Panel Extension Satellite (PETSAT)

0D#Q ryhd#Vdwhoolwh#Frqfhsw#Frqvlvwlqj#ri#

P rgxodu#Lxqfwlrqdd#dqg#Sdqhov

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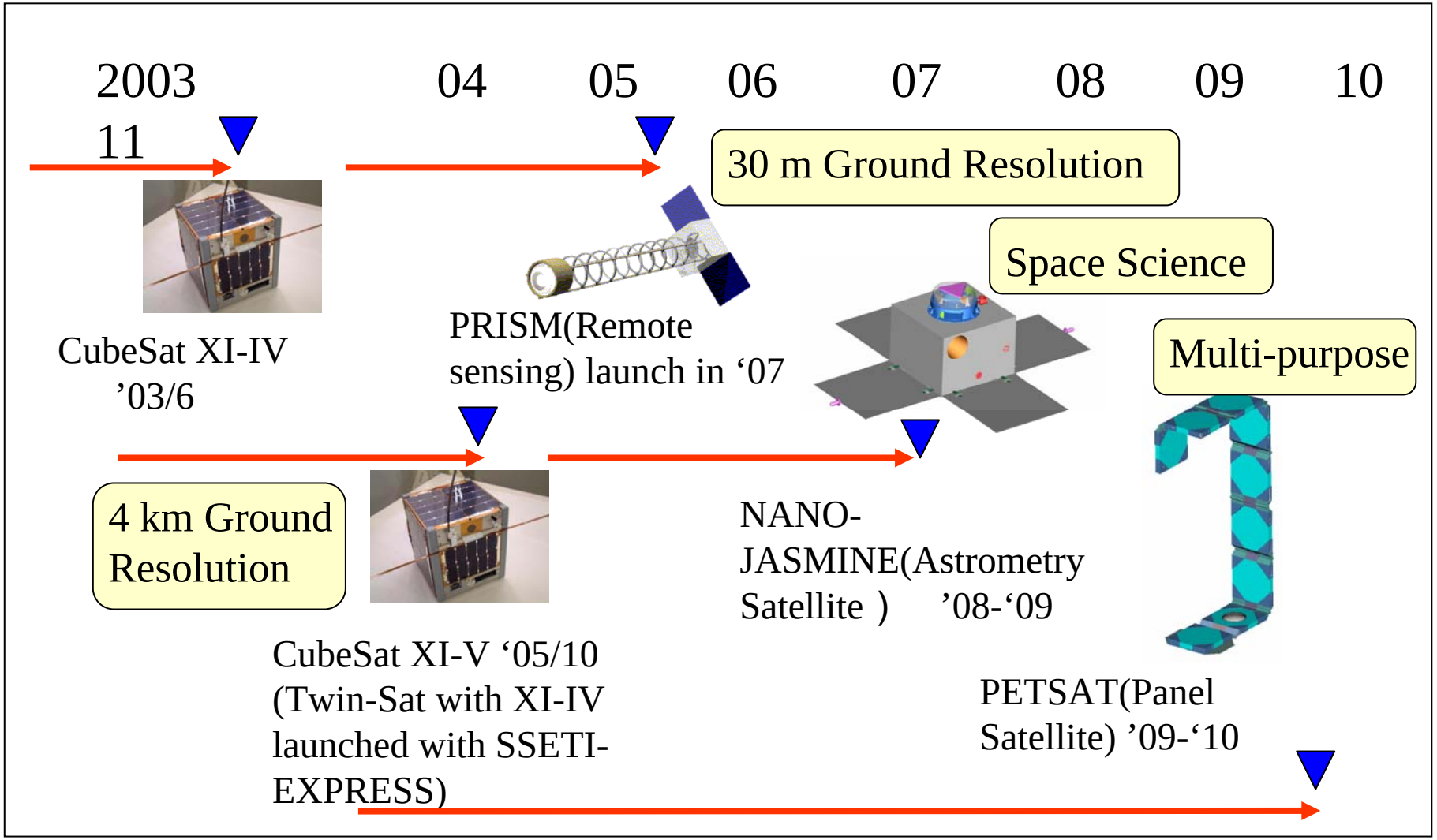
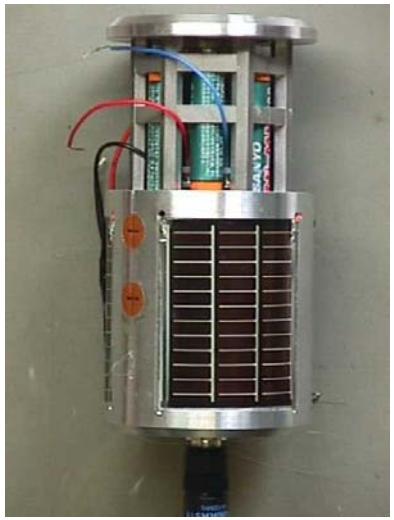
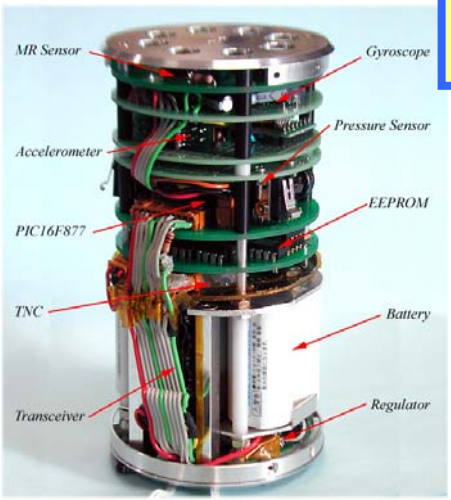
University of Tokyo's Nano-Satellite Projects

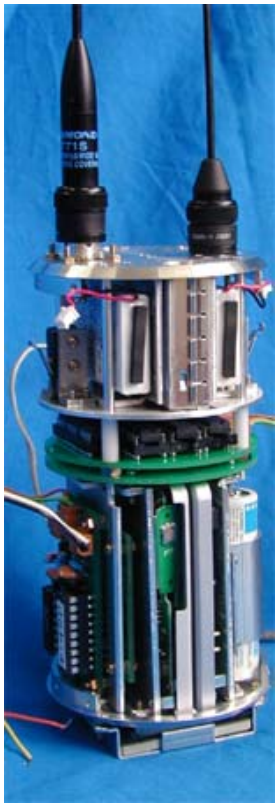


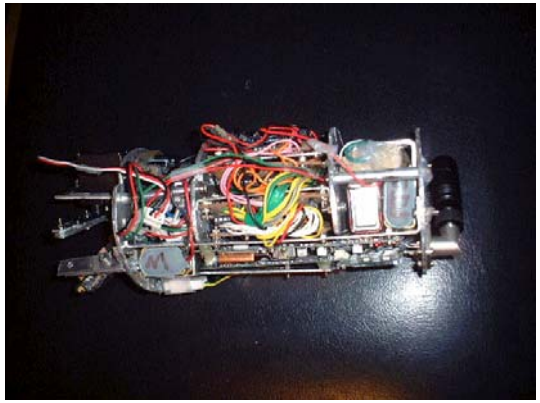
Development Launch

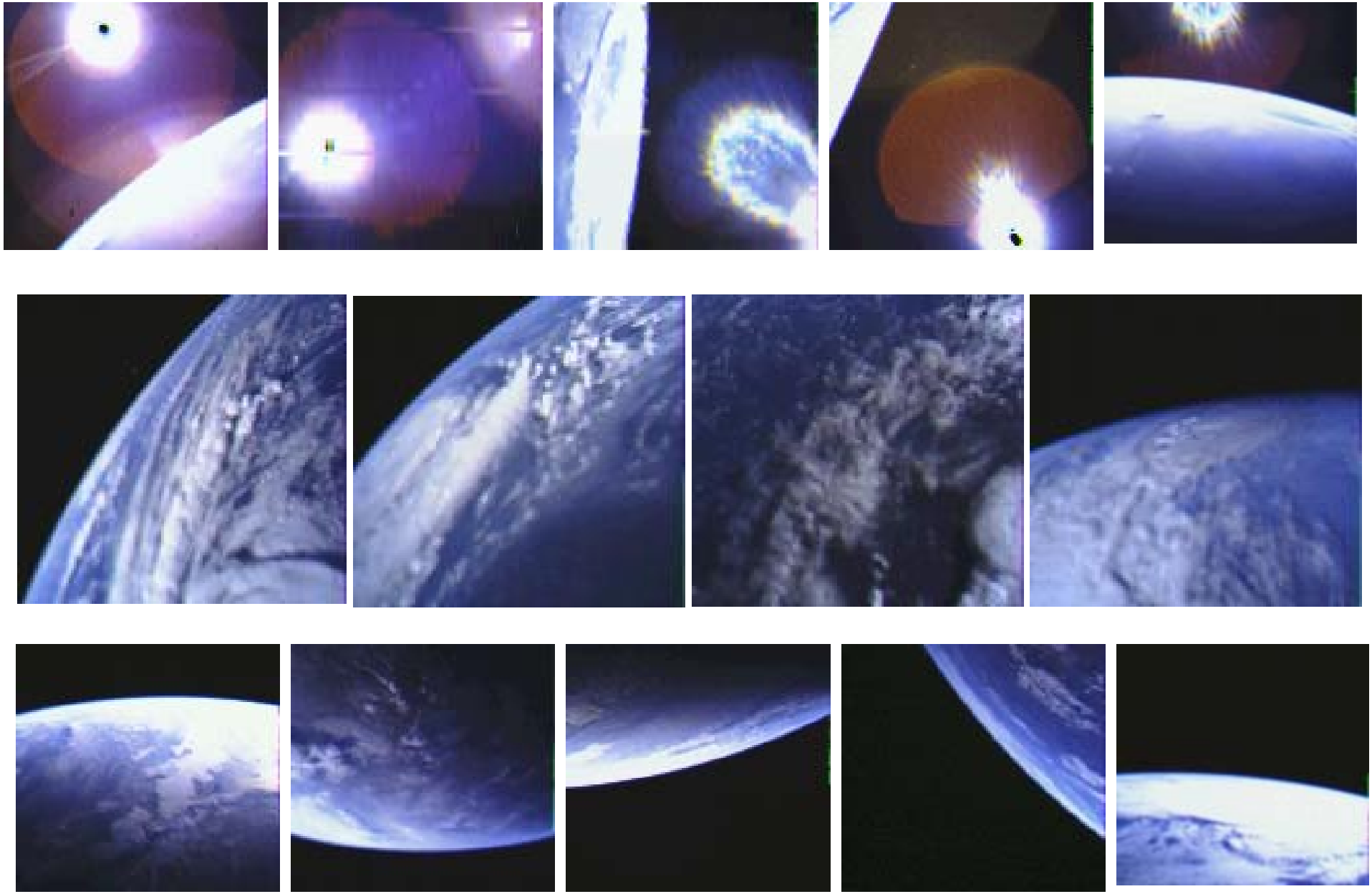
CanSats 1999-now

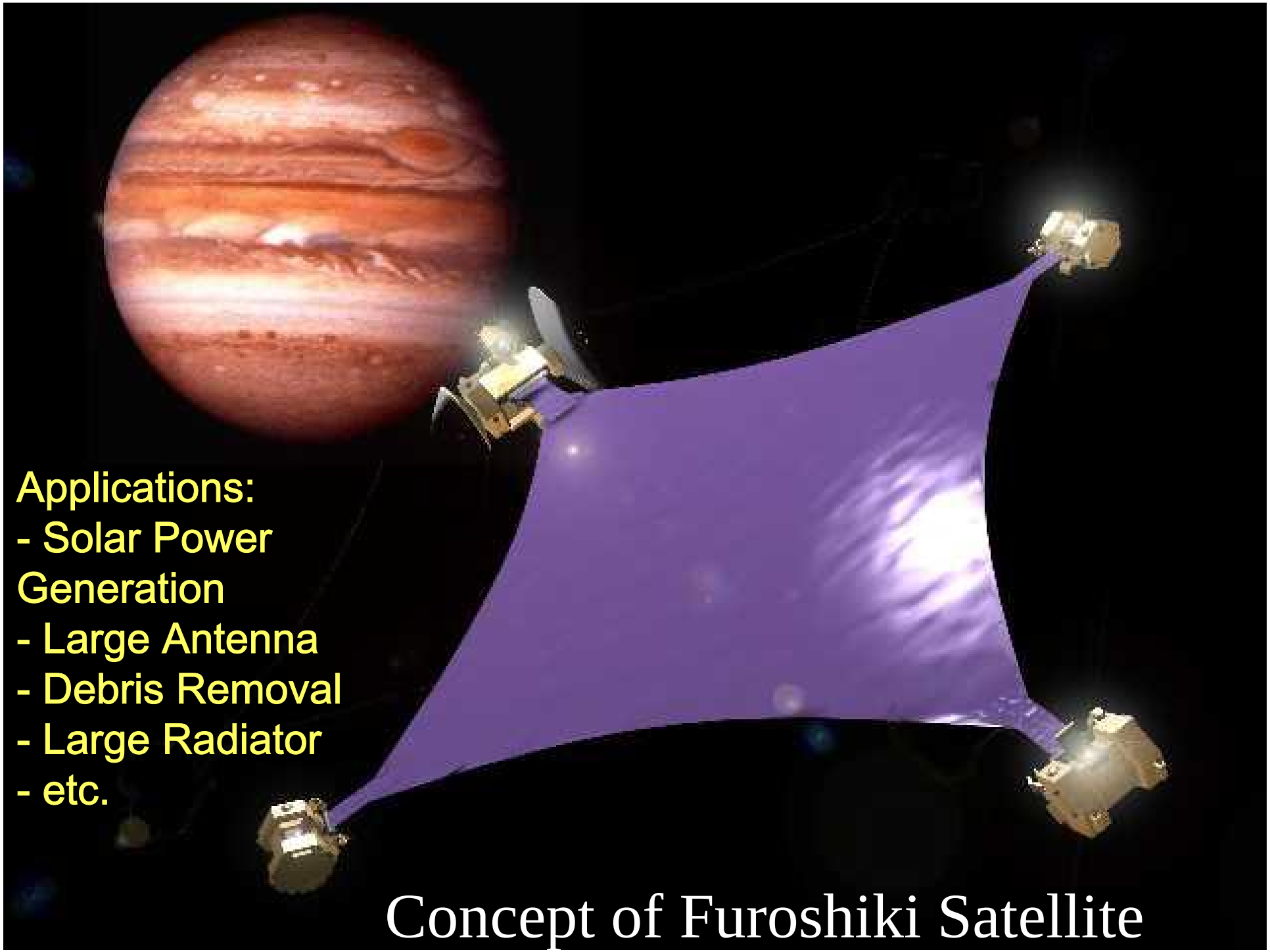






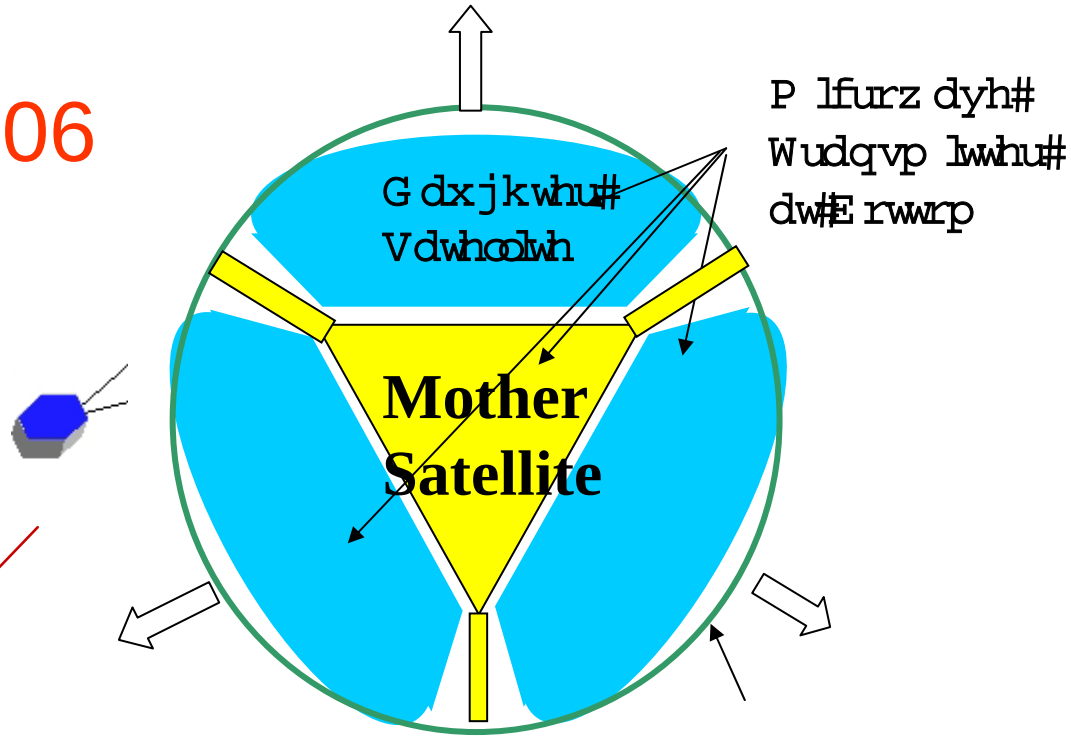




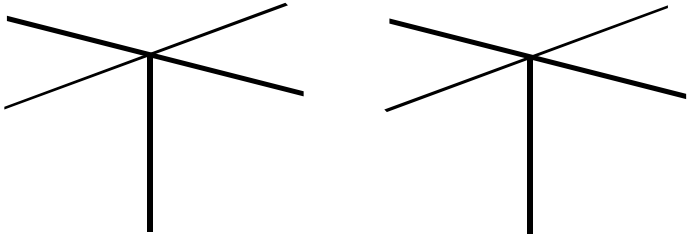


Concept of Furoshiki Satellite

Sounding Rocket Experiment 1/22/2006



Pilot Signal for retro-directive antenna



Antenna Pattern Measurement

Problems of Current Satellite Concepts

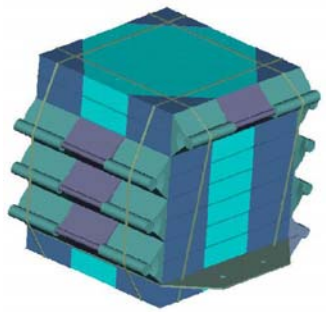
- Conventional Satellite
  - Development Period 2 ~ 7 years
  - Development Cost $20M ~ $500M

Because of "custom-made" style in order to deal with varied mission requirements.

Mass Production: Key to reduce cost anddevelopment time, and improve reliability

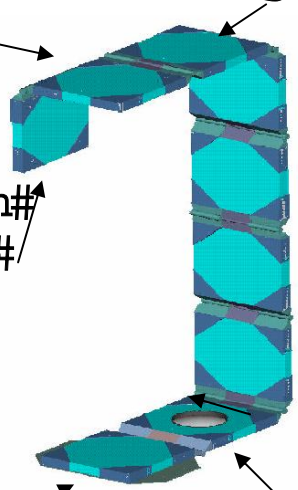
Question: ***How to satisfy the two conflicting requirements of "mass production" and "variety of performance"***

PETSAT(Panel ExTension SATellite)

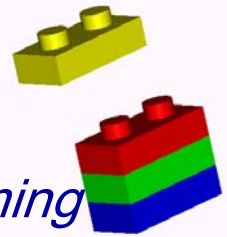


Before Separation
(Launch Locked)

extension



Plug-in of Panels having different functions deal with variety of mission requirements just like a “Lego Block”



→ Mass production of panels lead to low cost/high reliability

→ Plug-in makes system level test simple and less time consuming

→ Open architecture to allow participation of new companies with special tech.

→ Extending panels makes it possible to use small satellite as “large sat”

(1) Architectural Study

Function Distribution into Panels

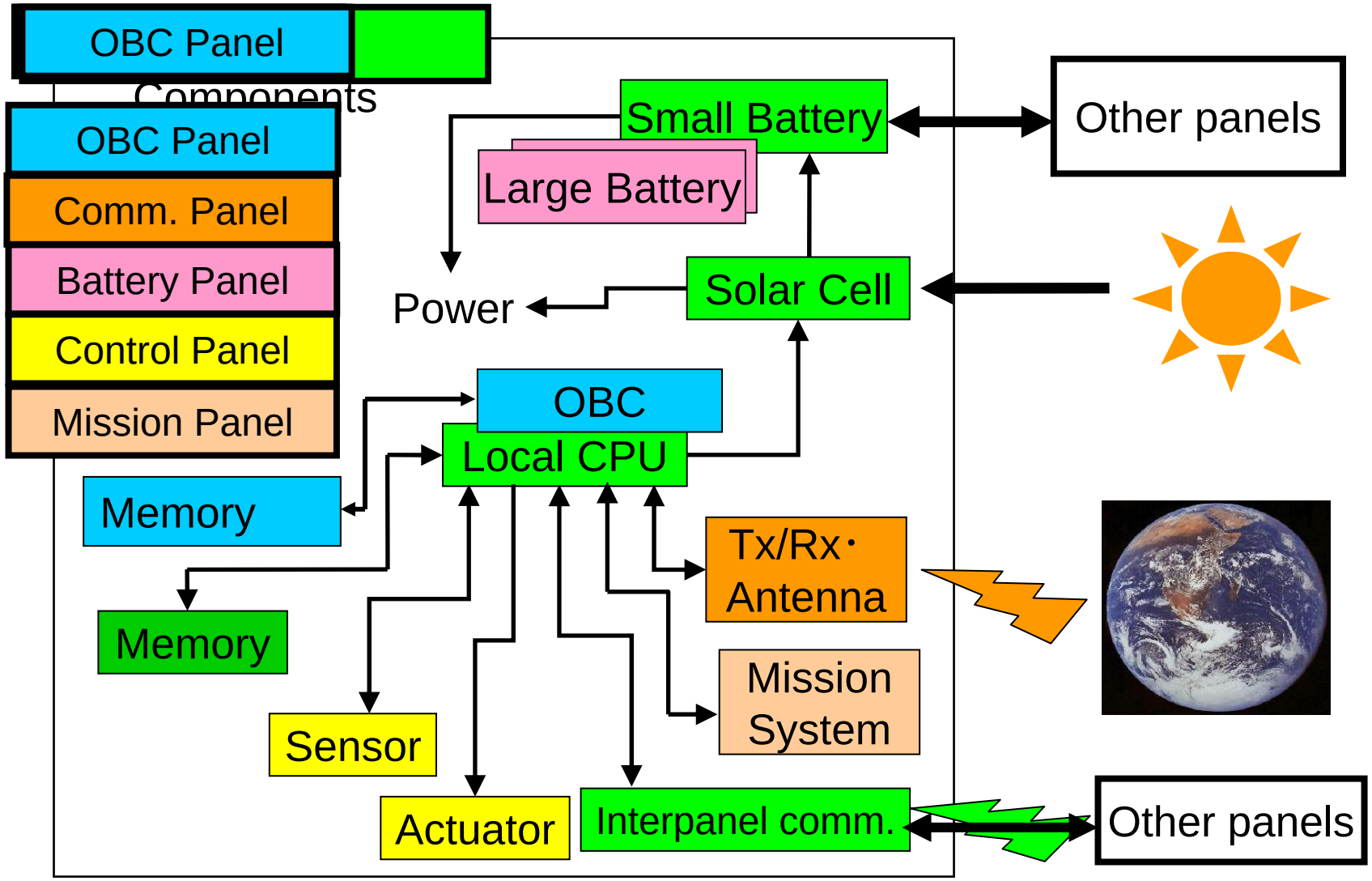
How to distribute OBC, memory, attitude control, power, communication, etc, into (how many) different panels

- **Each panel has "Standard compo." + "Special compo."**
  - **Inter-panel communication controller is indispensable**
  - **How about solar cell, battery, CPU ?**
  - **Inter-panel communication capacity should be considered**
- **Easy plug-in of any quantity of panels should be possible**
  - **Distributed architecture like "Personal Computer on Internet"**
- **Fault tolerance required including panel interface failure**
  - **Tolerant against electric or information line failure**
  - **Graceful degradation and reconfiguration capability**
- **Should deal with variety of mission requirements by changing types and quantity of panels**
  - **Ex) Two communication panels should have double capacity**

Overall Architecture of Functional Panels

- **Types of Panels：**
  - **①OBC+memory ②communication ③attitude control ④orbit control ⑤battery ⑥mission function (depends on mission)**
- **Standard components to be implemented on each panel:**
  - **Power-related: solar cells + small battery**
  - **Information-related：inter-panel communication components (local CPU taking charge of bus controller)**
- **Other important factors:**
  - **Power demands and generations are not balanced in each panel (e.g., Mission, communication panels require lots of power)**
    →Real time power distribution between panels is indispensable
  - **Many CPU exists including local CPUs and main OBC**
    →System management by multi-CPUs and enable grid computing
  - **Component shape should be aligned in the flat panel structure**
    →1-axis controller (gyro, wheels, magnetic torquer, etc) in 1 panel

PETSAT System Configuration



Example Requirements for Each Type of Panel

OBC+memory	Speed >30MIPS, Memory size > 1GB
Battery	Life time > 1 year in 30 %DOD >3W
Solar cells	> 10 w per panel
Communication	Downlink > 250kps (in S or higher freq.)
Orbital control	Safe propellant, ISP>100s、T>0.1N
Inter-panel com.	1 Mbps, redundancy
Information line	Weight < ½ of conventional harness
Structure	Weight ~ conventional fraction(10%)

(2) Interface Study

Requirements as to Four Interfaces

- Mechanical Interface
  - **Reliable folding/extension in space environment**
  - **Low shock extension and latch in several angles**
- Electrical Interface
  - **Self-supply within each panel in principle.**
  - **Autonomous power re-distribution between panels**
- Information Interface
  - **Distributed agent architecture, Plug-In simplicity**
  - **Fault tolerance, grid computing**
- Thermal Interface
  - **Suppress temperature difference between/within panels**

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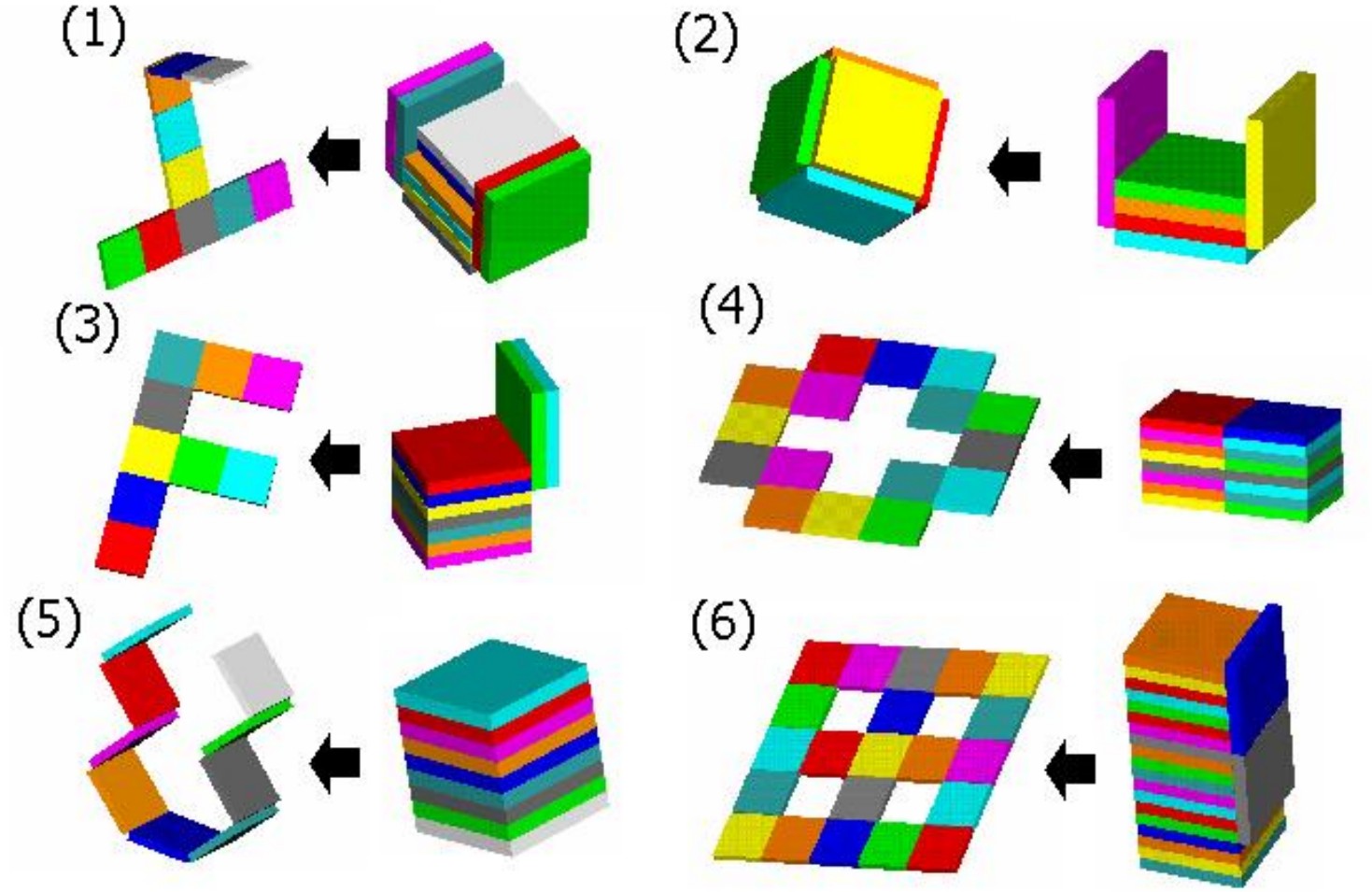
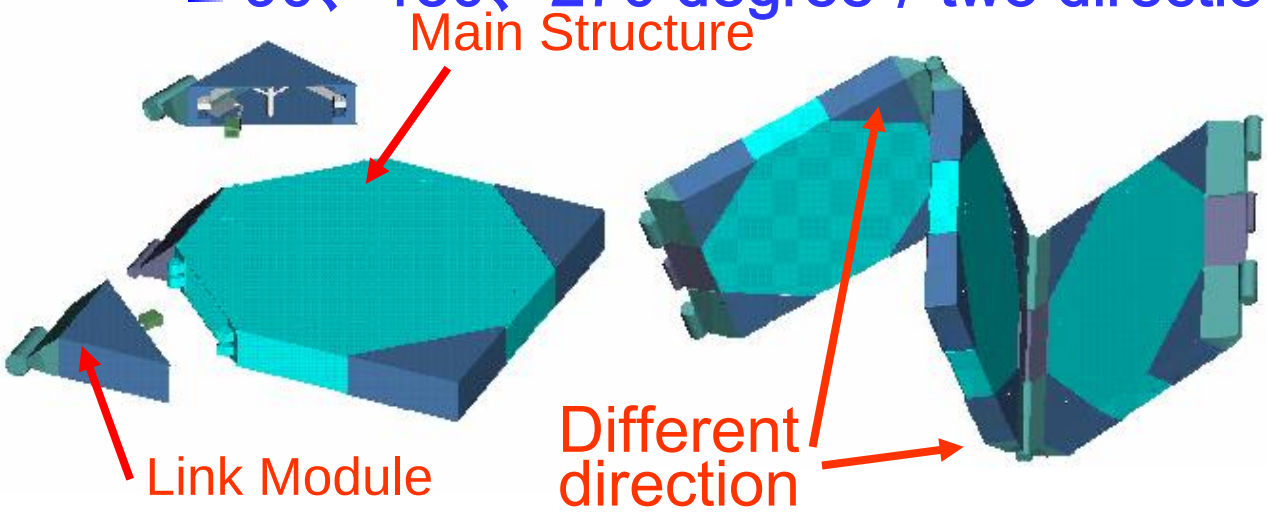
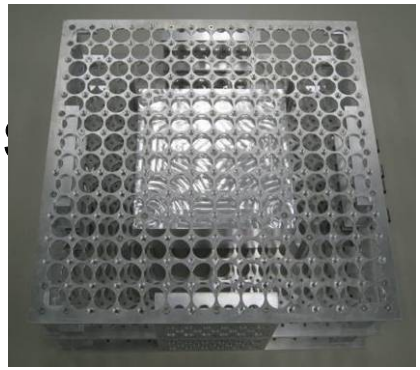
Mechanical Interface (1) - Launch locked panels and extended configuration



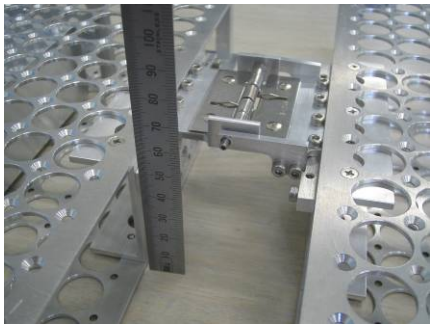
Mechanical Interface (2)

- Main structure (for components package) and Link Module at four corners
- Plug-in between Link module and main structure
- Link module variety (direction, angels
  - 90、180、270 degree / two directions





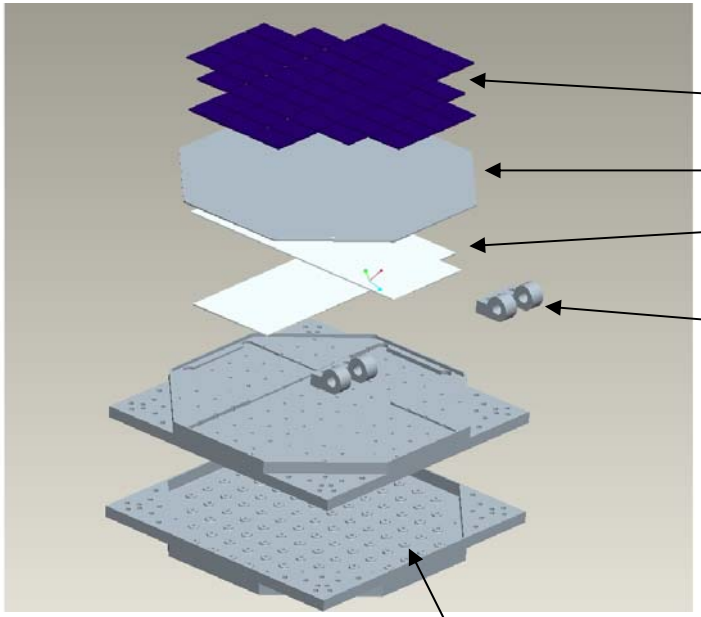
Current model of main structure

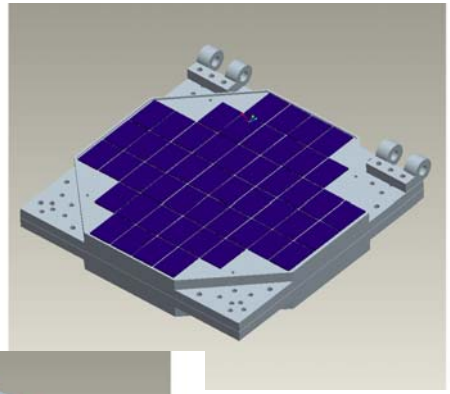


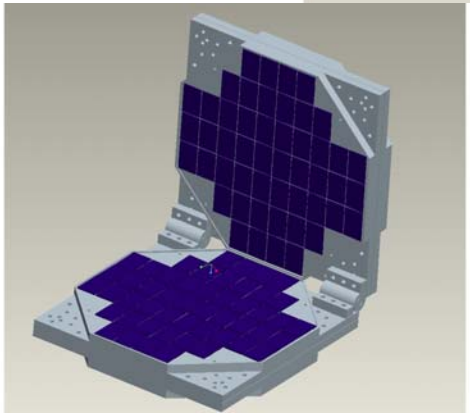
Current model of link module

Panel Trial Design

Design by CAD（Pro/Engineering）for interaction checks

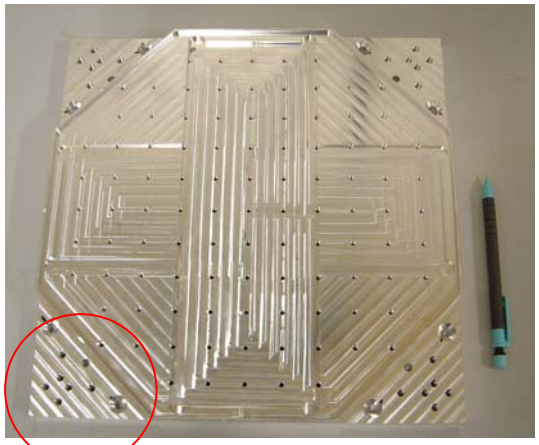


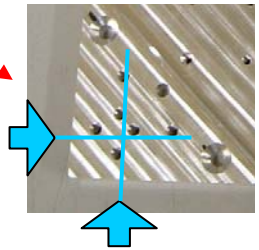




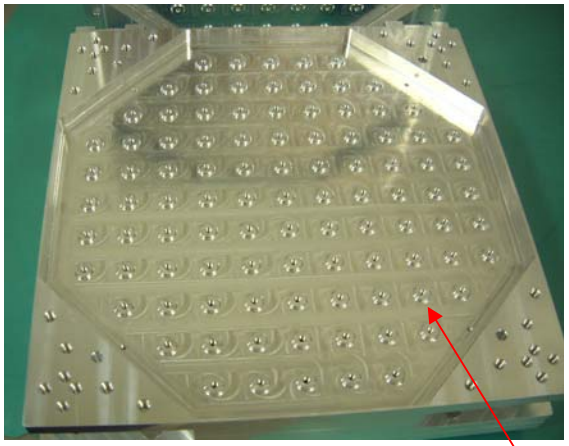
Fabricated Panel (1st Round Trial)

Component Bed (Outer Surface)

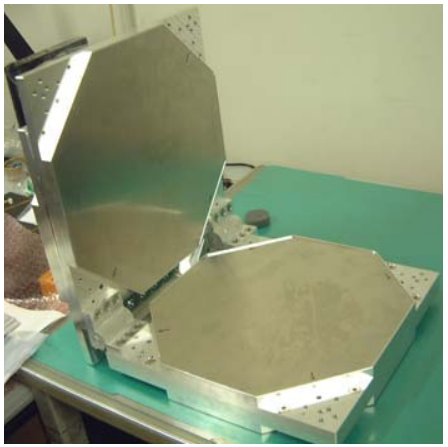




Component Bed (Inner Surface)



After Extension

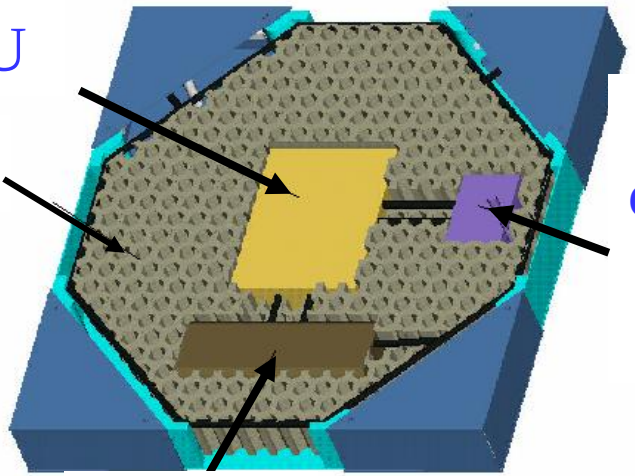


Attachment holes for components

Hinge can be attached in two directions

Example of Panel - CPU Panel

-



Requirements for Four Interfaces

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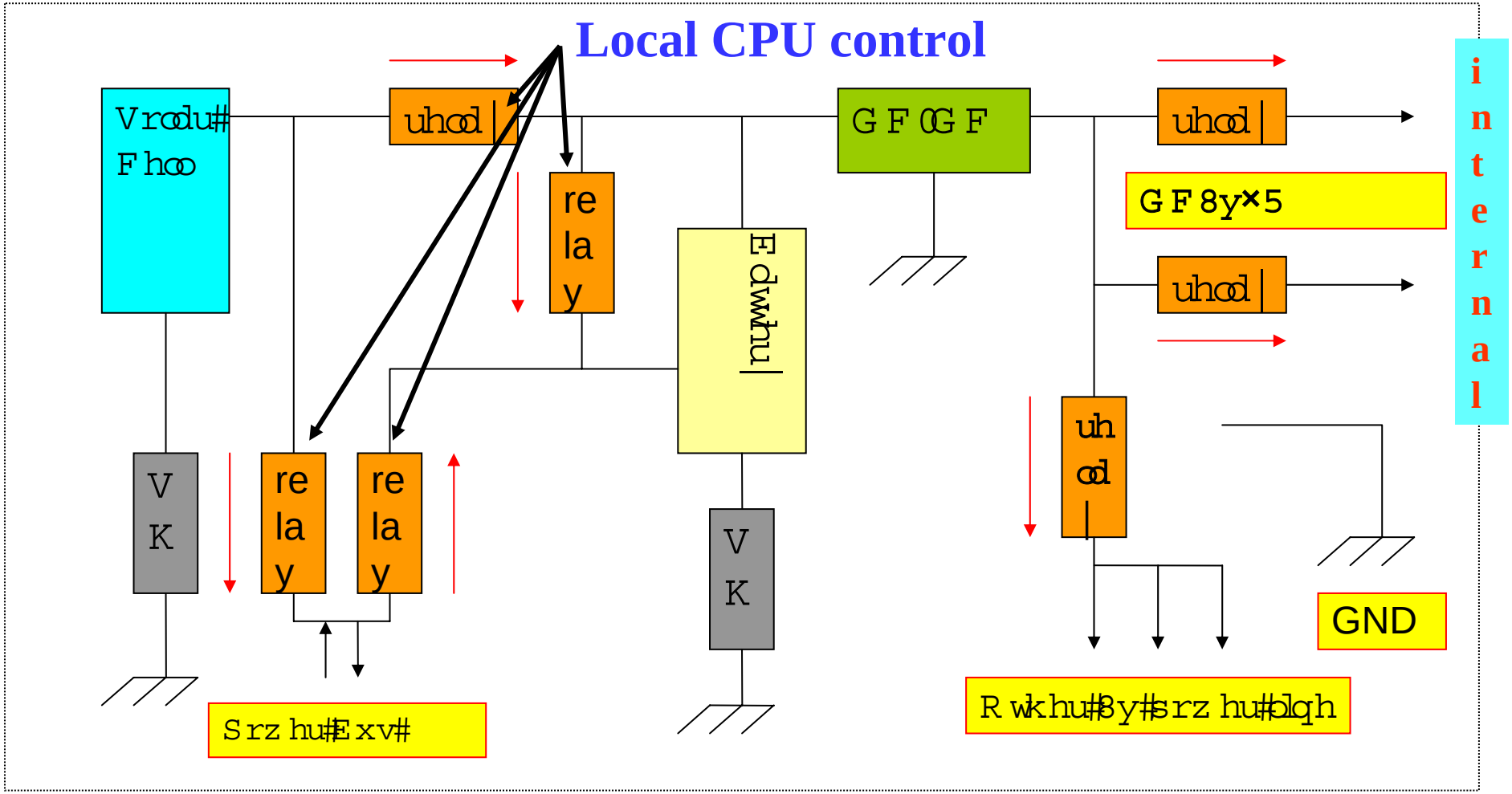
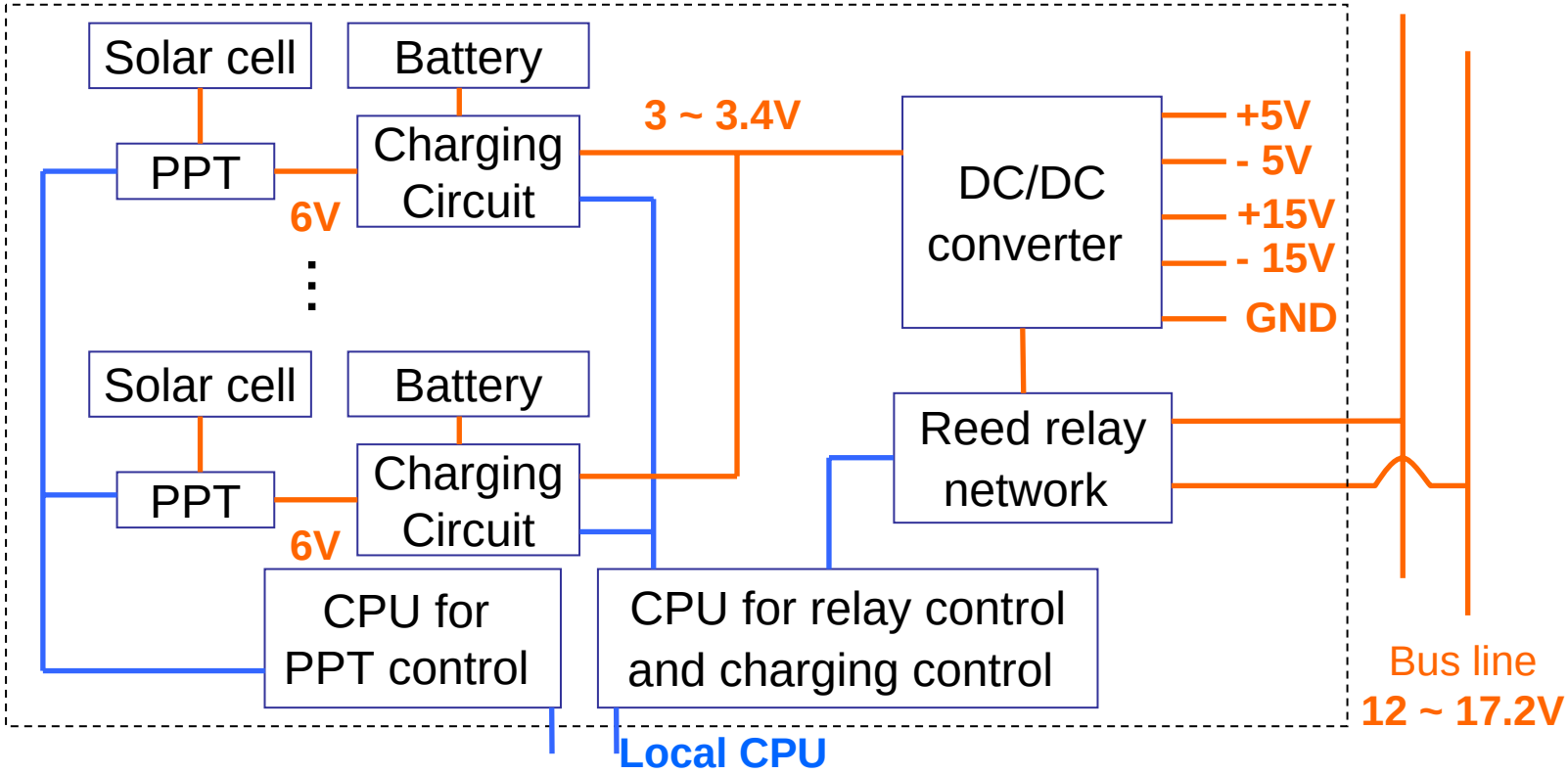
Electric Power Re-distribution Plan



Power By Pass Circuit

Electric Power Network for PETSAT(1)

Overview



- Electric power is self-supplied within each panel in principle.
- Electric power is managed efficiently by distributing surplus electricity through the bus line to the panels that run short of electric power.

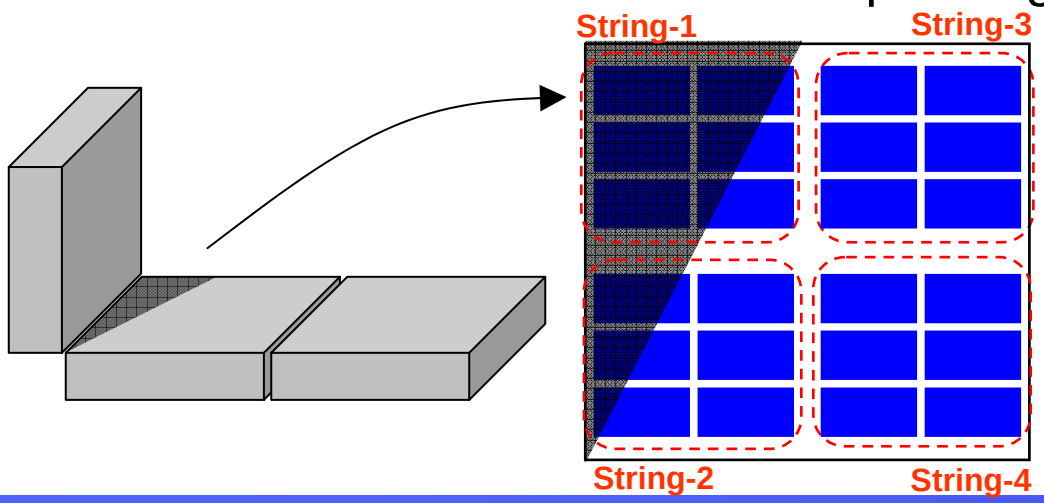
Electric Power Network for PETSAT(2)

Battery

Li-Ion batteries of COTS products
- Self-discharge is almost nothing.
- Energy density to the mass is high.

Solar cells

- GaAs solar cells is used.
- Solar cells on the panel are divided into 4 strings and each string has 1 battery to use batteries more efficiently. Because it is possible to make a shadow over solar cells depending on configurations.



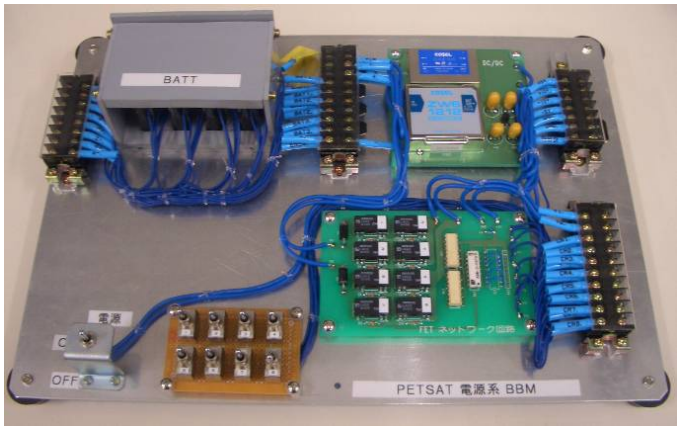
The shadow disturbs charging of the batteries under string-1 and -2, but the batteries under string-3 and -4 can be charged without the disturbance.

Electric Power Network for PETSAT(3)

■ Electric power controller (1/2)

(a) PPT circuit

- Each string of the solar cell has one PPT circuit.
- PPT circuits are controlled by CPU of each panel.



Breadboard model
of electric power controller

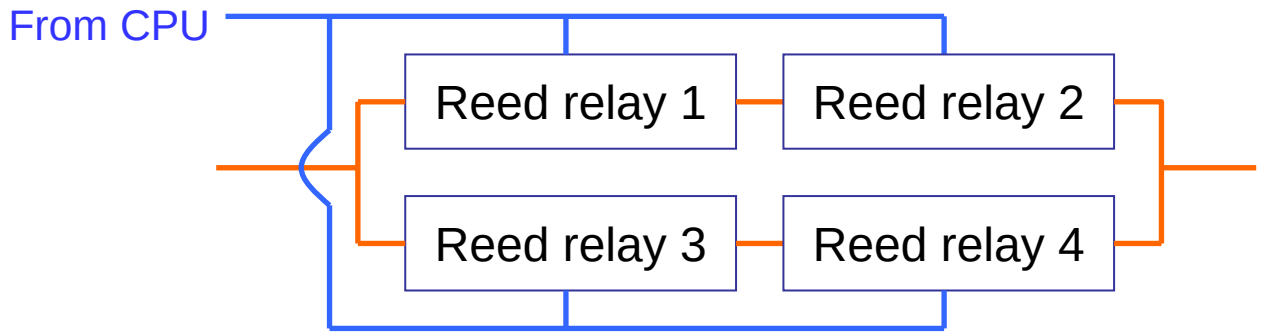
(b) Charging circuit

- Charging circuits are COTS products with small size and easy circuit.
- CPU of each panel controls charging circuits by cooperation with OBC to manage the electric power balance of the whole satellite. Consequently, the battery life can be extended by suppression of excess charging.

Electric Power Network for PETSAT(4)

- Electric power controller (2/2)

(c) Reed relay network



<u>For example</u>

- Reed relay 1 breaks down while disconnected

  ⇒ The line with reed relay 3 and 4 is used.

- Reed relay 1 breaks down while connected

  ⇒ Reed relay 2 is kept in disconnected state and the line with reed relay 3 and 4 is used.

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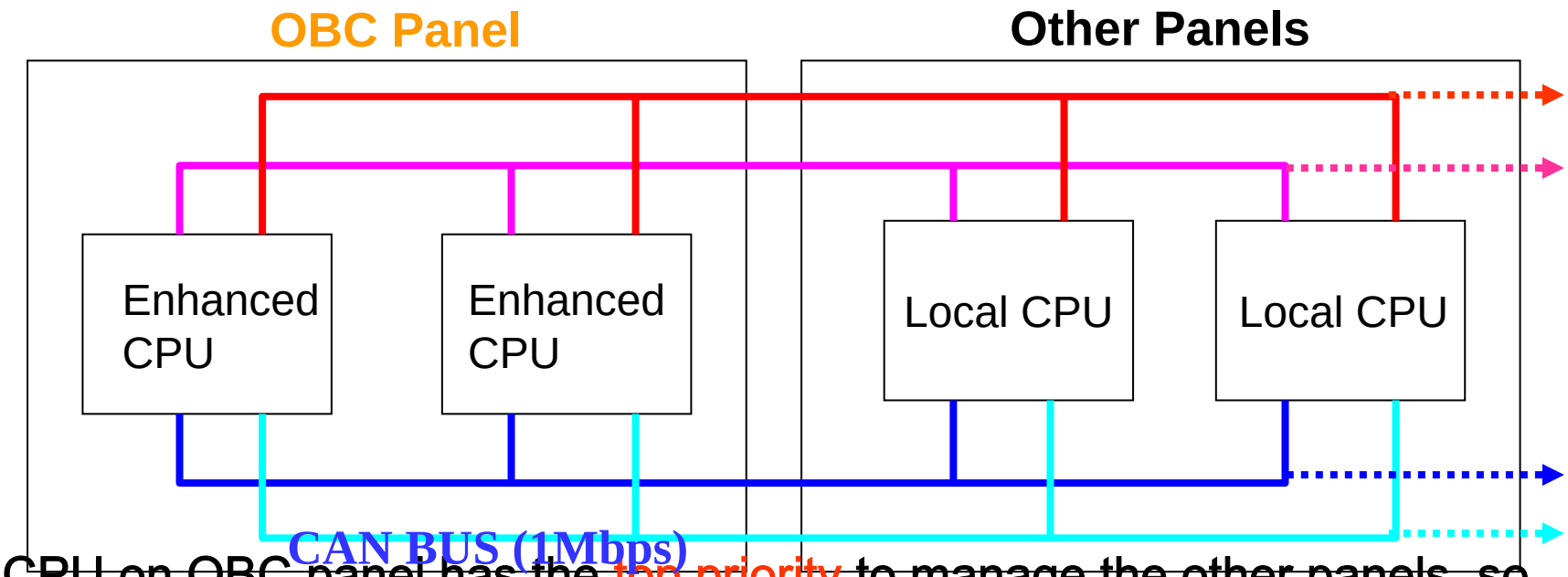
Information Architecture for PETSAT

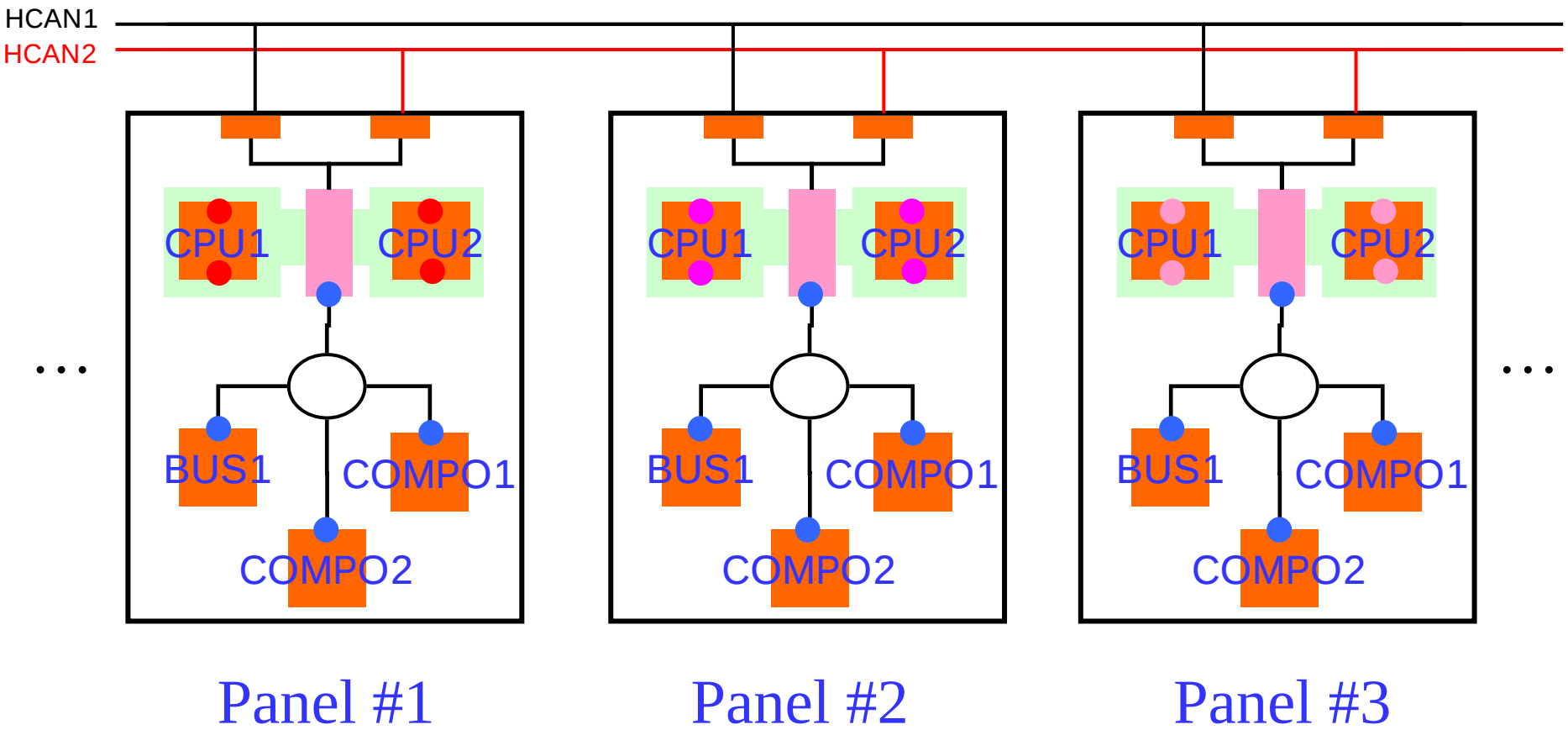


- CPU on OBC panel has the top priority to manage the other panels, so should be the most fault tolerant. In case of OBC panel failure, one of the other CPUs take over the manager's role.
- Distributed computing is made in case large calculation is required

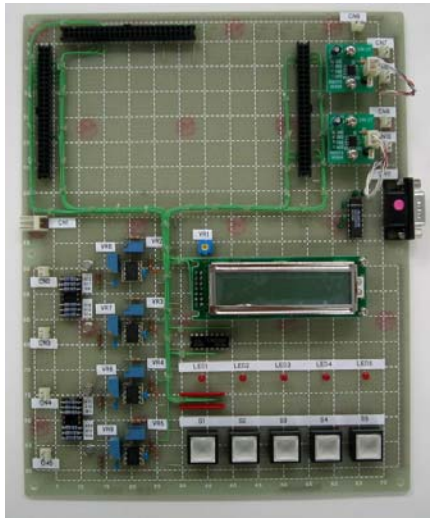
Power Line-1 — Bus line-1

Power Line-2 — Bus line-2

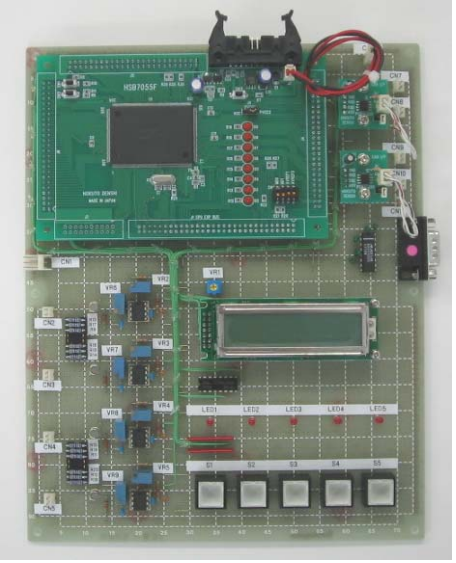
Concept of Information Flow



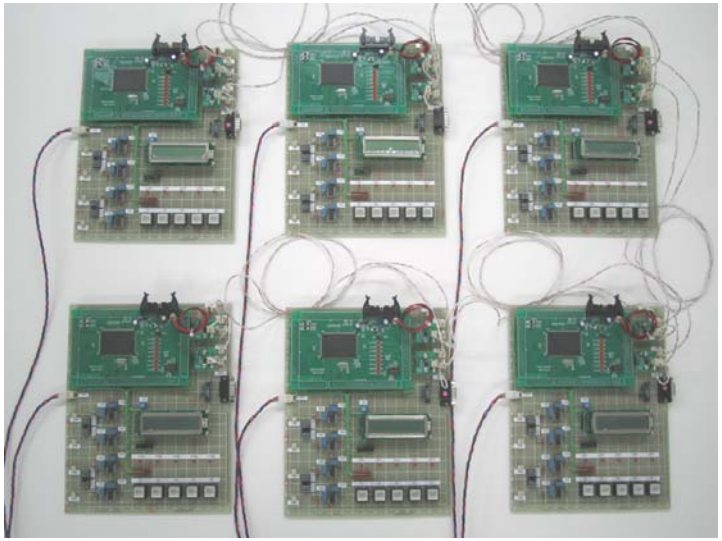
CAN Bus Test Board Development



CAN Bus Evaluation Board



With CPU Board and



Connected CAN Bus

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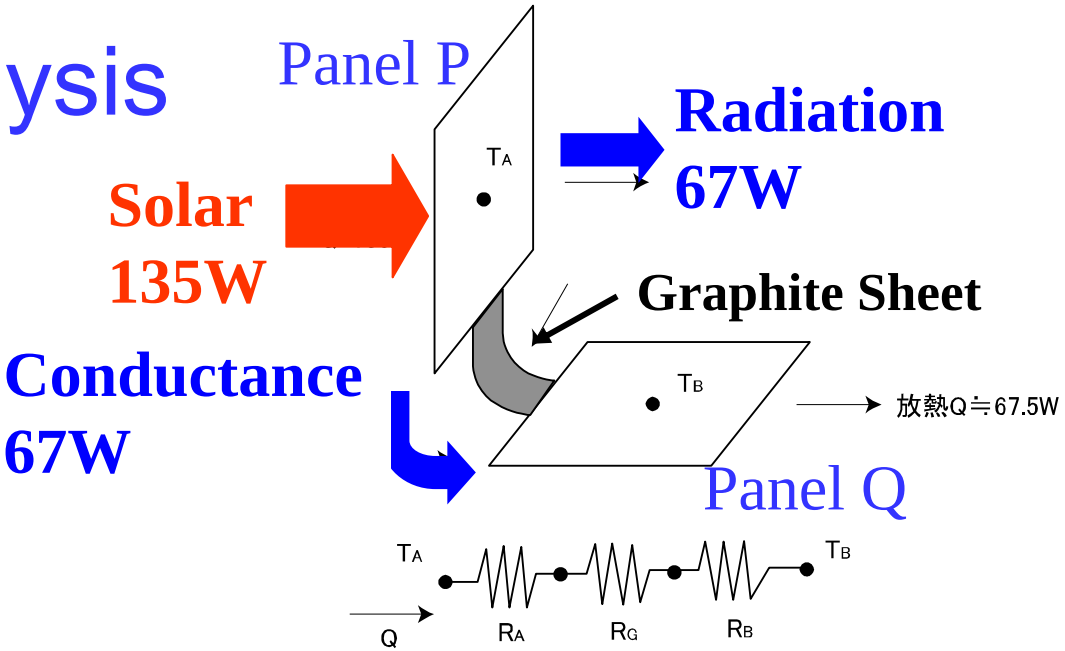
  - **Fault tolerance, grid computing**
- **Thermal Interface**
  - **Suppress temperature difference between/within panels (current target is less than 5 C deference)**

Worst Case Analysis

Solar heat insertion on one panel and no solar power insertion on the neighbouring panel (90°bent)



5 degree deference can be achieved using:

Inter-panel heat transfer: “Graphite Sheet” because of its flexibility

Intra-panel heat transfer: ”Heat Lane Plate” because of its high heat conductivity

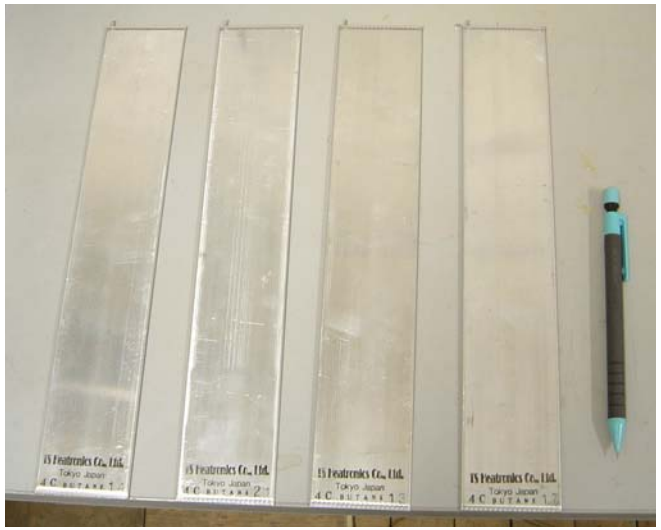
To Improve Heat Transfer

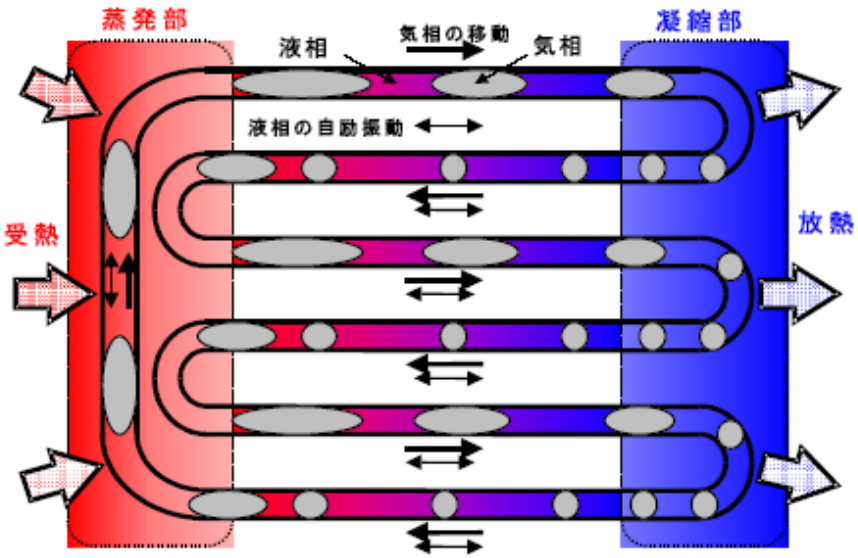
“Heat Lane Plate”

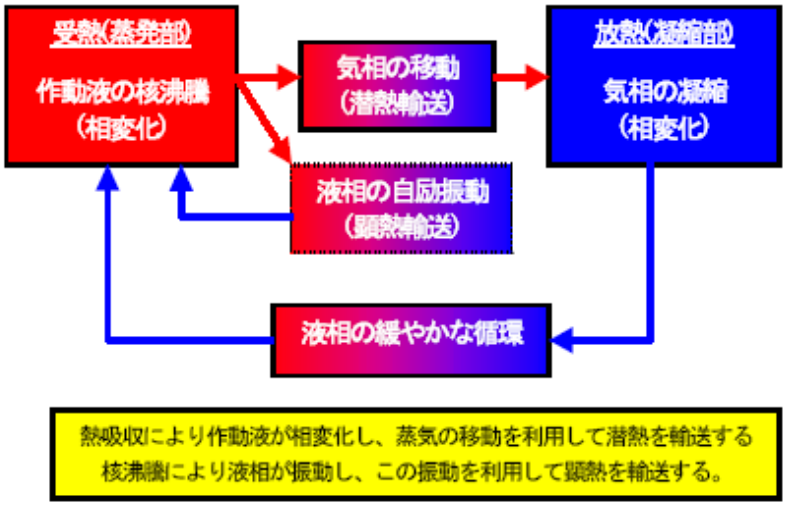
Heat Conductance Capability

$$2.96\times10^{6}(W/m^{2})$$

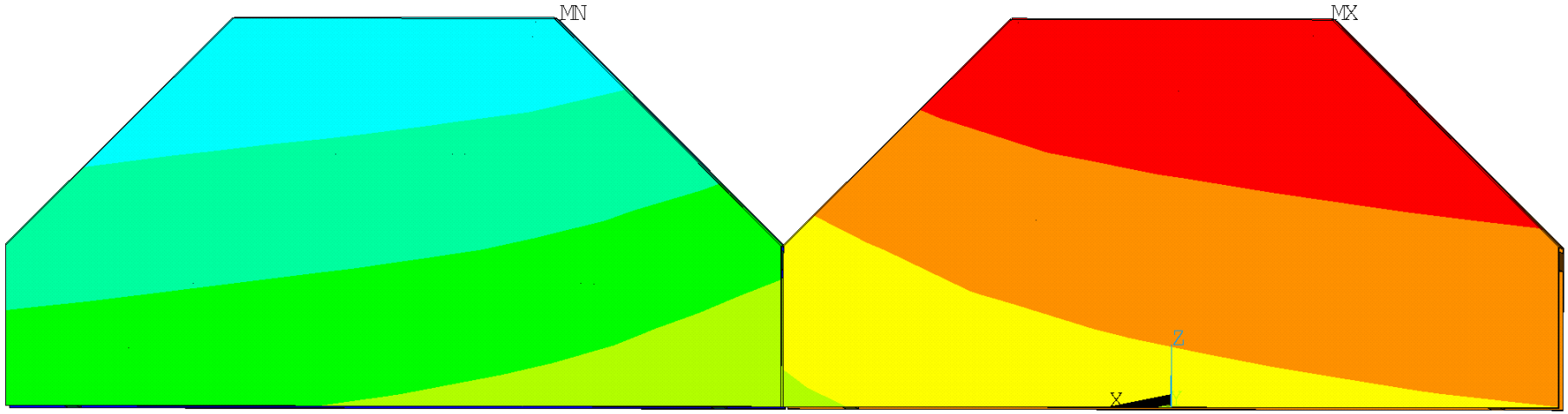
fi1#Judsklwh#Vkhhw#;33Z 2p 5N







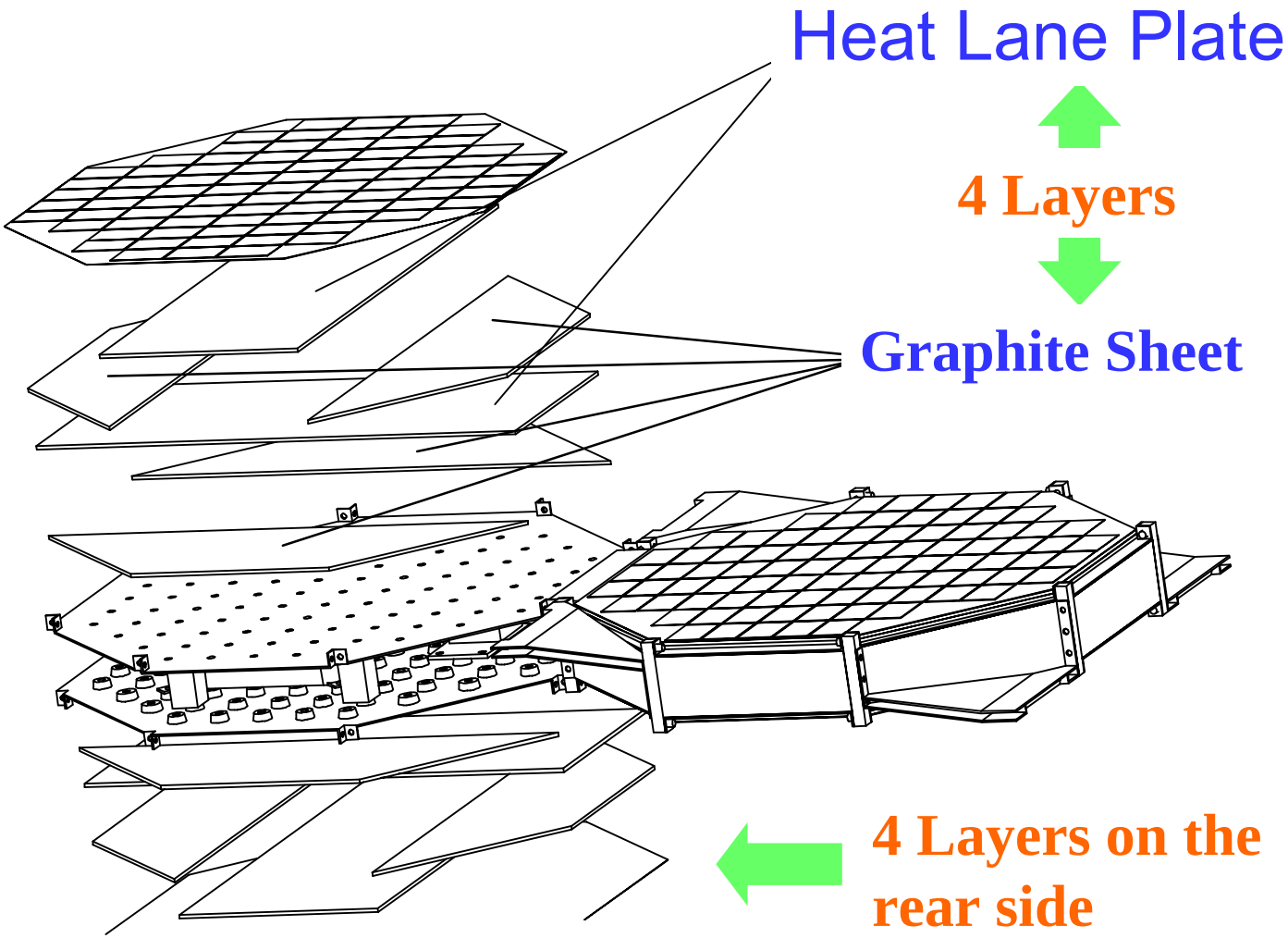
Thermal Simulation Results for Worst Case



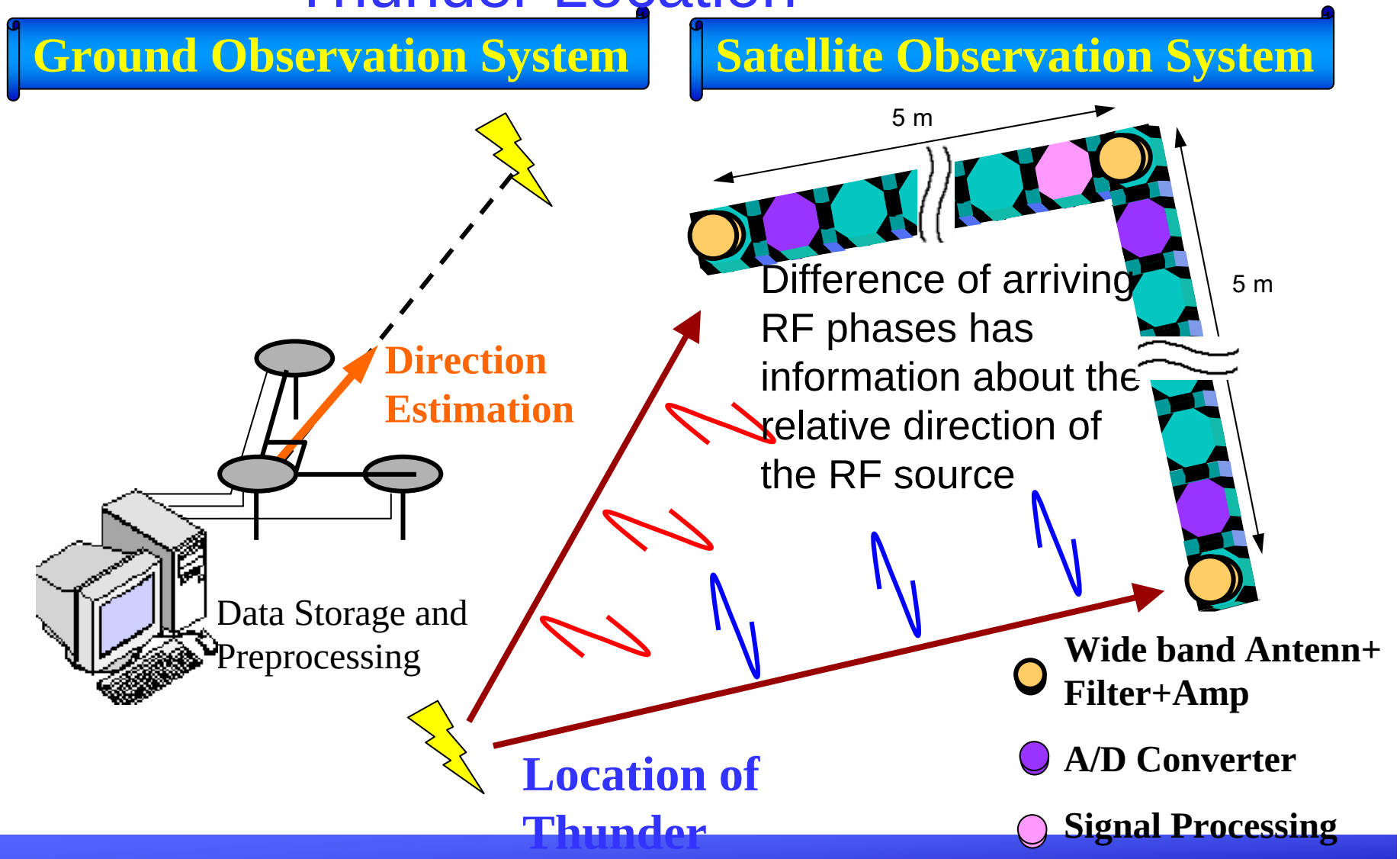
Sun Shining Side

22℃ 26℃ 30℃ 34℃

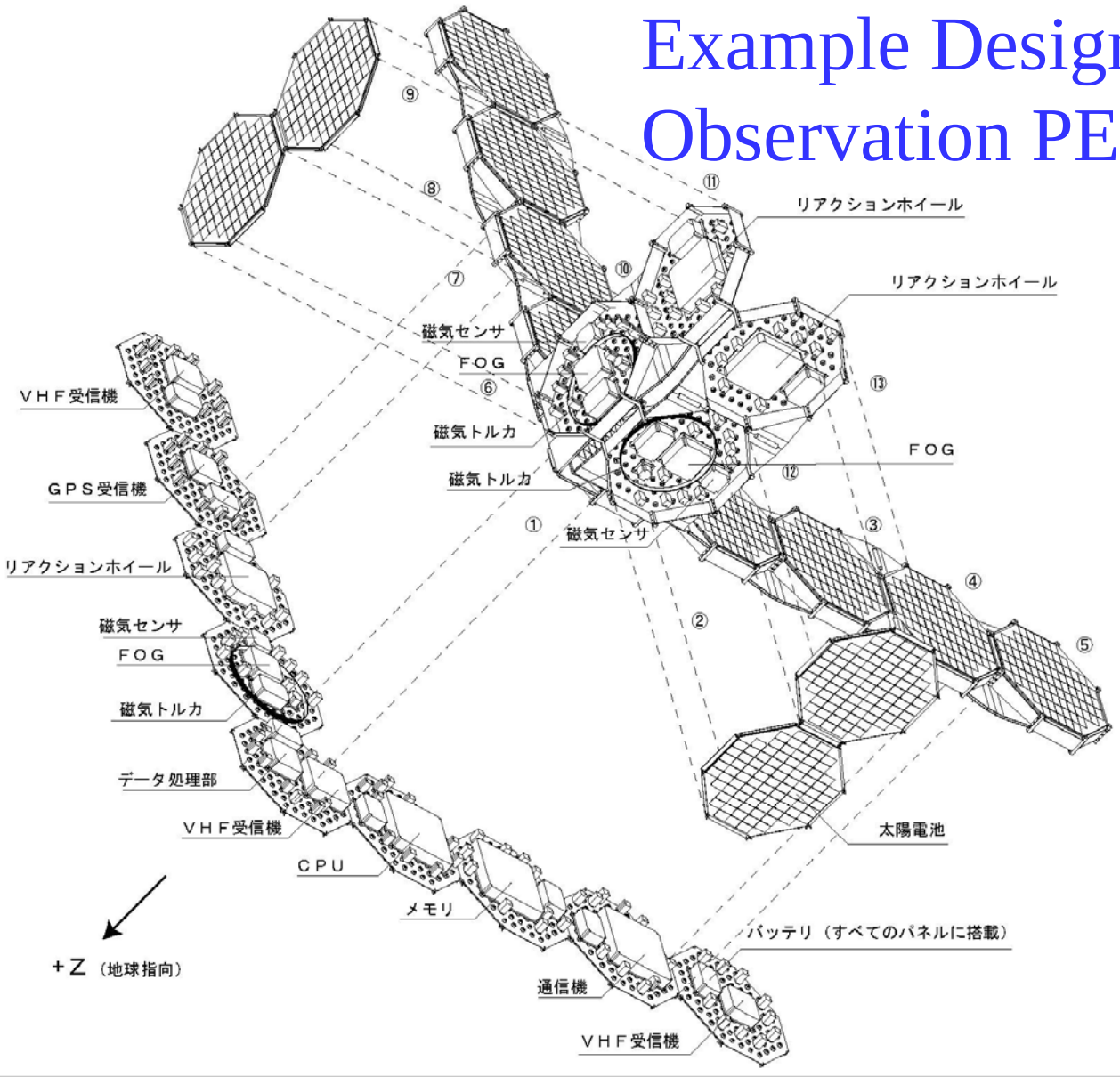
Heart Conductance Plan



Example Application of PETSAT (1)
- Thunder Location -



Example Design of Thunder Observation PETSAT



	バッテリ	ALL	13	0.3
	GPS	8	1	0.5
	リアクションホイール	7,11,13	3	1.7
	FOG	6,10,12	3	0.5
	磁気センサ	6,10,12	3	0.3
	磁気トルカ	6,10,12	3	0.1
	通信機	4	1	1.5
	メモリ	3	1	1.5
	CPU	2	1	1.5
	VHF受信機	1,5,9	3	1.0
	名 称	個数Number	総数(台)	質量 (kg/個)

氏名	20310 野尻 悠太 20320 山本 貴也	製図	2004. 2. 17		
図名	機器コンポネント	尺度	1:5	投影法	三角法
		図番		単位	mm

Development Plan

- Funded by NEDO for 2003 ~ 2008
- Joint Project by SOHLA (Higashi-Osaka), Univ. of Tokyo, Osaka Univ., Otowa Denki
  - Combination of university's system engineering and small manufacturing company's special technologies
- SOHLA-1 (~ 2007)
- SOHLA-2 (~ 2009) for on-orbit test of PETSAT concept and panels

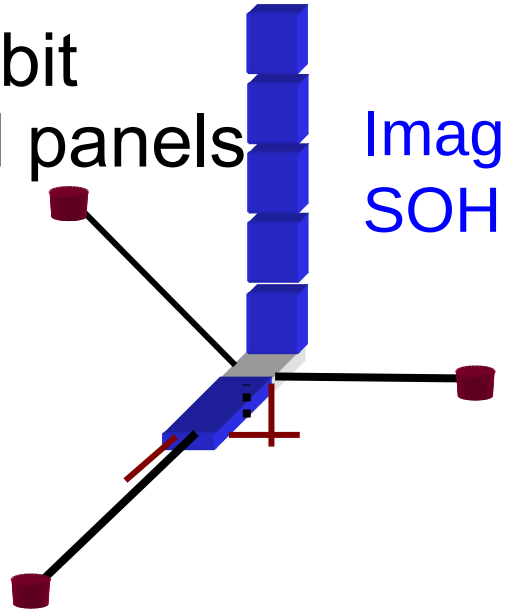


Image of SOHLA-2