2018 CubeSat Developers Workshop

# Development status of Software-Configurable Interface Board for 1U CubeSat

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# Focus of this work

- How do we reduce development time of CubeSat project?
- How to reduce workmanship error due to interface?

# BIRDS CubeSat Projects at Kyutech

## BIRDS-1


- Oct, 2015
- **Five 1U CubeSats**
- 15 students from 6 countries
- Deployed from ISS, July 7, 2017
- Operational phase

## BIRDS-2


- Oct, 2016
- **Three 1U CubeSats**
- 10 students from 4 countries
- Will be deployed from ISS, 2018
- Waiting for launch

## BIRDS-3


- Oct, 2017
- **Three 1U CubeSats**
- 7 students from 4 countries
- Will be deployed from ISS, 2019
- Development phase

*… learn the whole process of satellite development, foundation of sustainable space program and international human network to assist the infant space programs among each other.*

# BIRDS Bus system

## Interface

University of Wurzburg, Germany, 2013

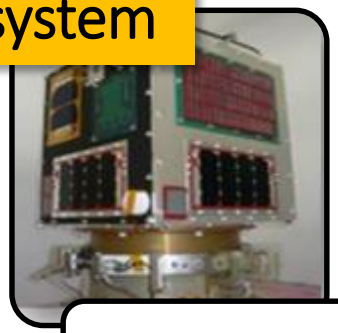
UWE -3 interface board

BIRDS-1
Interface board

## UNISEC Europe backplane interface

- Implemented entire harnesses on the PCB
- Plug in to interface board
- Easy to assemble and disassemble subsystem boards
- Smaller connectors
- Adaptable pin assignment

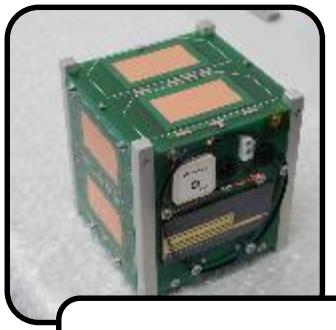
## Bus system



HORYU-2
May. 2012

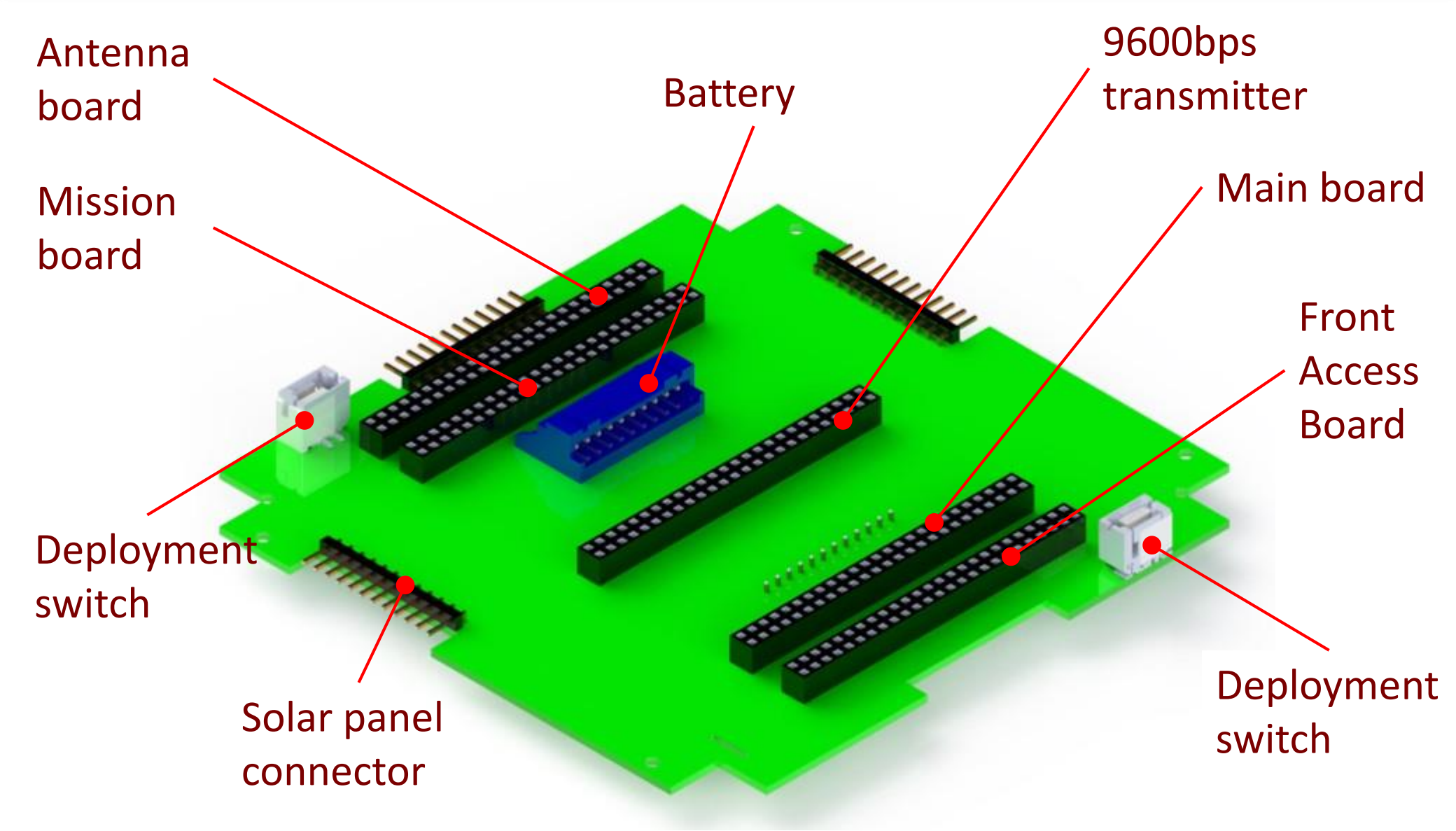
HORYU-4
Feb. 2016

BIRDS-1
June. 2017



BIRDS-2,
2018

# BIRDS-1 Backplane interface board



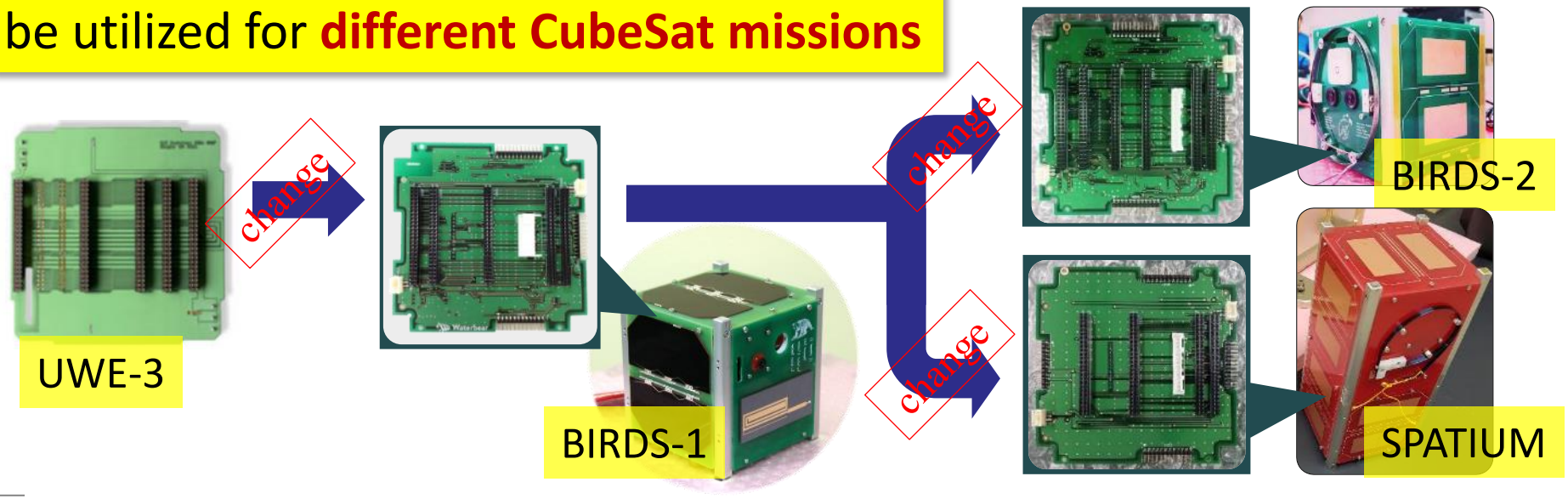
# Lessons learned from BIRDS

Different missions and payloads require different interface connection

| Number of connection changed on backplane | Not modified | Added and removed | Final connections |
|---|---|---|---|
| BIRDS-1 from UWE 3 | 82 | 216 | 109 |
| BIRDS-2 from BIRDS-1 | 81 | 55 | 114 |
| SPATIUM from BIRDS-1 | 22 | 126 | 61 |

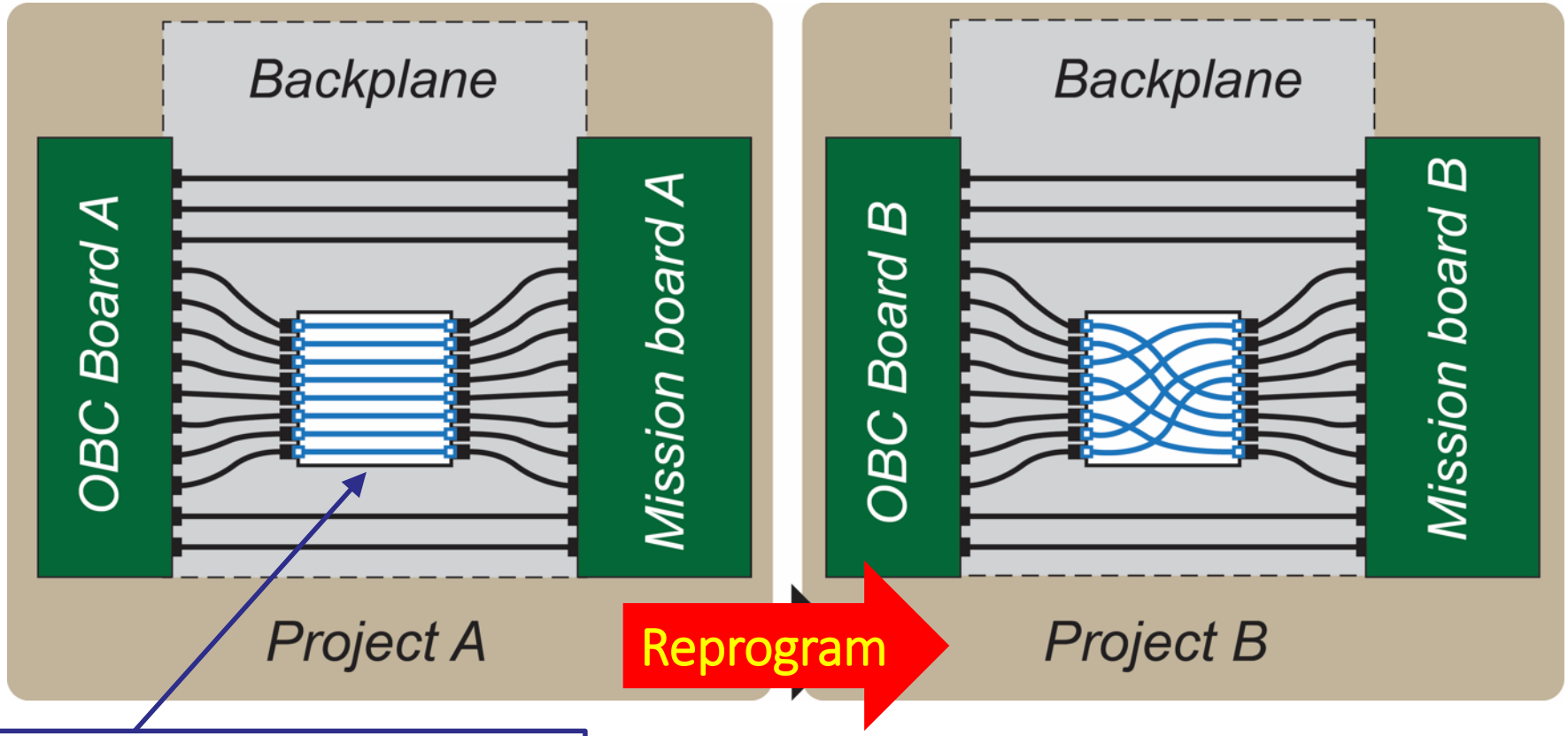
*Connections – routing on the PCB*

We need very **high flexibility** which could be utilized for **different CubeSat missions**



# Software Configurable Interface Board (SoftCIB)

## Concept of SoftCIB - Hardware and Software Codesign



# SoftCIB

## Merits

- ❑ No Harnesses and easy to assemble/disassemble
- ❑ No need to develop new interface board for every CubeSat mission
  - ❑ One design can be used for many different mission (Design changes always takes time)
- ❑ Interface defined by software
  - ❑ Any modification or changes with most of the digital signal line can be done in **one hour** or **less**
- ❑ There is no difficulties with software (simple)

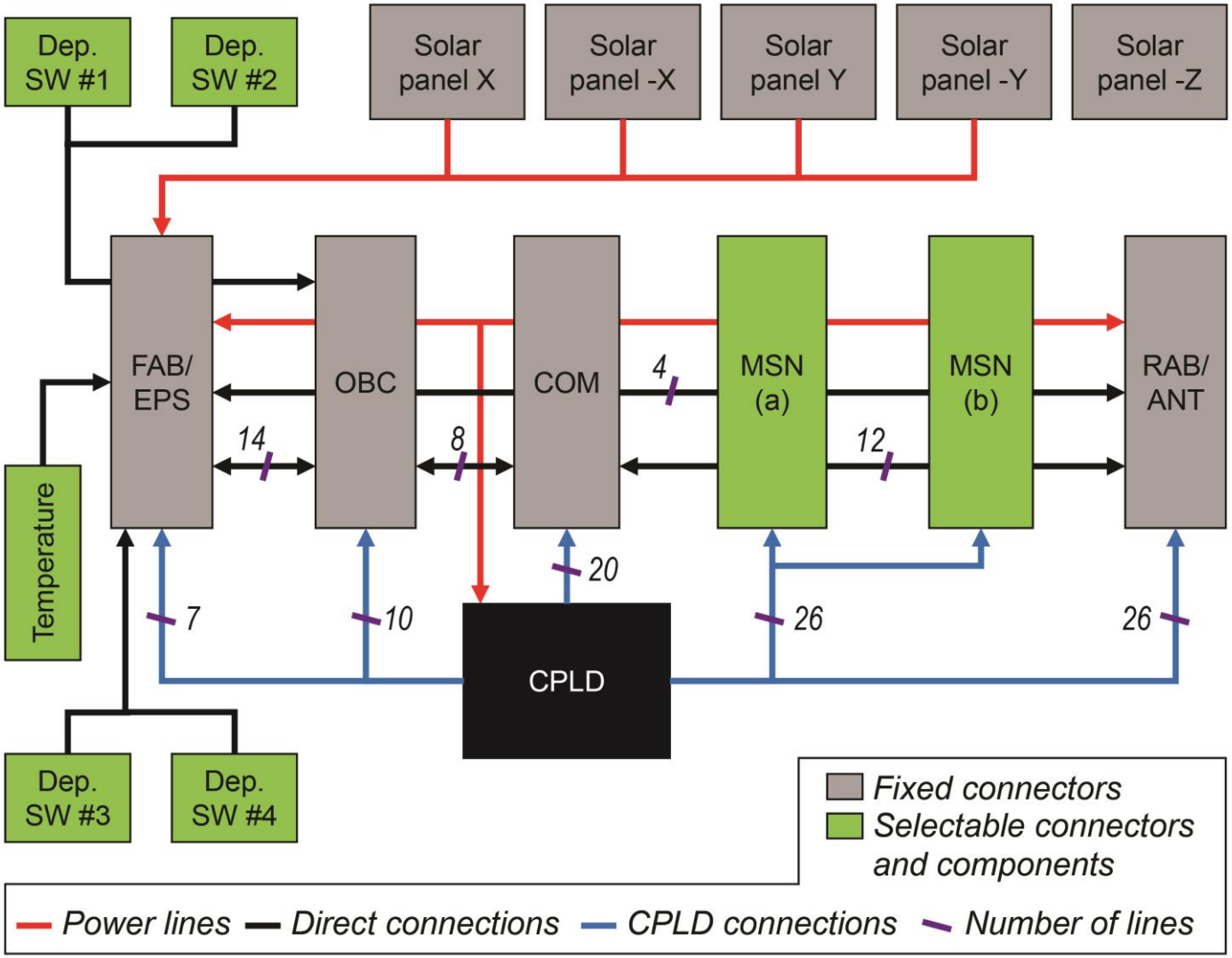
## Demerits

- ❑ Active semiconductor device operating on the interface board
  - ❑ Power consumption
  - ❑ Risks due to space environment (Radiation and Thermal)

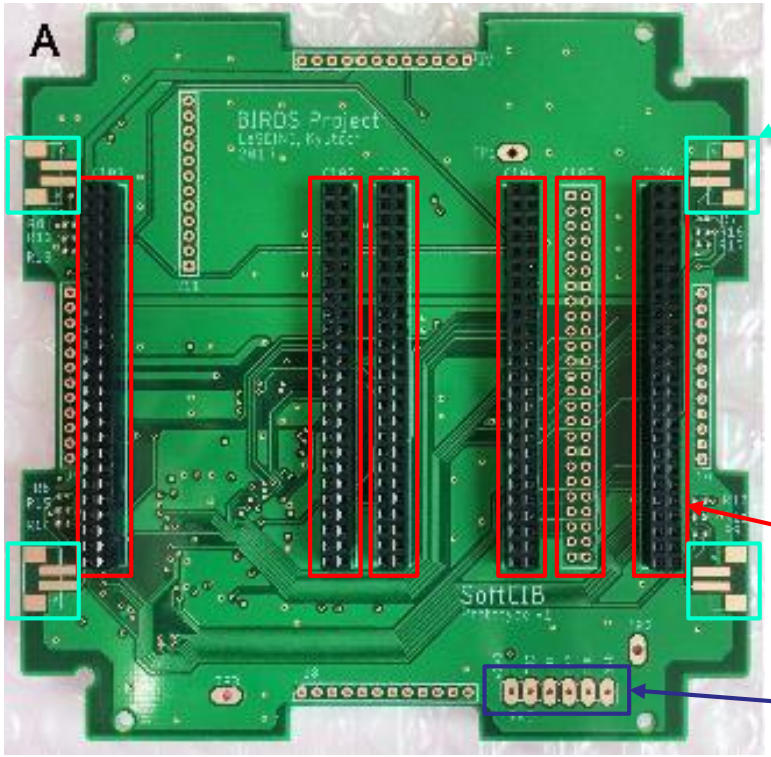
# Design Requirements for SoftCIB

- Main device shall be **Programmable logic Device** (i.e., FPGA or CPLD)
- Maximum **power consumption** shall be less than **200mW**
- Mechanical design similar to 1U CubeSats of BIRDS-1
- Same **50 pin connectors** shall be used for subsystem connectors
- Shall have minimum number of **permanent hardware connection** for critical connection
- **Power lines** shall be handled by **permanent hardware** connection

# SoftCIB – Block diagram



# Prototype board

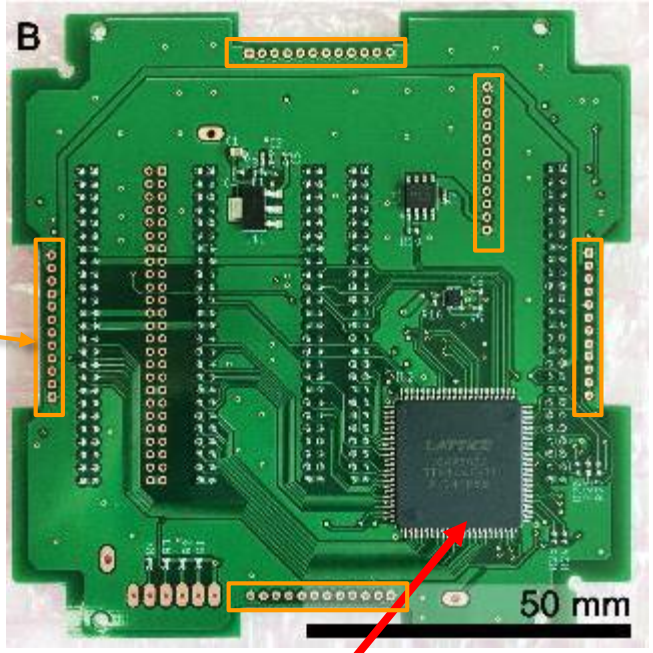



Deployment Switch connectors

Solar Panel Connectors

50 pin connectors

JTAG

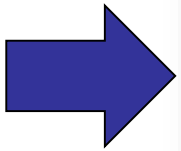



*CPLD: IspMACH4256ZE*
*Lattice Semiconductor*

- Functional tests have done and no failure or malfunction recorded
- Total power consumption during the test was **27mW** to **36mW**

# Simplest software in VHDL

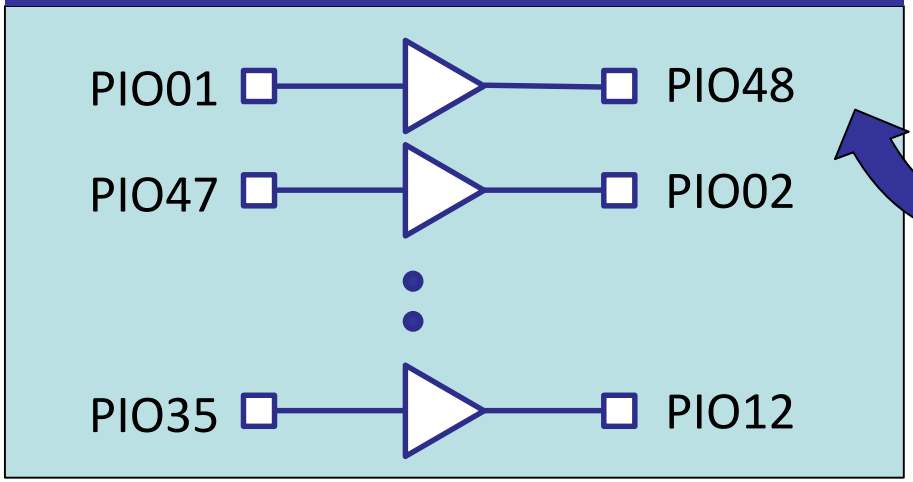
*Interface Control Document (ICD) defined CubeSat Project members*



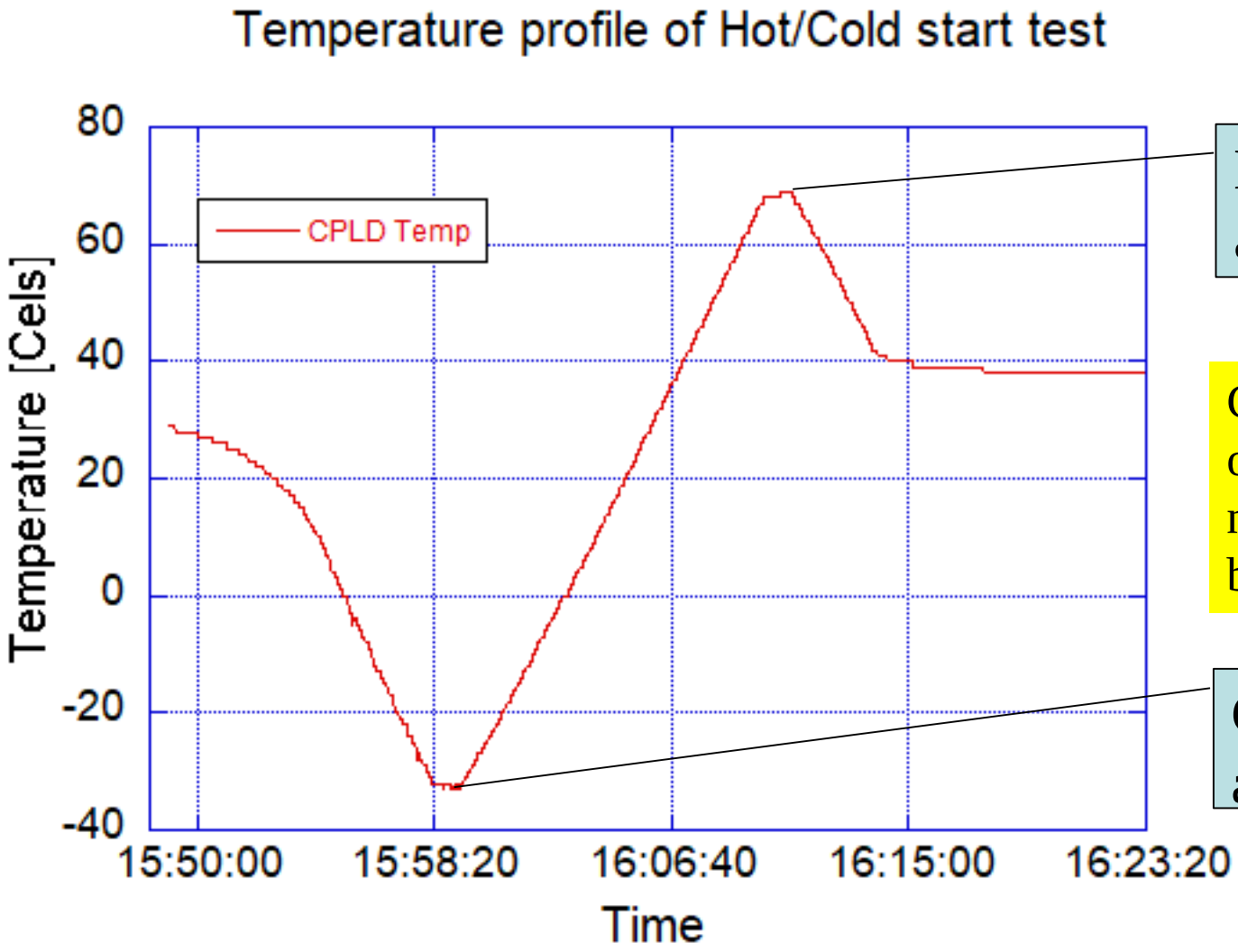
```
architecture Behavioral of bb_prototype_v1 is

begin

        PIO48 <=  PIO01 ;
        PIO02 <=  PIO47 ;
        PIO46 <=  PIO03 ;
        PIO45 <=  PIO04 ;
        PIO44 <=  PIO05 ;
        PIO43 <=  PIO06 ;
        PIO34 <=  PIO17 ;
        PIO33 <=  PIO19 ;
        PIO32 <=  PIO18 ;
        PIO23 <=  PIO31 ;
        PIO30 <=  PIO20 ;
        PIO42 <=  PIO07 ;
        PIO41 <=  PIO08 ;
        PIO40 <=  PIO09 ;
        PIO29 <=  PIO39 ;
        PIO10 <=  PIO13 ;
        PIO22 <=  PIO11 ;
        PIO28 <=  PIO38 ;
        PIO27 <=  PIO37 ;
        PIO26 <=  PIO36 ;
        PIO12 <=  PIO35 ;

end Behavioral;
```

Example of VHDL program

Equivalent circuit with Main program



# Hot/Cold start




Hot start at 69 ºC

CPLD start & operate normally at both condition

Cold start at -34ºC

# TID Radiation test & result

Test criteria, condition:

- CPLD shall survive at level of TID defined by ISO 19683:2017 standard

Estimated radiation dose

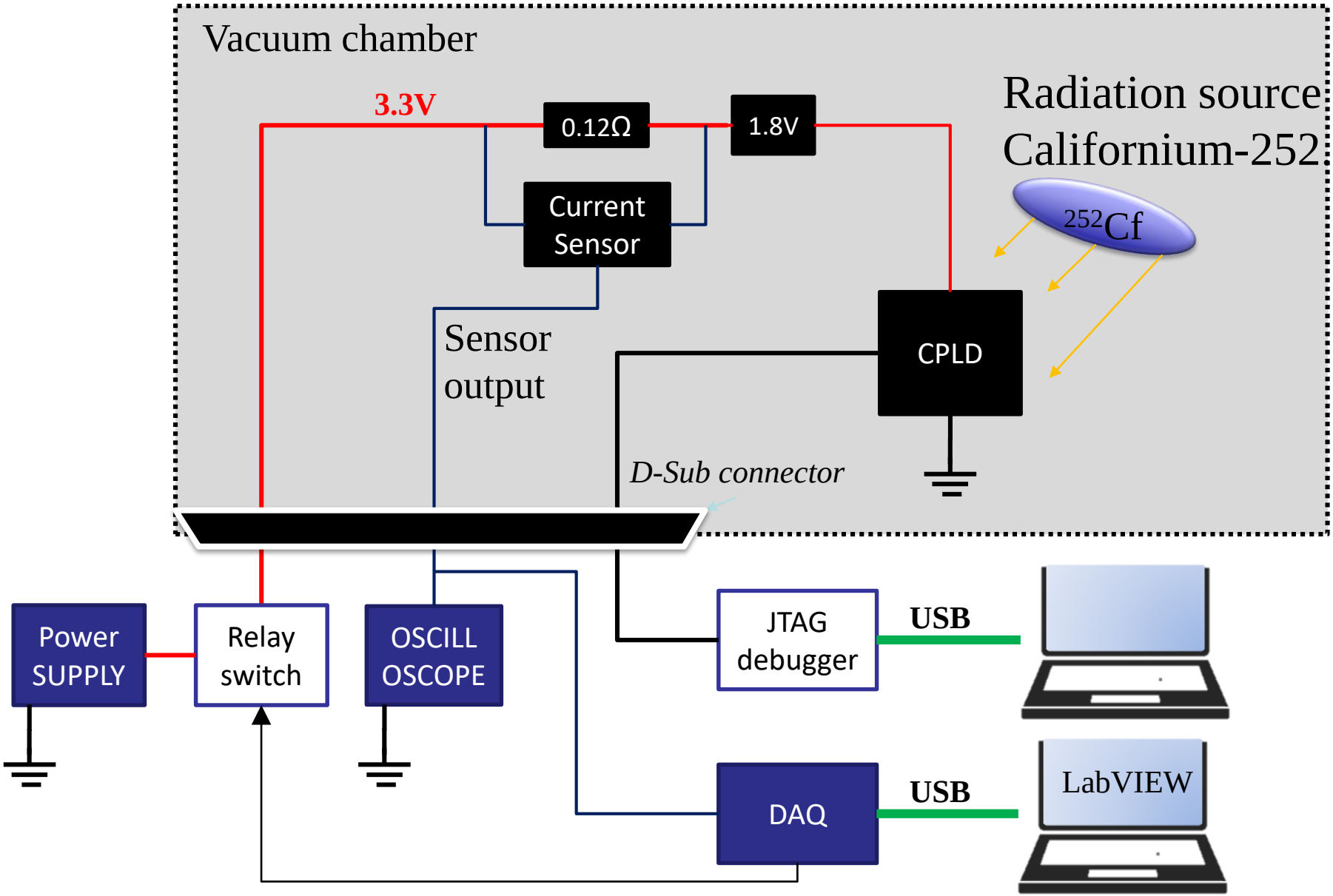
| Test article LC4256ZE7TN144I | Distance from the radiation source (cm) | Radiation dose (krad) |
|---|---|---|
| Sample 1 | 65 | **30** |
| Sample 2 | 120 | **10 (requirement)** |
| Sample 3 | 180 | **5** |
| **Test site** | **Center for Accelerator and Beam Applied Science, Kyushu University** | |
| **Radiation source** | **Cobalt-60** | |

- All CPLDs operated normally under radiation during the test (up to 30krad)

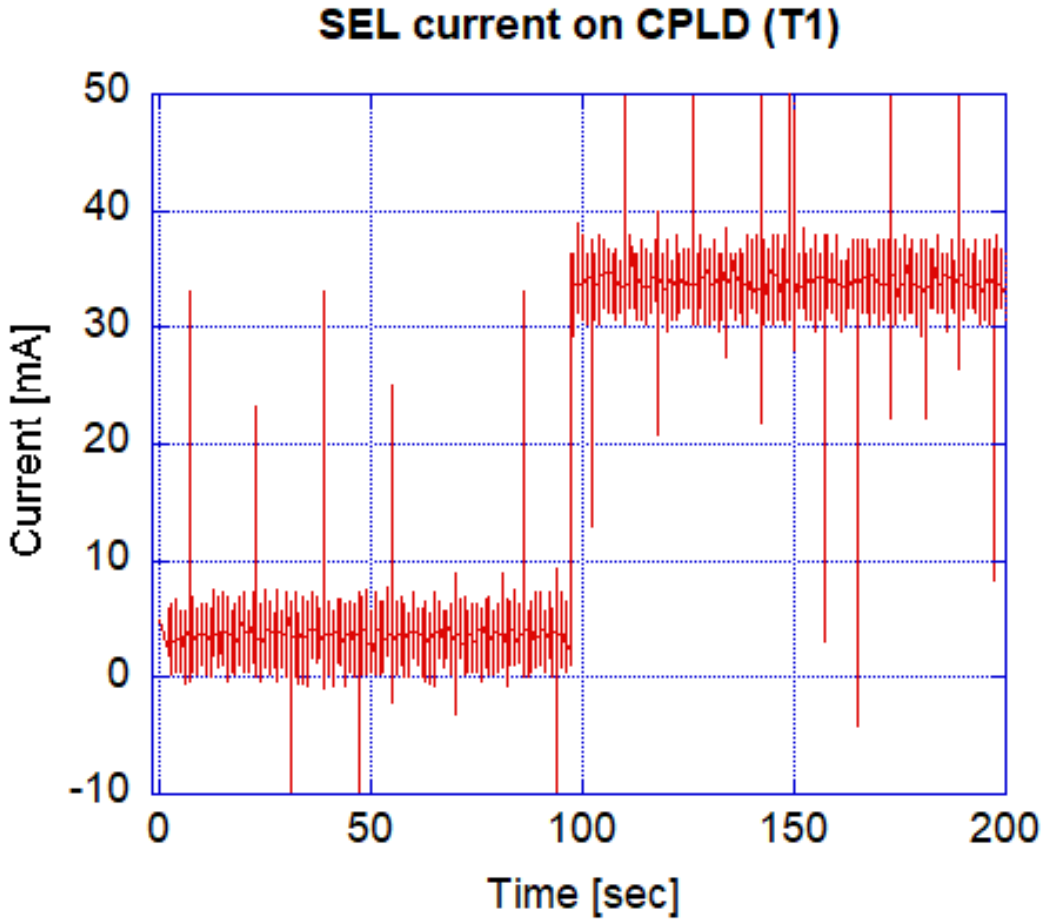
# SEE test for CPLD

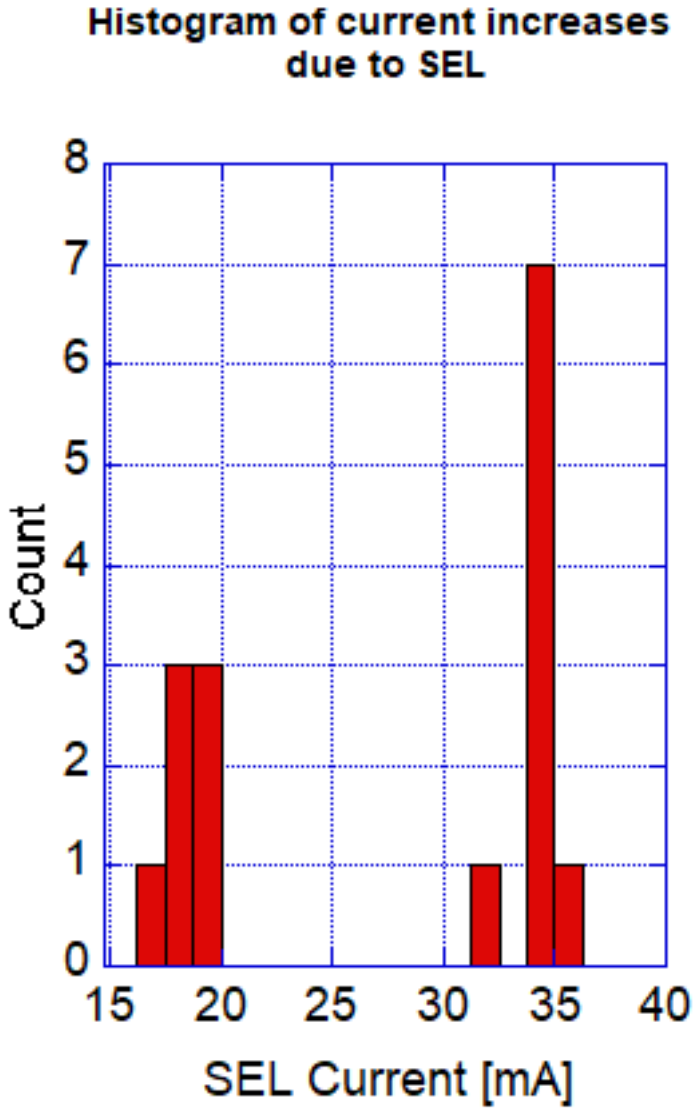
- Test purpose:
  - Detect SEL by current measurement
  - Observe SEU by bit changes in EEPROM
  - Study a behavior of SEL current
- Test article:
  - Lattice ispMACH4000ZE family - LC4256ZE7TN144I
  - Plastic package need to be removed
  - Total four samples were tested (all CPLDs are from lot).
- Testing Facility:
  - Kyoto University Research Reactor Institute
- Radiation source:
  - Heavy ions from californium-252 ($^{252}Cf$)

# Test setup for SEE



# Result of SEL test (2/3)



# Conclusions

- Software Configurable Interface Board (SoftCIB) is introduced and validated
- BBM and Prototype boards were developed to verify the design requirements, and number of tests were carried out.
- Based on test result, selected CPLD have enough strength against TID in LEO.
- SEE Radiation test for CPLD were carried out. Power reset will be needed to recover from SEL state, however SEL current increases were not severe
- One of the BIRDS-3 CubeSat will demonstrate SoftCIB in orbit. On orbit results will be compared with other two satellites of BIRDS-3.

# Thank you for your attention!

*The results have been supported by "**World-Class Space Human Resource Development via International Collaboration Work on Satellite Project**", the Ministry of Education, Culture, Sports, Science and Technology (MEXT), JAPAN.*

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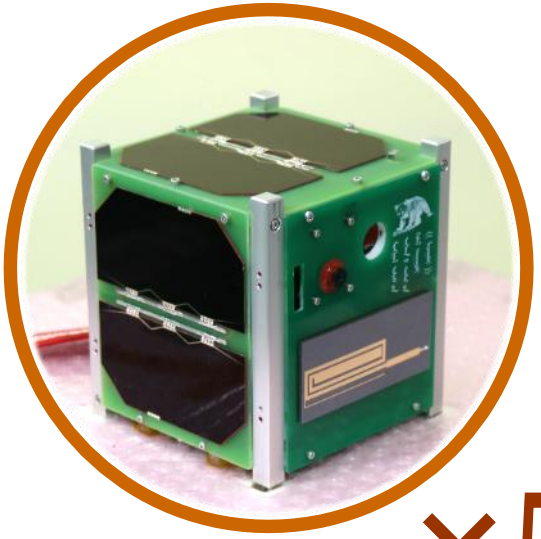
Kyushu Institute of Technology

# Appendix

# BIRDS-1 (Joint Global Multi-Nation Birds)



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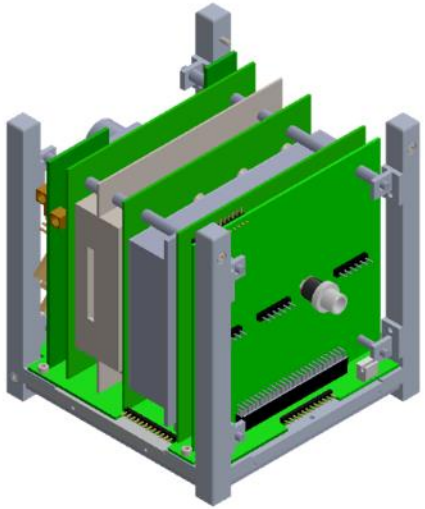


## Missions

- Taking photograph of homeland (CAM)
- Digi-singer, song exchange (SNG)
- Single Event Latch-up measurement (SEL)
- Determination of Satellite Precise Location (POS) without GPS
- Atmospheric Density Measurement (ATM)
- Demonstration of Ground Station Network for CubeSat Constellation (NET)

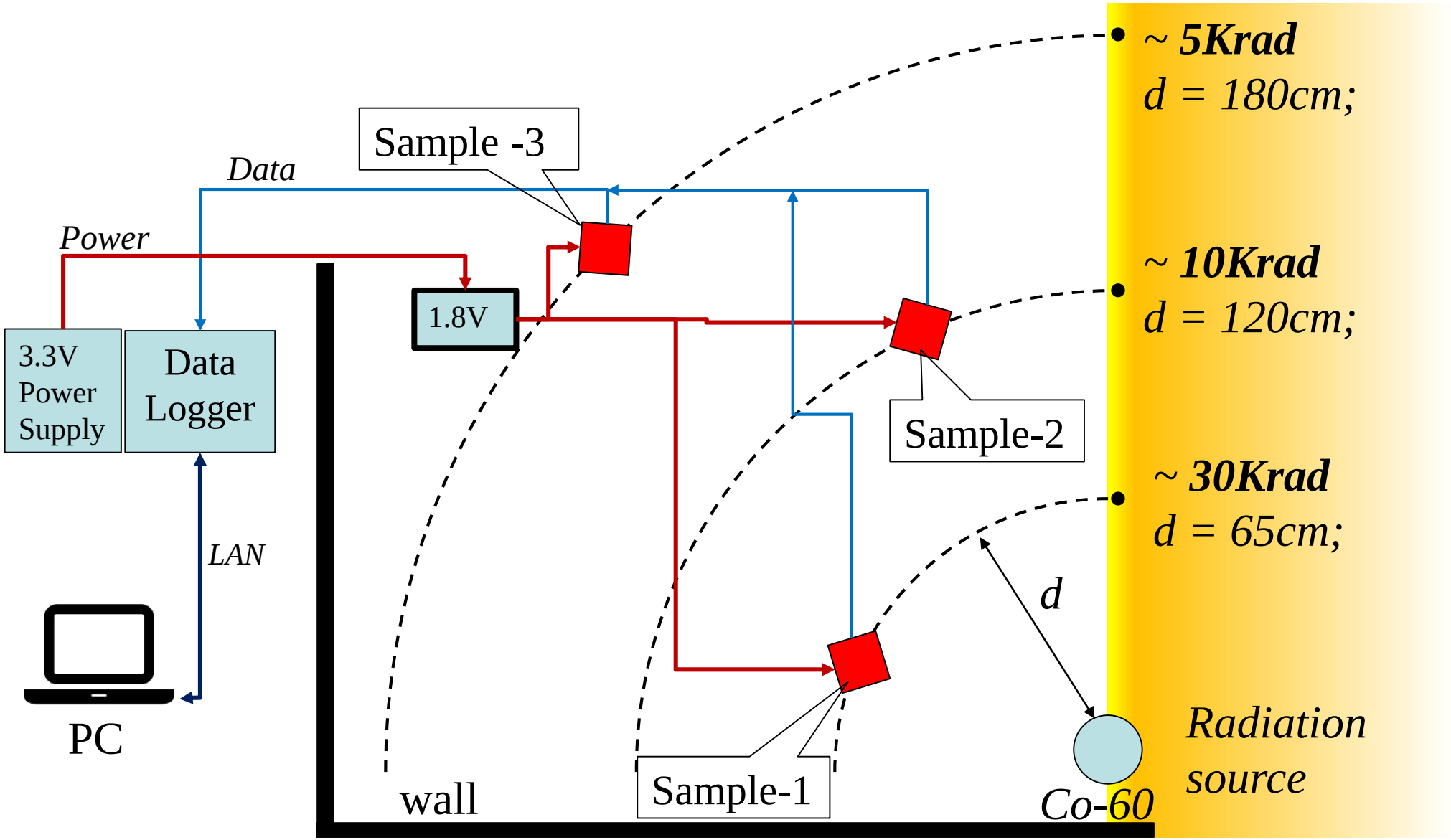
## Features

- Constellation of **five (5) identical** 1U CubeSat
- **Share same frequency** for TM & TC (UHF/VHF)
- **Less harness** design using **Backplane** style introduced by UWE-3

# Lessons learned from BIRDS-1 and BIRDS-2 interface design

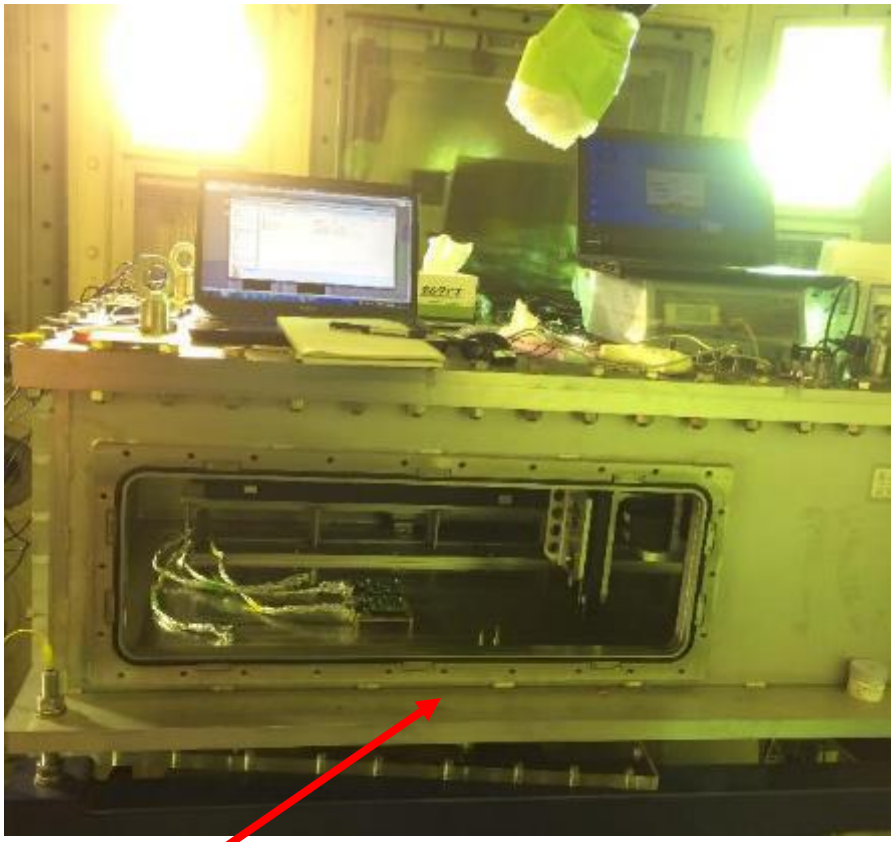
- Less demand for changing power lines (3.3V, 5V, Unregulated Voltage)
- High demand of changing digital signal connections (electrical)
- High demand for changing position of the connectors (physical)
- Reducing harnesses by using PCB is good trend (contributed to control quality)
- Easy to integrate and disintegrate the module boards
  - Structure design may affect to easiness of Assembly and Disassembly.

# TID Radiation test setup

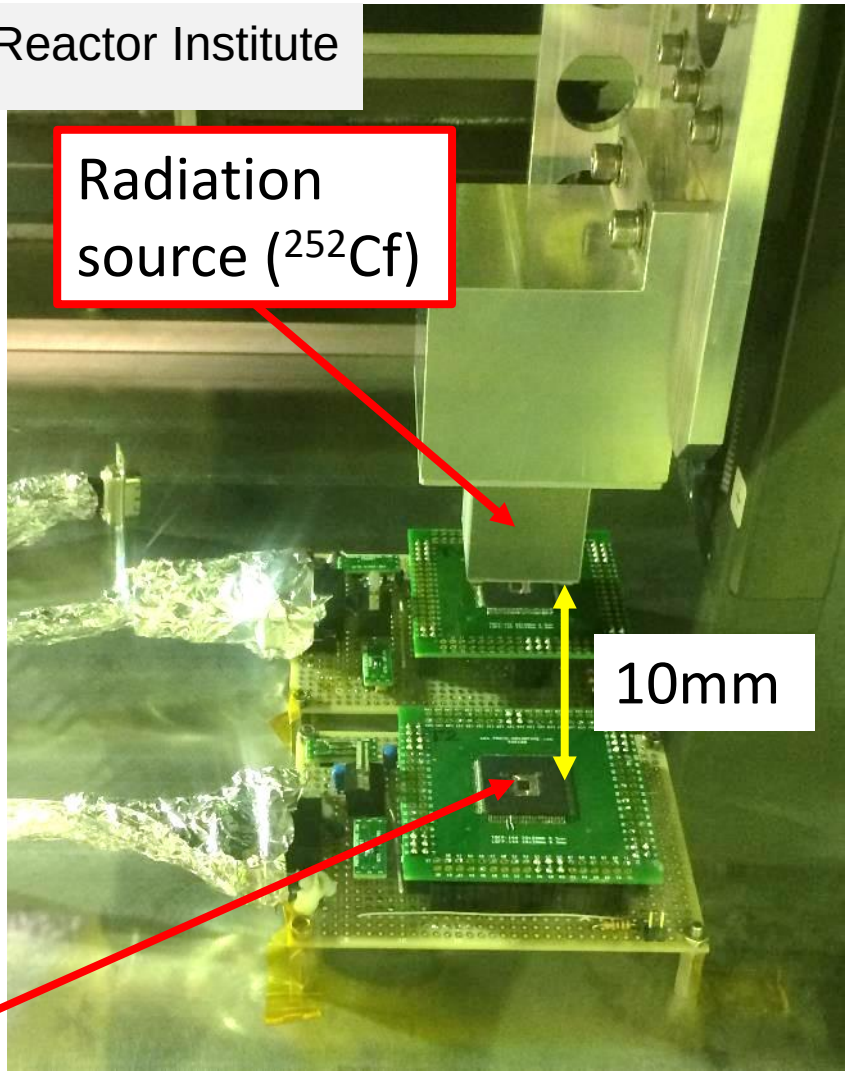


# SEE radiation test setup

Testing Facility: Kyoto University Research Reactor Institute



Test Chamber




Test Article

# Result of SEL test (3/3)

- Current increase due to SEL is observed
- In total 16 event were observed for four samples
- Current change was 13mA to 30mA
- Current became normal after power reset
- No SEU observed for all four CPLD.

| | |
|---|---|
| Number of data | 16 |
| Mean SEL occurrence time(sec) | 996.3 |
| Standard deviation | 915.4 |
| Max (sec) | 3540 |
| Min (sec) | 47 |