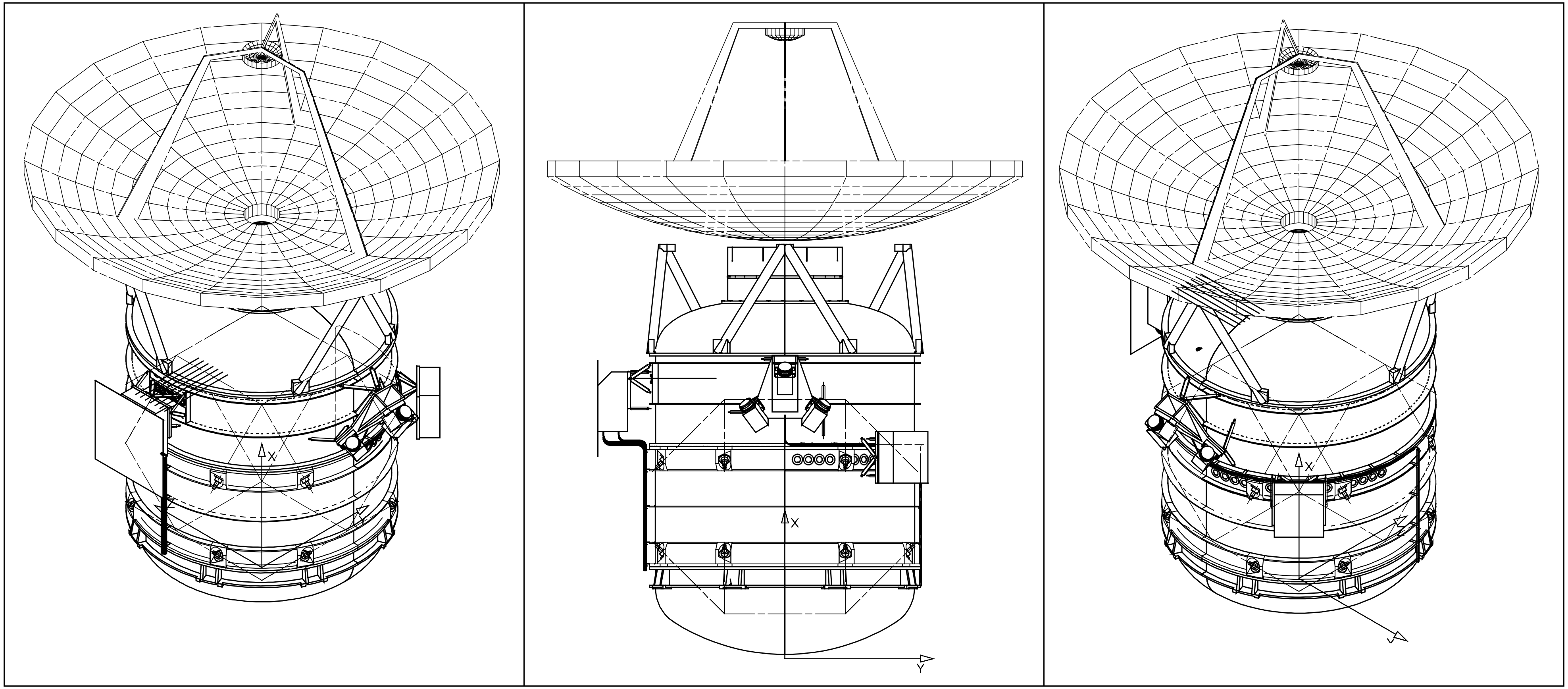
# Phase 1 Presentation – DSS part for FIRST PLM

## 3. Description of PLM baseline and harmonization activities
## 4.1 Review of Thermal Design/Sensitivities –PLM
## 5. Recommendation -PLM

# 3. Description of PLM baseline and harmonization activities

- PLM configuration of the FIRST I/F study with 2560 l HeII tank used

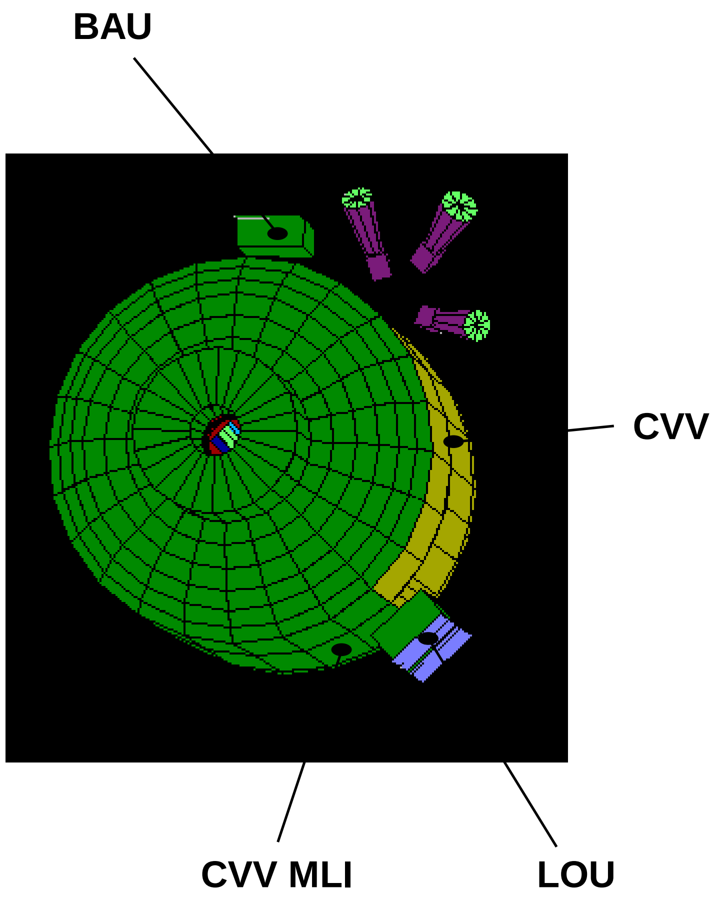
- The following modifications have been introduced:
- Update of FPU mass to 141 kg + 20% margin
- Adaptation of suspension (tank strap cross-section)
- Update of instrument harness (increase brass cross-section HIFI harness)
- Implementation of external harness
- LOU now in one box, with 13W dissipation and a radiator area of 0.5 m²

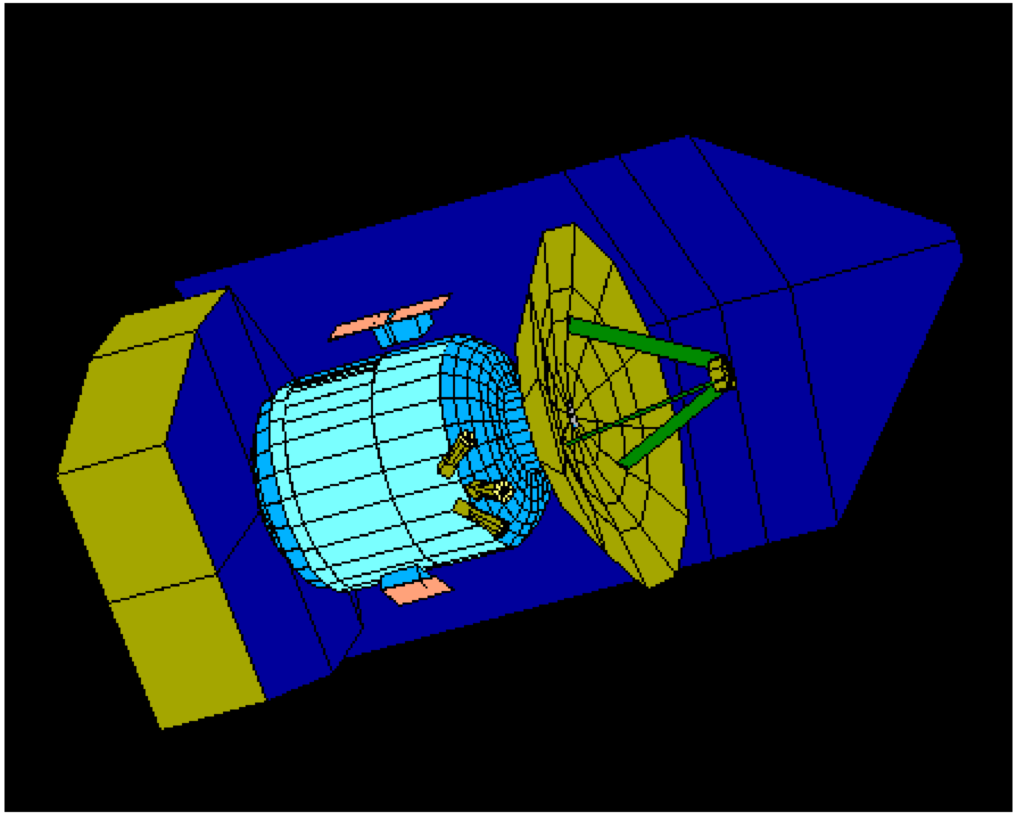



# PLM baseline configuration

- The environment of the PLM has been adapted to the configuration defined by Alcatel, the CVV external thermo-optical properties have been changed to harmonize the TMMs:

- Update of solar generator configuration, adaptation of absorptivity of solar cells and sunshade
- Emissivity of CVV MLI external layer reduced from 0.15 to 0.05
- Emissivity of CVV radiator reduced from 0.88 to 0.8
- Eff. Emissivity of sunshield MLI and SVM MLI adapted to $\varepsilon = 0.015$
- SVM strut and sunshield support struts cross-section/ length adapted



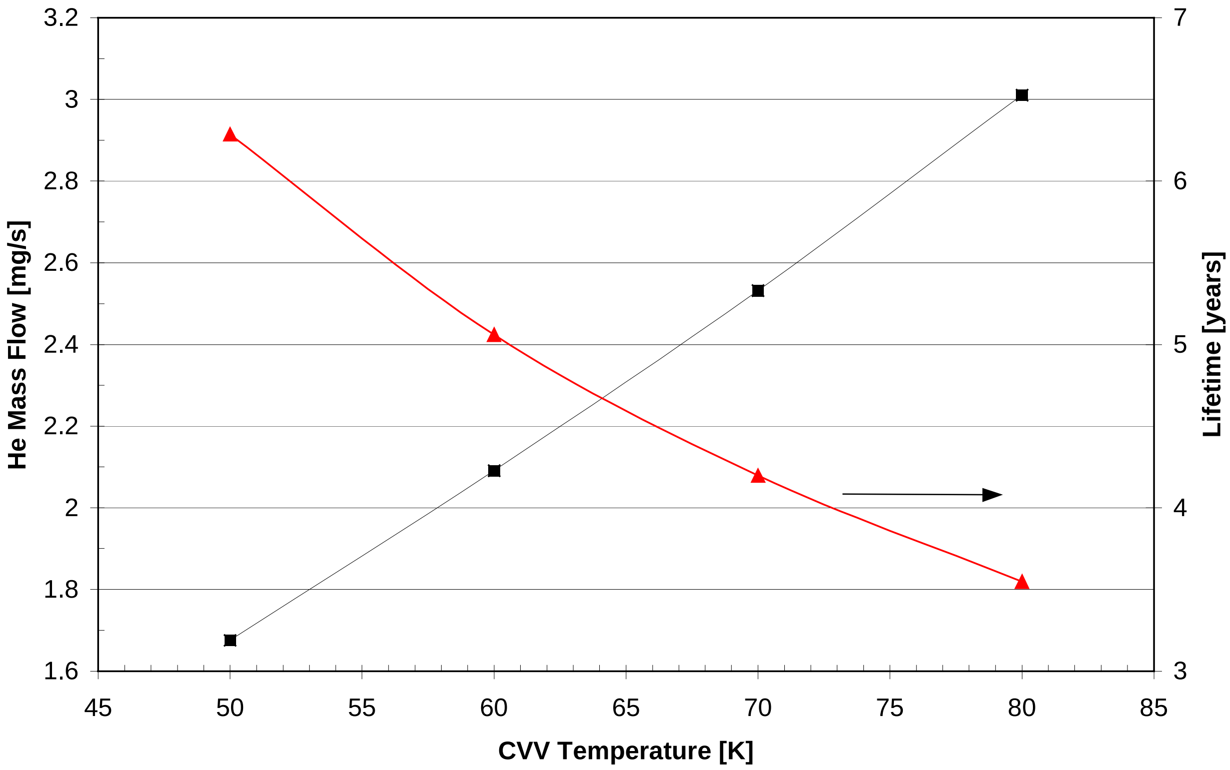
# TMM of baseline configuration

# 4. 1 Review of Thermal Design/Sensitivities – PLM

## 4.1.1 Baseline external heatbalance of CVV and sensitivities/ improvements

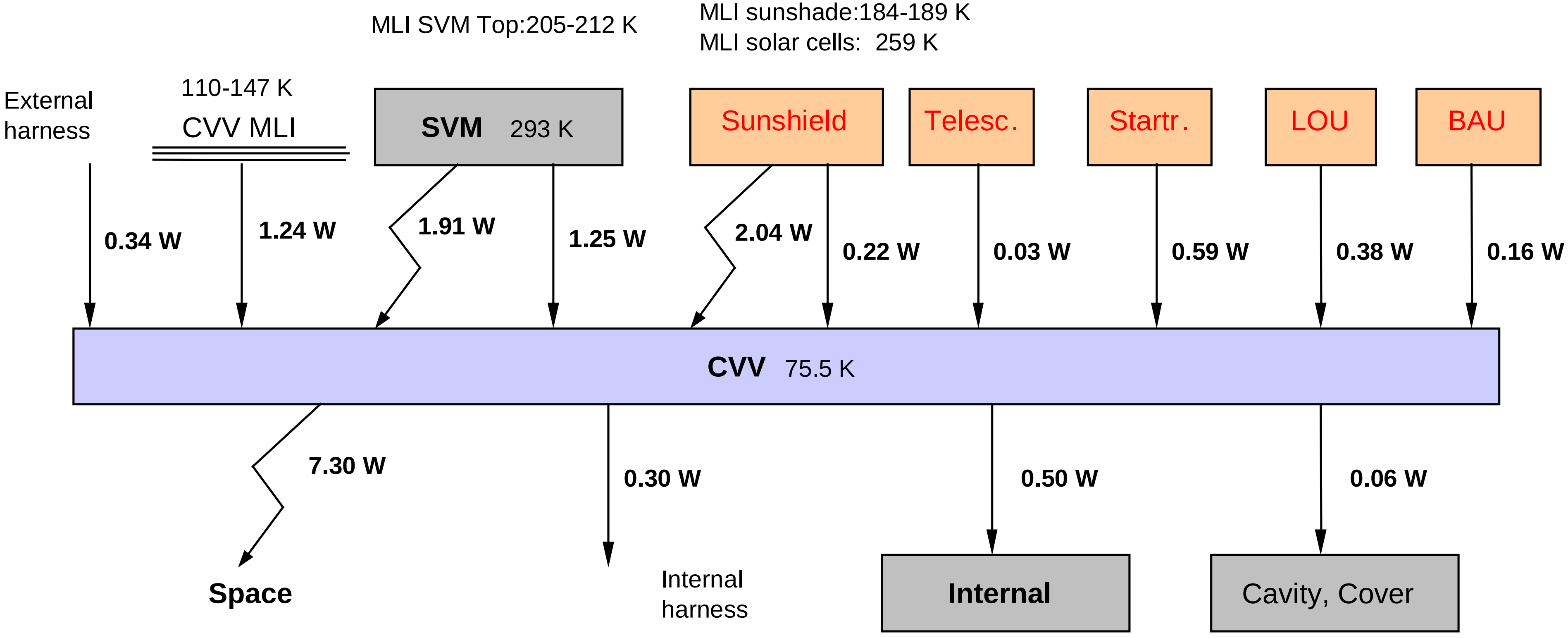
- Minimize CVV external heat load to reduce CVV temperature to

- extend lifetime and/or reduce mass & envelope of cryostat
- and/ or have sufficent margin to reduce complexity of internal cryostat design and cooling architecture




# Mass Flow / Lifetime versus CVV Temperature (baseline configuration)

# CVV external Heat Flow Chart for Baseline Configuration (Case 1)



# CVV external sensitivities – investigated parameters

- MLI on telescope rear side (black or aluminized)
- MLI coverage of CVV (angular and on bulkhead)
- Position of BAU (shift to MLI covered CVV side); Max. elongation of parts of BAU harness about 750 mm, depends also on routing of PACS instrument harness
- CVV radiator emissivity (open honeycomb)
- Isothermal Sunshield (e.g. heat pipe panel)
- FIRST tilt ± 30° around y-axis: input for ALCATEL thermoelastic assessment of STR location

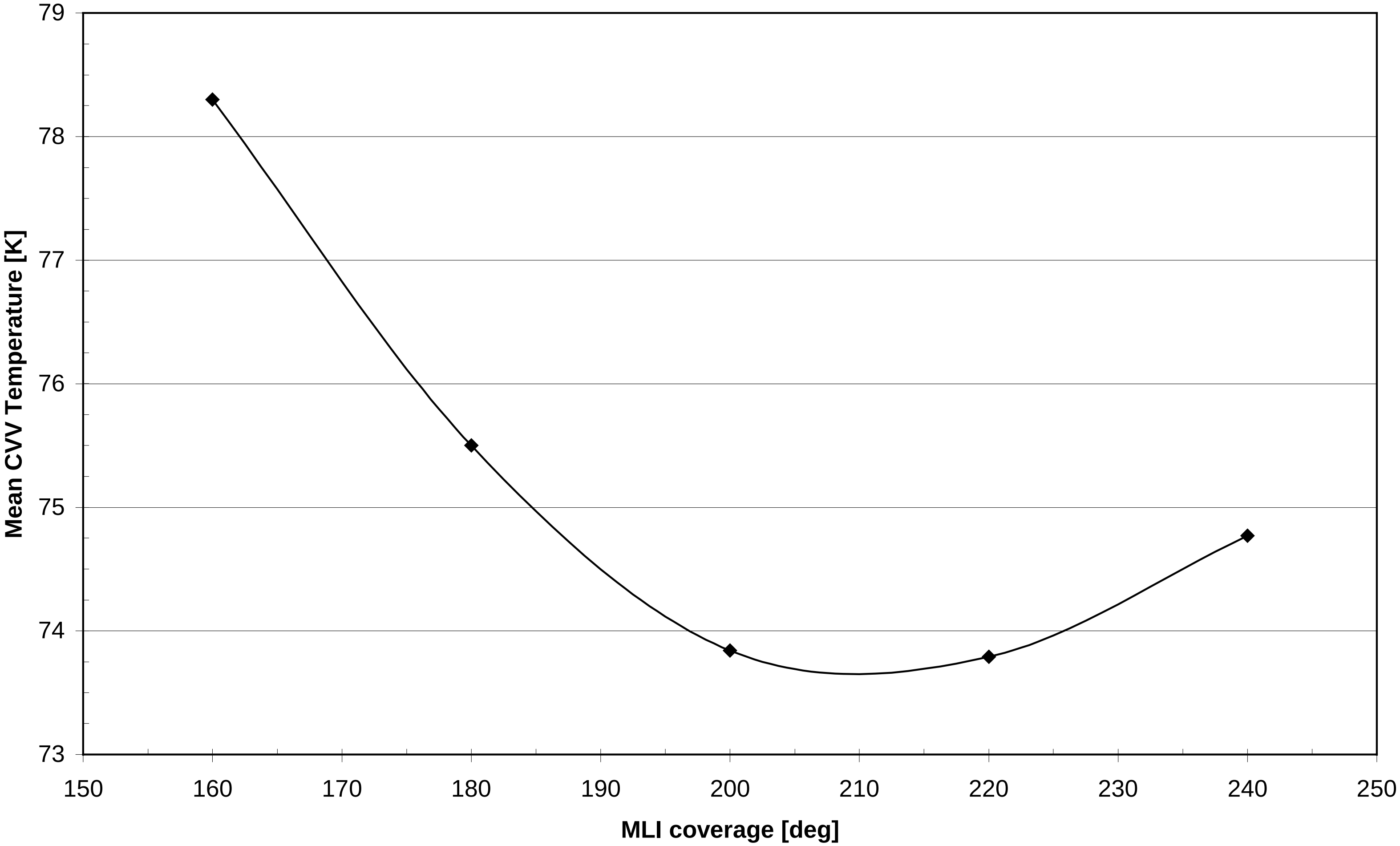
Further parameters might be interesting (not yet investigated by thermal analysis):

- LOU radiator arrangement (baseline position, tilted as in Alcatel-proposal)
- Sensitivity passive/ active cooling of cavity ,black paint on cavity (drawback straylight asymmetry)
- ODS use on LOU, BAU, STR, Sunshield
- Additional CVV radiator (depends on selected STR position)

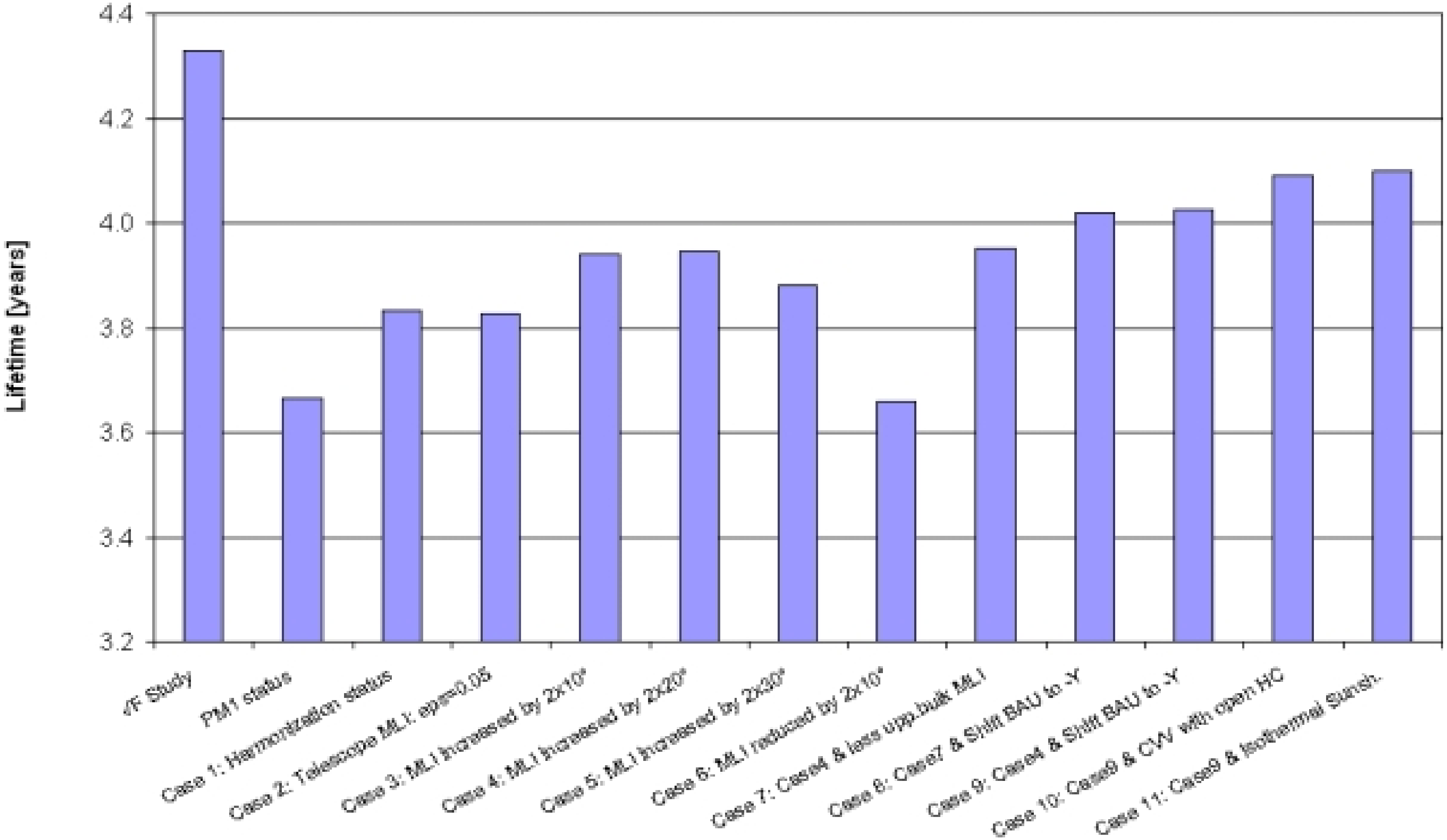
# CVV external sensitivities - Results

| Case | Description | T,cvv avg. | CVV Rad. | QR Sunsh./CVV | He massflow | Lifetime | Lifetime | Remark |
|---|---|---|---|---|---|---|---|---|
| | | [K] | [m²] | [W] | [mg/s] | [years] | [days] | |
| | | | | | | | | |
| | I/F Study | 77.5 | 5.482 | 2.09 | 2.45 | 4.33 | 1580 | see Report No. FIRST-GR-B0000.009, smaller harness cross-section |
| | PM1 status | 78.1 | 5.482 | 2.04 | 2.91 | 3.66 | 1338 | See page1 |
| 1 | Harmonization status (baseline) | 75.5 | 5.482 | 2.02 | 2.77 | 3.83 | 1399 | see page 7 |
| 2 | Telescope MLI: eps=0.05 | 75.6 | 5.482 | 2.07 | 2.78 | 3.83 | 1397 | Telescope MLI increased from 87 K to 104 K |
| 3 | MLI increased by 2x10° | 73.84 | 4.926 | 1.06 | 2.70 | 3.94 | 1439 | |
| 4 | MLI increased by 2x20° | 73.79 | 4.370 | 0.63 | 2.69 | 3.95 | 1440 | |
| 5 | MLI increased by 2x30° | 74.77 | 3.814 | 0.45 | 2.74 | 3.88 | 1416 | |
| 6 | MLI reduced by 2x10° | 78.3 | 6.038 | 3.66 | 2.91 | 3.66 | 1336 | |
| 7 | Case 4 & MLI upp.bulk 90° removed | 73.70 | 5.237 | 0.87 | 2.69 | 3.95 | 1442 | QR from STR to CVV increased from 0.28W to 0.62W |
| 8 | Case 7 & Shift BAU to -Y | 72.71 | 5.237 | 0.74 | 2.64 | 4.02 | 1467 | BAU from 125K to 130K. QR from BAU to CVV reduced from 109 mW to16.4 mW |
| **9** | **Case 4 & Shift BAU to -Y** | **72.63** | **4.370** | **0.50** | **2.64** | **4.02** | **1469** | QR from BAU to CVV 15.5 mW |
| 10 | Case 9 & CVV with open HC | 71.71 | 4.370 | 0.56 | 2.59 | 4.09 | 1493 | emissivity =0.9, see PLANCK report |
| 11 | Case 9 and Sunshield with heat pipes | 71.45 | 4.370 | 0.38 | 2.59 | 4.10 | 1497 | Solar array reduced from 95°C to 53°C |

# Sensitivity of CVV MLI angular coverage → Optimum at ~210° coverage



# CVV external sensitivities – lifetime summary



# Proposed ext. improvement: increase MLI by 2x 20° and shift BAU to -Y (Case 9)

- Significant reduction of sunshield radiation to CVV
- LOU, waveguides and BAU located at MLI covered section of CVV

  lead to a ~ 2 months lifetime increase

- Low complexity of introduced improvements

Drawback:
- Increase of harness length of BAU
- BAU temperature increase from 125 to 130K (radiator might be optimized)

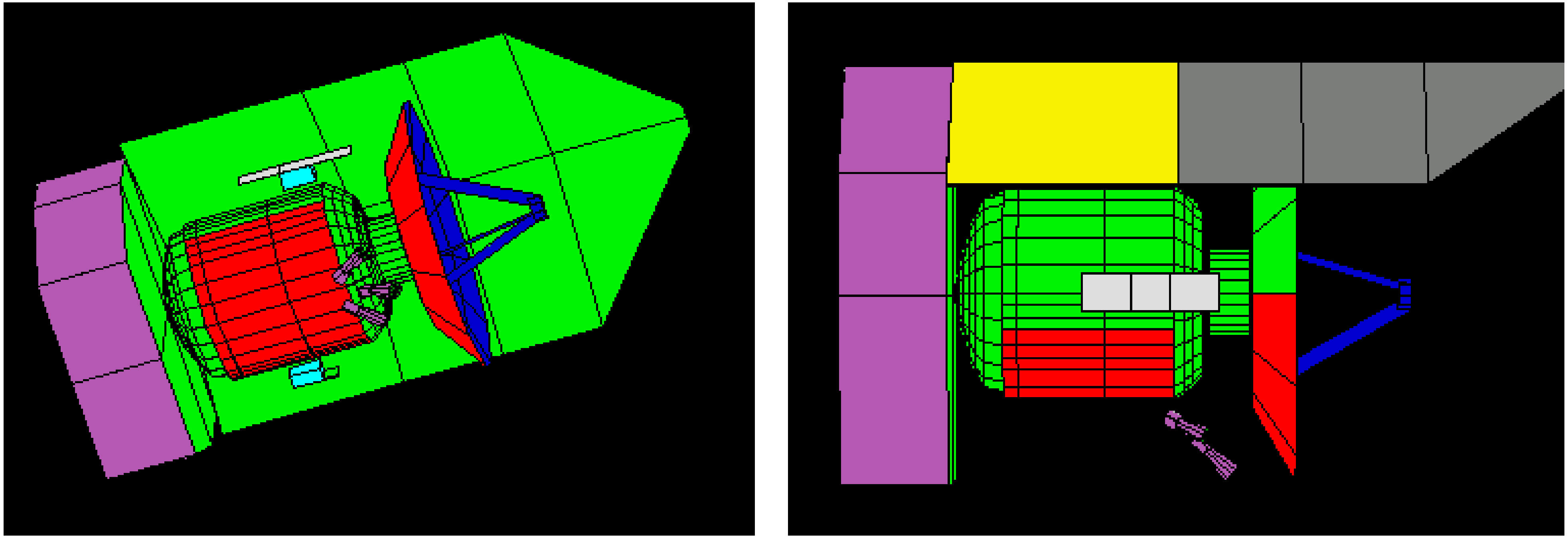
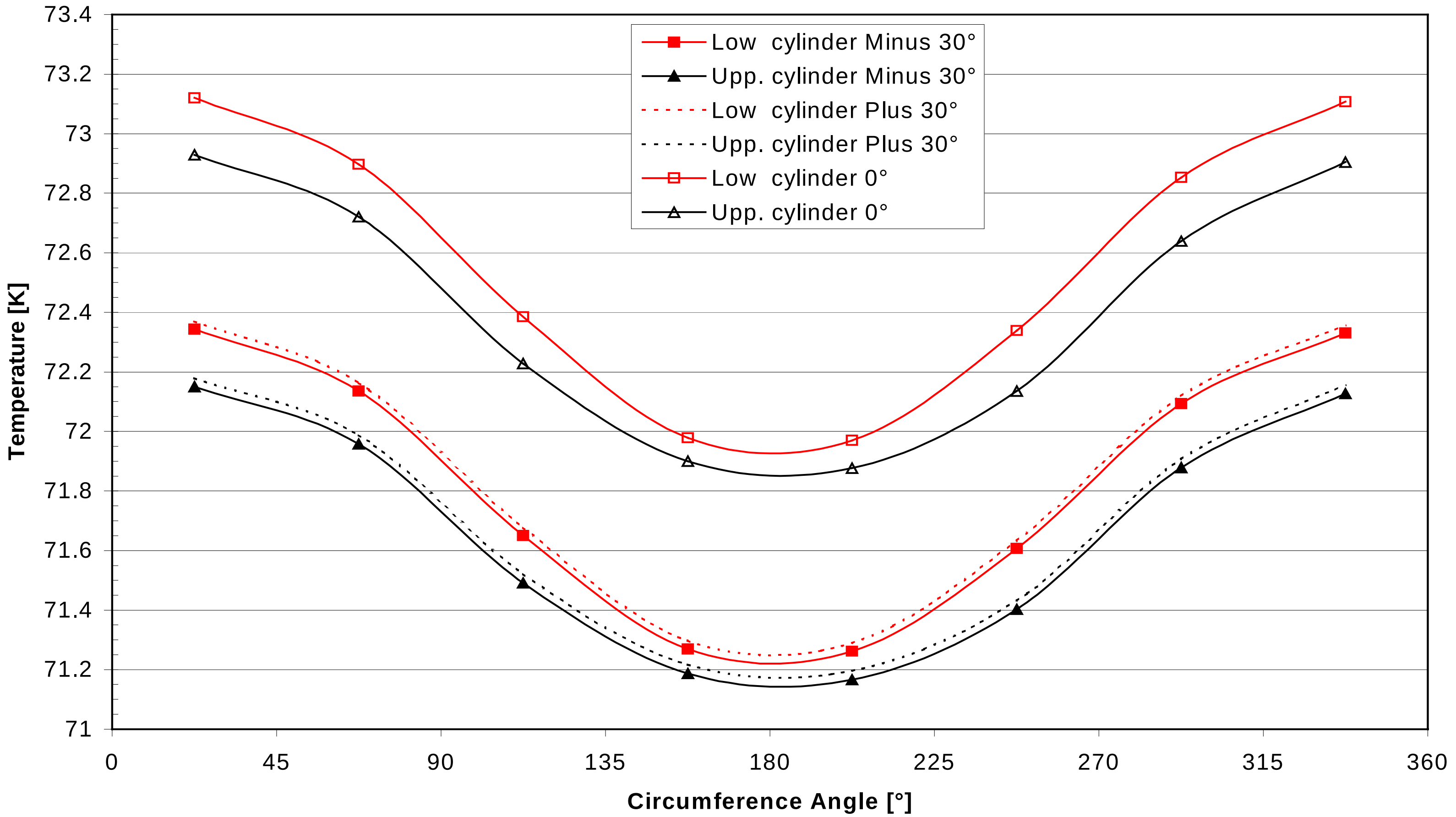


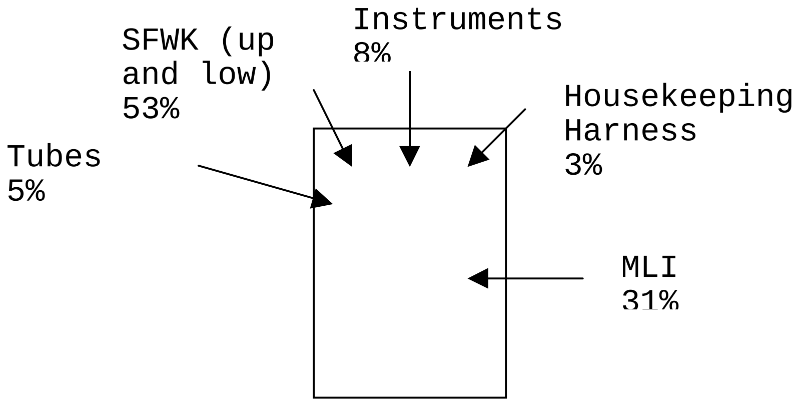
Fig.: TMM of proposed external modifications

# CVV temperature distribution versus FIRST rotation against Y-axis
## (Input for thermo-elastic investigations to assess Startracker location)



# 4.1.2 Baseline internal heatbalance of tank, OB and shield1, sensitivities/ improvements

HeII-tank balance:




- Main heatload from SFWK and via tank MLI

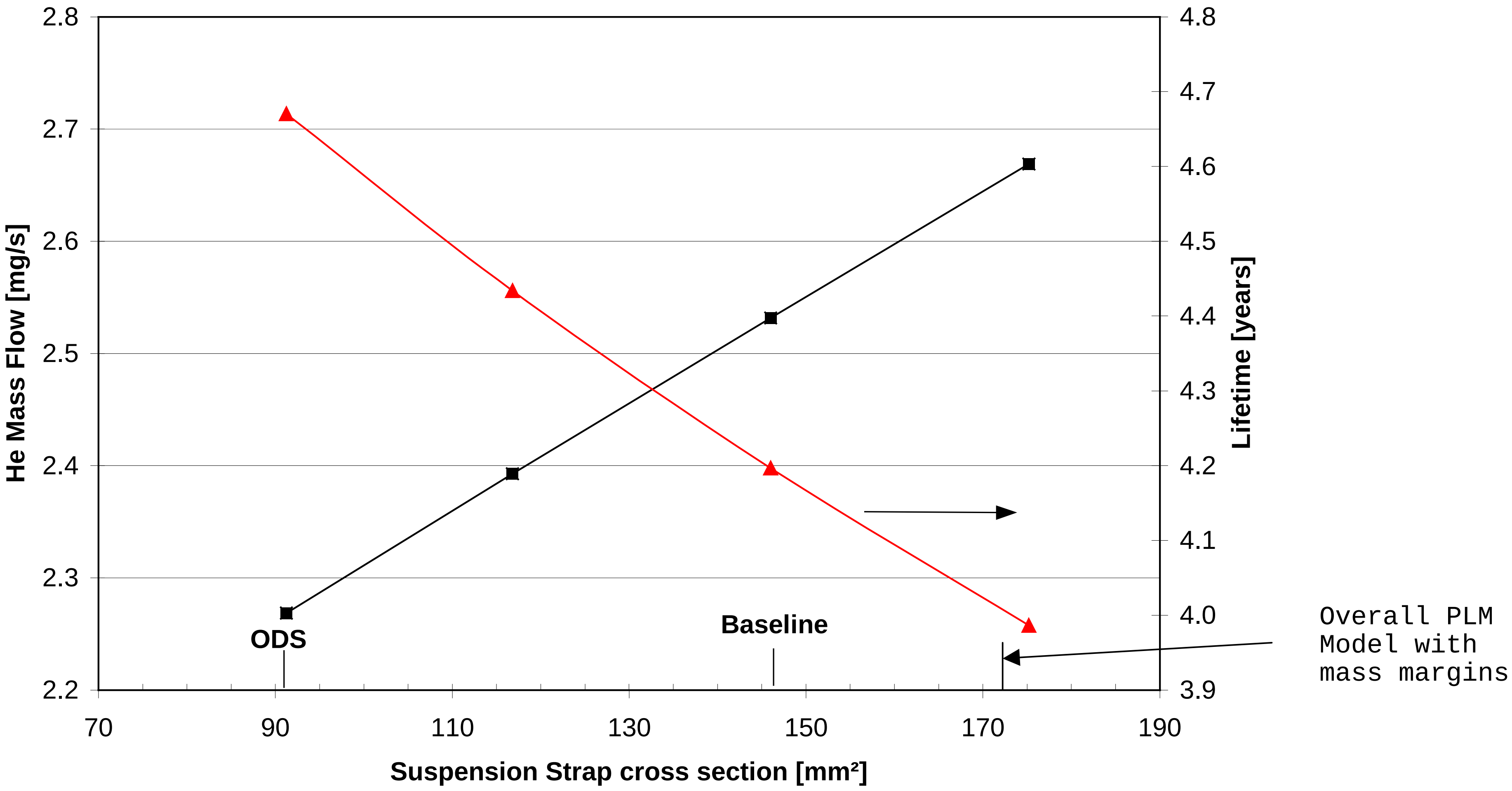
- MLI on HeII tank: 20 layers as on ISO, but conductance already reduced to 70%
  Sensitivity: Using the ISO MLI would reduce the lifetime by 1 month

- Shield 1 temperature (~35K) is the important parameter for heatload to tank via MLI (see balance of shield1)

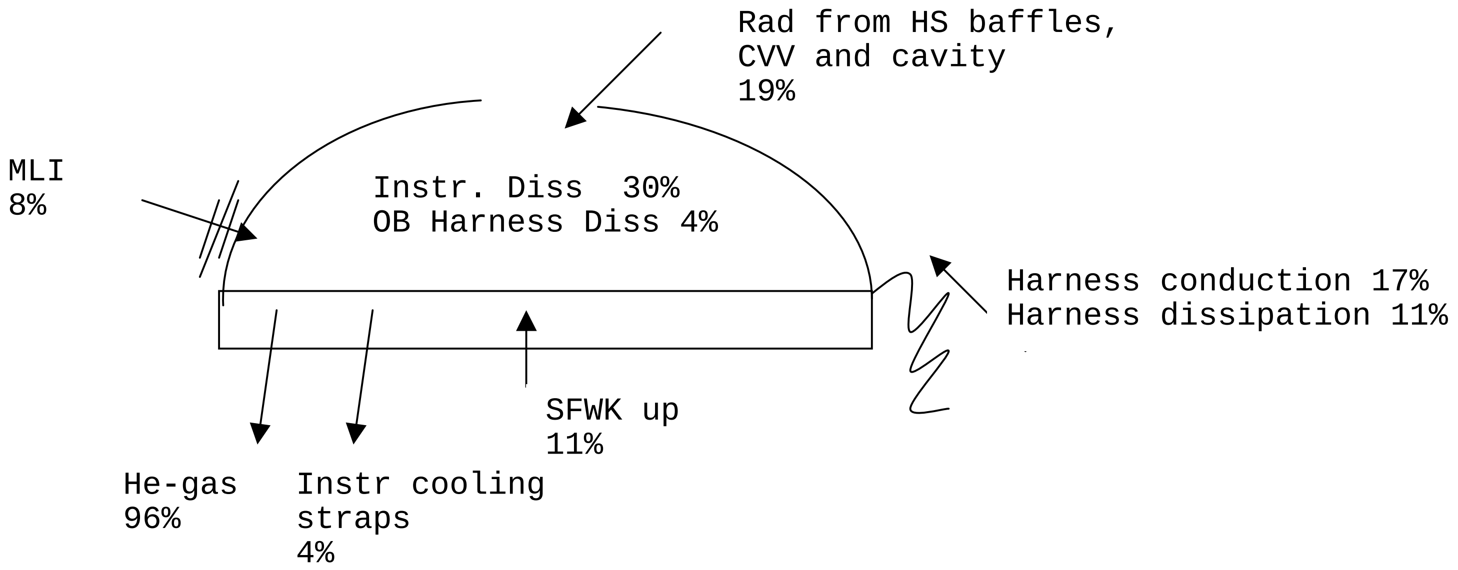
- Tank suspension on SFWK:A/l of corner struts might be improved by shifting of tank interface;
  Sensitivity: 50 % improvement of A/l of corner struts leads to a lifetime increase of about 1 months

- Temperature of SFWK (and the heatload to the tank) is mainly affected by tank strap cross-section (for lower SFWK) and tank strap cross-section and temperature of OB (for upper SFWK)
  (lifetime effect of tank strap cross-section, see next page)
  (for OB balance/temperature see p. 18)

# Variation of Tank Suspension Cross Section for 70 K CVV Temperature



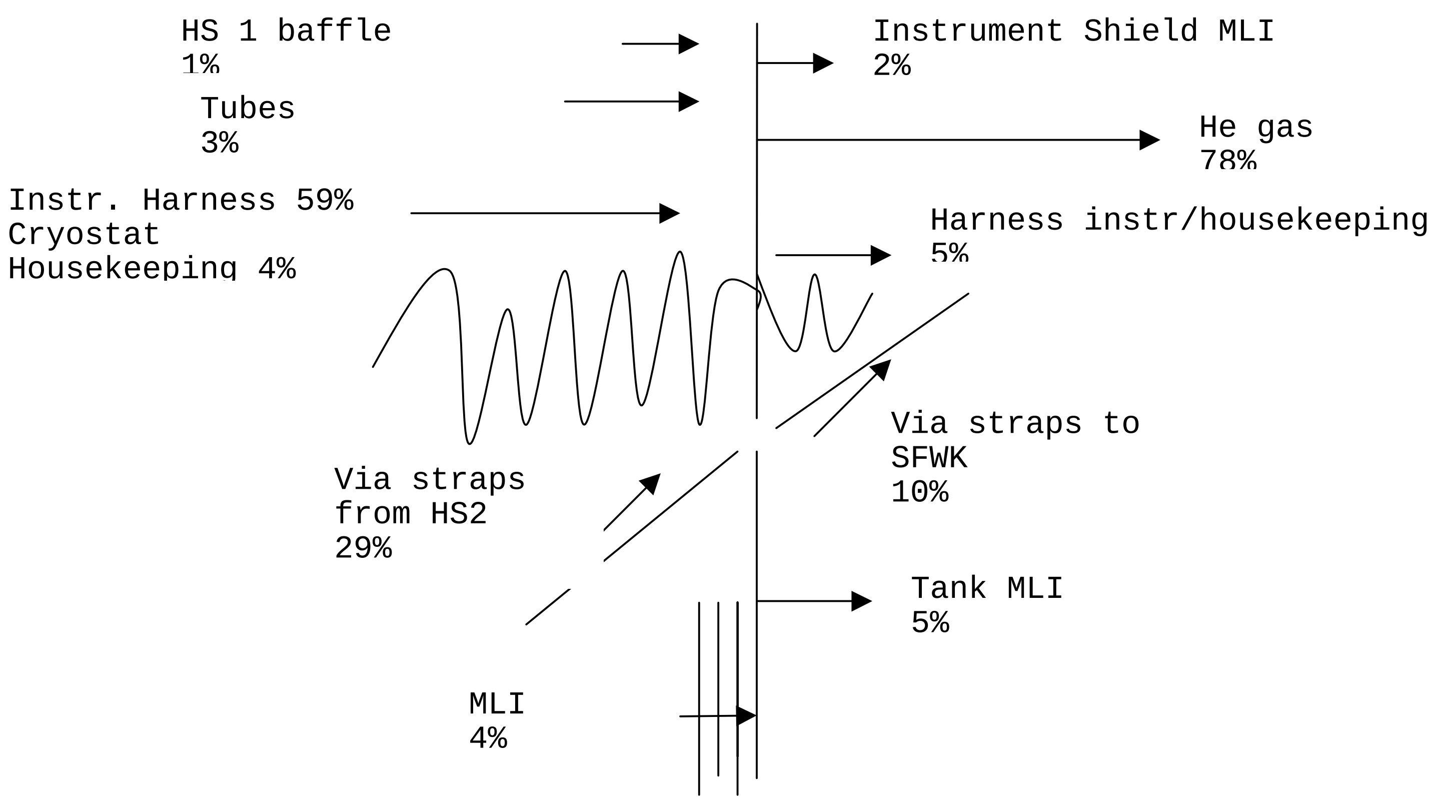
# OB assembly balance:




- OB (average ~9K) is cooling the SFWK
- Radiation from HS baffles, CVV and cavity already reduced by baffle on instrument shield
- Harness length between OB bracket and shield 1 is already 1.2 m assumed

For further investigations see also instrument cooling architecture

# Shield 1 balance:



# Shield 1 balance (cont´d):

- Instrument harness (cross-section change of 10 $mm^2$ brass gives 4 months lifetime effect)
- Elongation of harness `thermally effective length´ between CVV and shield 1 from 0.25 m to 0.35 m increases lifetime about 4 months
- Tank strap cross-section (see sensitivity tank strap, p. 17)
- Radiative input to shield 1 small since temperature difference between shield 1 and shield 2 is small

**Simplification of Cooling architecture** (external design based on Case 9):

- GHe Level 2 cooling loop replaced by direct coupling of the ventline to the OB and cooling of the JFET box and the HIFI FPU structure via the OB.
- Shift PACS GHe I/F before SPIRE and add the PACS Level 2 dissipation also to the Level 1

Advantage: Each instrument has only one I/F to the GHe ventline
Lifetime increases by ~20 days

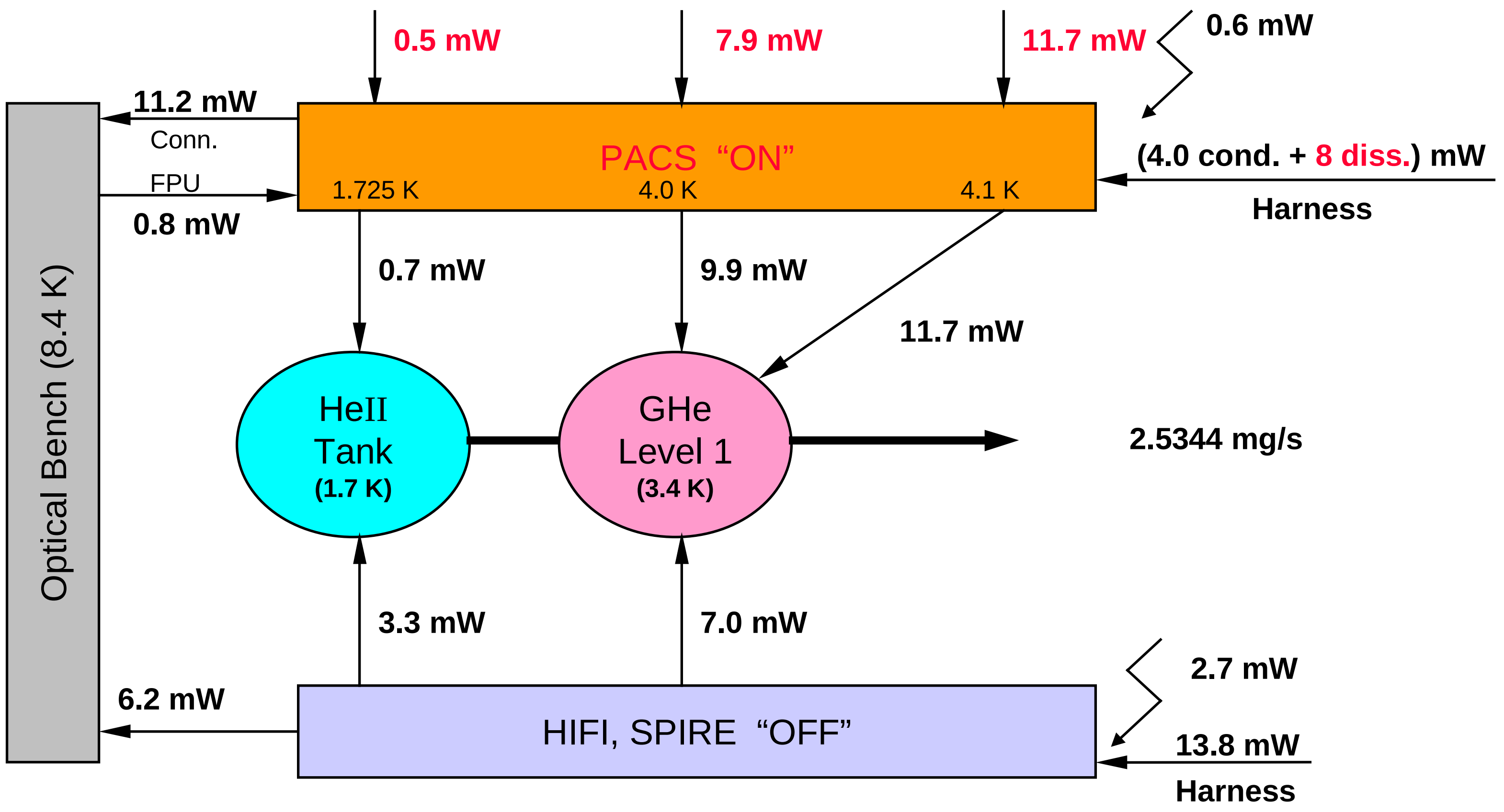
Constraint: OB would have to be made of Aluminium

# Instrument operation with simplified cooling architecture (Case 9a)

| | Level 0 | Level 1 | Level 2 | Opt.Bench | Massflow |
|---|---|---|---|---|---|
| PACS dissipation | 0.5 mW | 7.9 mW | 7.4 mW | | |
| Temp. req. PACS | < 1.75K | < 4.3K | < 15K | | |
| Temp. req SPIRE | < 2 K | < 6 K | < 15K | | |
| Case 9 Avg. | 1.71 K * | 3.8 K * | 9.3 K * | 9.7 K | 2.64 mg/s |
| Case 9a Avg. | 1.71 K * | 2.9 K * | 2.8 K * | 9.3 K | 2.60mg/s |
| PACS on only | 1.725 K * | 4.0 K * | 4.1 K * | 8.4 K | 2.53 mg/s |
| SPIRE on only | 1.74 K ** | 4.2 K ** | 9.5 K ** | 9.4 K ** | 2.61 mg/s |

* PACS temperatures
** SPIRE temperatures

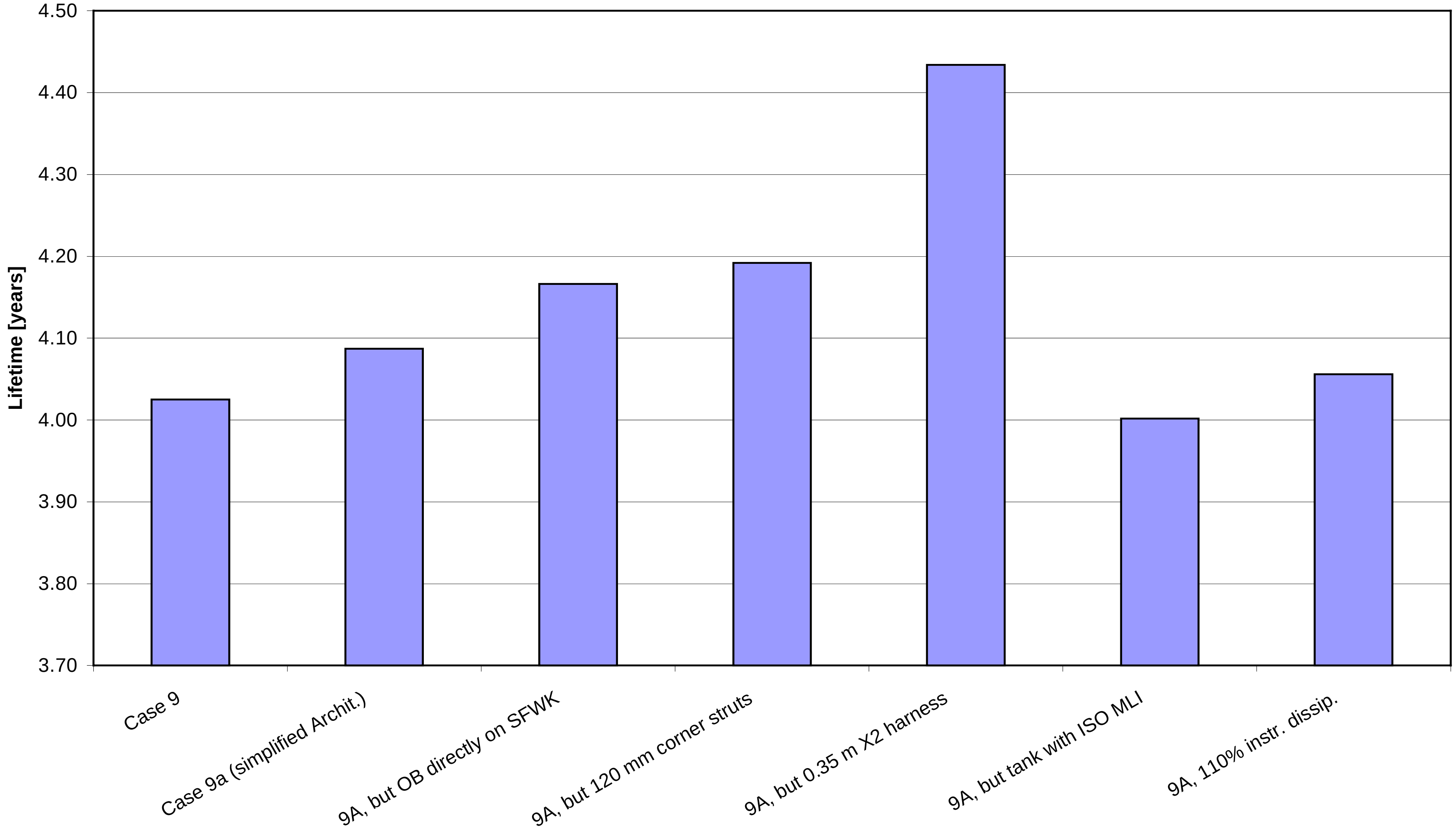
# Heat flow chart for PACS operation with simplified cooling architecture (Case 9a)



# Instrument Architecture and CVV internal sensitivities

| Description | T, OB | T, GHe Lev.1 | He mass flow | Lifetime | |
|---|---|---|---|---|---|
| | [K] | [K] | [mg/s] | [years] | [days] |
| | | | | | |
| Case 9 | 9.7 | 2.7-3.5 | 2.64 | 4.02 | 1469 |
| Case 9a (simplified cooling architecture) | 9.3 | 2.4-3.5 | 2.60 | 4.09 | 1492 |
| Case 9a, but OB directly on SFWK | 9.9 | 2.5-3.7 | 2.55 | 4.17 | 1521 |
| Case 9a, but 120 mm corner struts (instead of 80 mm) | 9.9 | 2.5-3.7 | 2.53 | 4.19 | 1530 |
| Case 9a, but 0.35 m harness between CVV and HS 1 (instead of 0.25 m) | 9.6 | 2.5-3.7 | 2.39 | 4.43 | 1618 |
| Case 9a, but tank with ISO MLI (no 0.7 reduction factor of MLI conductive coupling) | 9.0 | 2.4-3.4 | 2.65 | 4.00 | 1461 |
| Case 9a with 110% instrument dissipation | 9.5 | 2.5-3.6 | 2.62 | 4.06 | 1480 |

# CVV internal sensitivities – lifetime summary



# 5. Recommendation

Based on the above described sensitivities the following modifications are proposed to be introduced in the detailed design for Phase 2:

External modifications:

- MLI on CVV cylinder closed by 20°
- Shift of BAU to +y-side (if harness elongation acceptable)

Internal modifications:

- Simplification of cooling architecture (Al-OB required, not finally selected)
- OB not thermally insulated from SFWK
- Improvement of A/l of SFWK corner struts (if possible, tbc by struct. analysis)
- Improved tank MLI shall remain

Note: The harness `thermally effective length´shall remain, since there is at the moment no design solution visible for routing and for thermal coupling of this high number of wires to the shield1 (100% effective of coupling assumed in TMM)

# Resizing potential

- Implementation of the above proposed improvements is expected to improve the lifetime from 3.6 years to 4.1 – 4.2 years (~2.55 mg/s) for the PLM with 2560 l tank and a CVV at 72K
- Instrument dissipation margin of 10% and adaptation of strap cross-section to PLM with mass margins leads to a lifetime of 3.9 years (~ 2.7 mg/s)
- For a 280 mm height reduced cryostat (2000 l HeII tank) the corresponding lifetime is 3.1 years (~2.55 mg/s)

  For 3.5 years lifetime a maximum possible reduction of tank height about 120 mm is estimated

- It has to be taken into account for the detailed design in Phase 2, that the OB height has to be increased from 60 to 120 mm (tbc), which reduces the PLM resizing potential to 60 mm

## Other constraints for the resizing potential:

- The lifetime of the PLM is highly depending on the characteristics of the instrument harness (e.g. 10 $mm^2$ brass ≈ 0.25 mg/s ≈ 4 months lifetime) which is still under development

- The operation of the phase separator (during launch and on orbit) and the behaviour and testability of the He ventline will get more and more critical with decreasing massflow and increasing ratio between ground and orbit massflow

  A minimum on orbit massflow of 2.5 mg/s for the present configuration is considered necessary

  Assuming this minimum massflow and a lifetime of 3.5 years the minimum volume (incl. transient phase) is > 2160 l (red. about max 200 mm)

# FIRST OPTIMISATION STUDY

## Phase 1 Final Meeting

## ESTEC, 31/03/2000

# AGENDA

- ▼Introduction (ESA)
- ▼Study approach (ASPI)
- ▼Baseline configuration (ASPI)
- ▼Review of Thermal Design/Sensitivities (ASPI/DSS)
  - ❑ System
  - ❑ PLM
- ▼Trade Off/Recommendation (ASPI/DSS)
- ▼Next Steps-Phase 2(ASPI)
- ▼Conclusion (All)
- ▼AOB

## ▼Actions status from PM1

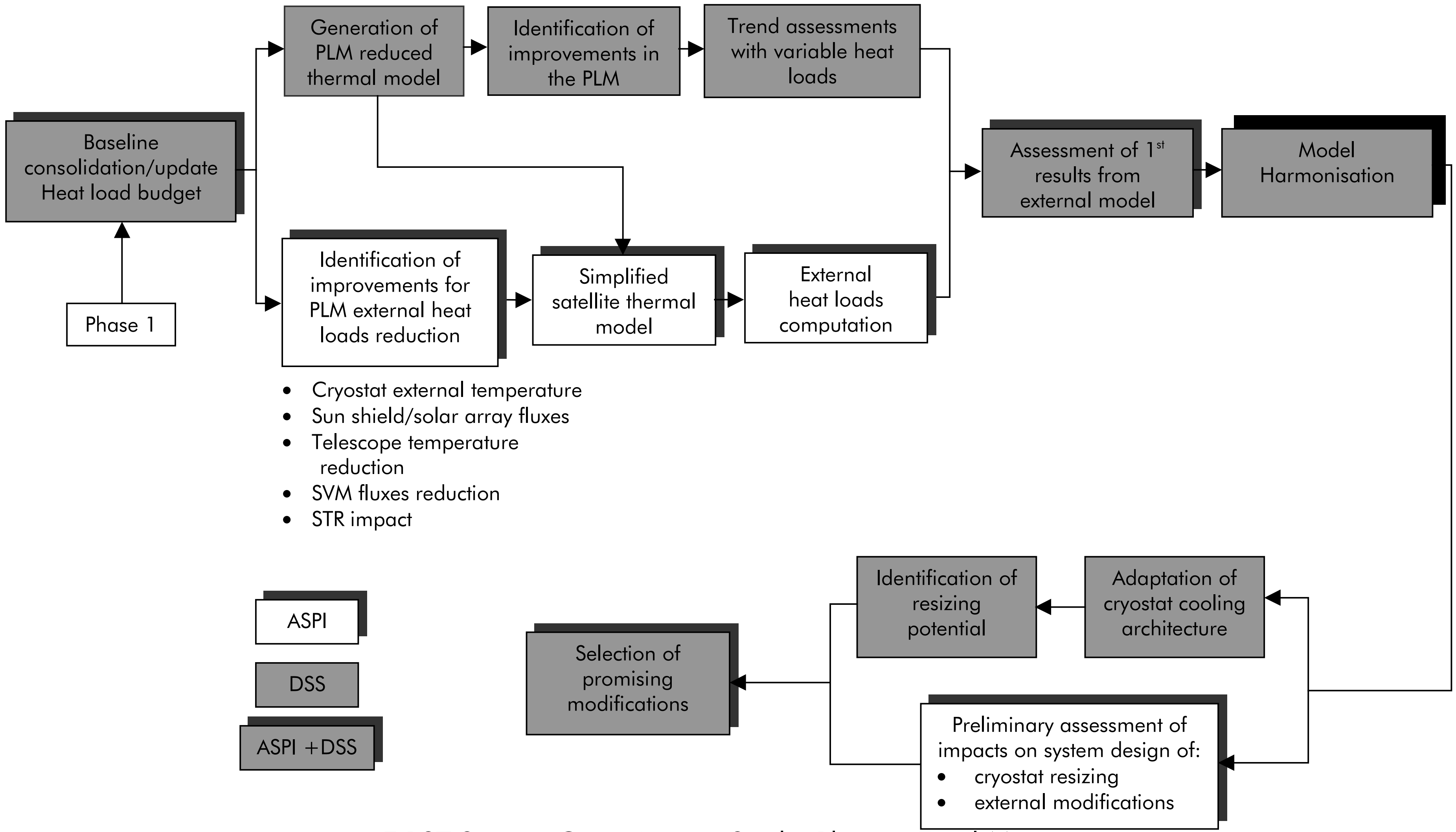
| Action | Actionee | Due Date | Description | Remark | Status |
|---|---|---|---|---|---|
| 1 | ASPI | 10/03 | To clarify instrument mass budget | Closed by e-mail 8/03 | C |
| 2 | DSS | 10/03 | To clarify the discrepancy in the lifetime presentation for short CVV | Closed by DSS Fax FP-039/00 dated 10/03 | C |
| 3 | DSS | 30/03 | To assess the possibility to move the BAU out of the CVV radiator | See presentation during Phase 1 final meeting | C |
| 4 | ESA | 30/03 | To review white paint degradation data | | O |

# STUDY APPROACH

# Phase 1 objectives

- Baseline definition : definition of a starting point for the study
- System level
  - Investigation of ways to reduce the heat loads on PLM
    - ➔ heat coming from the Sunshield/Sunshade
    - ➔ SVM fluxes reduction
    - ➔ STR impact
    - ➔ Telescope temperature reduction
  - System impacts of modifications
- PLM level
  - Sensitivity of PLM performance to external heat loads, straps cross section, CVV height reduction
  - Review of the CVV internal design
  - Adaptation of instrument cooling architecture
- Selection of system/PLM configuration to be studied during Phase 2

# Phase 1 Study Logic



# BASELINE CONFIGURATION

# "Baseline" or "reference" configuration based on following hypotheses:

- Sunshield/Sunshade from FIRST telescope specification
  - AsGa solar array on Sunshield
    - 2 panels of 2.3 mx2.3 m
    - Hi-eta + OSR solar array not selected because it exceeds limit of 100 mm below primary reflector front surface
  - Sunshade covered with OSR
- LOU and BAU implementation on cryostat
- FIRST SVM similar in design to Planck SVM
- Updated FIRST interface tube
- Cryostat from merger study
- STR on PLM top, heat load = 0.7 W (radiative + conductive)

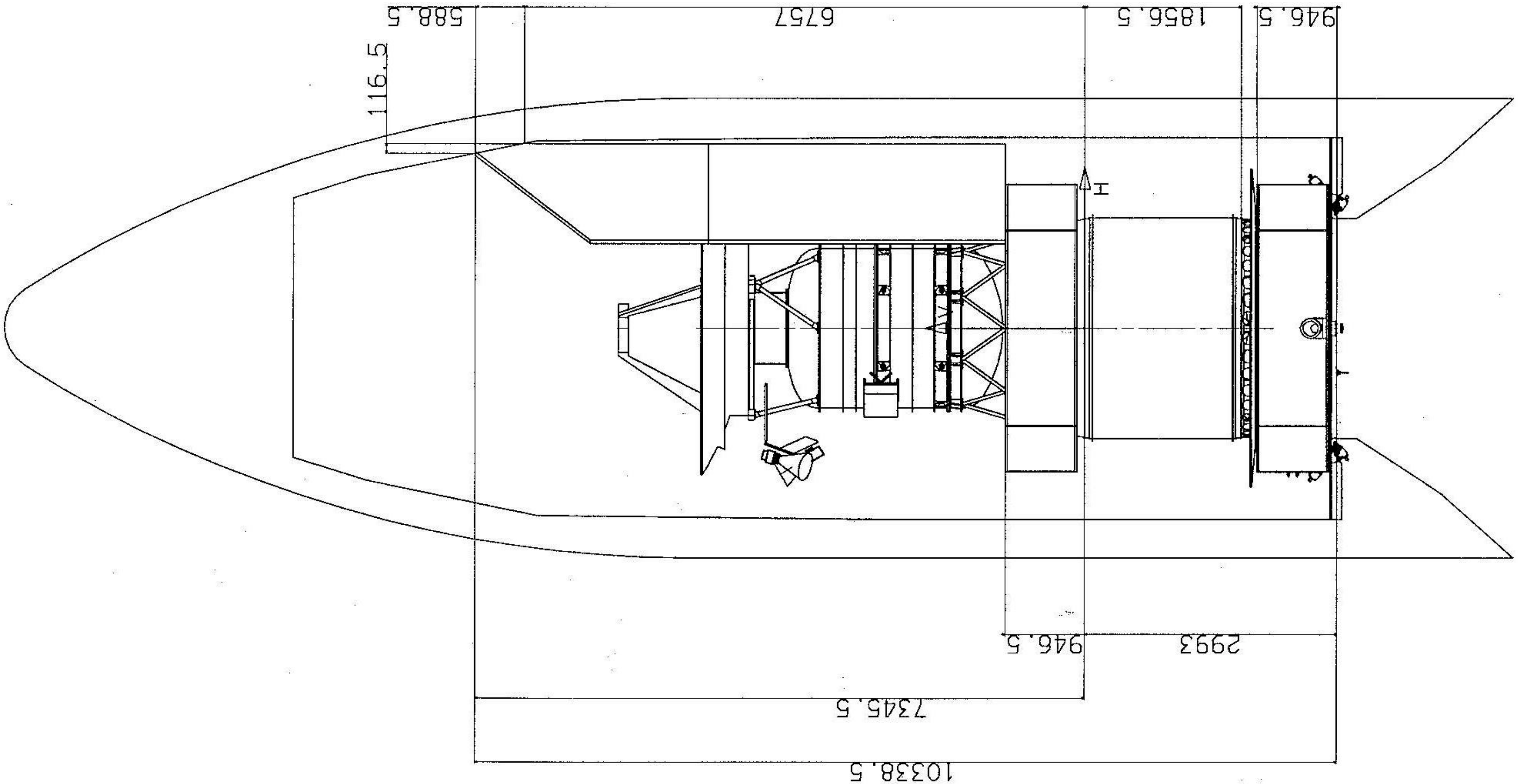
## Problem encountered:

- 588.5 mm interference between top of Sunshade and fairing
  - no cryostat reduction (450 mm cryostat reduction was considered in ESA Carrier Study)
  - Planck PLM height increase: latest configuration from Planck PLM Architect study
  - 30 mm margin between PLM top and panel closing FIRST central tube
  - use of dihedral Sunshield/Sunshade: 4 panels configuration was used in ESA Carrier Study

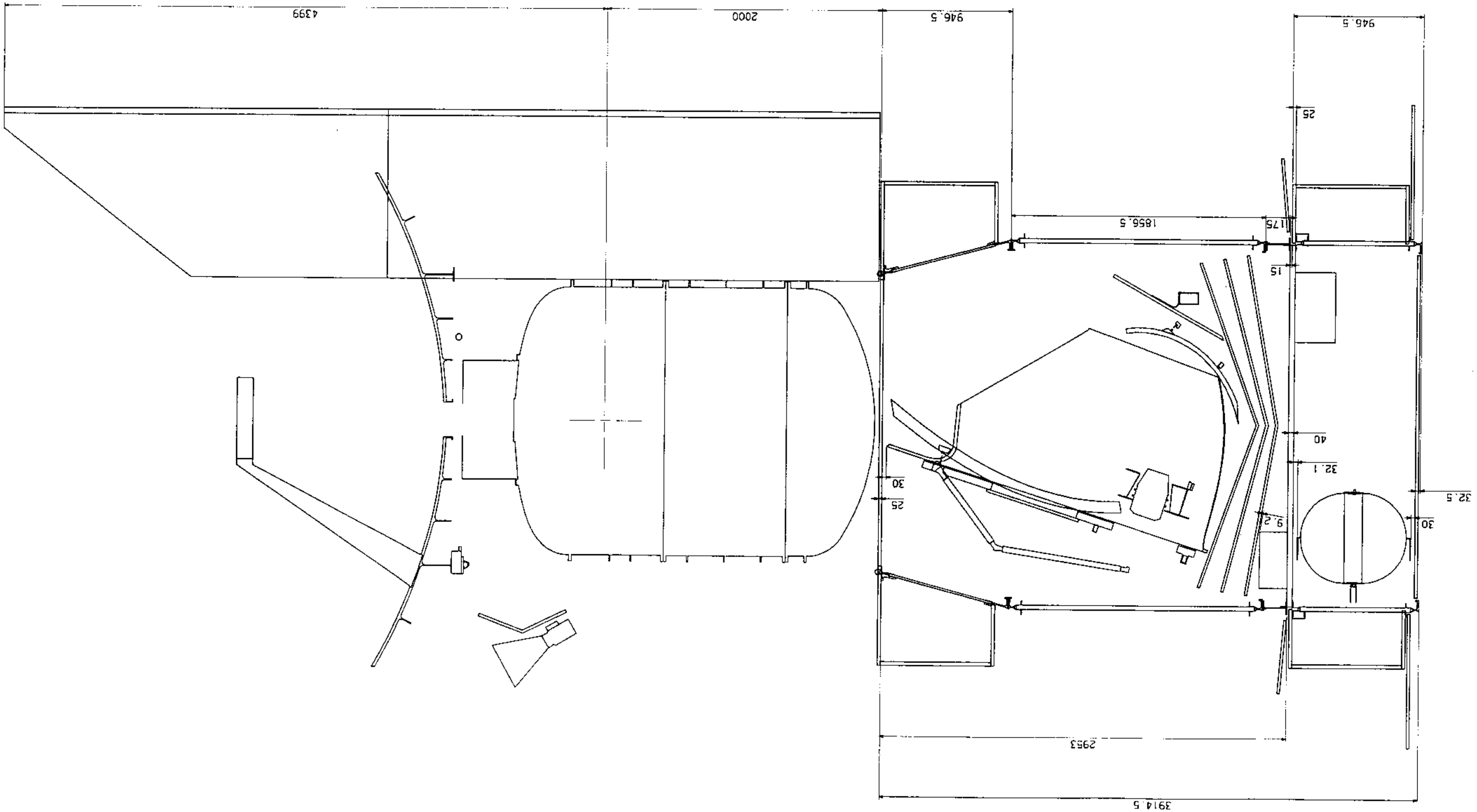
## Potential solutions:

- deletion of 3936/2624 adaptor cone (220 mm height): TBC by Arianespace
- cryostat height reduction
- Sunshield/Sunshade optimisation

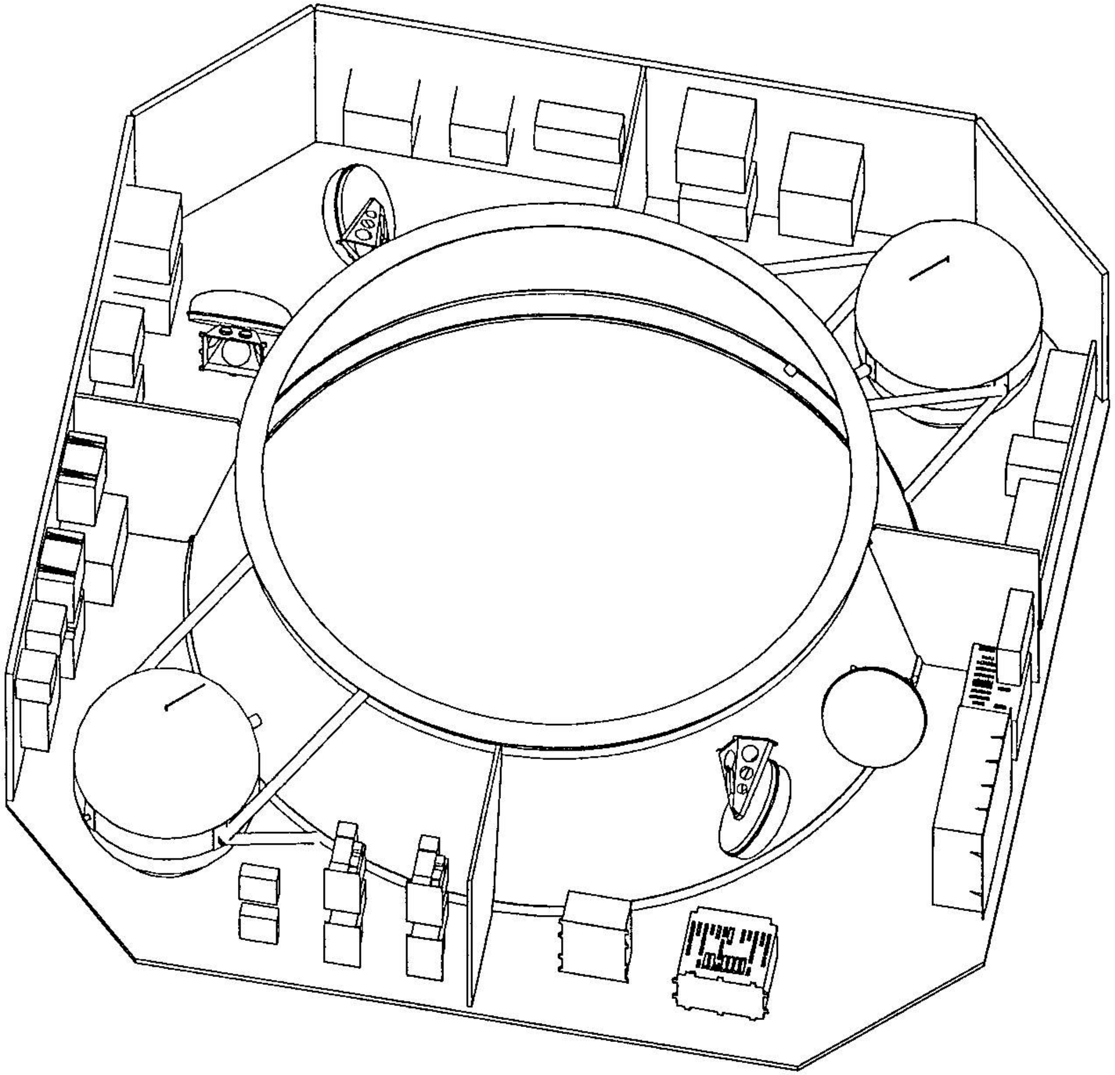
# Carrier Baseline Configuration



# Carrier Baseline Configuration



# FIRST SVM Baseline Configuration



## Hypotheses:

- Sunshield mass from Merger mass budget
- Cryostat mass from Merger mass budget, updated taking into account inputs from Instrument I/F Update Study
- Helium mass for a nominal PLM, without reduction
- Instrument mass from IID-B Rev 3, updated by ESA Fax SCI-PT/FIN-07539, dated 13/03/2000

## Adapters

- 2624 adapter for Planck (98 kg)
- 3936/2624 adapter cone
  - presented in ARIANE 5 User's Manual. Mass = 230 kg
  - Might not be necessary (TBC by ARIANESPACE). If not used need for USF (reinforcement plate on top of the EPS cone) = 50 kg

# Mass Budget

## FIRST SATELLITE OPTION "UPRIGHT"

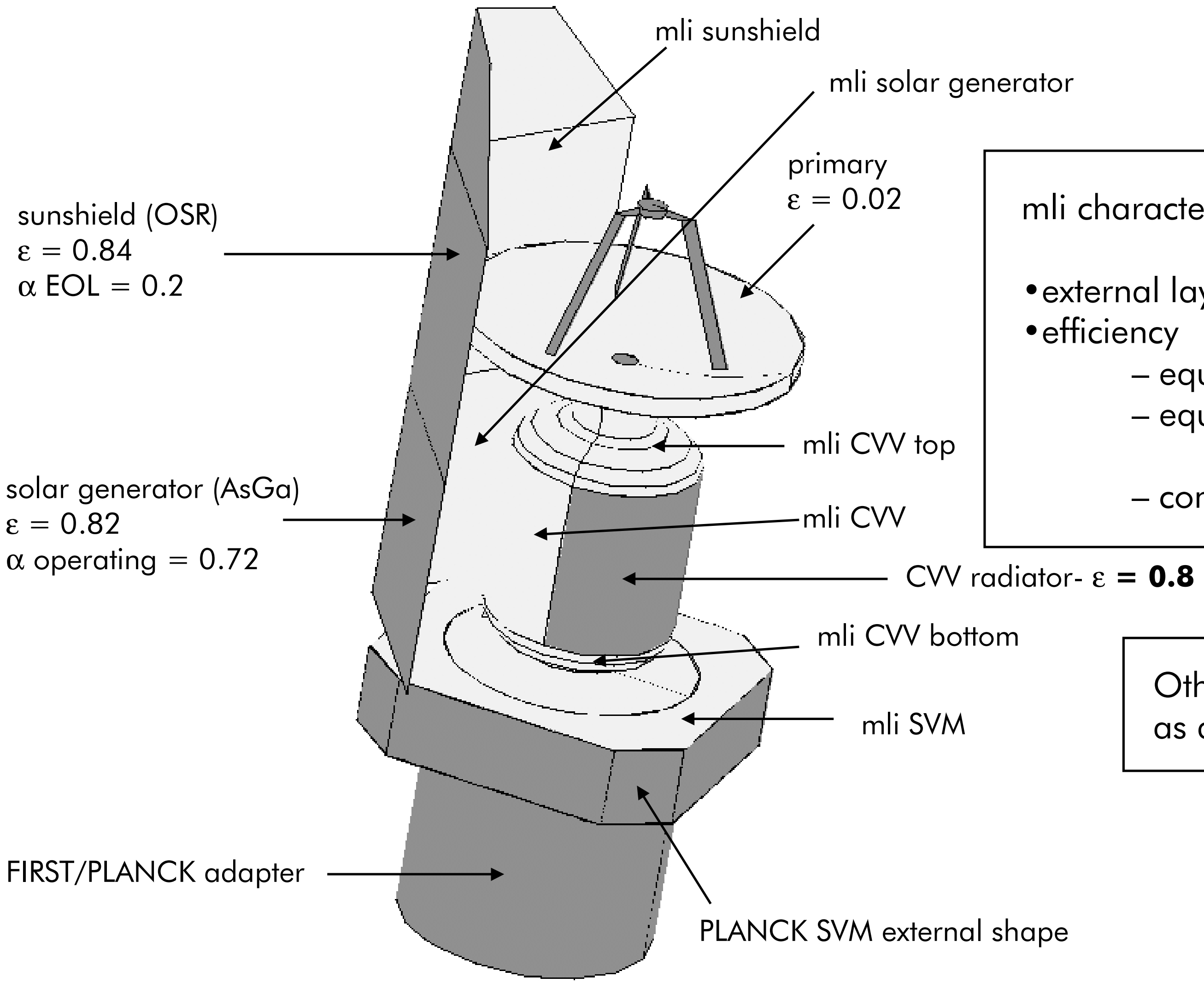
| MASS BUDGET | NOMINAL MASSES | | MARGIN | MAXIMUM MASSES |
|---|---|---|---|---|
| **PAYLOAD MODULE (PLM) DRY** | **1583.6 kg** | | **261.0 kg** | **1844.6 kg** |
| **Dry Cryostat** | 1042.2 kg | | 174.8 kg | 1217.0 kg |
| Cold instrument outside PLM | 25.0 kg | | 5.0 kg | 30.0 kg |
| Cold instrument inside PLM | 141.0 kg | | 28.2 kg | 169.2 kg |
| Warm instruments inside SVM | 140.4 kg | | 28.0 kg | 168.4 kg |
| **Telescope** | 235.0 kg | | 25.0 kg | 260.0 kg |
| **SERVICE MODULE (SVM) DRY** | **802.7 kg** | | **111.2 kg** | **951.9 kg** |
| Power | 35.1 kg | | 3.5 kg | 38.6 kg |
| AOCS | 69.7 kg | | 4.2 kg | 74.0 kg |
| OBDH - RF | 28.8 kg | | 4.9 kg | 33.7 kg |
| Sunshield with Solar Arrray integrated | 137.0 kg | | 22.0 kg | 159.0 kg |
| Structure | 258.0 kg | | 37.6 kg | 295.6 kg |
| Adapter FIRST / Planck | 193.1 kg | | 29.0 kg | 222.0 kg |
| Clampband System FIRST / Planck | | | | 38.0 kg |
| Thermal Control | 11.2 kg | | 2.2 kg | 13.4 kg |
| Harness | 25.0 kg | | 5.0 kg | 30.0 kg |
| RCS | 39.8 kg | | 2.7 kg | 42.4 kg |
| Assembling | 5.0 kg | | 0.0 kg | 5.0 kg |
| Balance mass | 0.0 kg | | 0.0 kg | 0.0 kg |
| ***DRY SATELLITE MASS*** | **2386.3 kg** | | **372.2 kg** | **2796.5 kg** |
| **FLUIDS** | **506.5 kg** | | **364.7 kg** | **530.2 kg** |
| Cryostat Helium | 364.7 kg | | 364.7 kg | 368.3 kg |
| Propellant plus pressurant **0.048** | 141.8 kg | | | 161.9 kg |
| ***WET SATELLITE MASS (in orbit)*** | **2892.8 kg** | | **433.8 kg** | **3326.6 kg** |

# Carrier Launch Budget

| Item | Maximum mass (kg) With 3936/2634 cone | Maximum mass (kg) Without 3936/2634 cone |
|---|---|---|
| FIRST | 3327 | 3327 |
| Planck | 1687 | 1687 |
| 3936/2624 adapter cone | 230 | |
| Planck 2624 adaptor | 98 | 98 |
| USF | | 50 |
| System margin | 200 | 200 |
| **TOTAL** | **5542** | **5362** |

- With 3936/2624 cone, launch mass exceeds ARIANE 5 capability with EPS upper stage (5310 kg)
- Without 3936/2624 cone, launch mass marginally above ARIANE 5 capability

# THERMAL BASELINE DEFINITION

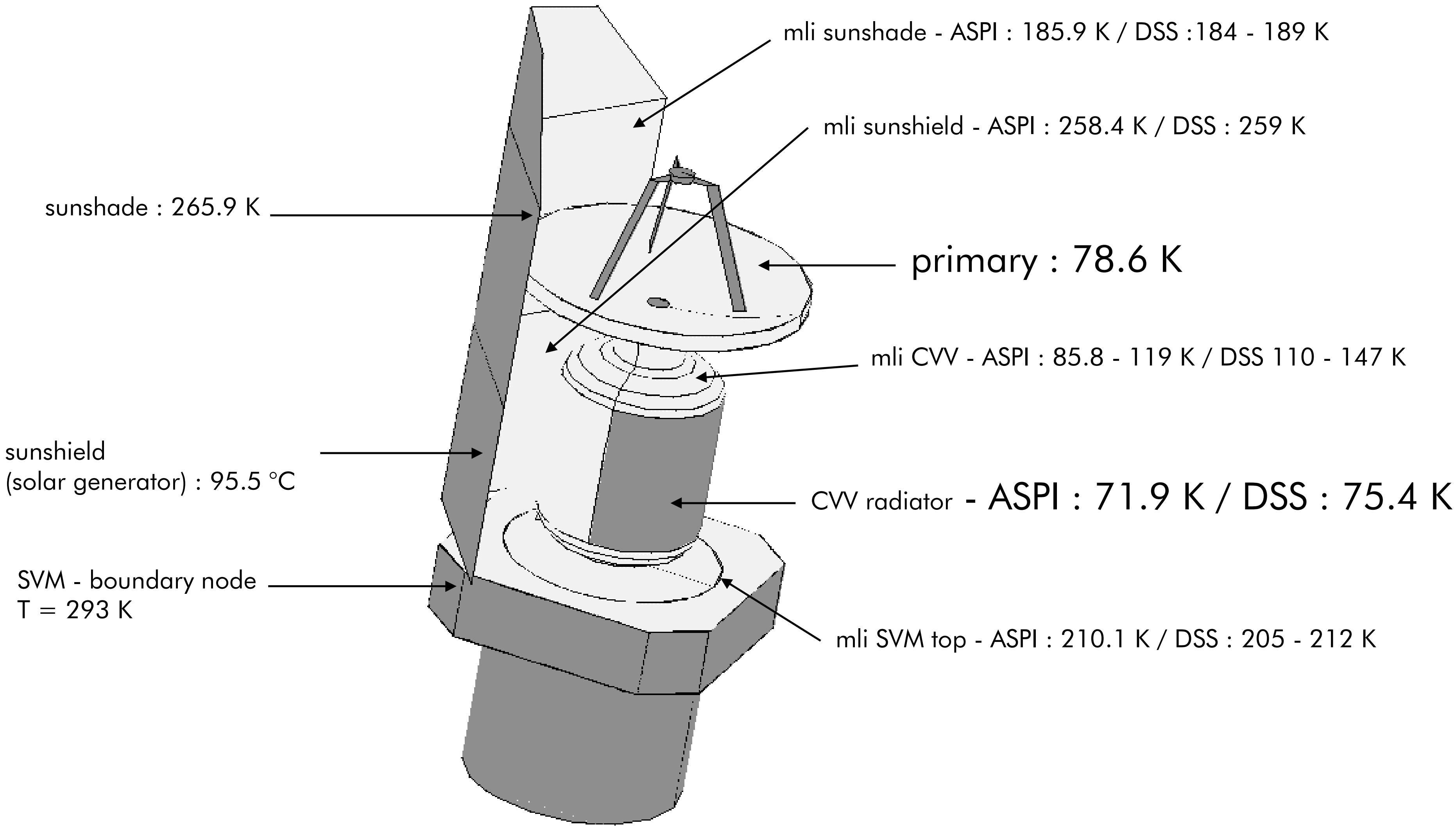



mli characteristics

- external layer ε : 0.05
- efficiency
  - equivalent ε : 0.015 (except on CVV)
  - equivalent ε on CVV : 0.007
  - conductive link in // (T dependent)

Other characteristics (struts, material…) as described during PM1

# TEMPERATURE DISTRIBUTION FOR THE BASELINE



# HEAT FLUX DISTRIBUTION FOR THE BASELINE

| | ASPI | DSS |
|---|---|---|
| T CVV | **72,1** | **75,4** |
| T primary | **79,1** | |
| | | |
| **CONDUCTIVE HEAT FLUXES ON CVV** | | |
| SVM - PLM truss | 1,08 | 1,25 |
| sunshield/sunshade - PLM struts | 0,37 | 0,22 |
| telescope - truss | 0,09 | 0,03 |
| harness | 0,52 | 0,34 |
| **ss total conduction** | **2,07** | **1,84** |
| | | |
| **RADIATIVE HEAT FLUXES ON CVV** | | |
| mli sunshield/sunshade | 0,97 | 2,04 |
| mli SVM | 1,97 | 1,91 |
| **ss total radiation** | **2,94** | **3,95** |
| | | |
| **OTHER HEAT FLUXES ON CVV** | | |
| mli CVV | 0,85 | 1,24 |
| LOU | 0,39 | 0,38 |
| BAU | 0,17 | 0,16 |
| STR (global dissipation) | 0,70 | 0,59 |
| CVV - inner (negative) | 0,72 | 0,8 |
| **ss total** | **1,39** | **1,57** |
| | | |
| TOTAL | 6,39 | 7,36 |
| **CVV - space** | **6,41** | 7,3 |

Δ with DSS from

- ≠ nodal breakdown for CVV radiator
- CVV radiator effective surface $5.26\ m^2$ / $4.8\ m^2$ (DSS TMM of LOU, BAU & STR)
- simplified CVV model from DSS (CVV + external boxes) will be included in TMM in phase 2

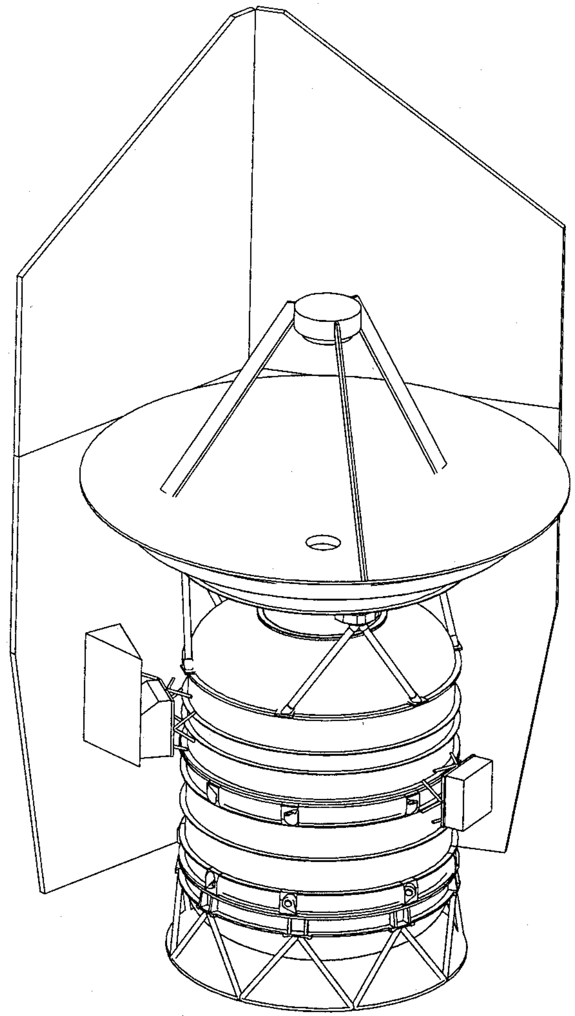
# REVIEW OF THERMAL DESIGN/SENSITIVITIES

- ▼LOU and radiator implementation
- ▼STR implementation on SVM
- ▼Sunshield/Sunshade optimisation
- ▼SVM radiative heat flux reduction
- ▼SVM at bottom of interface tube
- ▼Hole in SVM
- ▼CVV radiator optimisation

## LOU & Radiator implementations

- Review of LOU dimensions and location on CVV, according to DSS information
- LOU Radiator implementation :
  - LOU radiator positionned on LOU :
    - ➔ towards +X+Z side to minimize view factor with CVV radiator
    - ➔ out of view of SSH back side
    - ➔ radiator plate of 0.5 $m^2$, with growth potential
  - radiator and supporting concepts :
    - ➔ open Aluminium box with stiffeners, fixed to LOU, with additionnal beams (material TBD) to LOU baseplate
- LOU supporting : base to be enlarged for stiffness reason

# LOU and radiator implementation

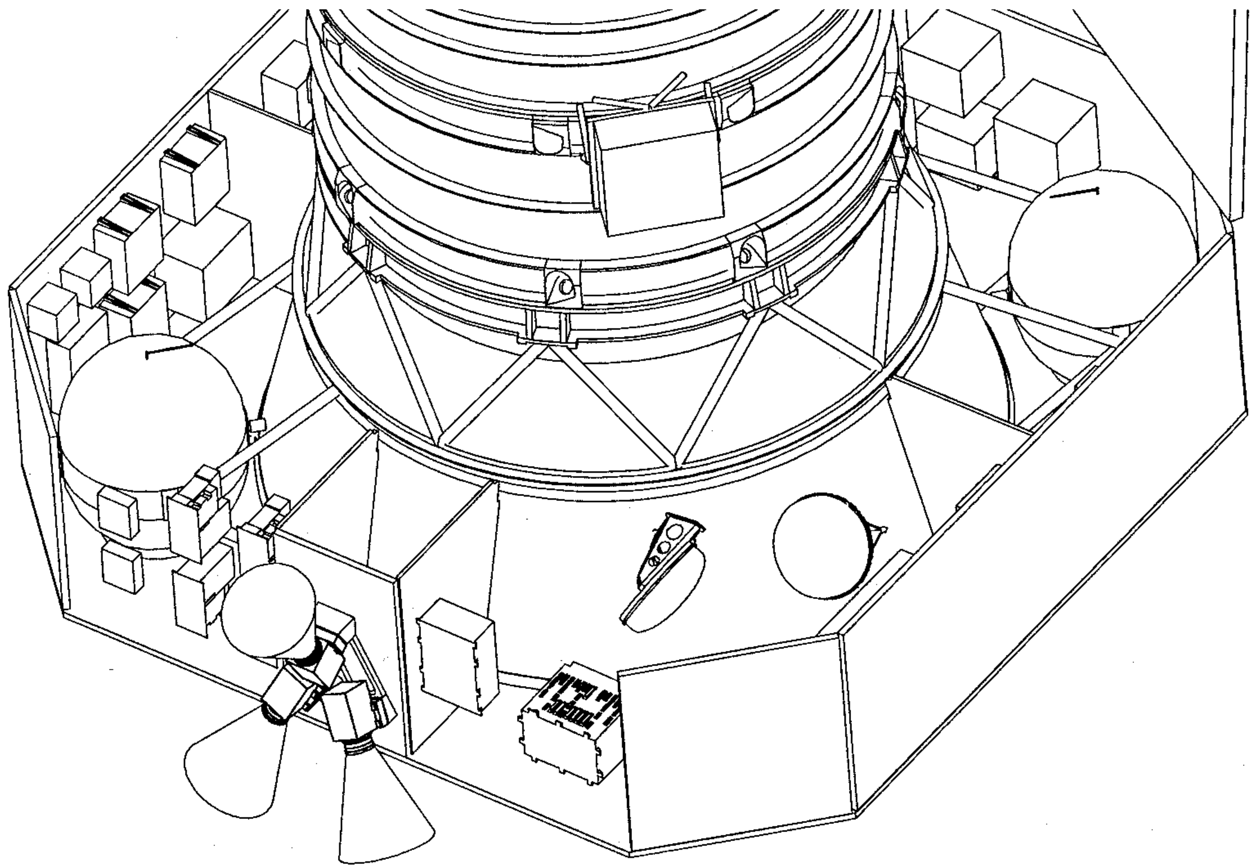


# STR implementation in SVM

- ▼Objective : to reduce thermal loads from STR on CVV
- ▼STR positioned in front of SVM -Z side :
  - ❑ STR supporting : candidate concepts :
    - ➔option 1 : simplest : STR baseplate, fixed on a small SVM wall
    - ➔option 2 : more stable : STR baseplate, fixed on 3 bipodes to the Central tube
  - ❑ SVM impact :
    - ➔SVM unit layout : rather neutral
    - ➔SVM Structure : mass impact to be expected
  - ❑ CVV impact : Potential gain on CVV temperature : **~3 K**

| | baseline | - STR |
|---|---|---|
| STR disipation | 0,7 W | 0 W |
| T CVV | **71,9** | **69,2** |
| T primary | **78,6** | **75,7** |

# STR implementation



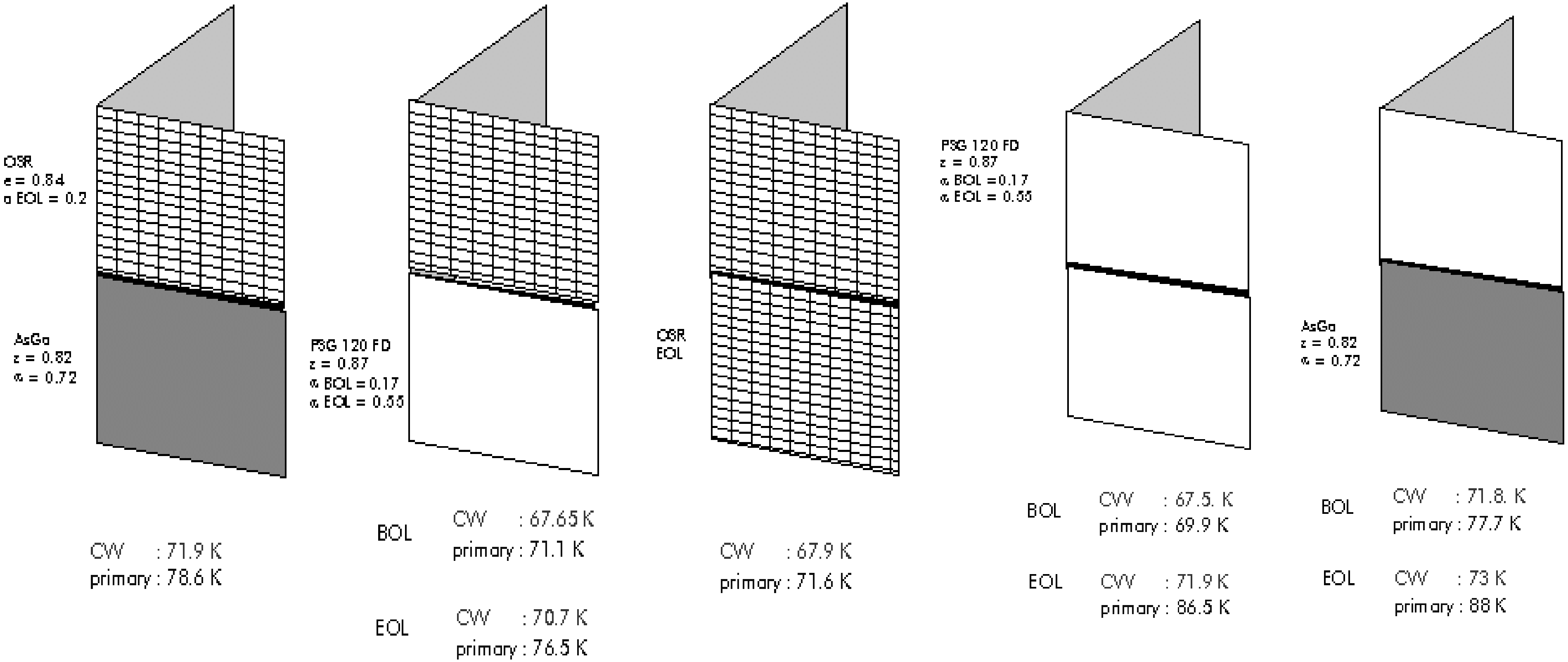
# STR implementation

- Thermo-elastic deformation between STR and focal plane instruments comes from 3 elements:
  - SVM + STR support
  - CVV truss
  - PLM
- SVM:
  - 10 deg gradient variation in central tube (hypothesis consolidated by ISO telemetry data)
- CVV truss:
  - estimated from data from ISO telemetry
- PLM
  - estimated from thermal model: DSS computation for +30/0/-30 rotation around Y

- SVM contribution : estimation = 0.8 arcsec maximum
- CVV truss contribution
  - ISO data corrected for influence of Earth at perigee passage
  - gradient variation estimated at 2.5 K
  - contribution estimation : 0.5 arcsec
- CVV contribution
  - +/- 30 deg SAA variation on CVV induces negligible gradient variation (1/100 K)

    ⇒no contribution from CVV
- First estimation of thermoelastic deformation between STR on SVM and focal plane instruments shows small deformation, compatible with PDE (1.2 arcsec) and APE (3.7 arcsec)

# Sunshield/Sunshade optimisation



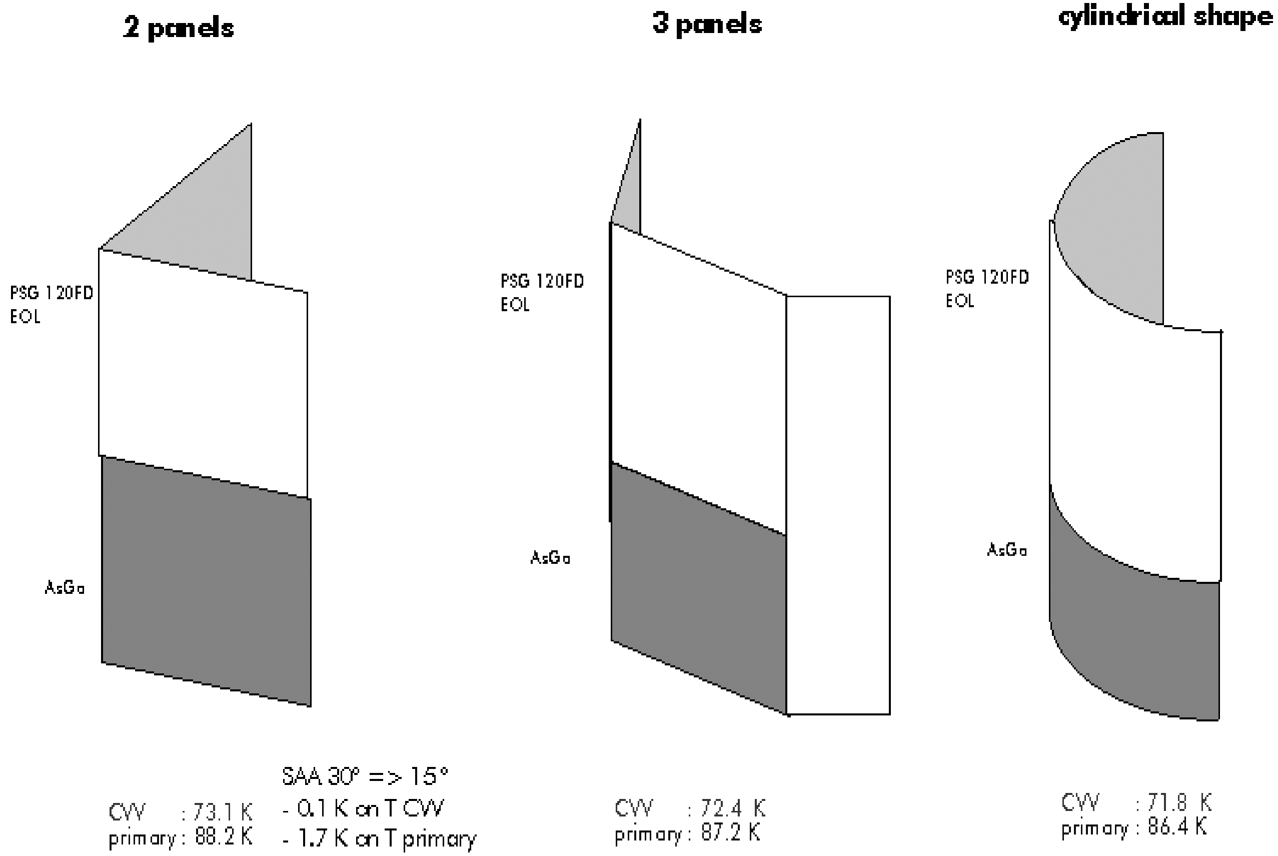
## CONCLUSION ON COATINGS TRADE OFF

- if $\alpha$ BOL PSG 120 FD = 0.55 : configuration with white paint is not retained
- in this case, OSR on sunshield/sunshade is the only improvement / baseline (- 4 K on CVV, - 7 K on primary)

- if $\alpha$ degradation is lower than considered in this study, configurations with AsGa can be envisaged

## IMPACT OF SUNSHIELD/SUNSHADE SHAPE

configuration for trade-off :
no STR on CVV
no conductive links
in mli modelization

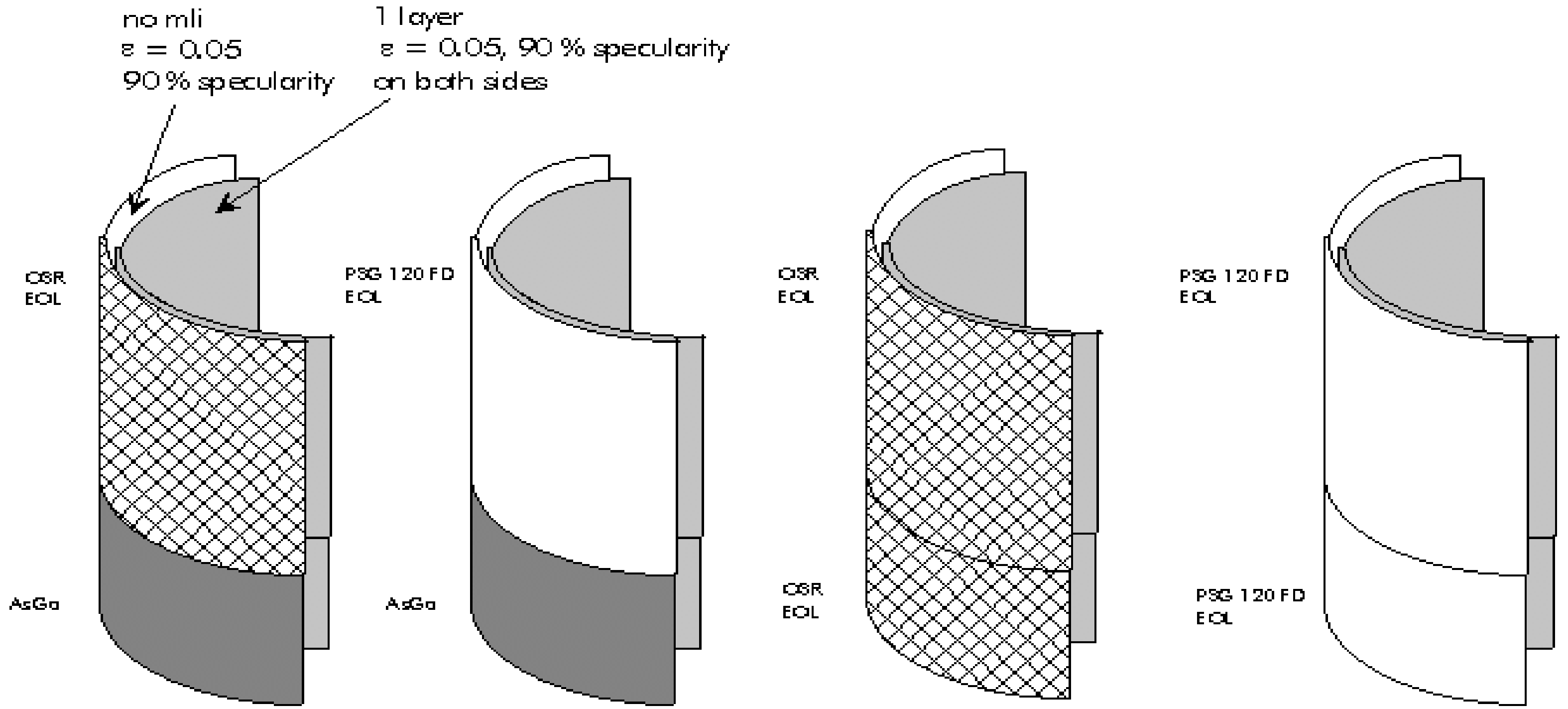



**CONCLUSION : LOW IMPACT OF THE SUNSHIELD/SUNSHADE SHAPE ON TEMPERATURES**

# Sunshield/Sunshade optimisation

## "GROOVE SHIELDS" IMPLEMENTATION

solar generator on sunshield ←→ no solar generator on sunshield




| | solar generator on sunshield (OSR EOL) | solar generator on sunshield (PSG 120 FD EOL) | no solar generator on sunshield (OSR EOL) | no solar generator on sunshield (PSG 120 FD EOL) |
|---|---|---|---|---|
| | CW : 69.8 K<br>primary : 74.3 K | CW : 71.3 K<br>primary : 80.4 K | CW : 66.5 K<br>primary : 67.6 K | CW : 70.1 K<br>primary : 78.5 K |
| **no groove** | CW : 69.8 K<br>primary : 77.6 K | CW : 71.4 K<br>primary : 87.1 K | CW : 65.5 K<br>primary : 70.4 K | CW : 69.8 K<br>primary : 85.8 K |

## CONCLUSION ON “GROOVE SHIELDS” IMPLEMENTATION

- ~ no gain on CVV temperature / configuration without “groove shields”
- decrease in PRIMARY temperature / configuration without “groove shields” between
  - 3 K if OSR on sunshade
  - 7 K if PSG 120 on sunshade

# Sunshield shape optimisation w.r.t. baseline

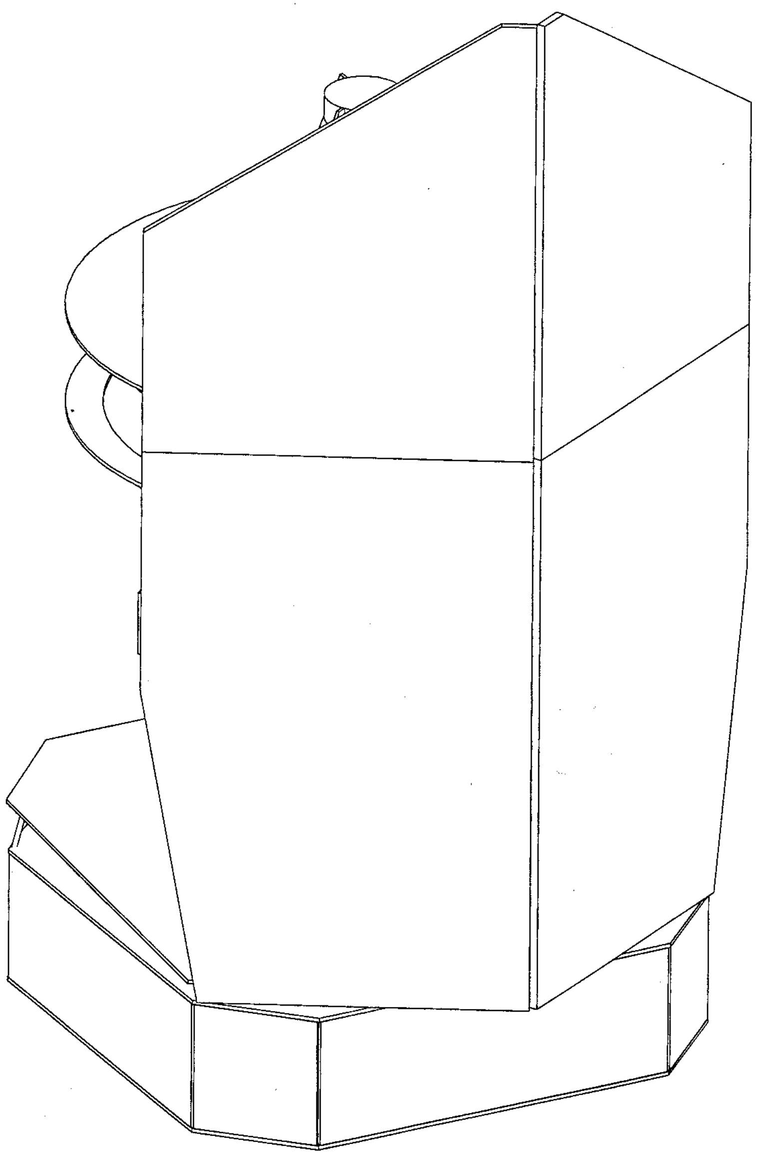
**Baseline :**

- Sunshield with dihedral shape at 30 ° :
  - derived from MERGER study
  - 2 Honeycomb panels :
    - lower part acting as Solar Array (SA)
    - upper part covered by OSR, acting as Sunshade
    - supporting by a GFRP truss
  - mass Sunshield / supporting : 115 Kg / 44 Kg from MERGER

note : the value of 115Kg/44Kg are considered as under-estimated

  - S/C accommodation : large interference with fairing, even without adapter 3936

# Sunshield/Sunshade optimisation

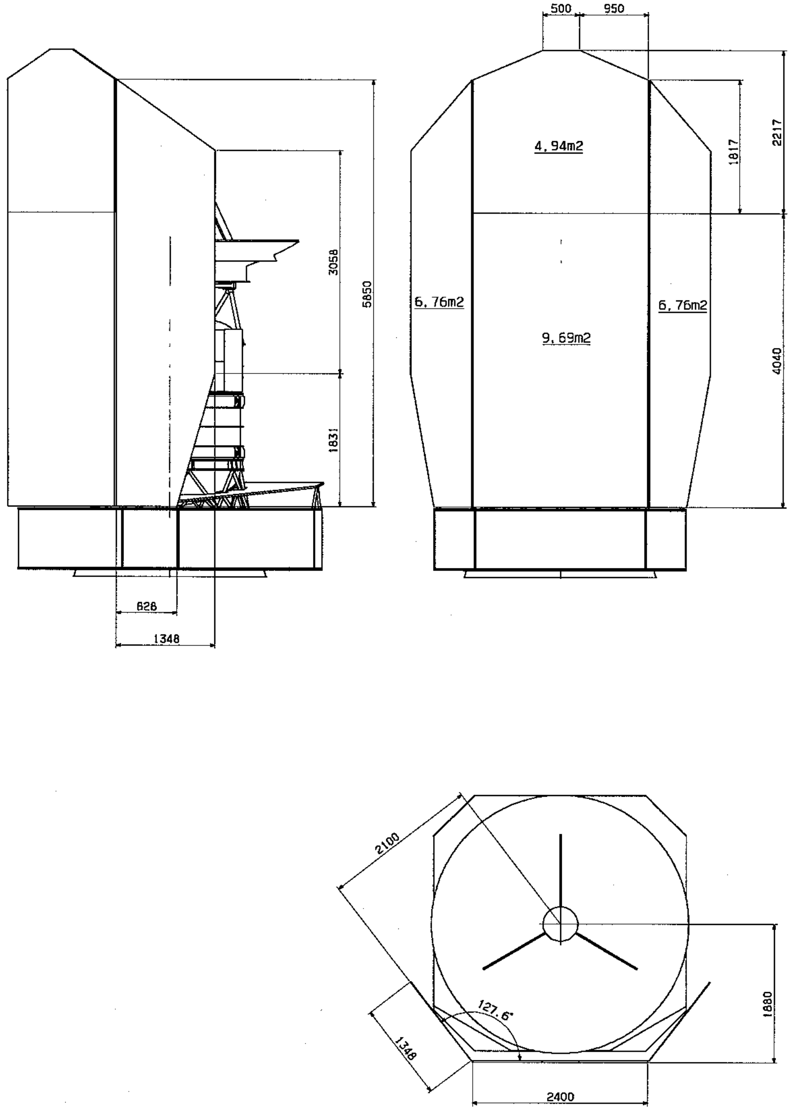


## Alternative 1 :

▼Sunshield with 3 panels :

- 1 large panel, with 2 auxilliary flaps :
  - ➔central Honeycomb panel, acting as :
    - **Telescope Sunshade** with OSR at upper level and flaps
    - **Solar Array (SA)** on the lower part
  - ➔auxiliary flaps with OSR, acting as Cryostat Sunshield
  - ➔supporting by a GFRP truss
- mass Sunshield / supporting : around 120 Kg / 65 Kg
- advantage :
  - ➔possible accommodation under AR5 fairing, considering no presence of adapter 3936/2624 (TBC AES)

# Sunshield/Sunshade optimisation

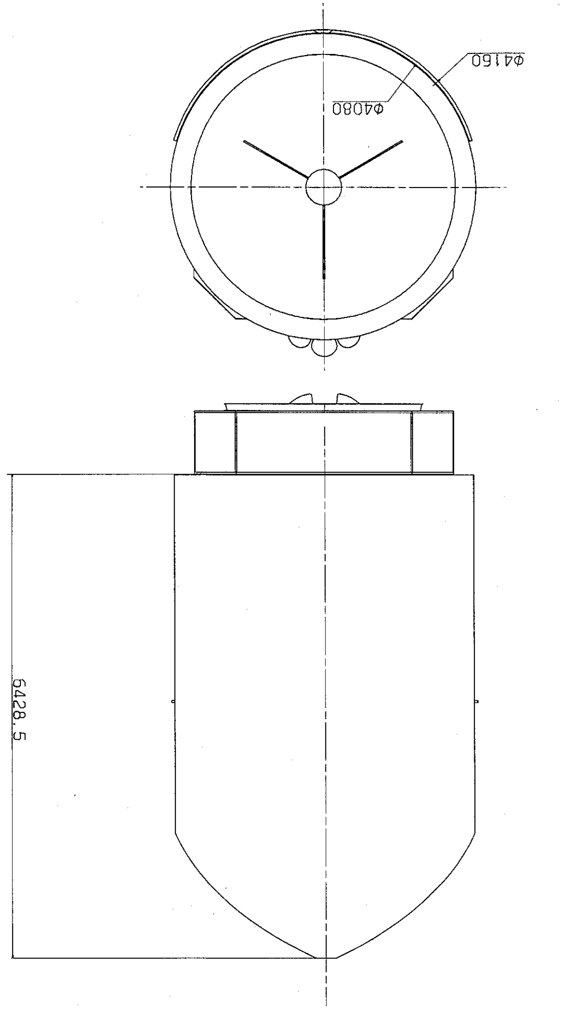


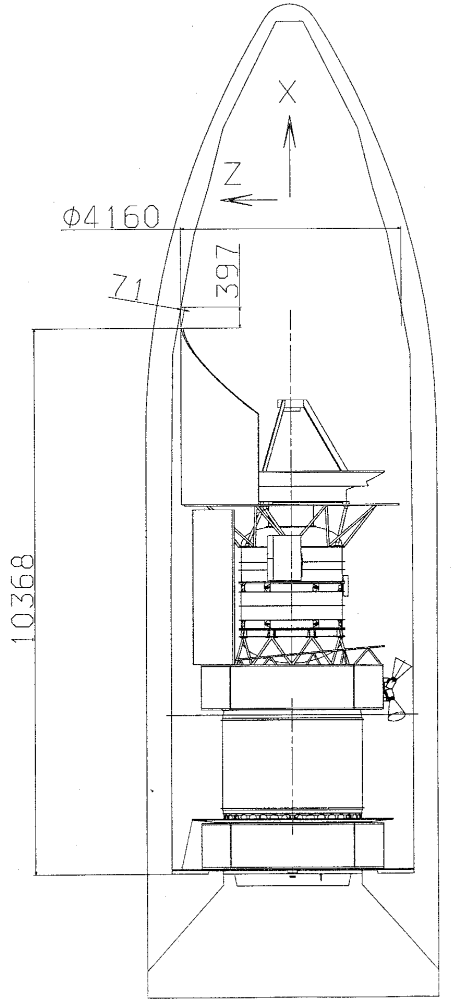
## Alternative 2 :

▼Sunshield with a circular shape :

- upper part acting as Telescope Sunshade, made of a Honeycomb panel with Alu. sheets
- lower part acting as Solar Array, , made of a Honeycomb panel with CFRP sheets
- supporting by a GFRP truss
- mass Sunshield / supporting : around 120 Kg / 65 Kg
- advantage :
  - ➔ possible accommodation under AR5 fairing with or without considering the presence of adapter 3936/2624
  - ➔ large clearance with Telescope about 290 mm, that enables implementation of circular «grooves» between SSH and Telescope
- drawback : higher manufacturing cost Vs baseline

# Sunshield/Sunshade optimisation



**Alternative 3 :** Sunshield with a double shape :

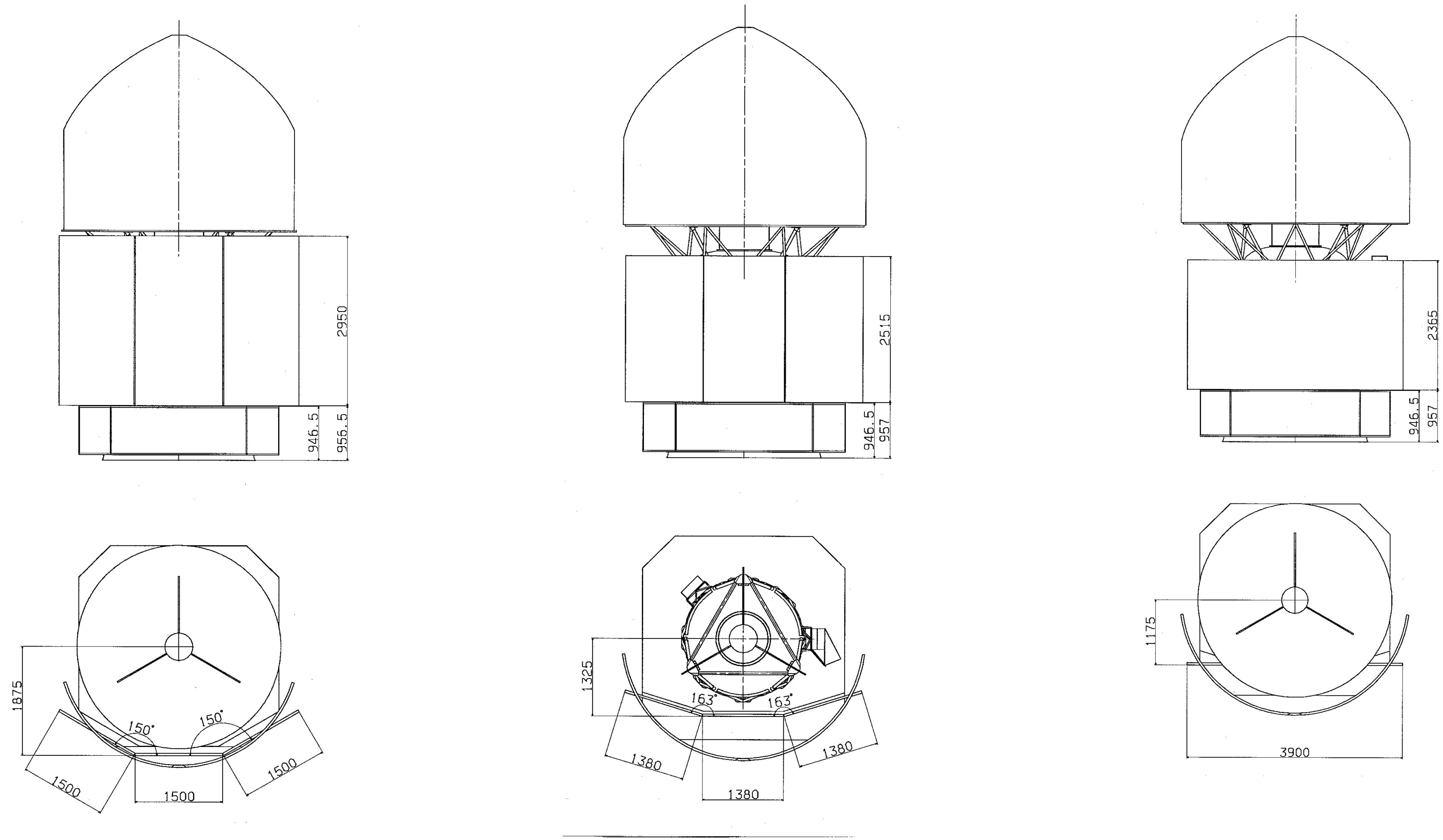
- 3 possible options, as summarised below, with the following common features :
  - circular upper part acting as Telescope Sunshade
  - lower part acting as Solar Array
  - advantage :
    - ➔ possible accommodation under AR5 fairing as alternative 2 with or without considering the presence of adapter 3936/2624
    - ➔ large clearance with Telescope about 290 mm, that enables implementation of circular «grooves» between SSH and Telescope, as for Alternative 2
    - ➔ implementation of SA on a flat shape, Vs alternative 2
  - drawback : higher manufacturing cost Vs baseline ?

# **Alternative 3 :** options summary :

| | | shape | construction | usable area for cells (m²) | Sunshade / Sunshield transition | estimated mass (Kg) |
|---|---|---|---|---|---|---|
| **Option 1** | Sunshade | circular | Honeycomb panel(s) with Alu. Sheets (1) | 12 | quasi-ideal | 115/65 |
| | Sunshield | trihedreal, aligned with SVM dimensions | 3 identical Honeycomb panels with CFRP sheets | | | |
| **Option 2** | Sunshade | same all options | same all options | 10 | large gap to be closed by MLI | 110/65 |
| | Sunshield | trihedreal, moved towards CVV | 3 identical Honeycomb panels with CFRP sheets | | | |
| **Option 3** | Sunshade | same all options | same all options | 9 | large gap to be closed by MLI | 105/60 |
| | Sunshield | plane, moved towards CVV | 1 Honeycomb panels with CFRP sheets | | | |

**Note 1 :** the circular shape can be also achieved by and assembly of flat panels (cylindrical shape with facets)

# Sunshield/Sunshade optimisation



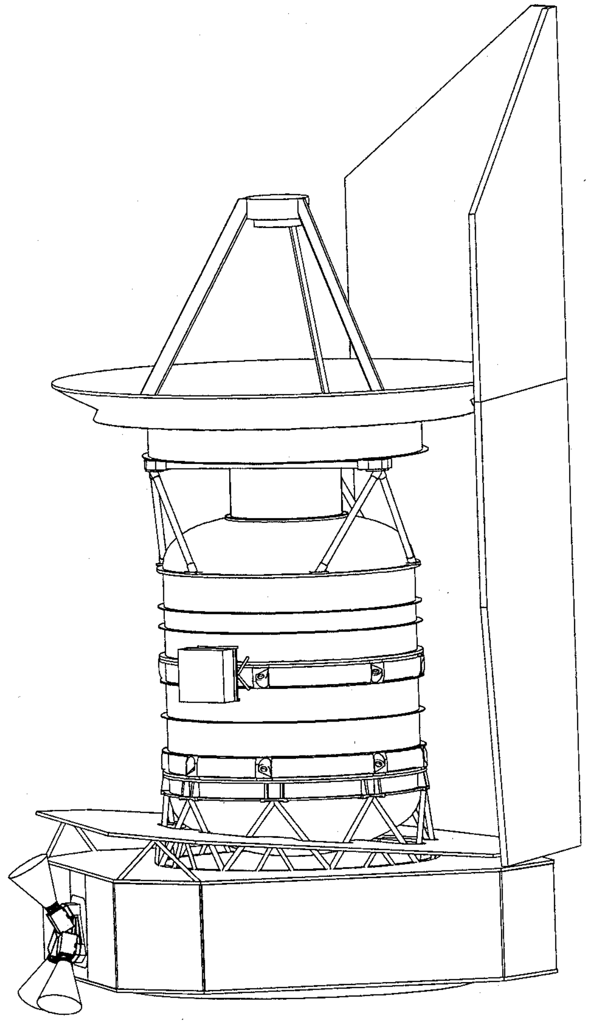
## Trade-off conclusion :

- ▼Trade-off criteria :
  - ❑ functional / destructive criteria :
    - ➔S/C accommodation beneath AR5 fairing
    - ➔Telescope and Cryostat shadowing
    - ➔minimum usable area for SA on Sunshield
    - ➔compatibility with a growth of the telescope
  - ❑ performance / evaluation criteria :
    - ➔minimum thermal loads on the Telescope and Sunshield
    - ➔minimum thermal loads on SVM (secondary Vs Tel. and SSH)
    - ➔concepts efficiently in term of mass, relative manufacturing cost
- ▼best candidate : alternative 3 / option 1 :
  - ❑ fully achieves destructive criteria
  - ❑ owns the best potential to satisfies the performance criteria

## SVM shield implementation

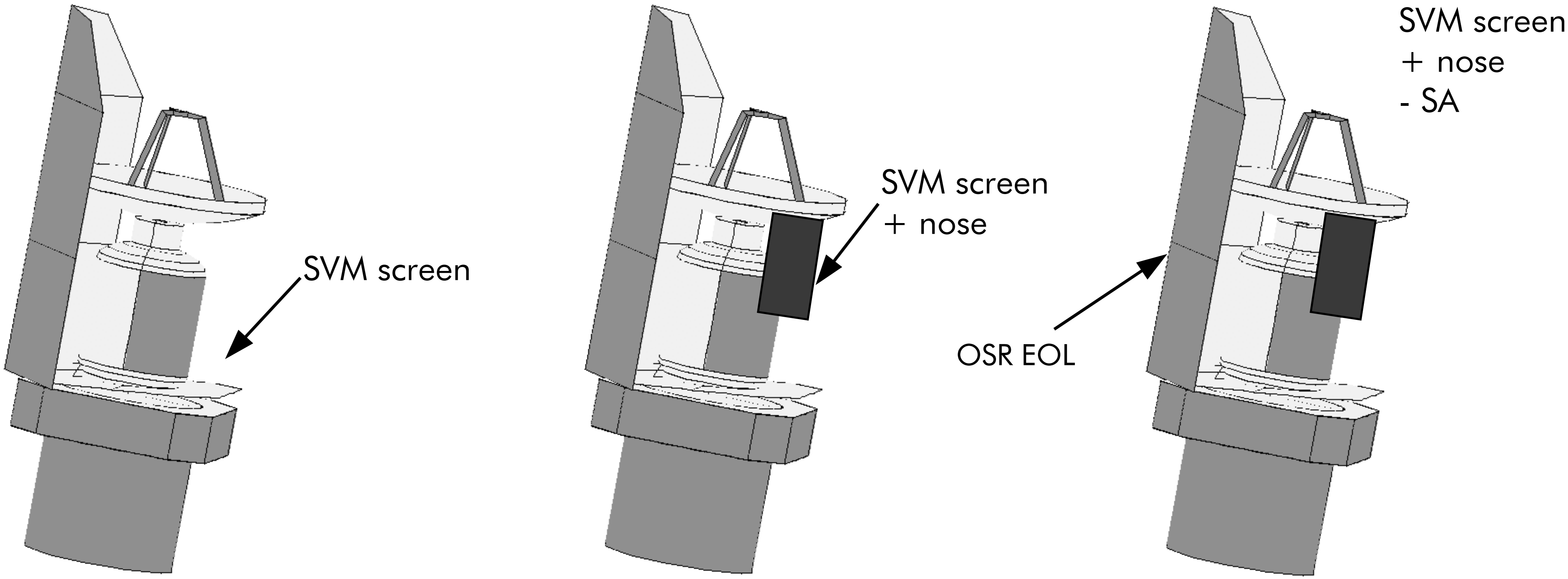
- objective : to reduce thermal loads from SVM on CVV
- SVM shield positioned between SVM and Cryostat :
  - SVM shield tilted about 5° to favour a «V-groove» effect
  - SVM shield in a sandwich form with Al.sheets, large cut-out for CVV, and additional cut-out for Cryostat support truss
  - supporting concepts :
    - ➔ a set of 8 (TBC) inner bipodes with GFRP beams
    - ➔ a set of 2 peripheral bipodes with GFRP beams, and 2 additional GFRP shims
  - mass impact : around 15 Kg (TBC)

# SVM radiative heat flux reduction



# SVM radiative heat flux reduction

## IMPROVEMENTS OF THE BASELINE CONFIGURATION (1)

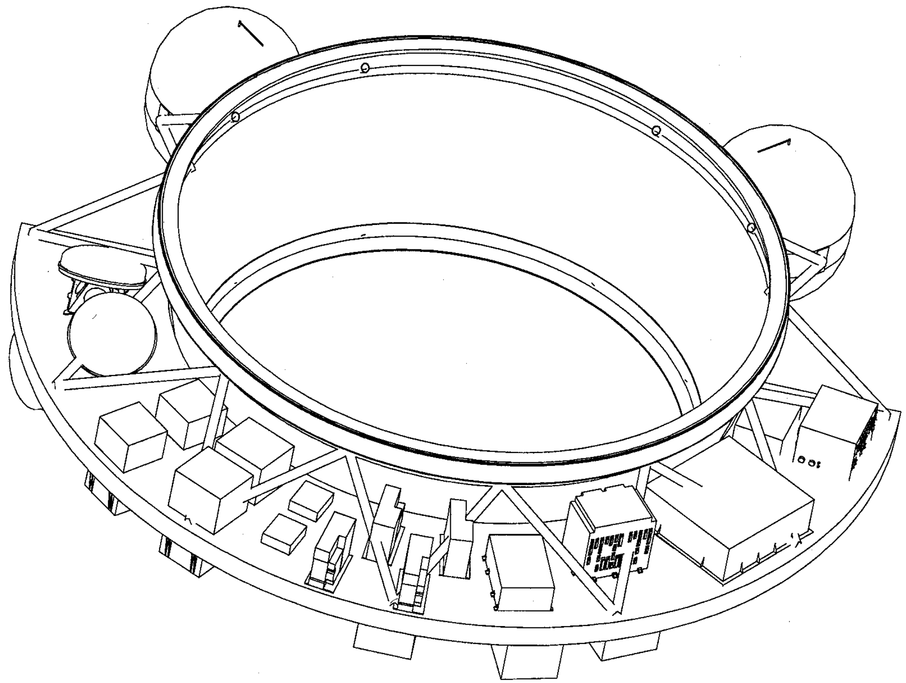



| | baseline | SVM screen | SVM screen + nose | SVM screen + nose - SA |
|---|---|---|---|---|
| STR on CVV | | | | |
| T CVV | 71,9 | 66,5 | 63 | 58,65 |
| T primary | 78,6 | 75,6 | 74 | 66 |
| STR on SVM | | | | |
| T CVV | 69,2 | 64,2 | 61 | 56 |
| T primary | 75,7 | 75,1 | 73,5 | 64,8 |

## SVM reduction on - Z side

- ▼objective : to reduce thermal loads from SVM on CVV
- ▼SVM cut on - Z side, necessitating a new SVM architecture :
  - ❑ SVM Structure reduced to a half thick panel, made in a sandwich form with Alu. sheets, supported by a set of GFRP struts
  - ❑ servicing and Pay-load units laid-down on the 2 sides of the half sandwich panel :
    - ➔ problem of units accommodation and units accessibility, linked to the reduced usable area on the half sandwich panel
  - ❑ 2 P.Tanks and supporting installed on the + Y side of the SVM :
    - ➔ SVM balancing preserved
    - ➔ problem of P.Tanks thermal control, as exposed on the «cold» side
  - ❑ SVM reduction, even if not deeply analysed, not very promising as inducing large and complex SVM modifications

# SVM radiative heat flux reduction



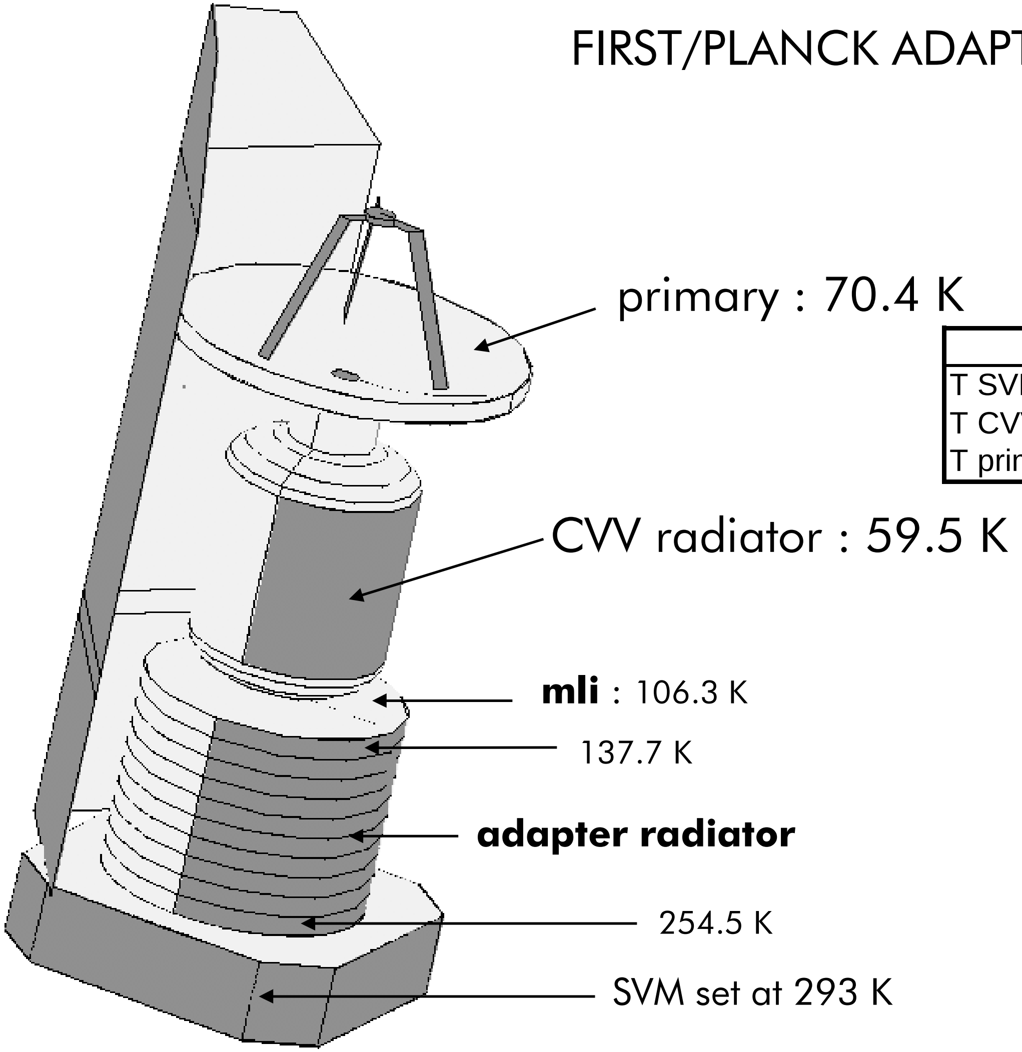
▼alternative solution to reduce the flux between the SVM and CVV =>reduction of the SVM size in -z direction

- ❑ T CVV diminution estimated around 3 K

(diminution of T CVV with a screen between CVV and SVM = 5.4 K)

# SVM at bottom of interface tube

## FIRST/PLANCK ADAPTER USED AS A RADIATOR (1)




| | SAA = - 30° | SAA = 0° | SAA = 30° |
|---|---|---|---|
| T SVM (K) | 303,8 | 296,3 | 287,9 |
| T CVV (K) | 56,3 | 55,9 | 55,1 |
| T primary (K) | 67,9 | 69,4 | 67,1 |

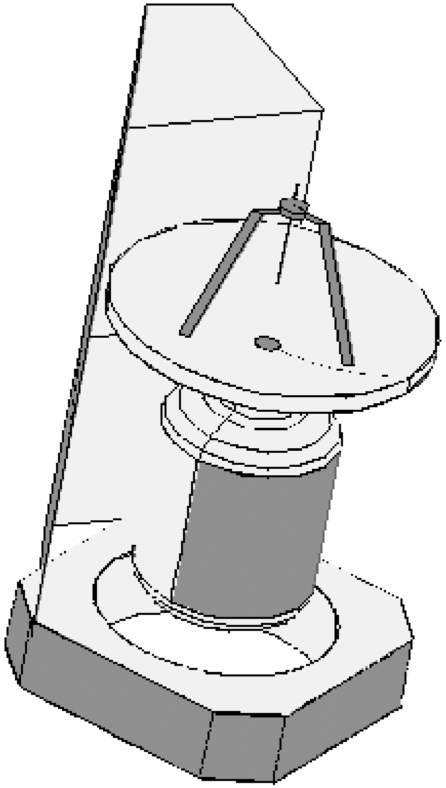
# SVM at bottom of interface tube

- Struts between SVM and adapter and no struts between adapter and CVV
  - T CVV = 83.8 K
  - T primary = 76.5 K

  => a thermal discoupling between the adapter and the CVV is required

- Improvement of the configuration

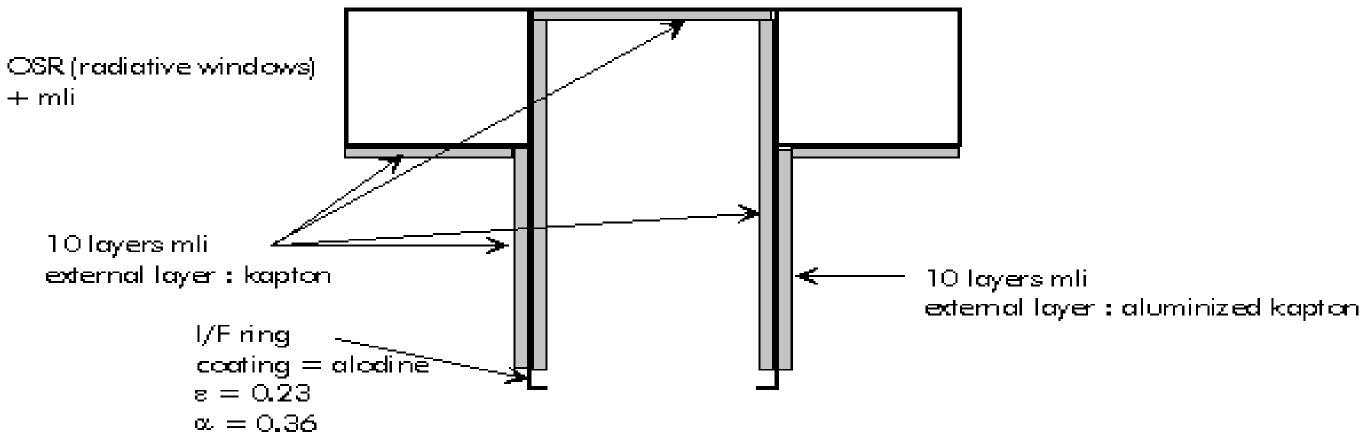
| | adapter = radiator | + nose |
|---|---|---|
| STR on CVV | | |
| T CVV | 59,5 | 56,4 |
| T primary | 70,4 | 69,5 |
| STR on SVM | | |
| T CVV | 56 | 53,7 |
| T primary | 69,2 | 68,8 |



- hole + adapter
  - T CVV = 71.9 K
  - T primary = 78 K
- hole without adapter
  - T CVV = 71.4 K
  - T primary = 77 K

=> no significative gain / baseline

Rk : a sun shield below the SVM is mandatory configuration studied




=>minimisation of the external heat load changes with attitude

- reduction of thermo-elastics effects in SVM (STR implement)
- simplification of the SVM thermal design

## SVM THERMAL CONTROL : preliminary consideration (2)

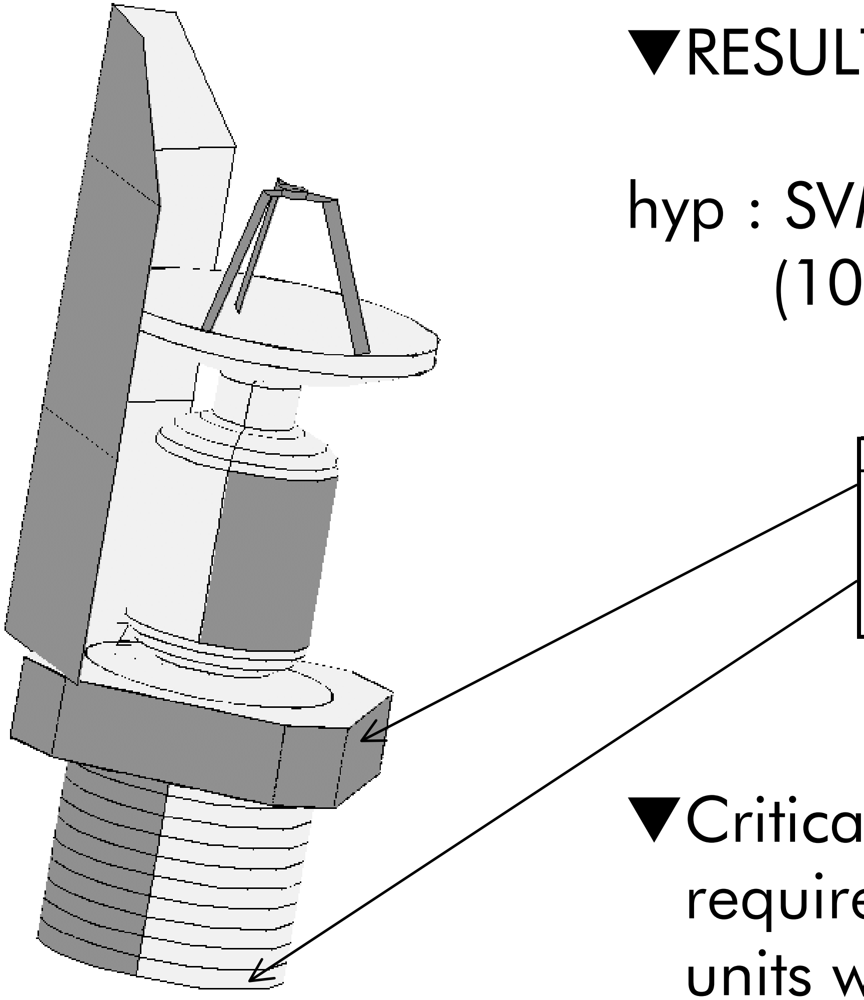
- open point related to the I/F ring due to Ariane 5 specifications :
  - significant surface not covered with mli
  - coating = alodine ($\varepsilon = 0.23$ - $\alpha = 0.36$)

  => thermal leak towards cold space

  => solar flux depending on FIRST attitude

=> preliminary study :

- 10 thermal nodes for the adapter in the baseline configuration
- estimation of the external loads - from sun and space (no TMM of the I/F ring)



▼RESULTS

hyp : SVM radiator = 3.6 $m^2$
(10.1$m^2$ available)

| | SAA = - 30° | SAA = 0° | SAA = 30° |
|---|---|---|---|
| T SVM (K) | 306,7 | 300,4 | 291,5 |
| T CVV (K) | 72,5 | 72,5 | 71,1 |
| T primary (K) | 77,3 | 79 | 76,5 |
| T adapter bottom | 317 | 243 | 235 |
| ∇ in adapter | -10,3 | 57,4 | 56,5 |

▼Criticality / temperature stability requirements of the instruments warm units will be studied in phase 2

# Sunshield Optimisation Summary

- CVV/Primary temperature not sensitive to Sunshield/Sunshade shape : can be optimised independently of other parameters
- Mass of the Sunshield/Sunshade not sensitive to shape
- Primary temperature sensitive to coatings on Sunshield/Sunshade:
  - OSR : OK
  - White paint : rejected pending EOL characteristics confirmation
- Fairing compatibility: dihedral configuration is not compatible
- Preferred solution for Sunshield/Sunshade
  - 2 parts : cylindrical Sunshade, 3 panels Sunshield.
    - ➔ Growth potential for Primary reflector diameter increase
    - ➔ good margin w.r.t. fairing
    - ➔ good Sunshield/Sunshade thermal decoupling
    - ➔ lighter supporting (TBC)
  - Cost sensitivity : cylindrical sunshade can be made at low cost if approximated by small flat panels

# Solutions not retained

- ▼Hole in the SVM to radiate CVV heat:
  - ❑ Deployable sunshade mandatory at SVM bottom
  - ❑ No improvement w.r.t. baseline
- ▼Equipments on +Z
  - ❑ Complex solution: spacecraft balancing, SVM architecture and thermal control
  - ❑ SVM shield more efficient to decrease radiative coupling between SVM top and CVV

# Retained solutions

| | | SVM at tube top | | | | SVM at tube bottom | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Baseline | +SVM Shield | +SVM Shield + Nose | +SVM Shield +Nose -STR | +SVM Shield +Nose -STR +SA on tube | | -STR (Implementation on tube feasibility TBC) | +Nose | +Nose -STR |
| **CVV Temperature** | 71.9 | 65.5 | 63.1 | 61.2 | 56.2 | 59.5 | 56 | 56.4 | 53.7 |
| **Primary Temperature** | 78.6 | 75.6 | 74.5 | 74 | 65.2 | 70.4 | 69.2 | 69.5 | 68.8 |
| **Mass impact (kg)** | 0 | 15 | 19 | 19 | 60 | 30 | 34 | 30 | 34 |
| **Delta cost (w.r.t baseline)** | | SVM shield implementation: small delta cost | + Nose implementation: small delta cost | STR on SVM: cleaner interfaces. Cost reduction expected | + SA on tube:: significant delta cost | Larger Sunshield: significant delta cost | STR on SVM: cleaner interfaces. Cost reduction expected | + Nose implementation: small delta cost | |

# Proposed solution

- Helium flow limitation to 2.5 mg/s (see DSS presentation)
  - for 3.25 y lifetime + 10 % margin : 315 kg He = 2150 l
  - potential reduction of 180 mm on CVV height/78 kg
- 2.5 mg/s corresponds to:
  - 69 K CVV temperature for baseline design
  - 71.25 for 180 mm reduction (interpolated)
  - 72.5 K for short CVV (-280 mm)
- Candidate solution:
  - SVM on top + SVM Shield + Nose + STR on SVM
  - CVV temperature estimated at 63 K with CVV reduction : provides an 8 K margin w.r.t. required temperature for 2.5 mg/s

# PLM activities

# DSS presentation

# TRADE OFF/RECOMMENDATION

# Conclusion

- 3 main areas of improvement have been investigated during this phase 1 of the study :
  - 1 - reduction of CVV external heat loads by changes in the system configuration (Alcatel)
  - 2 - reduction of CVV external heat loads by changes in the PLM configuration (DSS)
  - 3 - reduction of Helium tank heat loads by changes in the PLM internal configuration (DSS)

# Conclusion

- From the first point above the following changes are recommended
  - add a SVM shield
  - move the STR on the SVM
  - add a “nose” to the PLM radiator (-Z)

- Potential impacts
  - CVV reduction by about 180 mm
  - CVV temperature ~ 63K (decrease by 9K versus reference case)
  - mass reduction around 60Kg
  - moderate cost impact
  - thermo-elastic aspect to be confirmed in phase 2

# Conclusion

- From the second point above the following changes are recommended
  - consider an optimised CVV MLI coverage
  - move the BAU out of the CVV radiator area

- Potential impacts
  - CVV temperature decrease by ~3K versus reference case
  - about mass neutral
  - cost neutral

# Conclusion

- From the third point above the following changes are recommended
  - implement a simplified cooling architecture
  - implement an OB thermally connected to the SFWK
  - improve corner struts design

- Potential impacts
  - CVV temperature decrease by ~2K (about 0.1mg/sec)
  - CVV height increase by 60mm (Aluminium OB)
  - mass impact TBD (>0)
  - cost impact negative or neutral

# Conclusion

- All together, by implementing the proposed optimisation the following delta performance are expected :
  - CVV height reduction by 180 - 60 = 120 mm
  - Mass flow < 2.5 mg/sec (if necessary adjusted by heating)
  - Lifetime = specification incl. 10% margin
  - Mass reduction < 30Kg
  - Marginal cost impact

# Conclusion

- Concluding considerations
  - considering a minimum Helium flow rate of 2.5mg/sec is a major limitation in the optimisation exercise
  - the proposed modifications
    - ➔ reduce the cryostat volume
    - ➔ keep design margins necessary in view of potential instrument design changes or worst case characteristics (design robustness must be kept to minimise risks and cost margins)
    - ➔ use simple concepts with low development risks

# NEXT STEPS-PHASE 2

# Phase 2 activities

- Pre-dimensioning of selected concept
- Spacecraft pre-dimensioning
  - Spacecraft configuration definition
  - Spacecraft thermal modelling and analyses
  - Spacecraft structural modelling and analyses (FIRST + Planck)
  - Budgets update
- PLM pre-dimensioning
  - Design of PLM modification
  - PLM thermal modelling and analyses
  - PLM structural modelling and analyses
- 3.8 m telescope implementation