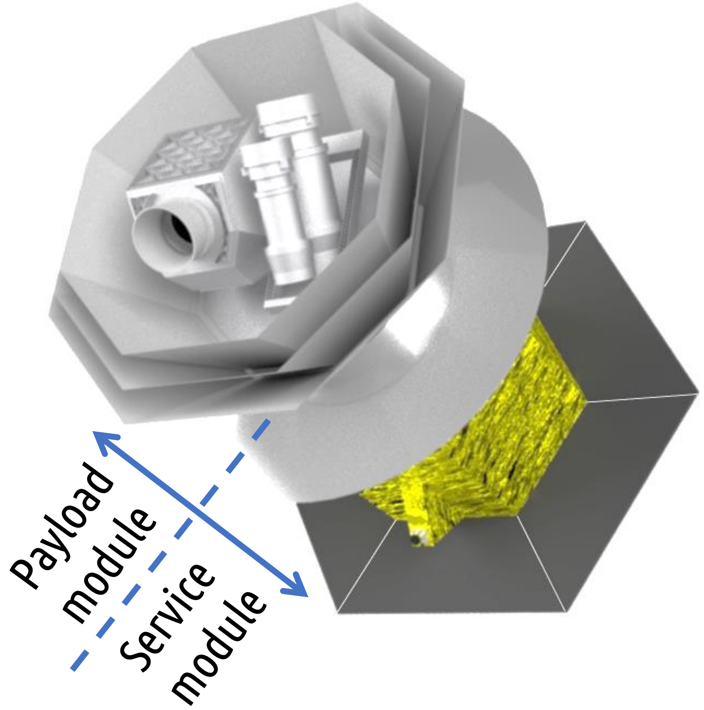
International Center for
Quantum-field Measurement Systems for
Studies of the Universe and Particles

Multi-disciplinary design of Focal Plane Sub-System of LiteBIRD Low Frequency Telescope

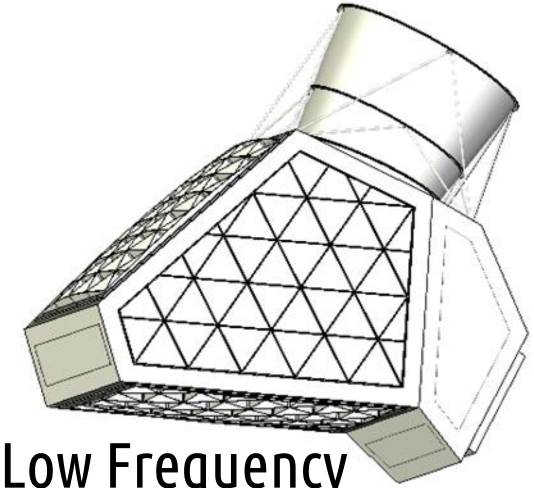
Daisuke Kaneko, Systemology Support Section,
on behalf of QUP SSS and CMB group

wpi KEK

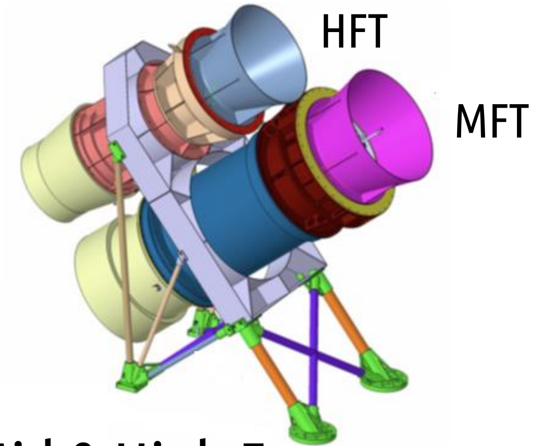
QUP apportionment of LiteBIRD system



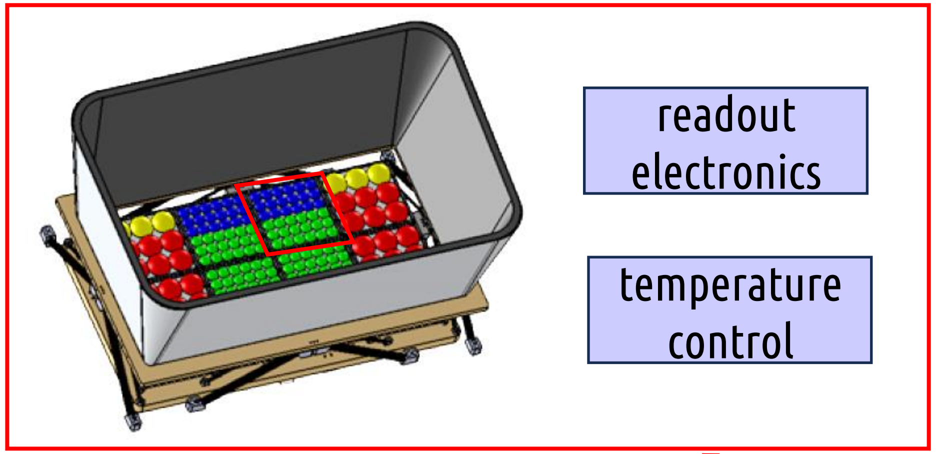
LiteBIRD satellite



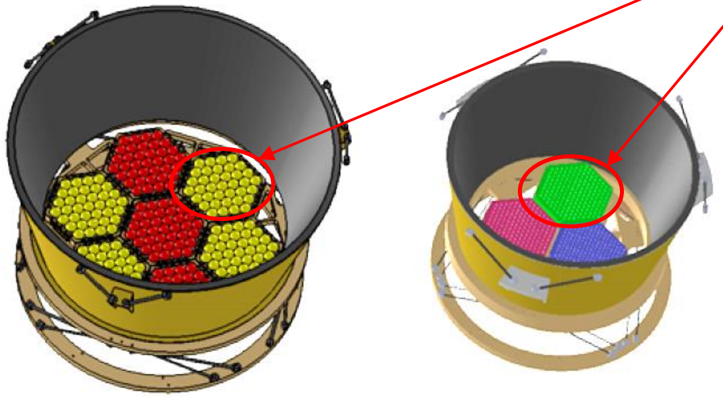
Low Frequency Telescope (LFT)



Mid & High Frequency Telescope (MHFT)

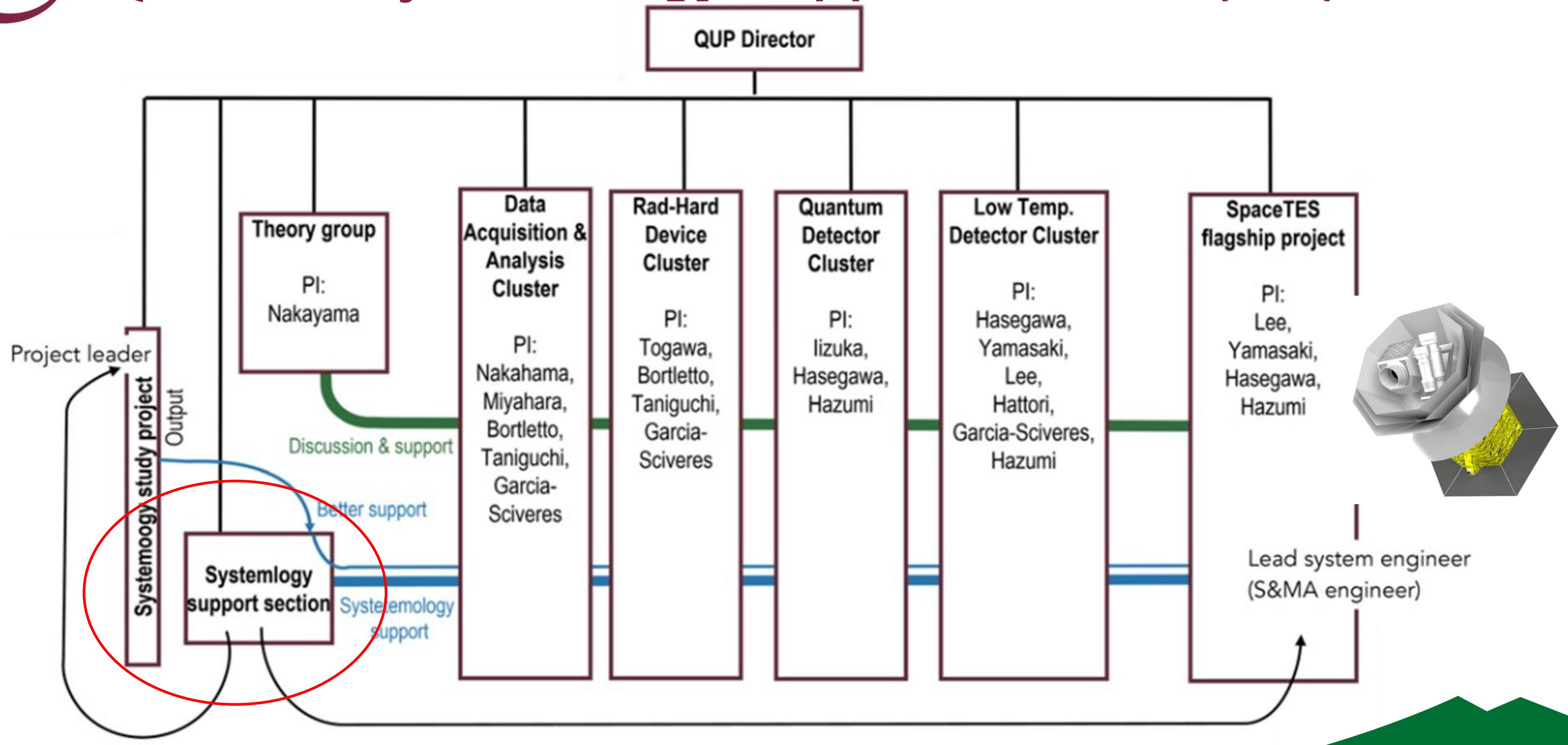


Focal Plane Sub-system (FPSS)



Focal Plane Unit of MFT & HFT

QUP and Systemology Support Section (SSS)



SSS organization

- Section leader Mitsuda

- Systems Engineering unit leader Mitsuda
  - System Engineer Kaneko
  - System Engineer Shiomi
  - Principal Engineer Kagawa
  - S&MA from HIREC company
  - System Engineer Mori (from Toyota)

- Multi-discipline Engineering unit leader Narasaki
  - 3D CAD designer Hirasawa
  - Mechanical/thermal Engineer Part-time assignment from KEK
  - Electronics engineer Part-time assignment from KEK

Concurrently assigned as the lead system engineer and the S&MA engineer of SpaceTES (LiteBIRD QUP) project, respectively.

Concurrently assigned as the project leader of the systemology study project

S&MA = System safety & Mission Assurance

(C) Senior members who are responsible to foster young system architects.

Systems Engineering of FP Sub-system

In design of FPU,
the input is requirements, not only directly for observation, but the all items must also be integrated.

SSS aids in finding realistic design solutions through engineering, involving experts from various disciplines such as

- Mechanical
- Electrical
- Cryogenic
- etc.

These disciplines often interrelate.

Types of requirements to consider

Functional	Performance
Interface	Operational
Environmental	Reliability
Safety	Other

Topics in this talk

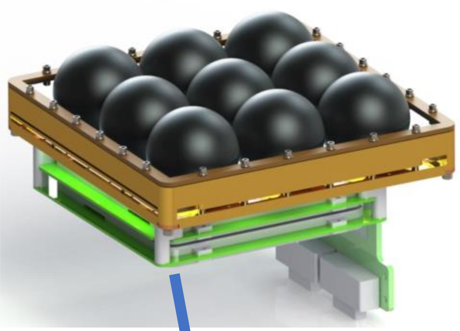
(1) Structural design and vibrational analysis

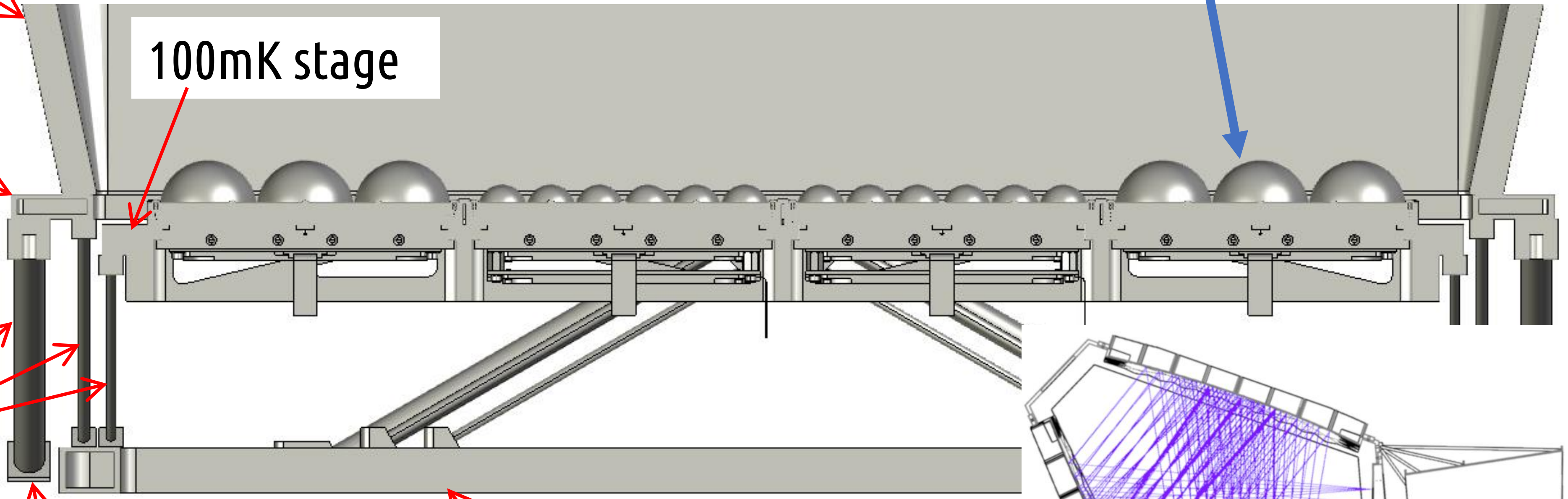
(2) Faraday cage to protect from EMI

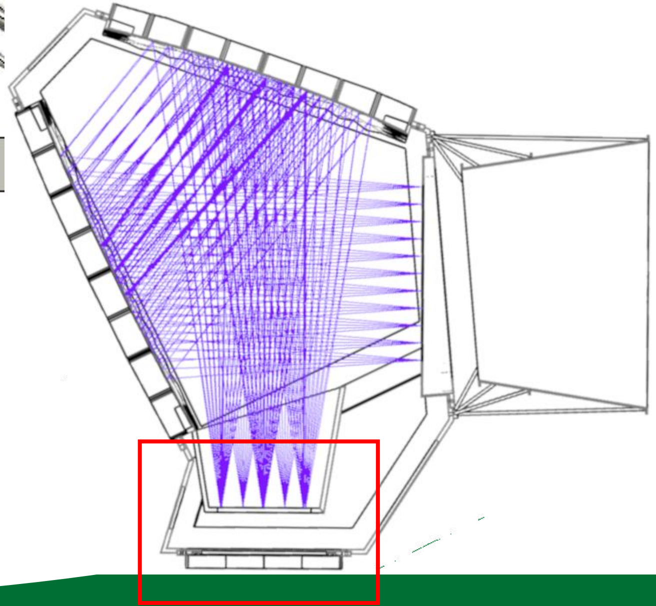
(3) Our current FPU design

Basic design of LFT FPU

Focal plane subassembly (detector)





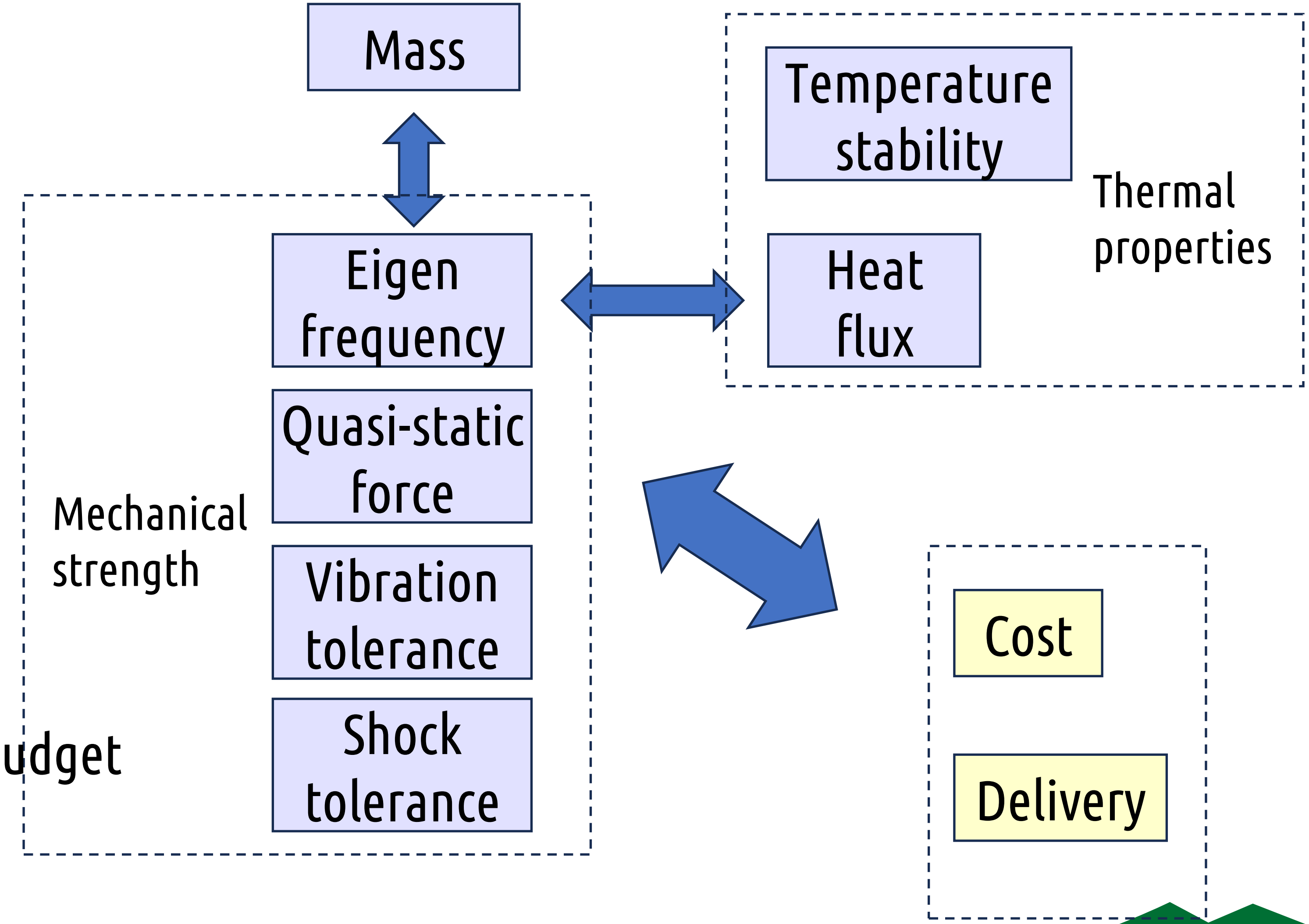


Requirements and conditions

There are lots of trade-offs
in the design of the system.

Ex. "Minimum eigen frequency
of FPU > 141Hz"
To meet this requirement,
shorter or thicker CFRP struts
increase heat flux
stronger stage structure
increase mass
cost and delivery to keep within budget

If no feasible solution can be found,
need redesign (of subsystem or parent system)



Structural analysis

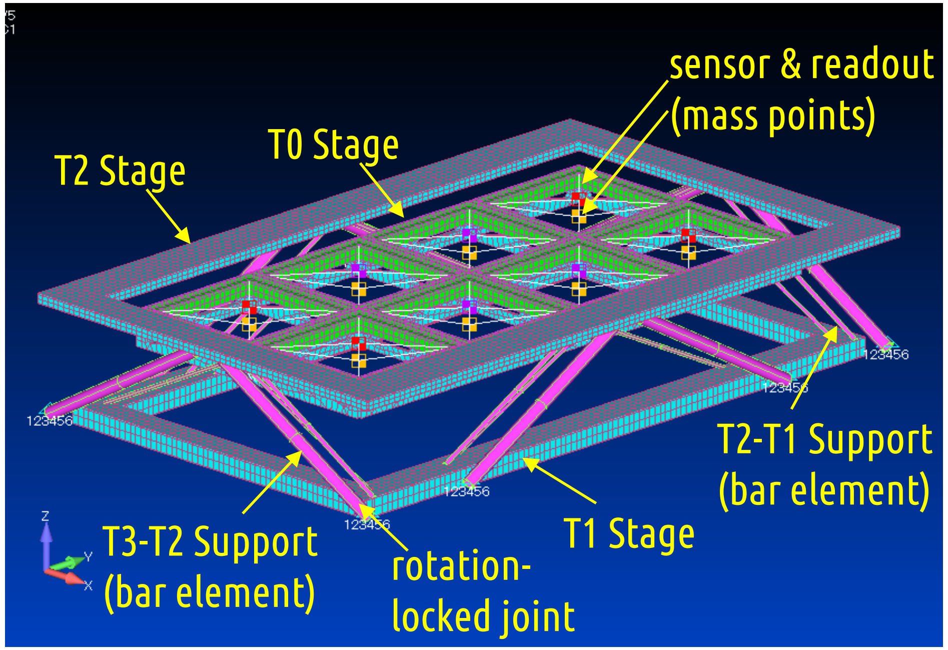
We prepare to model and analyze structural analysis with NASTRAN.

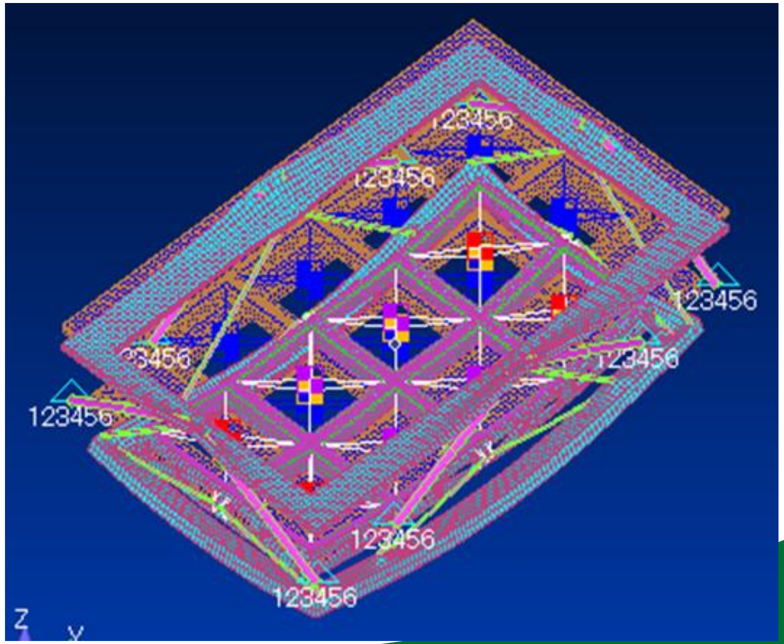
A preliminary calculation was performed on the initial design of the FPU.

We demonstrated the reliable results by comparing with the results from the manufacturing company.

We found that this version and some simple modification didn't meet frequency requirements.

We will start analysis with our updated FPU





Optimization of structures

We plan to optimize design on simulation

(1) Dimension of stage, position, length of CFRP etc.

(2) Topological optimization of structure also in scope

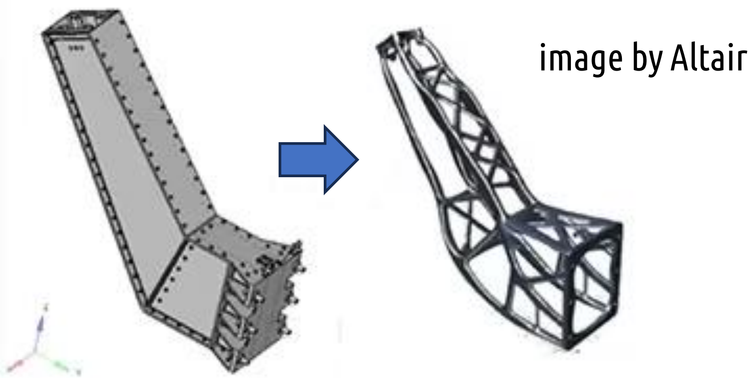
Asking support of external specialist

Performance of CFRP struts is one of the critical point

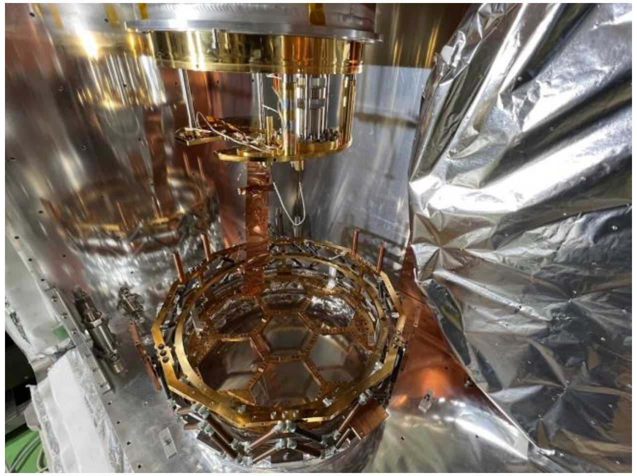
Thermal conductance and its dependence on the choice of material is known precisely enough

Prototype measurement at QUP laboratory is planned

Reinforcement of CFRP against launch stress is planned too



An image of topological optimization



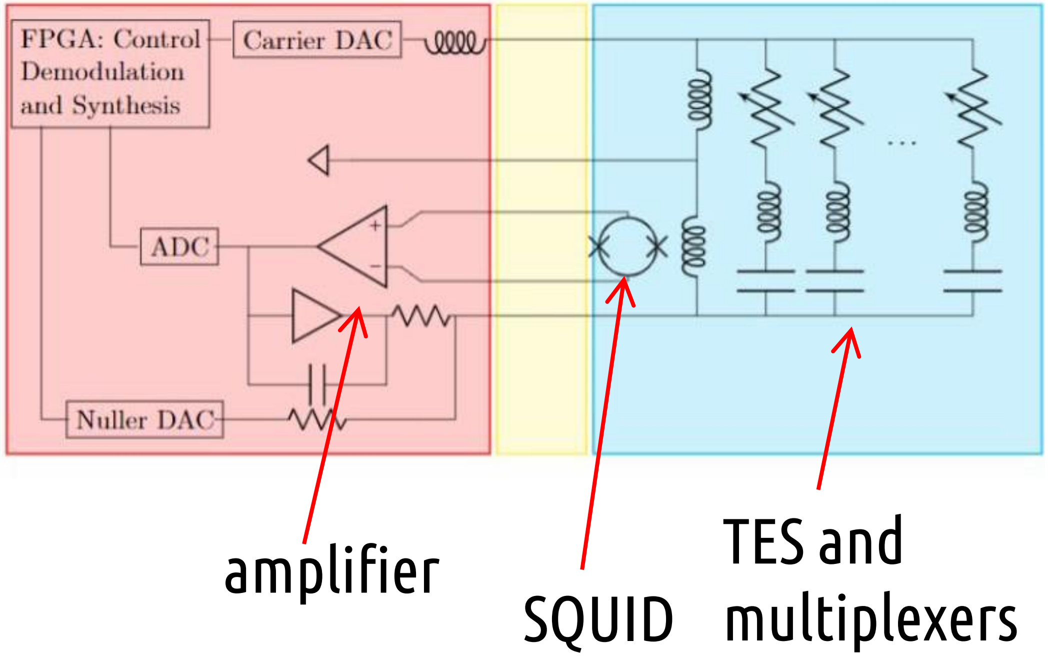
Cooling test image with dilution refrigerator cryostat at QUP lab.

Electromagnetic integrity

Readout schematic image

Electromagnetic requirements:

- Tolerance to DC and AC magnetic field
- Compliance with EMI standards
- Grounding scheme must follow required structure
- etc.

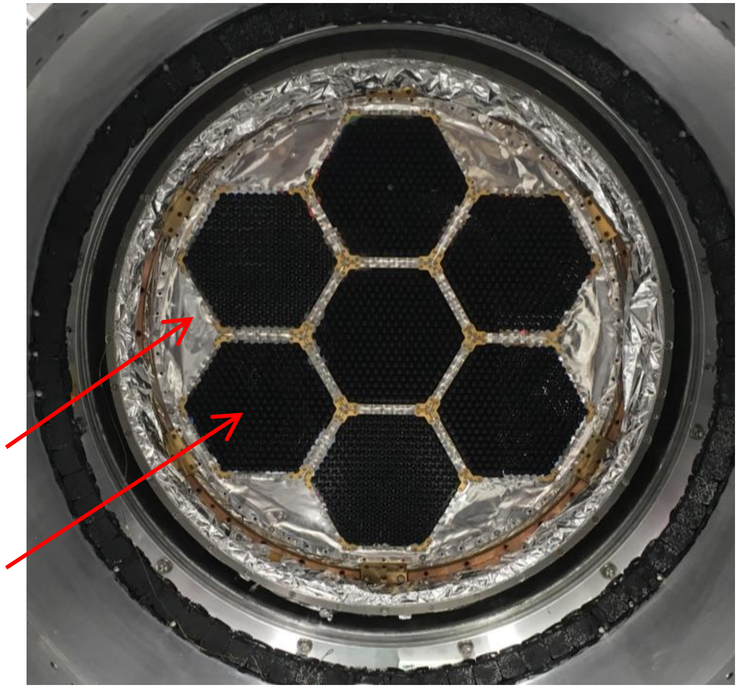


In addition, as we adopt SQUID readout scheme,

- SQUID must be inside of Faraday cage to protect from outside RF noise
  ← there are readout bundle and heat link inside of the vacuum shell
    ↑ mechanism to close cage
    ↑ readout bundle and heat link to pass through
  ← additional thermal pass appears
    ↑ thermal budget must be reconsidered

Fundamental idea of LFT Faraday cage

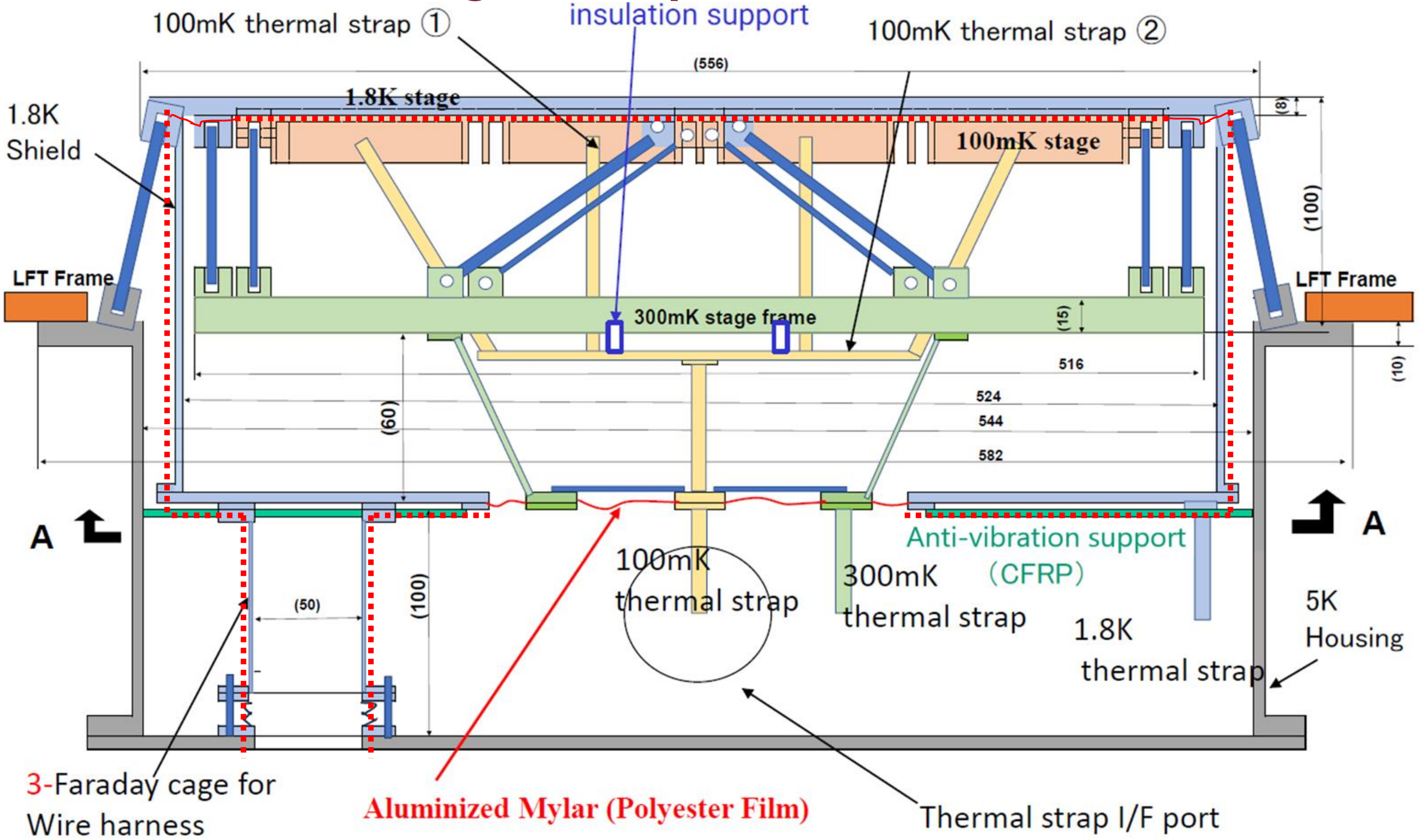
Sky side
- Design after ground CMB experiments PB/PB-2 receiver
- Material
  - Aluminized Mylar film
  - Nb deposited on wafer



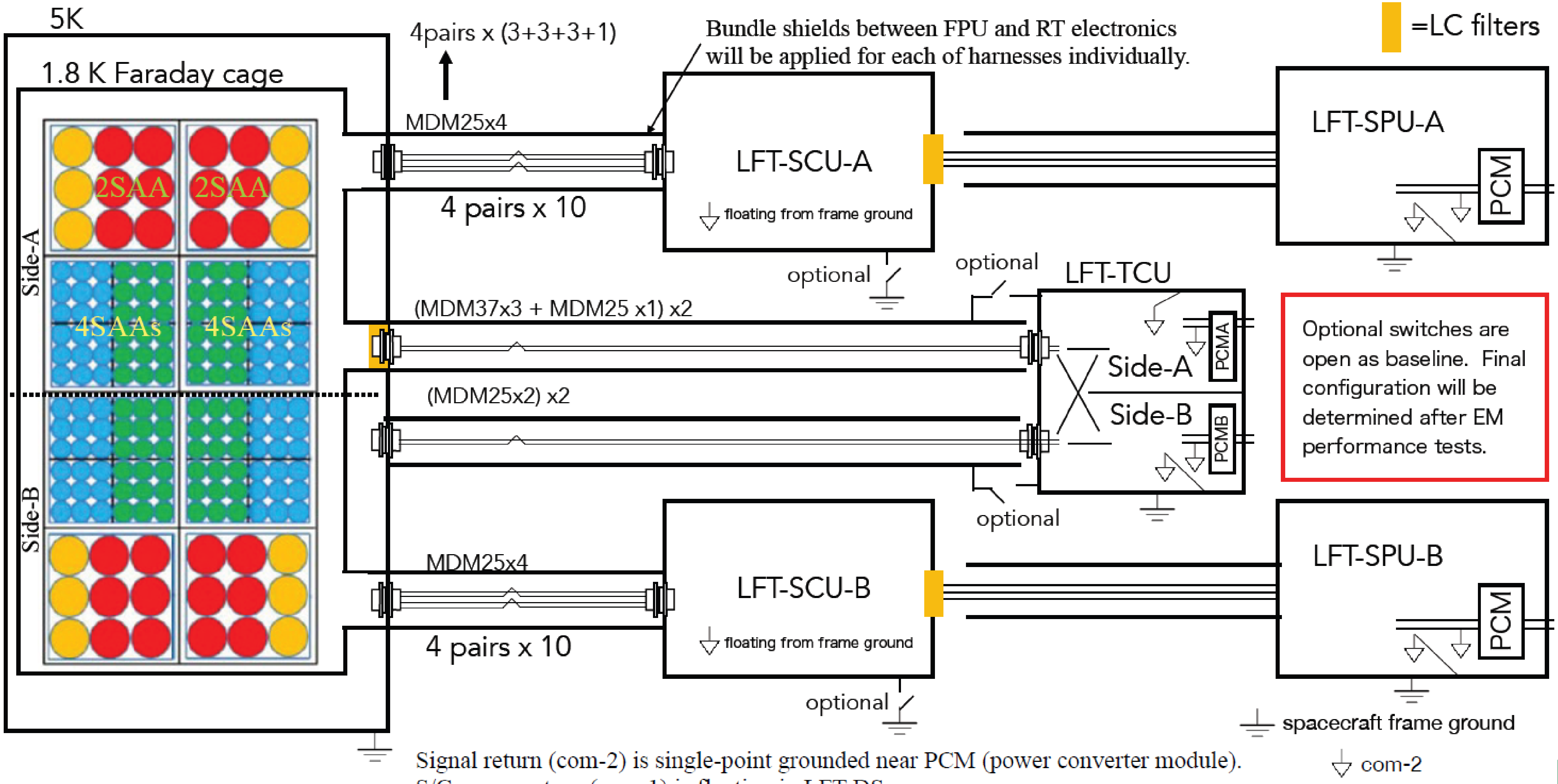
PB-2 focal plane

Anti-sky side
- Cannot be like PB/PB-2, as readout shares vacuum chamber
  - add shell structure of Faraday cage
  - at T2 to surround SQUID circuits

Schematic image of updated FPU

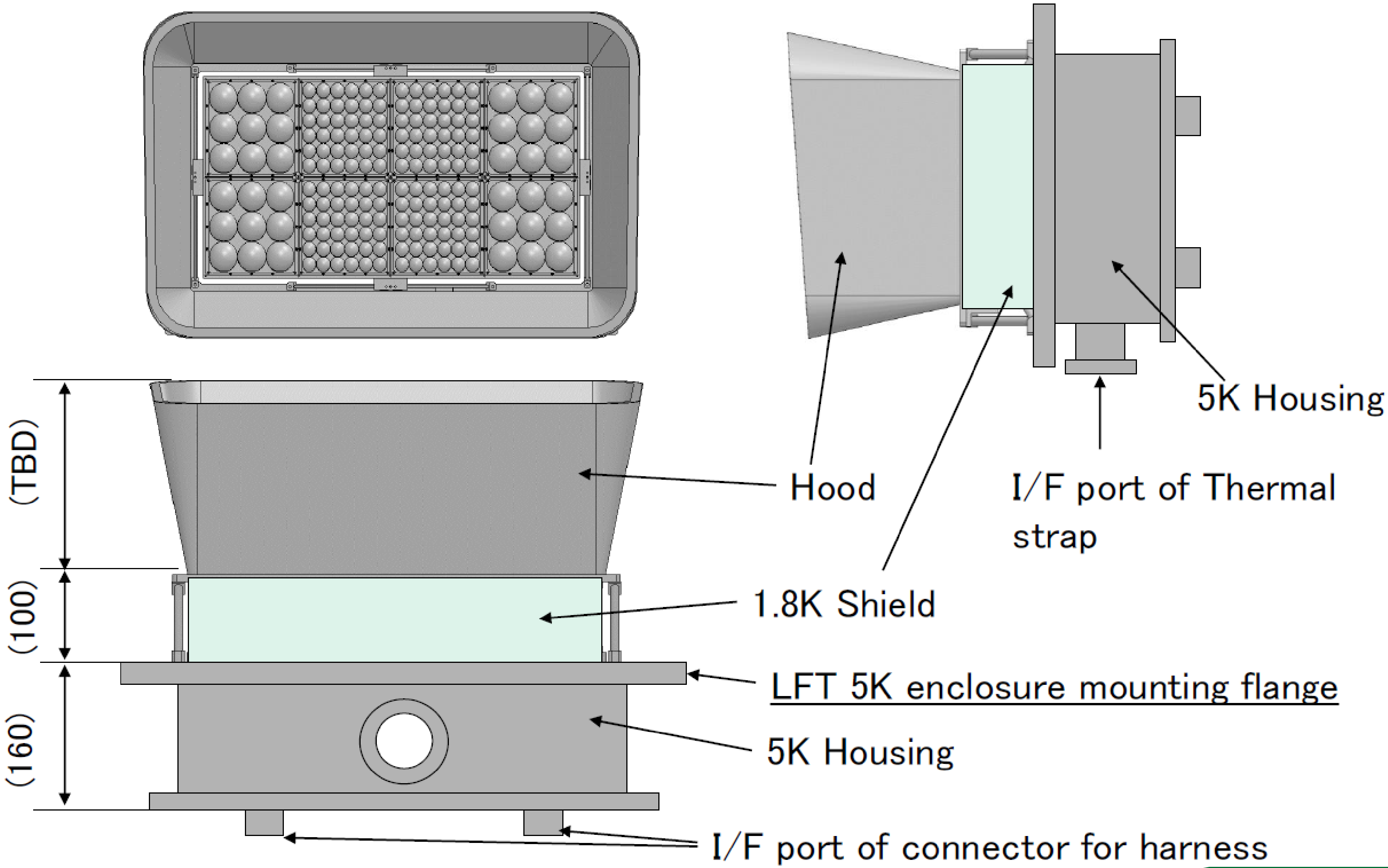


Grounding scheme plan

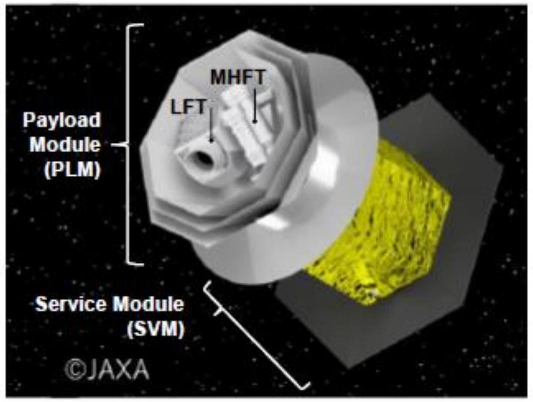


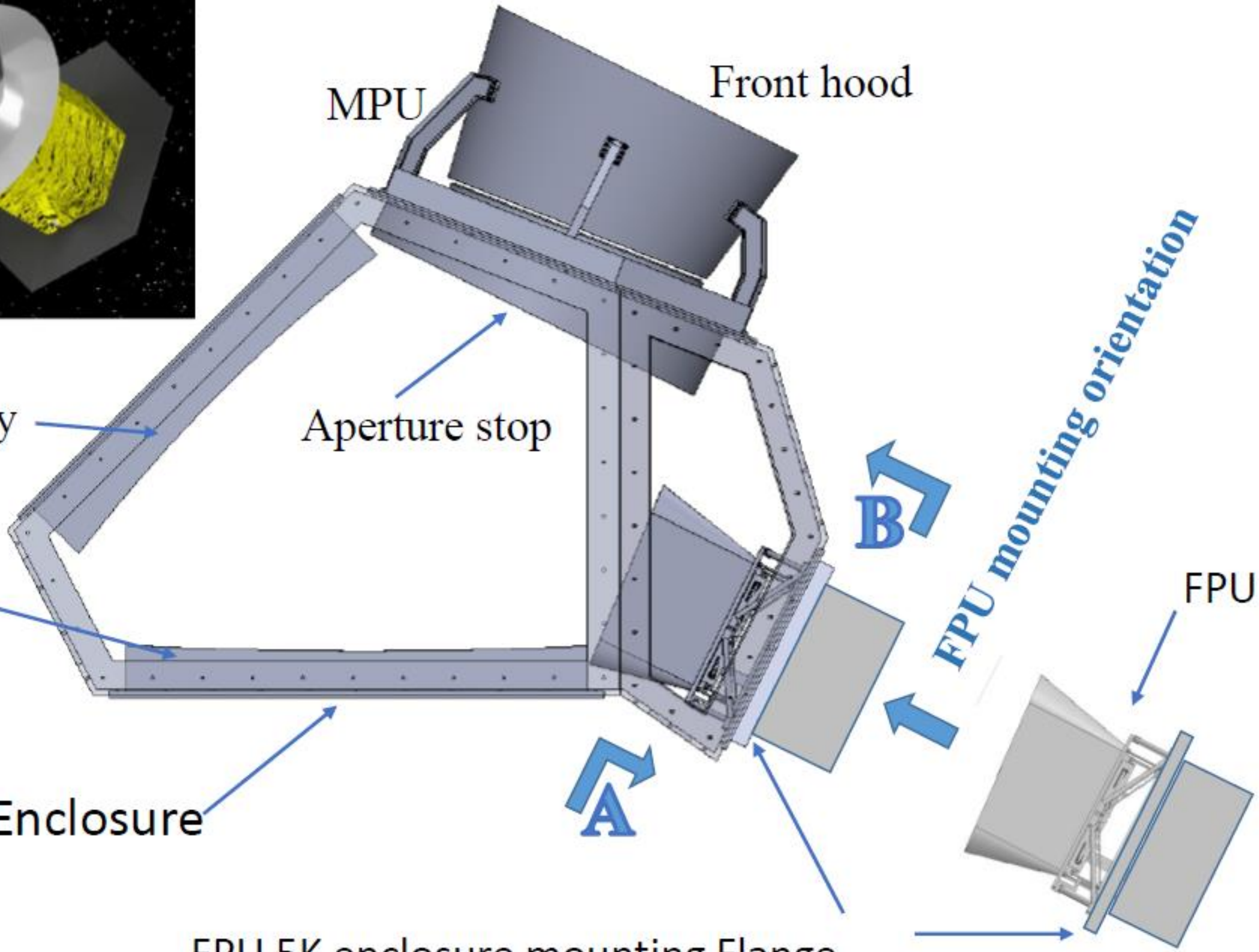
Signal return (com-2) is single-point grounded near PCM (power converter module).
S/C power return (com-1) is floating in LFT-DS.

Current plan of FPU structure

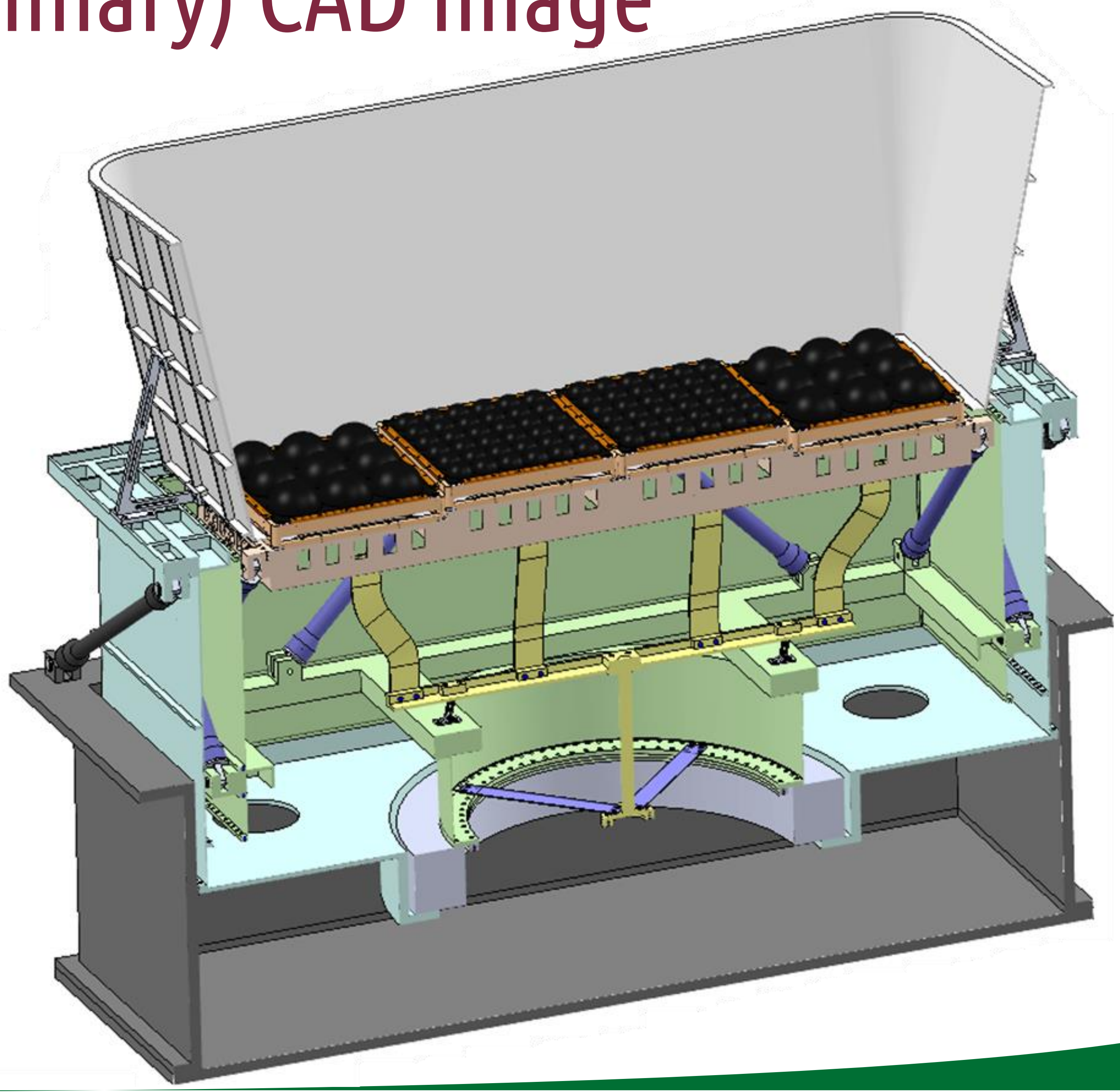


Mounting plan onto LFT





(preliminary) CAD image



Summary

QUP is in charge of design and production of FPSS.

Many challenges in design of FPU.

Systemology support section is establishing
a multi-disciplinary design infrastructure in QUP.

FPU design is now in progress with supports of experts of different disciplines.

Design integrity will be confirmed with simulations and prototyping tests.