Hardware and Software Modularized Approach for On-board Processing Capabilities of Small Satellites

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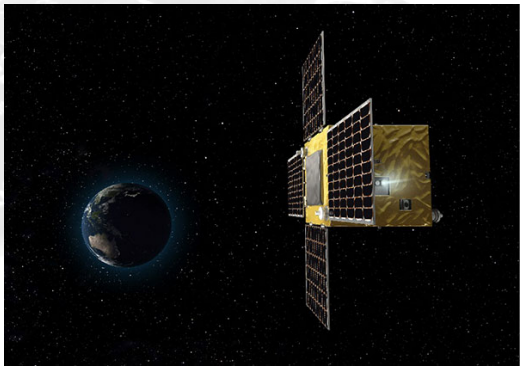
Requirement for the On-orbit Intelligence

- Utilization of small satellites urgently increasing, due to their advantage in cost and schedule.
- According to utilization diverge, the mission of small satellites become more complicated, and the requirement of on-board intelligence is rapidly increasing.
- Therefore small satellites expected be more intelligent in limited cost.



PROCYON: Deep Space Inspector using micro satellite

Complex Missions in Low Cost

- On-orbit intelligence improvement is important to realize many complicated missions
  - Utilization of small satellite diverge
  - Complexity of on-board function and architecincreases
    - A lot of functions to be developed and tested
  - Sure operation and high reliability
  - Cost and load should be kept in low to keep advantage of small satellites

Not only high performance but also high productivity and reliability is required for the on-board computer system

High Performance On-board Computer System

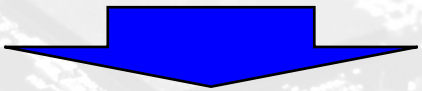
- To realize drastic improvement of on-board intelligence, we have developed high-performance on-board computers using SOI-SOC technologies.
- The SOI-SOC computers are successfully demonstrated in missions, such as Hodoyoshi-3 and expanding its possibilities in various missions

SOI(Silicon on Insulator) CPU OBC

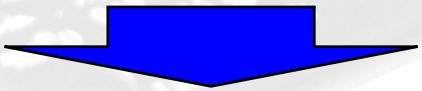
Size	156×153×85.5mm
Weight	1.62kg
Power	10W
Interfces	SpW, RS422 UART
	SPI, GPIO, Active Analog
	Passive Analog

Key Points to Increase Productivity and Reliability in Software

- Software is highly depending on missions and architectures
- Developed mission by mission



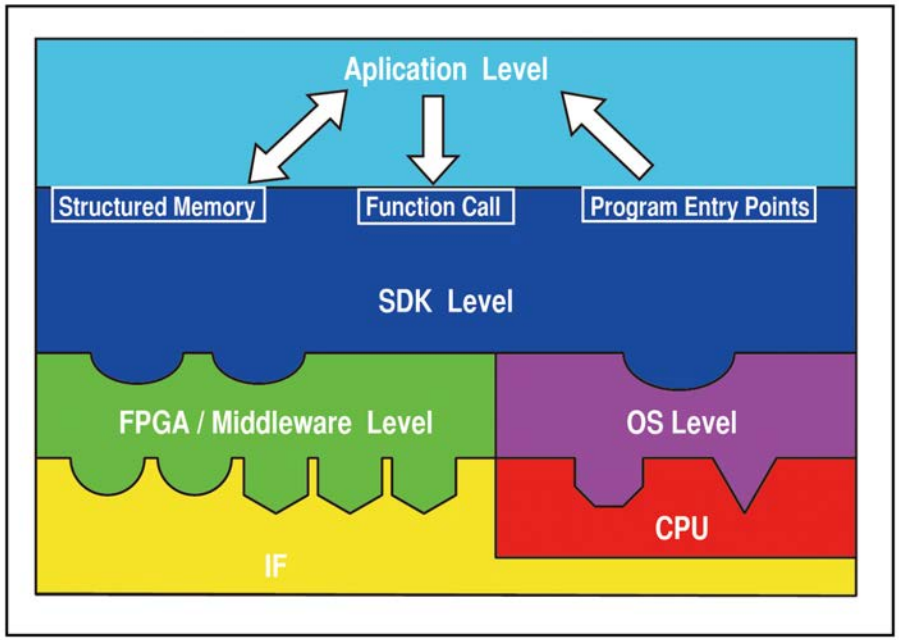
- Key Point to Increase Productivity and Reliability in Software: Recursive Utilization
  - Development work load can be decreased
  - Increases reliabilities of software



- Software development framework to compensate variation of missions and architectures

Modularization of Software Resource and Recursive Utilization

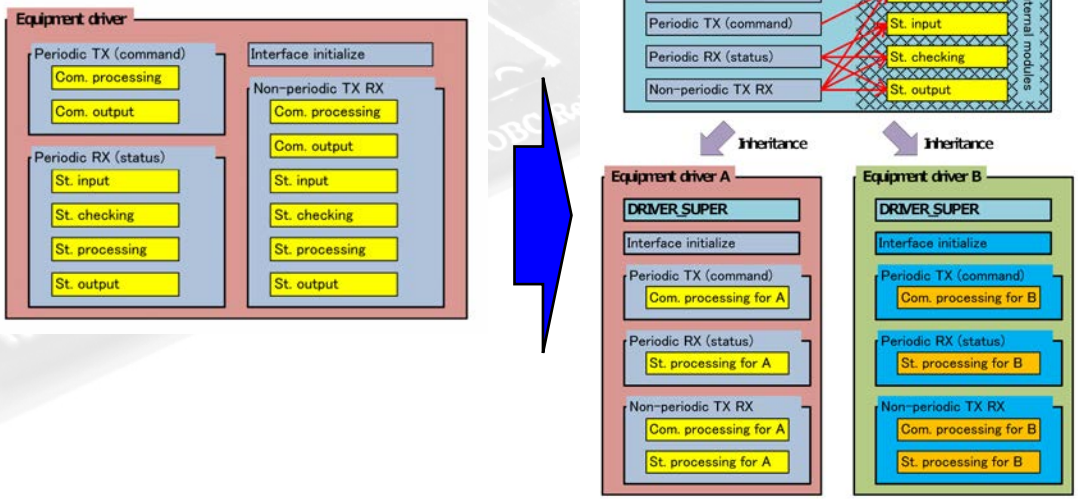
- At a glance, on-board software is highly depending on the satellite structure, platform and missions.
- It is barrier for recursive utilization.
- So, we distinguish hardware dependent part from on-board software and adopt software framework to wrap up the hardware dependency.
- Based on such framework the software can be utilized across the hardware platform.



Class Structure

- Using such framework, we can find the similarity in the each software fragments.
- We categorized such software fragment into class libraries to enhance recursive utilize of software fragments.
- Such class structure is quite effective not only to acquire reliability but also to reduce programing load

Hodoyoshi SDK

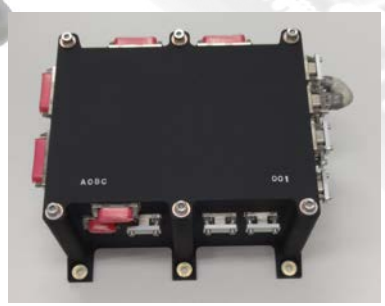


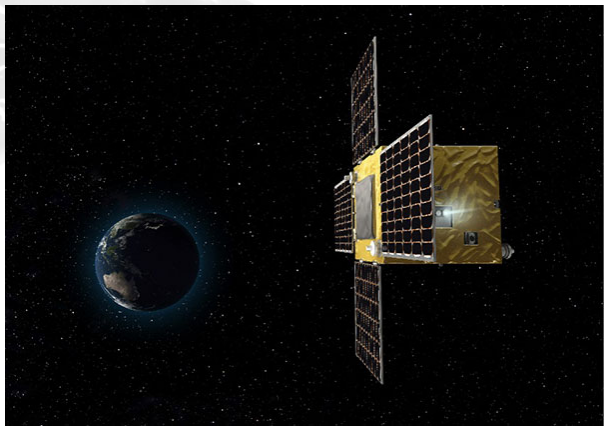
Demonstration and Utilization of Hodoyoshi SDK Framework

Hodoyoshi SDK framework is successfully utilized and demonstrated in following missions

- **Hodoyoshi Satellite-3 and 4, UNIFORM PROCYON**

Plan to be utilized in MicroDragon



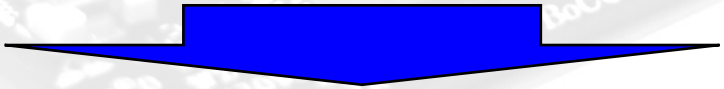


Good News and Bad News

- Good news:
  - Possible users for Hodoyoshi SDK are emerged, and they expect to utilize Hodoyoshi SDK for various missions.
  - It is good opportunity to expand Hodoyoshi SDK and enhance its productivity and reliability .
- Bad news:
  - Variation is quite large not only in interfaces but also in satellite structures, such as CubeSat or MicroSat.
  - Mission resources are limited
    - Cost, size, weight, power.... etc.
  - Our manpower is also limited to develop multiple system

How to Overcome Difference of Hardware Architecture?

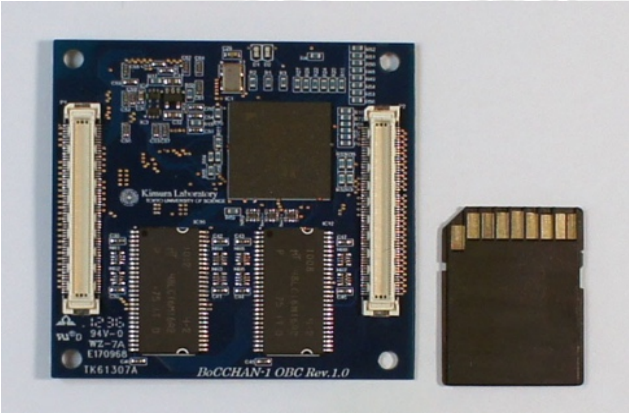
- To enhance merit of software recursive utilization, the software expected to utilized many cases and qualified various situation
- Hodoyoshi SDK can be adapt various satellite architectures, but its core structure is depending on CPU architecture.
  - such as operating system, time slice, processing performance, etc.



- How to enhance hardware recursive utilization in various class satellites

BoCCHAN-1
Low Cost Solution of Hodoyoshi-SDK

- Computer board using SH-4 processor.
- LINUX operating system.
- Rich interface capability
- Software compatible with SOI-SOC OBC based on Hodoyoshi SDK.



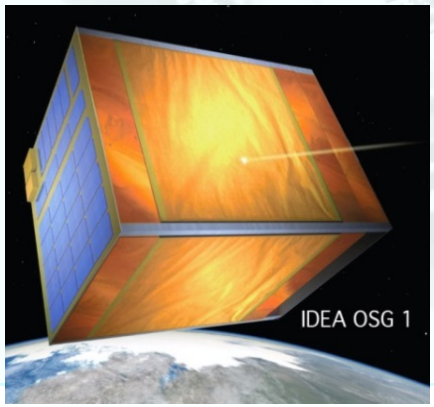
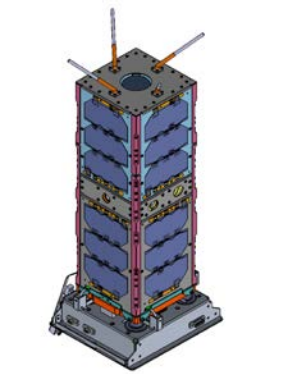
Processor	Renesas Electronics SH7760 Processor @ 200MHz 360MIPS / 1.4GFLOPS
Memory	SDR SDRAM 64MB (32MB *2)
PROM	NOR Flash memory 64MB
Interfaces	UART 15ports I2C 2ports SPI 1port Control Area Network 2ports A/D Converter 4 channels Pulse counter 3 channels Digital I/O port 8 ports PWM Max 4 ports
Size	60 x 60mm
Power supply	Input power: 3.3V DC Power consumption: 1.5 W

Key Points for the Hardware Recursive Utilization

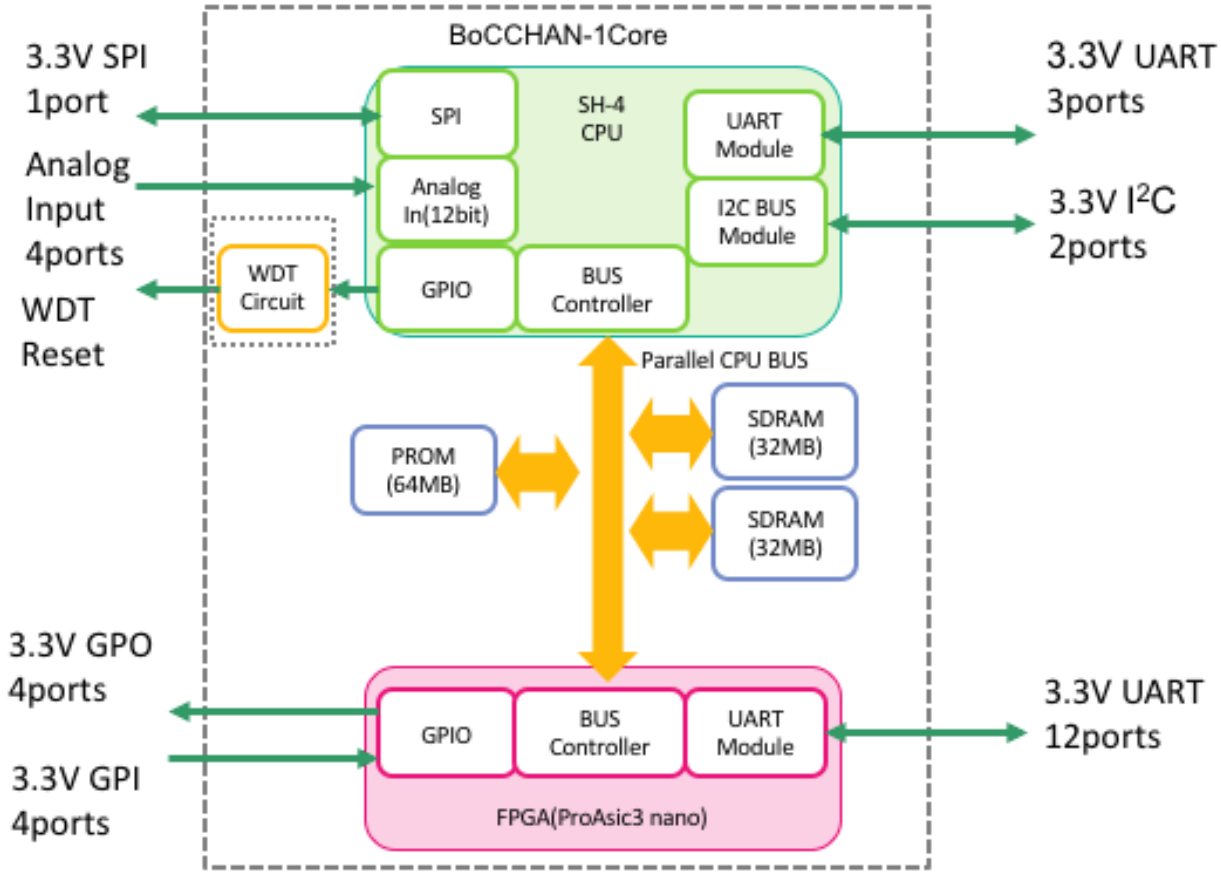
How to utilize BoCCHAN-1 hardware resource in various satellite architectures

- **Distinguish processor core function from interface and/or additional function**
  - CCSDS, Data Recording, AD converter, etc..
  - If we keep core function same, we can use the same software architecture.
- **Utilization of FPGA connecting to the CPU bus**
  - FPGA compensates difference in interface by software technologies
  - CPU bus connection expands CPU capability

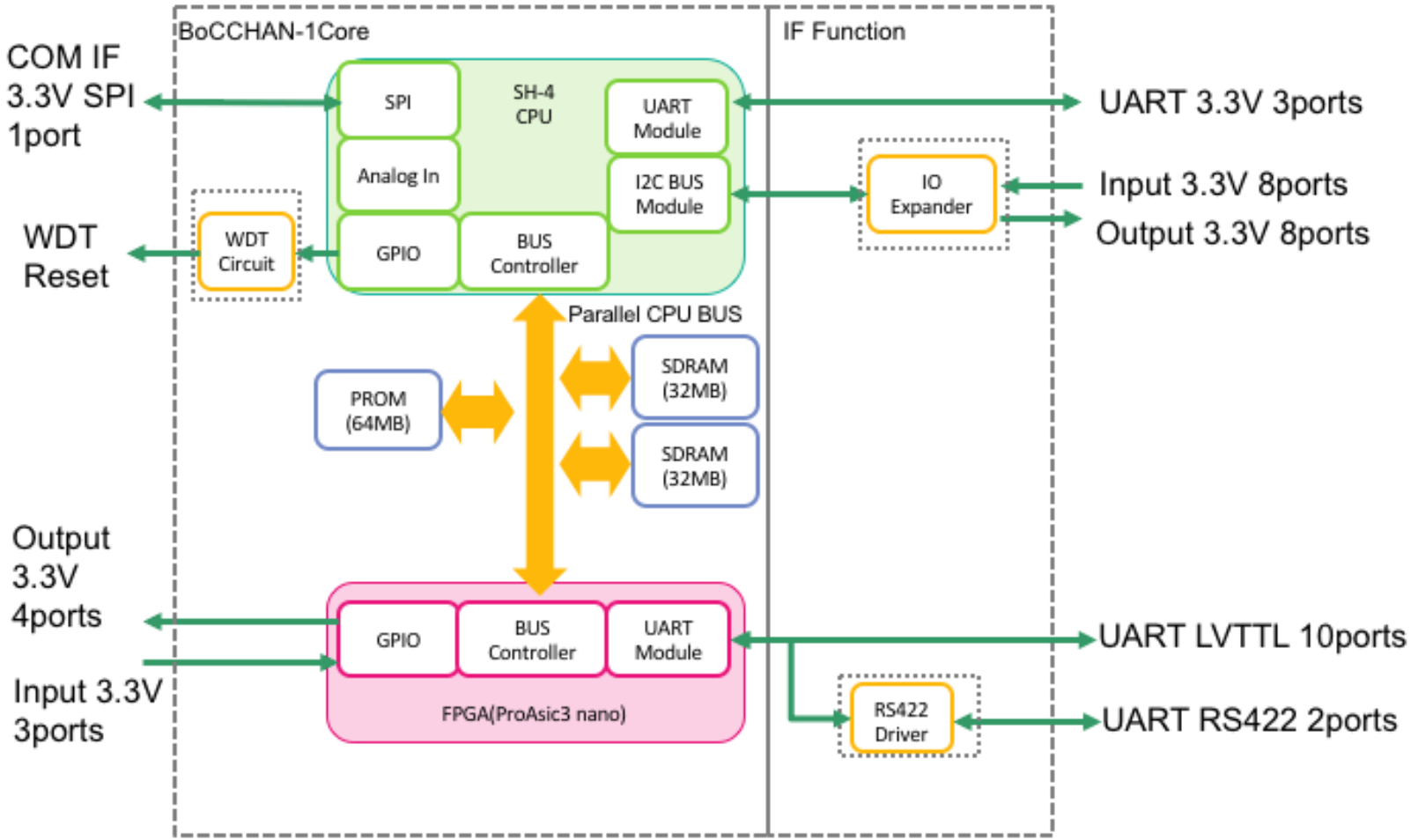
Trial for Recursive Utilization in Different Platform

IDEA OSG 1	Example	TriCom-1
MicroSat	Category	3U CubeSat
25kg	Weight	<3kg
380×380×600mm^3	Size	116×116×346mm^3
Space Debris Inspection	Mission	Tech. Demo of COTS Devices
	Image	

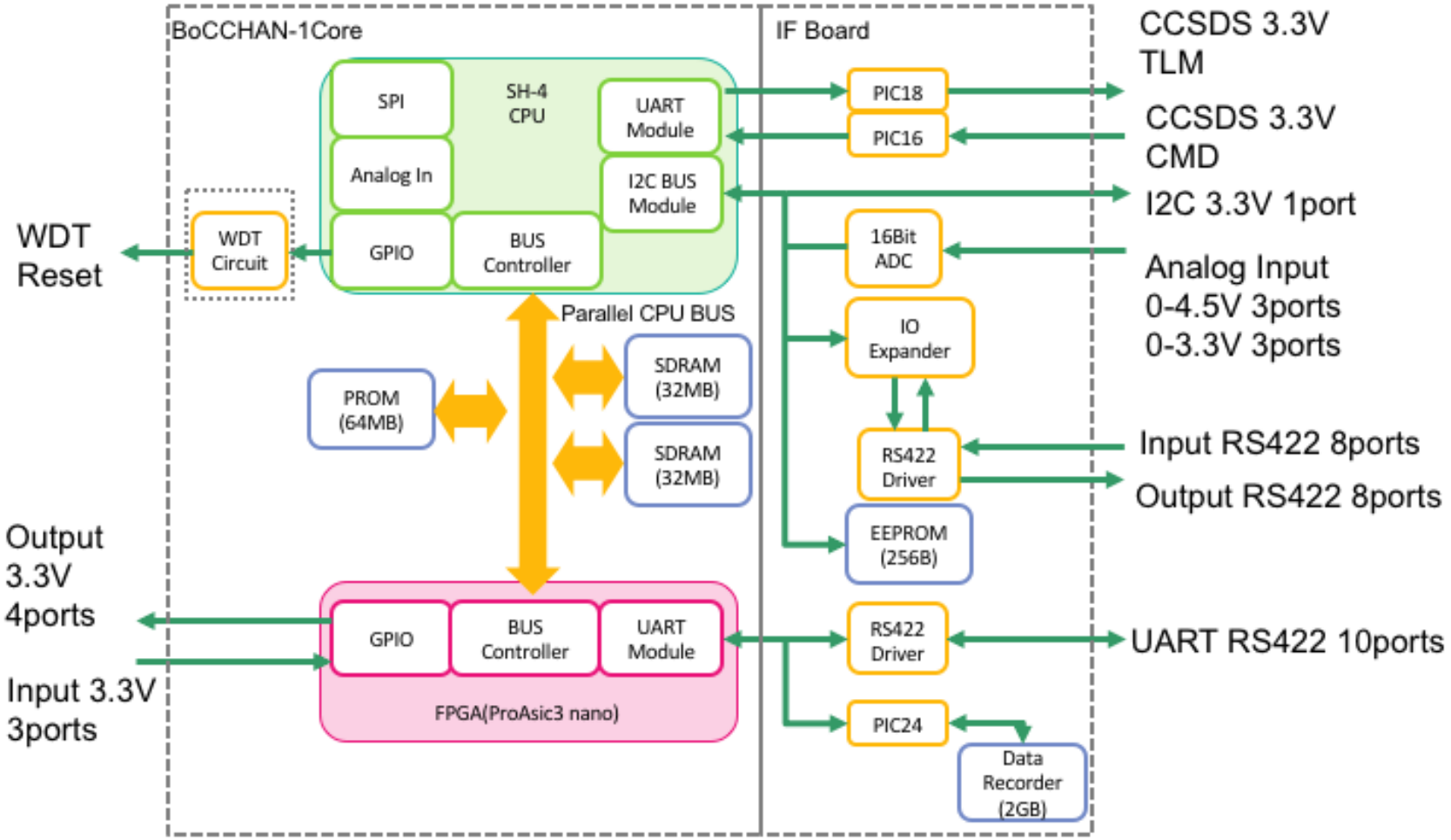
BoCCHAN-1 Core Structure



TRICOM-1 OBC Structure

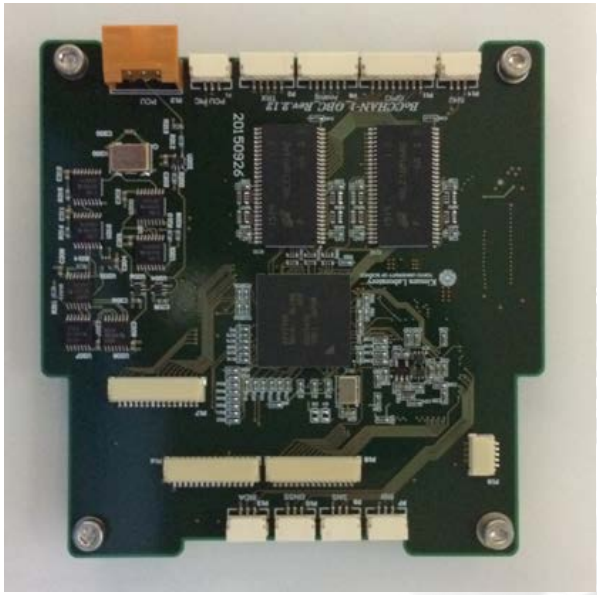


IDEA OSG 1 OBC Structure

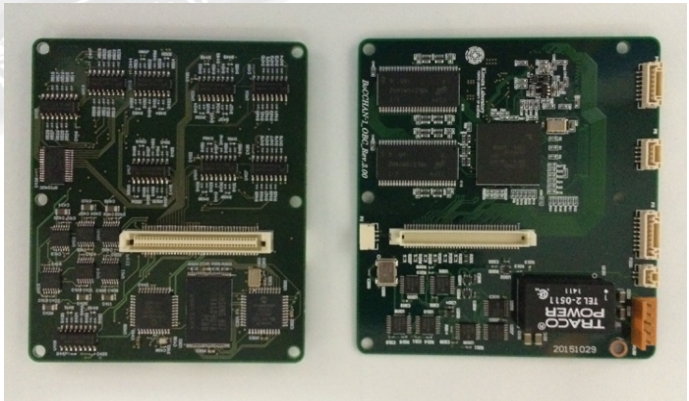


OBC Units for Two Different Type Satellites

CPU Board for TRICOM-1



CPU Unit for IDE OSG 1



Conclusion

- In this paper, the basic concept of our modularized approach to the on-board processing system.
- The modularized structure and mutual utilization are quite effective in reducing the development load and increasing the reliability in not only in the hardware architecture, but also in the software architecture.
- The effectiveness of modularized architecture will be demonstrated in two different missions, IDEA-OSG-1 and TRICOM-1.