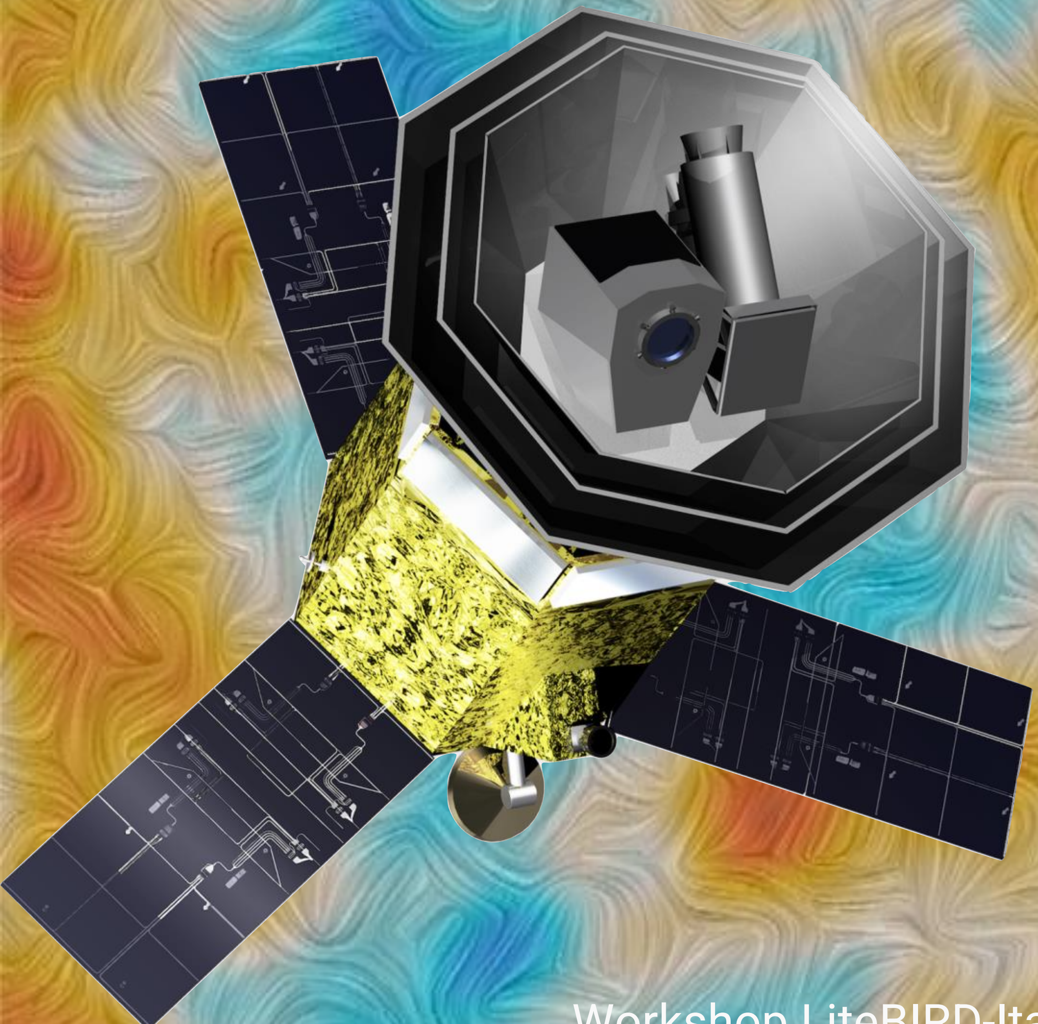
SCU mechanics (design, simulations, models)



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On behalf of INFN Pisa team

Workshop LiteBIRD-Italia 2023 @ INFN-LNF

Topics

- Starting point and objectives
- SCU and SCA - Mechanical design
- Vibrational simulations
- Thermal simulations
- SCE on-going studies
- Conclusions

Starting point and objectives

Starting point (mechanical point of view): McGill's TRL5 Squid controller assembly (SCA board)

The "main" road (was) is:

→ Interact with our electronic experts to have the final SCA's form factor

→ Mechanically analyze the board and the boundary conditions….do we need anti-vibrational frame? How can we transfer the heat loads of the board? Where are we in the satellite? Which is the temperature of the fixing flange on the sat?....and *more and more* questions

→ Vibrational simulations (natural frequencies, quasi-static loads, random vibrations…)

→ Thermal simulations

→ And *more and more* activities and details definition

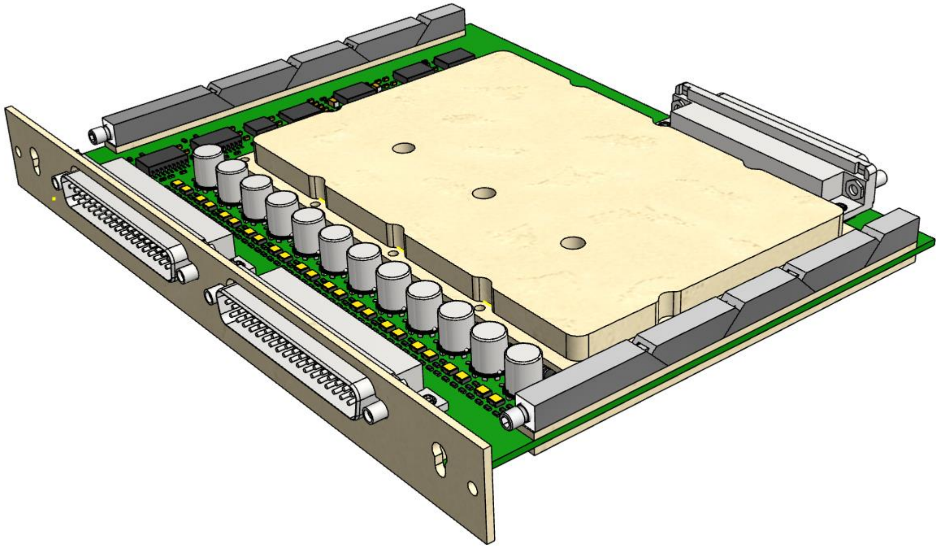
Objective: Design a space grade crate (SCE) holding 8 or 6 SCA (redesigned by INFN)

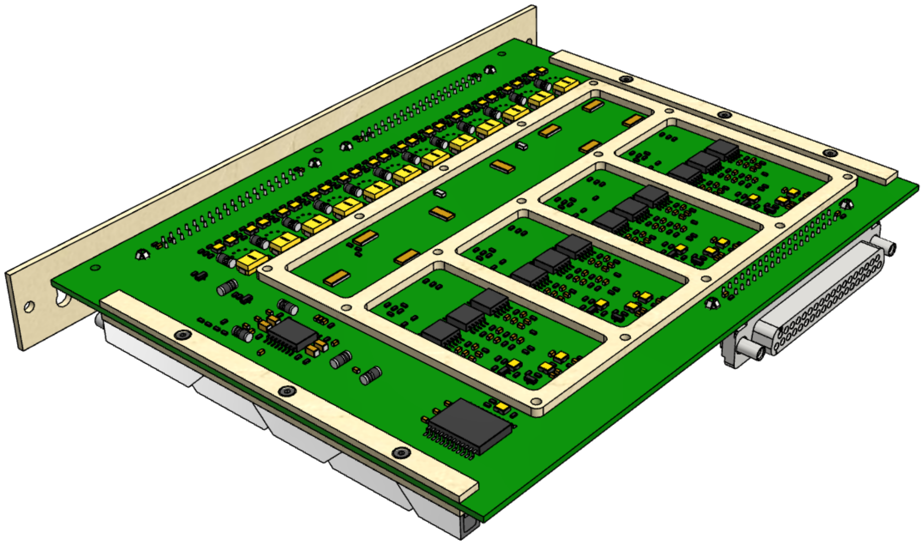
SCA Mechanical components design

After the definition of the SCA form factor (4U –160 mm x 188.9 mm approximately)

The following components were designed/chosen:

- Frontal panel to fix boards and crate
- Card-lock to fix the board inside the crate and to manage the thermal contacts
- EMI-shield (upper side) with “nut-frame” (lower side) to protect signals from being disrupted by external electromagnetic signals





SCA card-locks (wedge-lock)

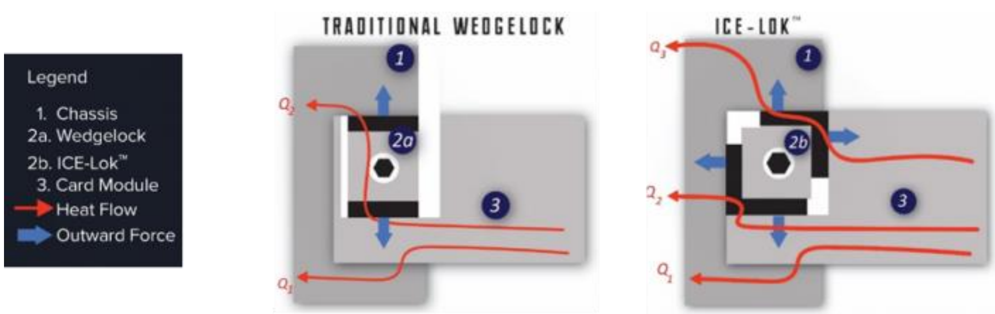
Requirements:

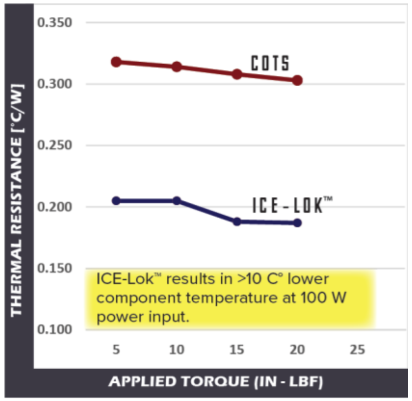
1. Heat generated by electronic components must be conducted to a chassis to prevent failures
2. An easy replacement of the board is required, this implies a ***weak*** thermal link (mechanical clamp allows the card to be swapped quickly)

Card-lock solution advantages:

- Easy implementation
- Well known in space projects (Large literature)
- Wide choice of space qualified components
- Good experience in INFN Pisa (e.g., AMS-02 crate)

In case of an issue in thermal management: ICE-LOK (backup solution)





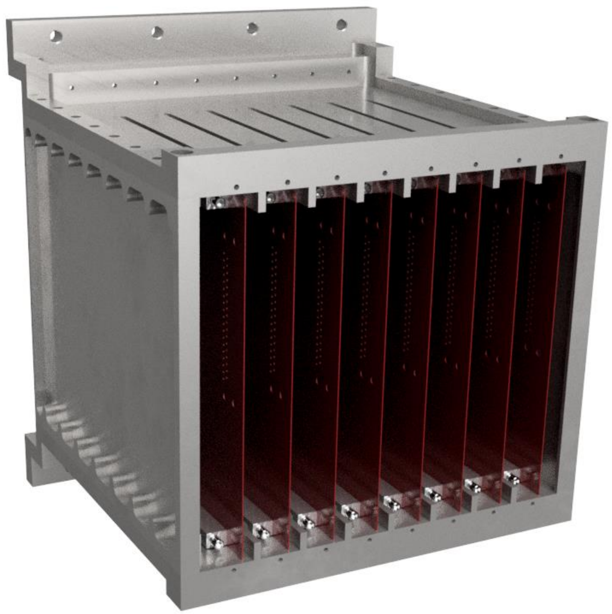
The thermal resistance is reduced by increasing contact surface area.

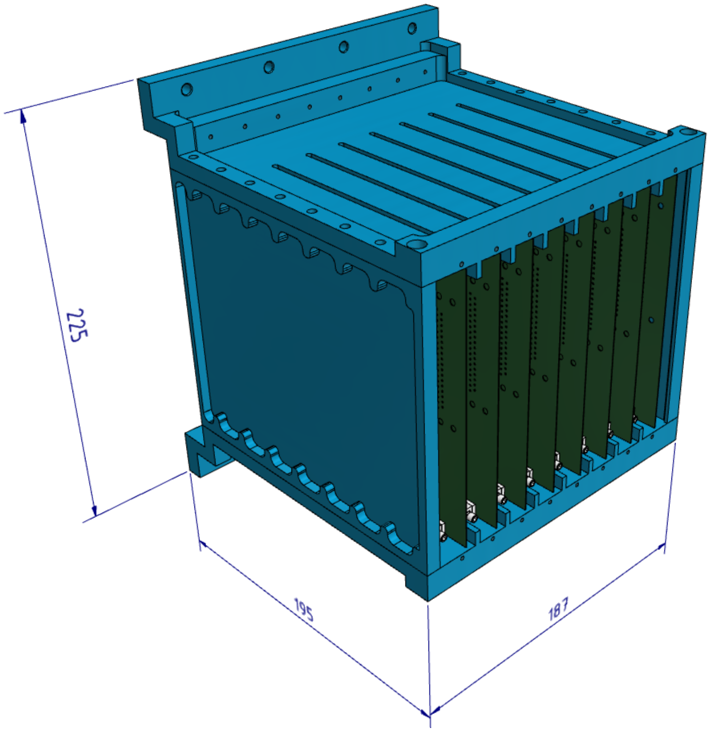
(4 sides VS 2 sides)

33% of reduction in thermal resistance from equivalent size COTS wedgeloks

SCE Design – six-sided crate

First design Idea: use the experience acquired in the design of AMS crate → six-sided crate





Crate realized with 6 independent components clamped with screws.

Main drawbacks:

1. Too much weight (more than 2 kg – mechanical components only)
2. NOT good thermal management → too much thermal interfaces between walls

SCE Design – 4-sided crate - #1

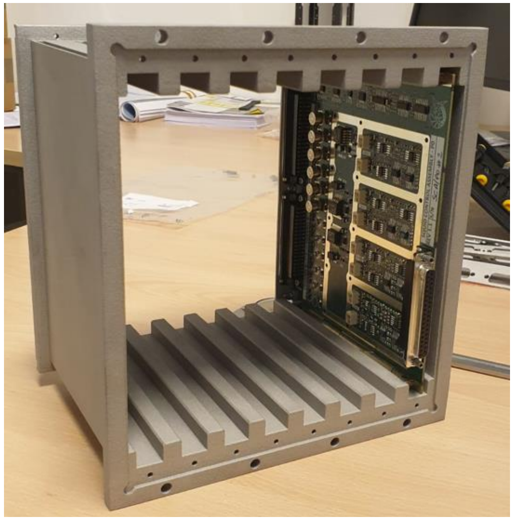
The second attempt was the design of an enclosure (4-sided unit) with:

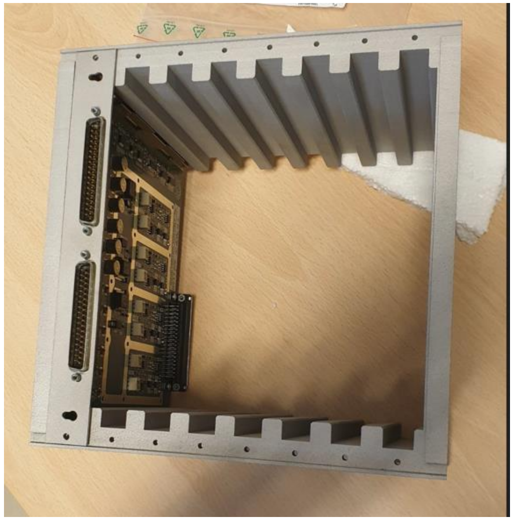
#1 Main body - #8 front panels - #1 back-panel

Main advantages:

- Reduced weight – less than 2 kg (mechanical components only)
- Optimized thermal contacts
- Reduced number of components and their couplings (e.g., less EMI gaskets).

We realized the first prototype with a metal 3d printing technology.



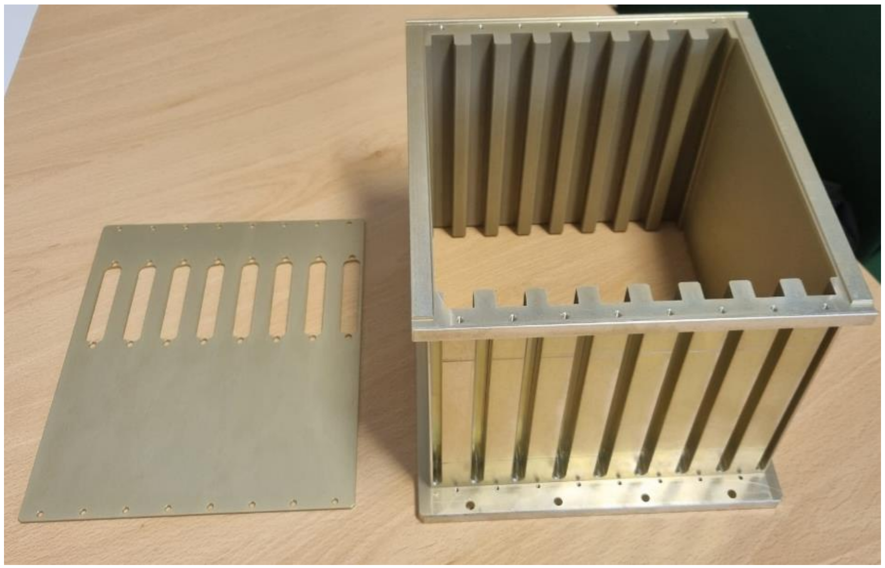


We had some issues on the geometrical tolerances and on the surface finishing BUT the prototype was good enough to study geometry and interfaces.

SCE Design – 4-sided crate - #2

The technology used for manufacturing the second 4-sided prototype is a mix between traditional milling and EDM (Electro-discharging-machine).

In the INFN Pisa machine shop we have both technologies → cheaper trying to optimize the crate



We received the components (with Alodine) the first days of May. Next steps:

- To make a metrological survey in our clean room facility
- To try the SCA's assembling

Preliminary SCE modal analysis

Modal Analysis ➔ To understand the value of the lowest natural frequency of vibration

- Enclosure itself (with no boards) → simplified model

The first 50 modes were extracted and the first mode meets the requirement (> 150 Hz)

Mode	Frequency [Hz]
1	597,13
2	719,59
3	856,13
4	957,24
5	1192,8
6	1312,2
7	1598,9
8	1807,5
9	1846,8
10	1850,3
11	1932,9
12	2023,5
13	2205,5
14	2313,1
15	2565,8
16	2657,4
17	2713,9

Mode	Frequency [Hz]
18	2736,1
19	2865,9
20	2957
21	3080,9
22	3093,6
23	3270,8
24	3271,5
25	3323,2
26	3324,6
27	3484,2
28	3484,4
29	3731
30	3740,6
31	3882,5
32	4153
33	4174,7
34	4237,4

Mode	Frequency [Hz]
35	4376,4
36	4519,8
37	4582,9
38	4589,6
39	4654,5
40	4726,5
41	4866,9
42	4878,8
43	4967,4
44	4969,6
45	5129,8
46	5197,3
47	5264,7
48	5272,8
49	5362,1
50	5416,7

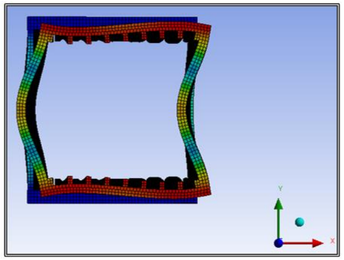


Figure 9 - Major X mode (Mode 13), 2205,54 Hz

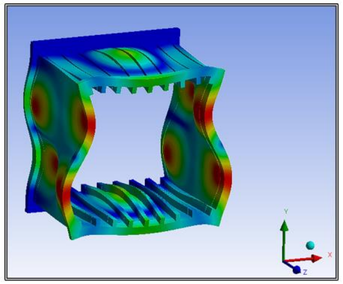


Figure 10 - Major Y mode (Mode 20), 2957 Hz

It's important to know the major modes of vibration with a modal mass contributions of >3%.
All major modes are well separated by mass participation and frequency, this means that when a major mode is different from zero in one axis the participation factors in the other two axis are zero.

# Mode	Frequency (Hz)	X-MASS (%)	Y-MASS (%)	Z-MASS (%)
2	719,595	31,3	0	0
3	856,134	0	26,35	0
8	1807,46	3,24	0	0
13	***2205,54***	***32,76***	0	0
17	2713,89	0	19,25	0
20	***2957***	0	***58,44***	0
26	3324,61	0	19,74	0
36	4519,82	0	0	4,21
37	***4582,88***	0	0	***52,71***
38	4589,57	3,07	0	0

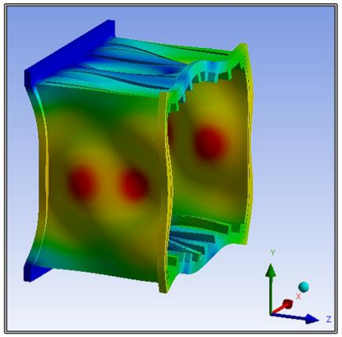


Figure 11 - Major Z mode (Mode 37), 4582,88 Hz

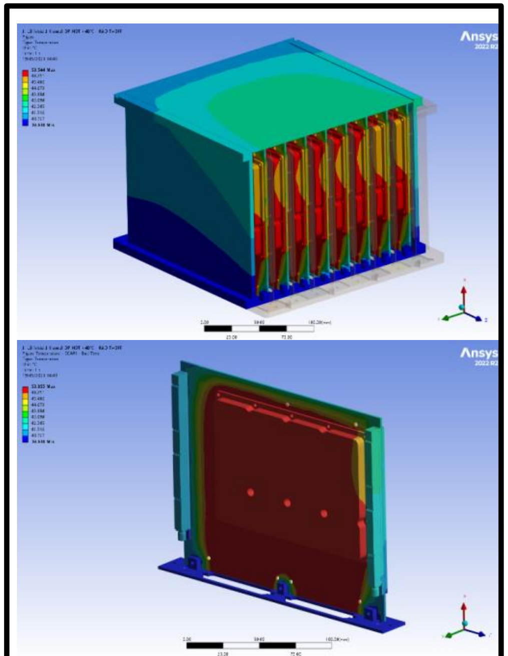
Other steps: Modal analysis of the whole system, quasi-static analysis, random analysis according with JAXA inputs

Preliminary SCE thermal analysis

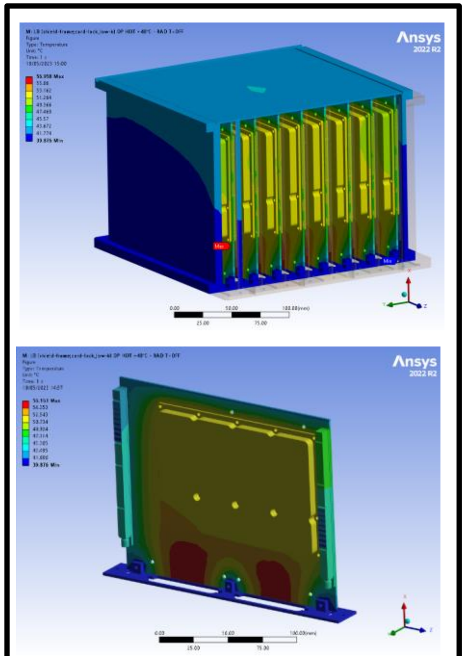
A preliminary thermal analysis was conducted (SCE+SCA) – the results seem promising, but we must investigate better (e.g., PCB thermal conductivity):

Case Description	HOT +40C (RAD T=OFF)	COLD -20C (RAD T=OFF)
Case 0011 Shield-frame, card-lock high k	sim , max temp +53.5C	
Case 0001 Shield-frame, card-lock low k	sim , max temp +57C	
Case 0101 Full-frame, card-lock low k	sim , max temp +46C	
Case 0110 Full-frame, card-lock high k, pcb FR4	Sim , max temp +59.7C	Max temp -3C
Case 0111 Full-frame, card-lock high k	Sim A , max temp +45C	Sim S , max temp -15C

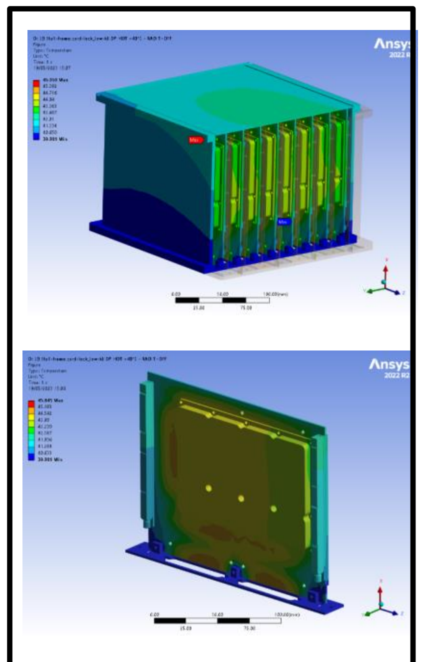
Case 0011 HOT



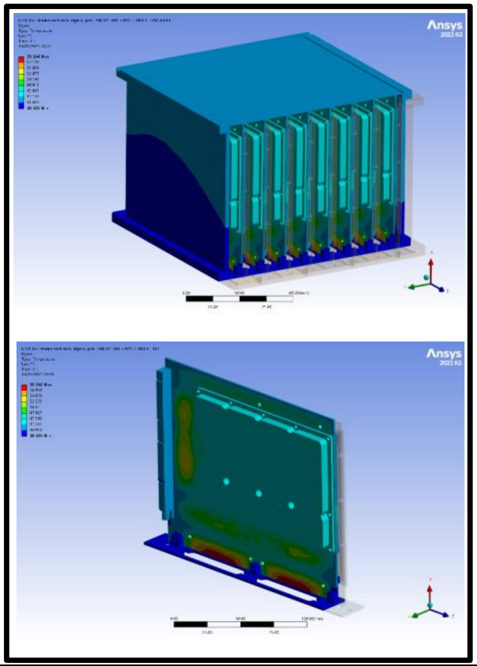
Case 0001 HOT



Case 0101 HOT



Case 0110 HOT

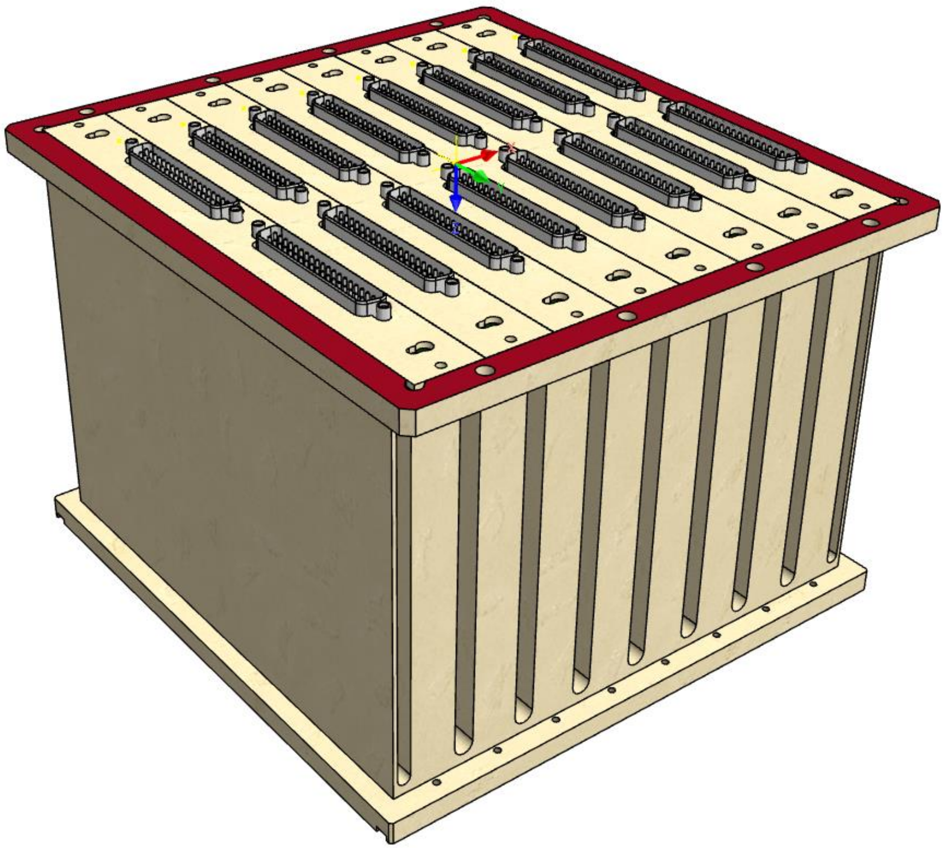


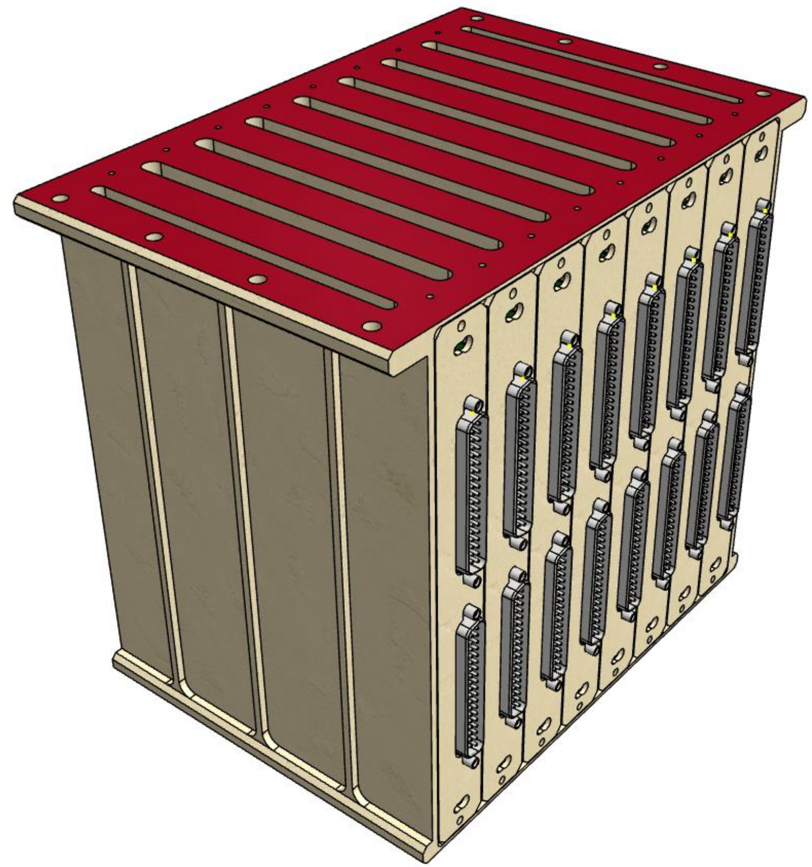
SCE studies

In order to prevent a possible issue on the thermal management we are studying a backup geometry.

The new geometry has a total thermal exchange area (red area) greater than the actual.

All the board are mounted from left to right (or right to left) instead of the top-down assembling.





Conclusions and further actions

- The design of the crate is strictly coupled with the vibrational and thermal analysis.
- The design of the SCE for Phase A seems to be promising from the vibrational and thermal point of view

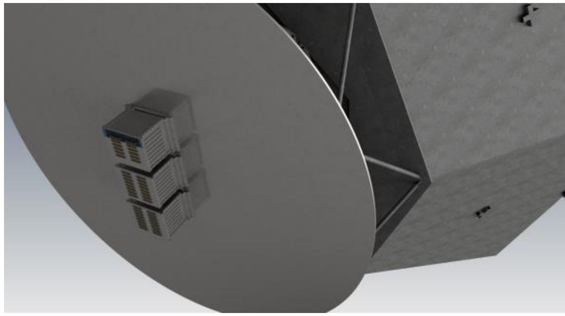
What we have to do?

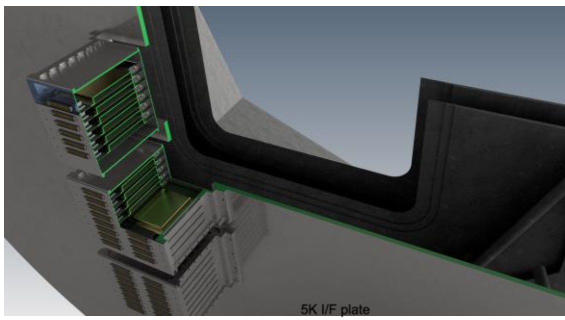
- Optimization of the mechanical structure thinning as much as possible the walls
- Optimization of the vibrational studies
- Optimization of the thermal studies
- A lot of work…

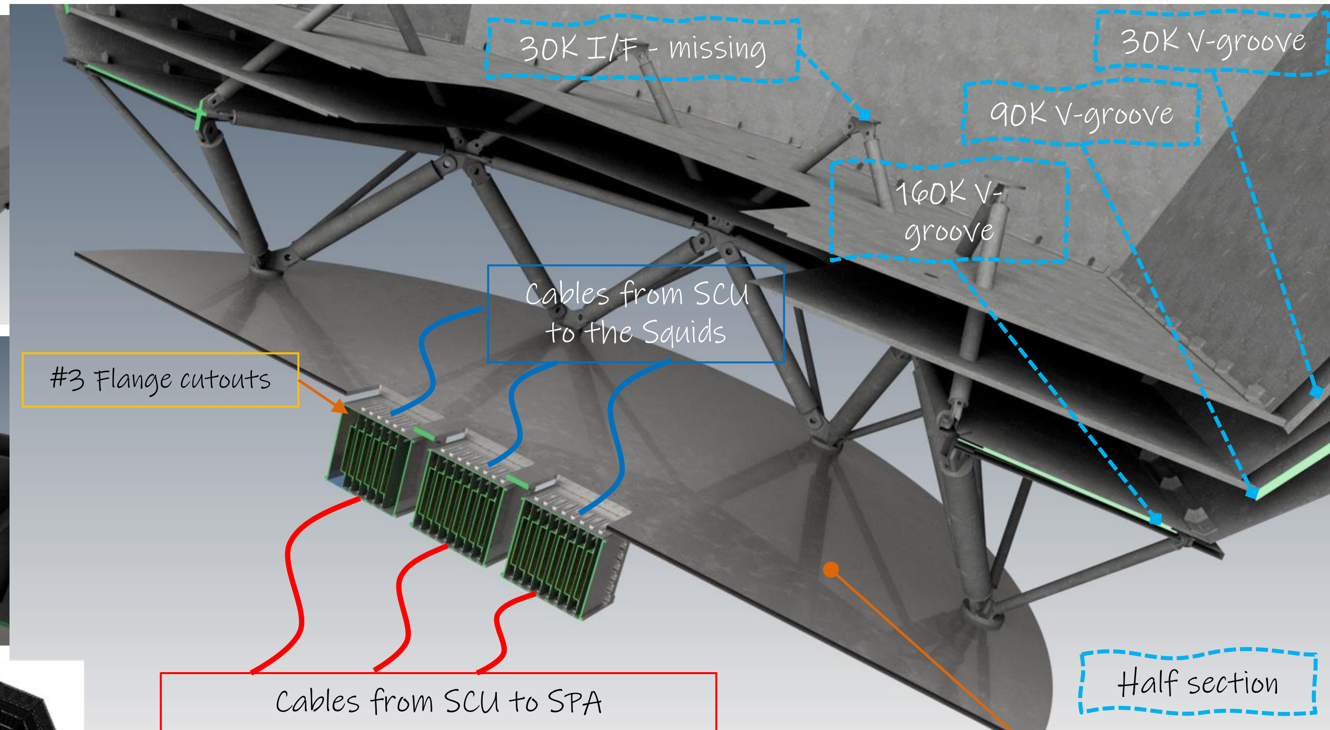
Thank you

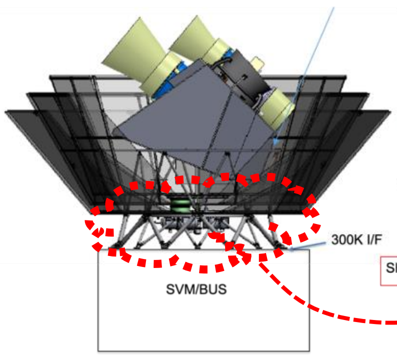
BACKUP

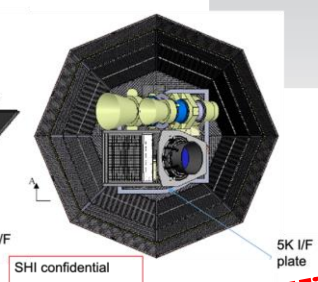
Where are we? 1st Proposal











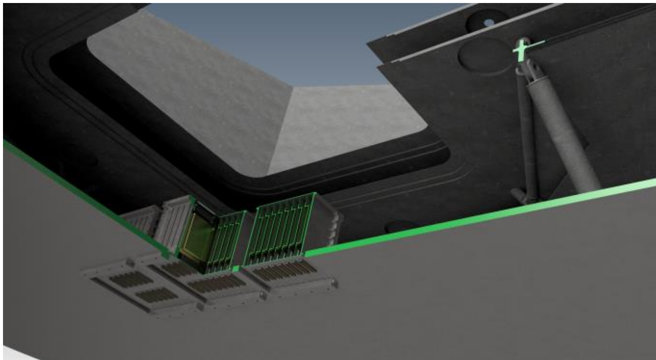
The SCUs are entirely in the worm side

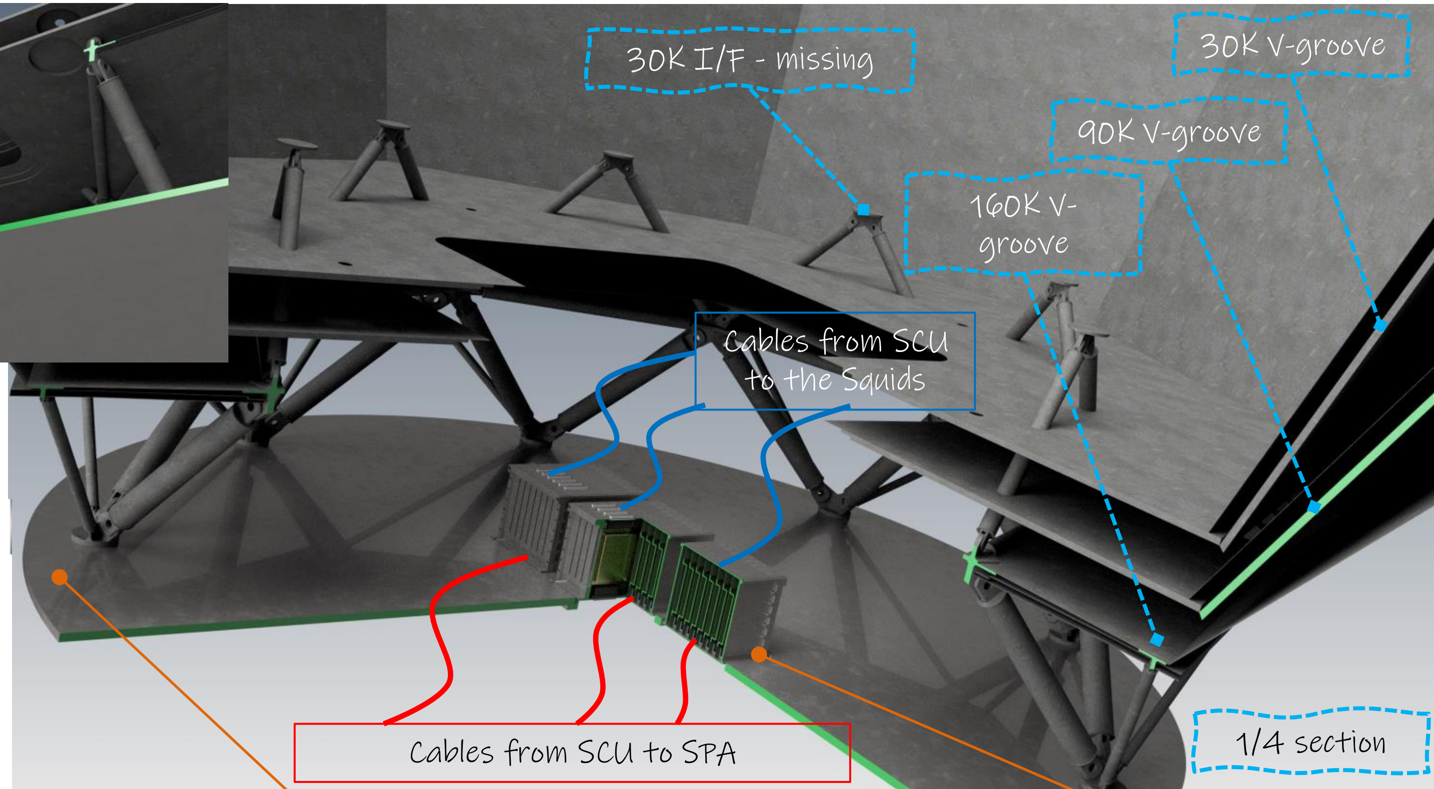
Possible issues:

1. Length of cables
2. Presence of the cooler in the middle of the flange

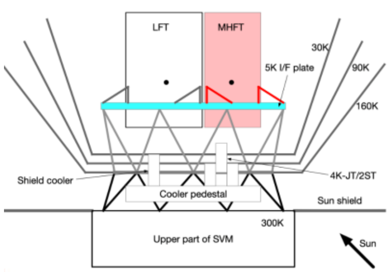
Mechanical I/F btw PLM and SVM

Where are we? 2nd Proposal





Cryo structure



Possible issues:
Same of 1st proposal

Mechanical I/F btw PLM and SVM
300K

3 Flange cutouts
Slightly bigger than 1st proposal

The SCUs extend towards the cold section to reduce the harness length