KiboCUBE Academy

Live Session #1-2

System Integration of CubeSats

Tohoku University

Department of Aerospace Engineering

Associate Professor Dr. –Ing. Toshinori Kuwahara

This lecture is NOT specifically about KiboCUBE and covers GENERAL engineering topics of space development and utilization for CubeSats.
The specific information and requirements for applying to KiboCUBE can be found at:
https://www.unoosa.org/oosa/en/ourwork/psa/hsti/kibocube.html

JAXA UNISEC JAPAN University Space Engineering Consortium

United Nations Office for Outer Space Affairs ★ Japan Aerospace Exploration Agency Kibo CUBE

Contents

1. Introduction to CubeSat System Engineering

1. Introduction to CubeSat System Engineering

1.1. Advanced Applications of CubeSats

There are a wide range of applications for CubeSats.

Earth Observation

- Optical observation
- SAR (Synthetic Aperture Radar)
- Radio signal analysis
- Weather observation measurement

Communication

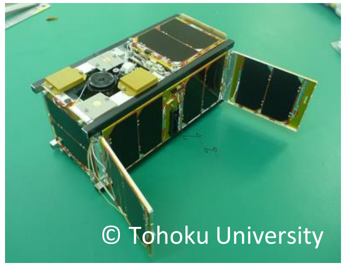
- Data relay
- M2M (Machine-to-Machine) communication
- AIS (Automatic Identification System)
- High-speed laser communication

New technologies

- GNSS signal occultation measurement
- Space robotics
- Electrodynamic Tether
- Re-entry and return capsule

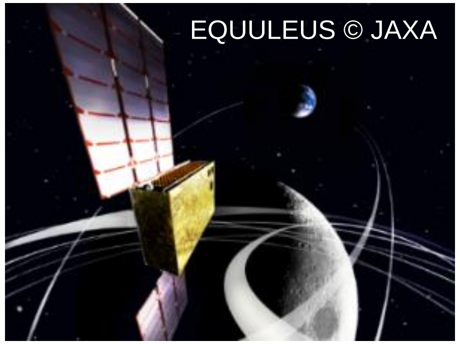
Science

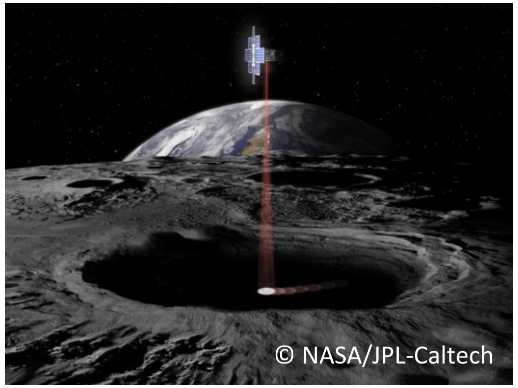
- Astronomy
- Bioscience experiment
- Moon, Asteroids, Planets, and Deep Space Exploration.

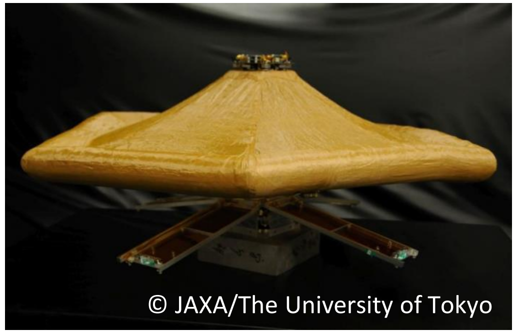

© Tohoku University

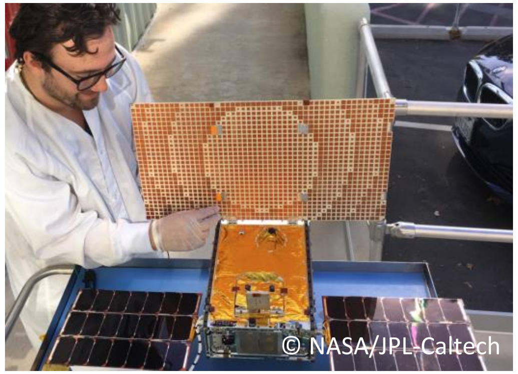

© NASA/JPL-Caltech


© NASA/JPL-Caltech

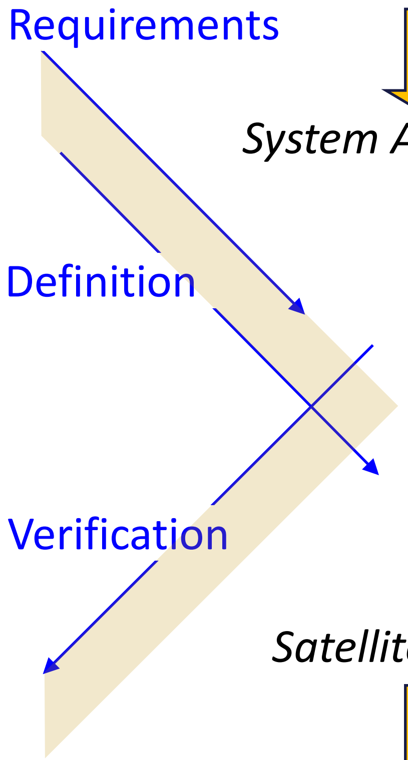

EQUULEUS © JAXA


© NASA/JPL-Caltech


© JAXA/The University of Tokyo


© NASA/JPL-Caltech

1.2. System Engineering Process



CubeSat Mission Initiation

Output

- *Mission Analysis and Design* — Mission Definition
  - Mission Definition Review (MDR)
- *System Analysis and Design* — System Definition
  - System Definition Review (SDR)
- *Preliminary Design* — Development of **Breadboard Model (BBM)**
  - Preliminary Design Review (PDR)
- *Detailed Design* — Development and Verification of **Engineering Model (EM)**
  - Critical Design Review (CDR)
- *Satellite Manufacturing* — Manufacturing and Testing of **Flight Model (FM)**
  - Qualification Review (QR)
  - Launch Readiness Review (LRR)

Launch and Operation!

1.3. Mission Analysis and Design

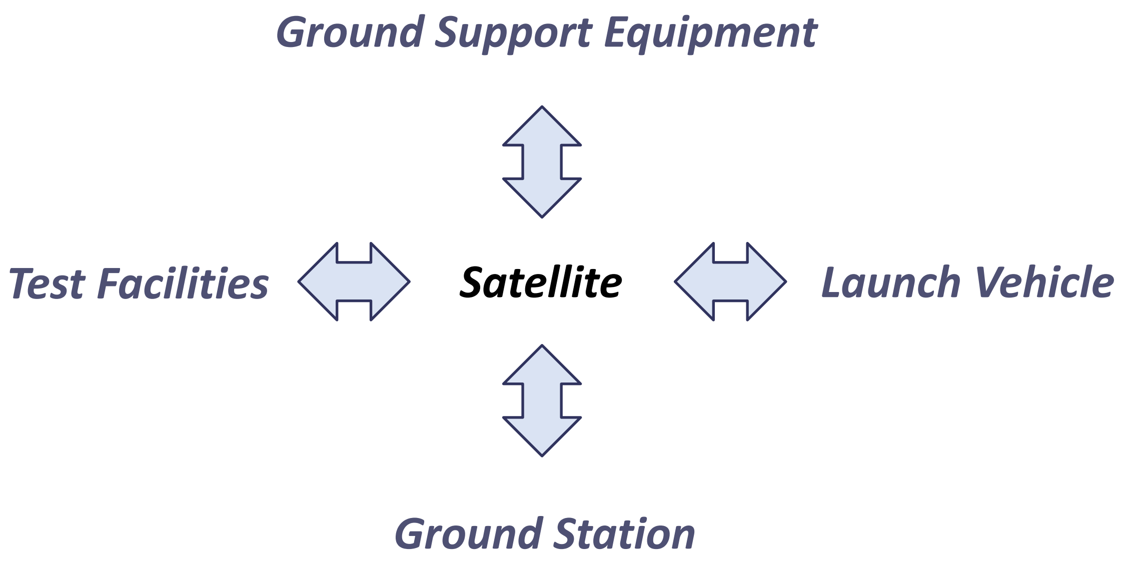
Input: Mission Objectives

Output: Mission Requirements

- Functional Requirements
- Operational Requirements
- Constraints

Mission Constraints:

- Launch Opportunities
  (Mass properties, Size, Launch Environment, Orbit, etc.)
- Schedule
- Cost
- Human Resources
- Development Facilities
- Interfaces
- Regulations
- Space Environment



1.4. System Analysis and Design

Input: Mission Requirements

Output: System Definition

- Preliminary Mission Concept
- Satellite Orbit, Number of Satellites
- Payload Instruments
- Satellite Bus System
- Launch Vehicle Selection
- Operation Planning
- Ground Station
- Ground Support Equipment

Payload Instruments

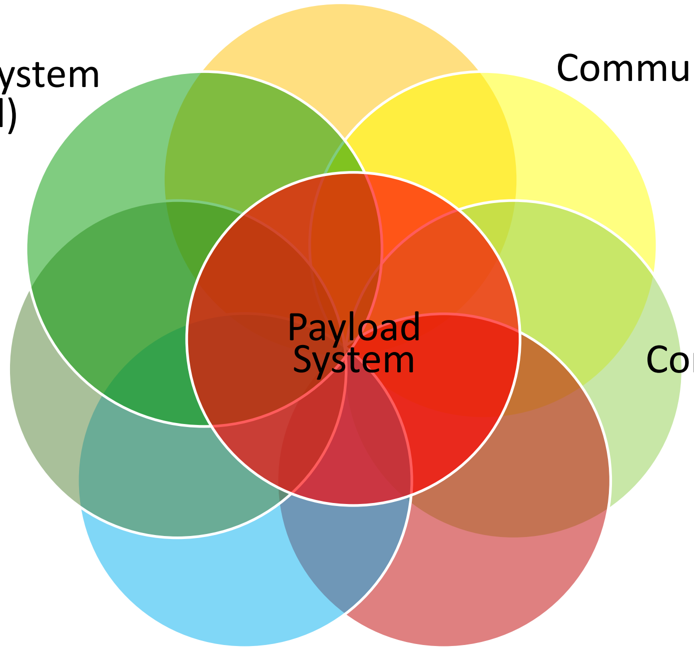
- Types of Instruments
  - Communication
  - Optical Observation
- Mass
- Size
- Power Consumption
- Voltage
- Telemetry Data
- Mission Data
- Command Data
- Thermal Control
- Pointing Accuracy
- Operational Constraints

Bus System

- Mass
- Size
- Power Consumption, Generation
- Attitude Control
- Telemetry Data
- Command Data
- Computational Capability
- Communication Capability
- Thermal Control Capability
- Orbit Control
- Propulsion
- Autonomy

1.5. Satellite Subsystems

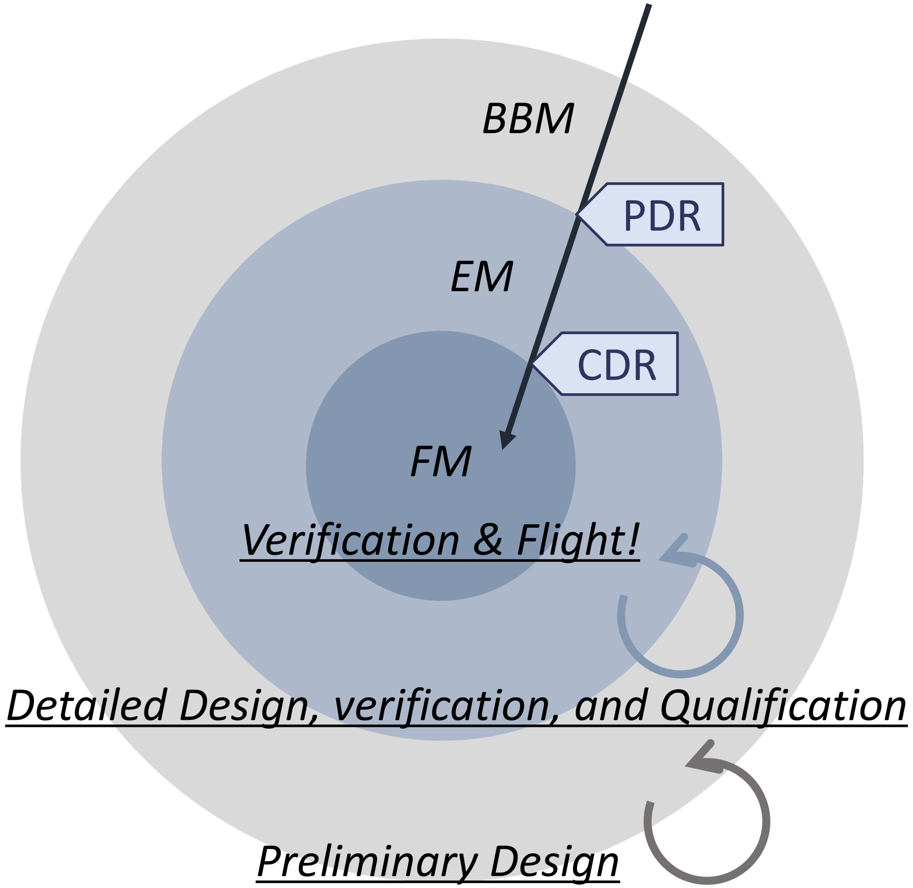
A satellite system consists of several subsystems. Typical categorization is as follows:



+ Harness System

1.6. Satellite System Design

- Iterative design refinement and verification process
- Satellite system sizing and budget control through trade-offs
  - Mass Budget (Mass Property)
  - Power Budget (Power consumption, generation, and storage)
  - Size Budget
  - Communication Budget
  - Data Storage Budget
  - Computational Budget
  - Operation Time Budget
  - Financial Budget
  - Schedule Budget



Satellite system design is an art!

2. CubeSat Standards

2. CubeSat Standard

2.1. CubeSat Standardization History

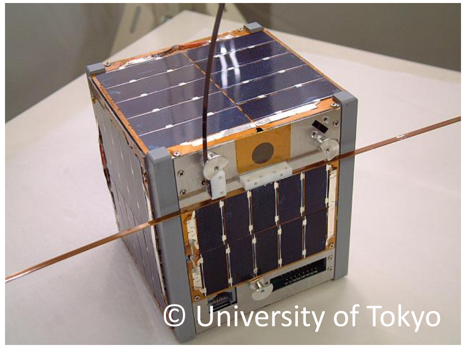
Some standards are available:

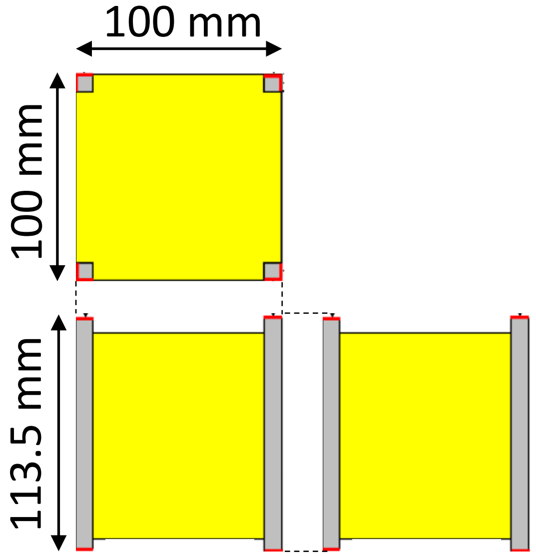
- CubeSat Design Specification rev.13 (2014/2/20)
  6U CubeSat Design Specification rev. 1.0 (2018/6/7)
  - California Polytechnic State University
  (https://www.cubesat.org/)

- CubeSat Subsystem Interface Definition version 1.0
  - UNISEC Europe (2017/8/24)
  (http://unisec-europe.eu/wordpress/wp-content/uploads/CubeSat-Subsystem-Interface-Standard-V2.0.pdf)

- ISO Space systems – Cube satellites (CubeSats)
  (https://www.iso.org/standard/60496.html)

- JEM* Payload Accommodation Handbook Vol.8 D
  - JAXA (* Japanese Experiment Module (JEM) = Kibo)
  (https://iss.jaxa.jp/kibouser/provide/j-ssod/#sw-library)
  English (2020/7/31)
  (https://humans-in-space.jaxa.jp/kibouser/library/item/jx-espc_8d-d1_en.pdf)
  Japanese (2020/5/25)
  (https://humans-in-space.jaxa.jp/kibouser/library/item/jx-espc_8d-d1.pdf)





1 Unit: 10 cm cube, 1.33kg

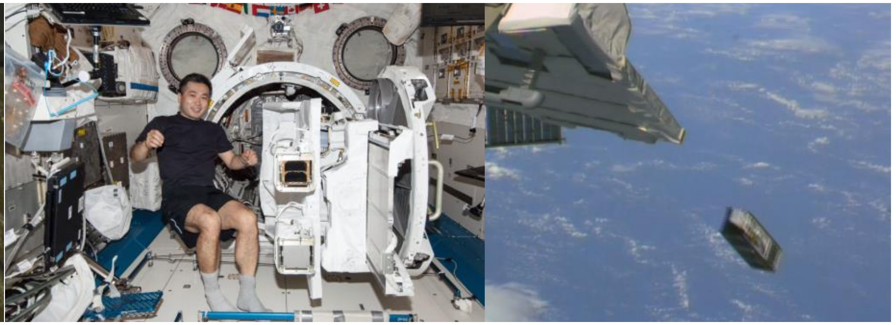
Refence Document: JAXA Common Technical Documentation (https://sma.jaxa.jp/en/TechDoc/index.html)

2. CubeSat Standard

2.2. KiboCUBE Launch Opportunity

- “KiboCUBE” provides deployment opportunities from the ISS Kibo module.
- The possible launch vehicle can be one of the transfer vehicles to the ISS:
    - HTV: H-II Transfer Vehicle
    - SpX Dragon: SpaceX Dragon
    - Orbital Cygnus
- The launch environment is different in each vehicle.
- CubeSats are installed in the satellite deployment POD (J-SSOD: Japanese Experiment Module (JEM) Small Satellite Orbital Deployer) and stowed inside the Cargo Transfer Bag (CTB) with soft packing material.
- Vibration conditions are very mild relative to those encountered during a direct launch.
- Frequent launch opportunities are provided, up to 4 times per year.
- Adopting an approximate orbital altitude of 400 km ensures the CubeSats re-enter the atmosphere after their mission lifetime without becoming space debris.

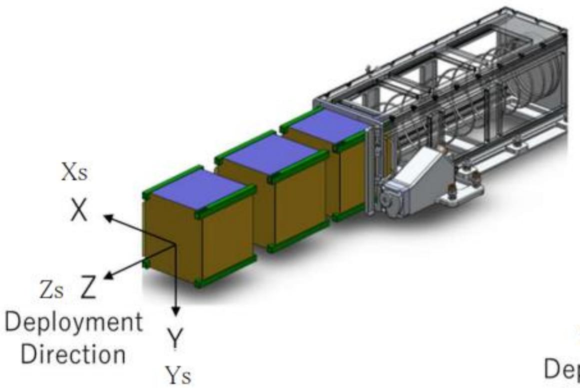
CubeSat Transfer to the ISS © JAXA

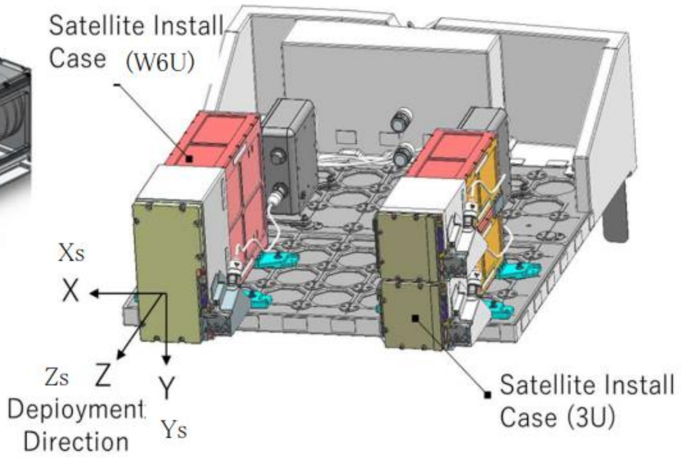


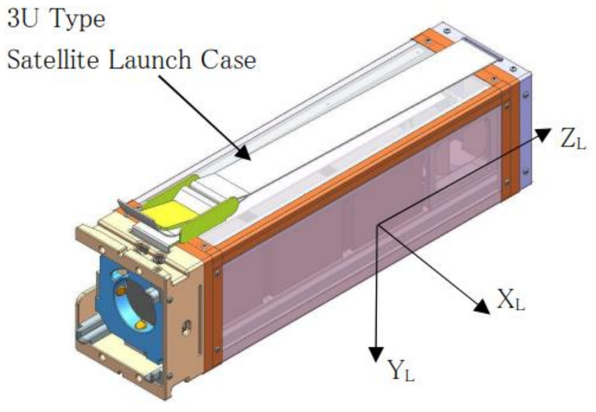
Deployment from the ISS © JAXA

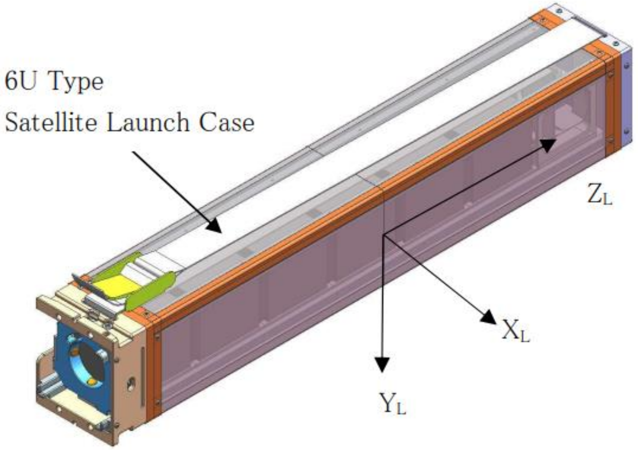
2. CubeSat Standard

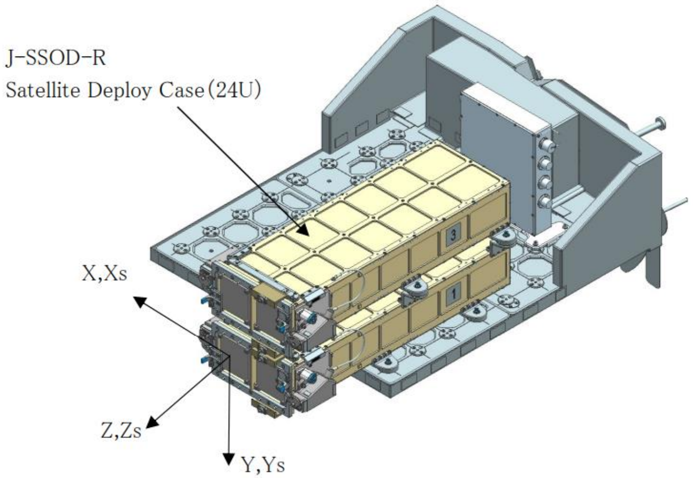
2.3. Kibo Release Opportunities











		Exterior Dimensions (*1)	Rail Dimension	CubeSat Installation
10cm Class satellite	1U	X:100×Y:100×Z:113.5mm	More than 8.5mm squares	Ground / ISS
	1.5U	X:100×Y:100×Z:170.2mm		ISS
	2U	X:100×Y:100×Z:227.0mm		Ground / ISS
	3U	X:100×Y:100×Z:340.5mm		Ground / ISS
	4U	X:100×Y:100×Z:454.0mm		ISS
	5U	X:100×Y:100×Z:567.5mm		ISS
	6U	X:100×Y:100×Z:681.0mm		ISS
	W6U	X:100×Y:226.3×Z:340.5 or 366.0mm		Ground

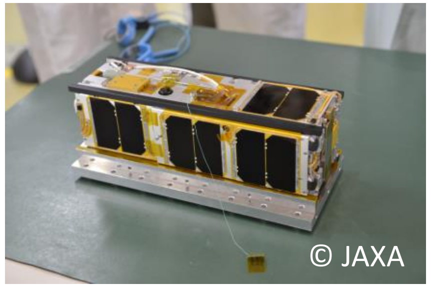
(*1) Nominal dimension including rails

Reference: JEM Payload Accommodation Handbook Vol. 8 D
https://iss.jaxa.jp/kibouser/library/item/jx-espc_8d.pdf

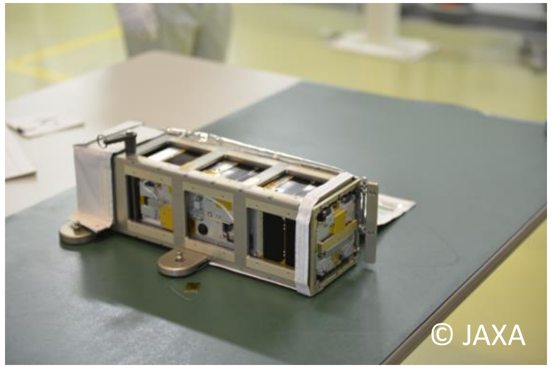
2. CubeSat Standard

2.4. Types of CubeSats

- CubeSats are installed in launch and release “pods.”
- There are several different types of CubeSats, listed below:
  - 1U: 1 x 1 x 1 Unit
  - 1.5U: 1 x 1 x 1 Unit
  - 2U: 1 x 1 x 2 Units
  - 3U: 1 x 1 x 3 Units
  - 4U: 1 x 1 x 4 Units
  - 5U: 1 x 1 x 5 Units
  - 6U-long: 1 x 1 x 6 Units
  - 6U-wide: 1 x 2 x 3 Units
  - etc.

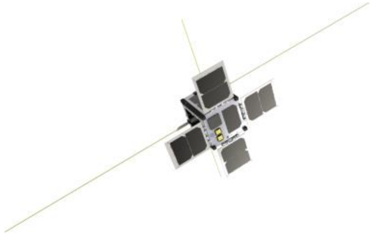


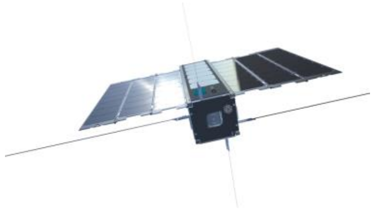
3U CubeSat



Types of Pods:

- 3U: 1 x 1 x 3 Unit
- 6U-wide: 1 x 2 x 3 Units
- 6U-long: 1 x 1 x 6 Units
- etc.





2. CubeSat Standard

2.5. CubeSat Subsystem Interface Definition – UNISEC-Europe

- Standardization of CubeSat specification can expedite world-wide application of CubeSats.
- CubeSat subsystem interface standards suggested by UNISEC-Europe defines the interface specifications of the electrical interfaces based on the experiences of UWE projects, with the goal to promote a generic satellite platform.
- The design has been optimized with respect to mass, size, and energy efficiency, while trying to maintain a modular and flexible architecture.
- The proposed bus supports robust and rapid development, integration and testing of the satellite as well as simple maintenance, extension, and replacement of subsystems.

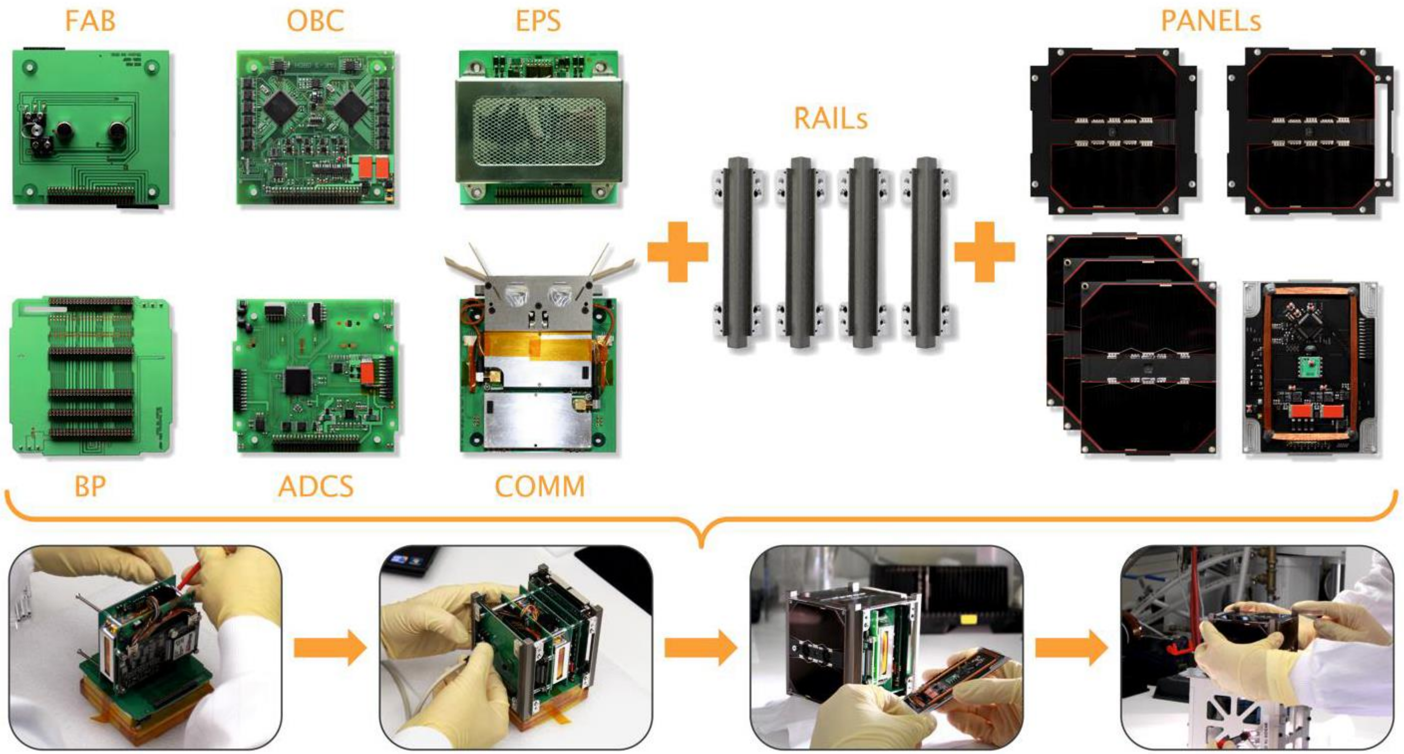


Figure: Overview of the modular UWE-3 pico-satellite bus being optimized for rapid integration and testing. Acts as a first reference implementation of the UNISEC bus.

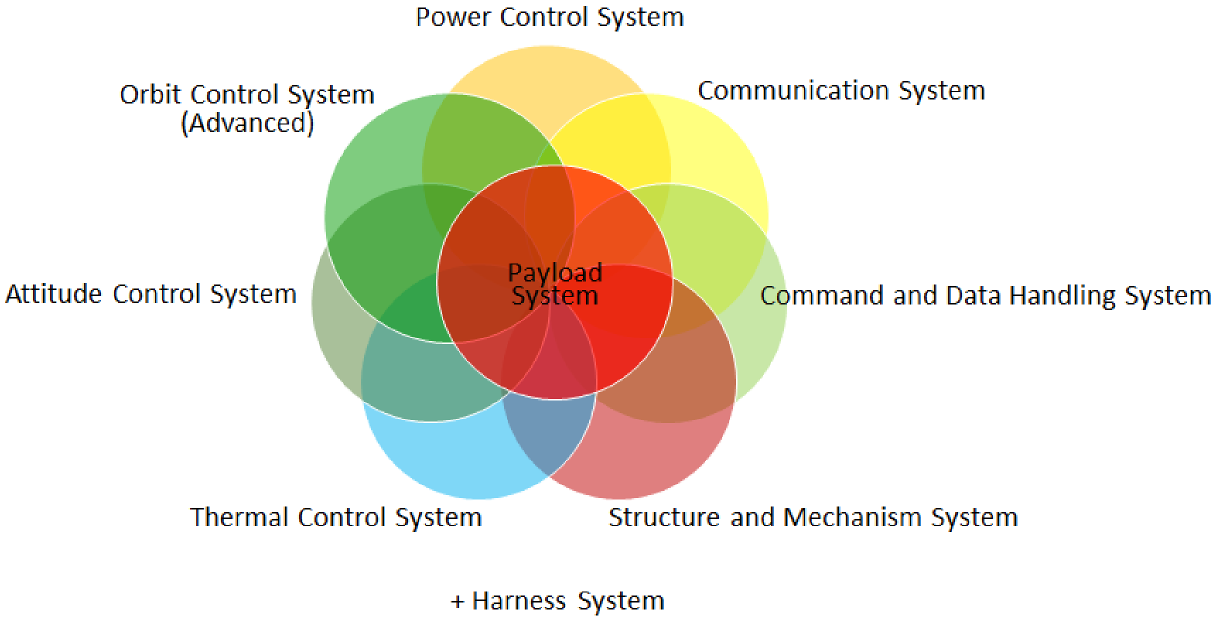
CubeSat Subsystem Interface Definition version 1.0

http://unisec-europe.eu/wordpress/wp-content/uploads/CubeSat-Subsystem-Interface-Standard-V2.0.pdf

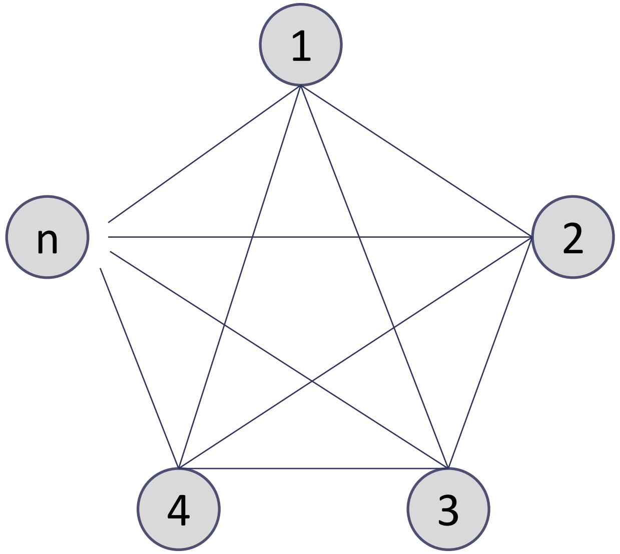
3. CubeSat System Interface

3.1. Interface between Subsystems

- A system with n components has $\frac{n(n-1)}{2}$ interfaces in between.
- For CubeSat system integration, the interfaces between subsystems, as well as components, shall be clearly defined.



Satellite Subsystems

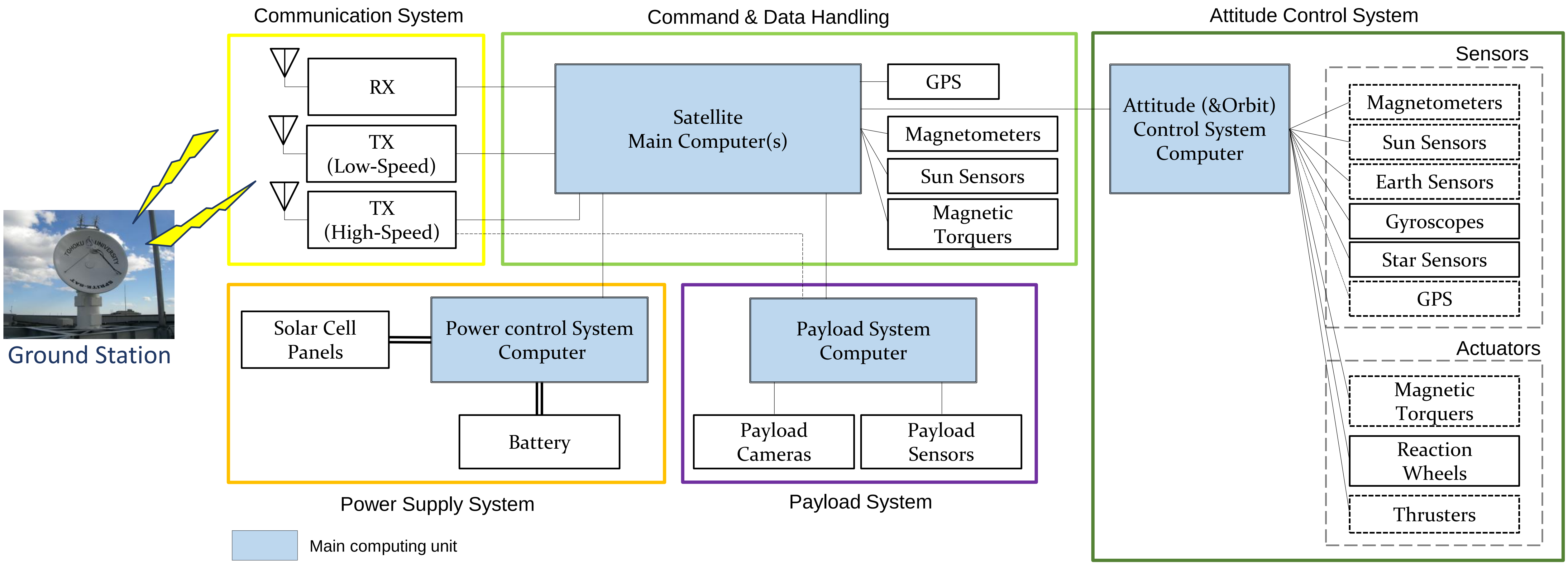


$$Number\ of\ Interface = \frac{n(n-1)}{2}$$

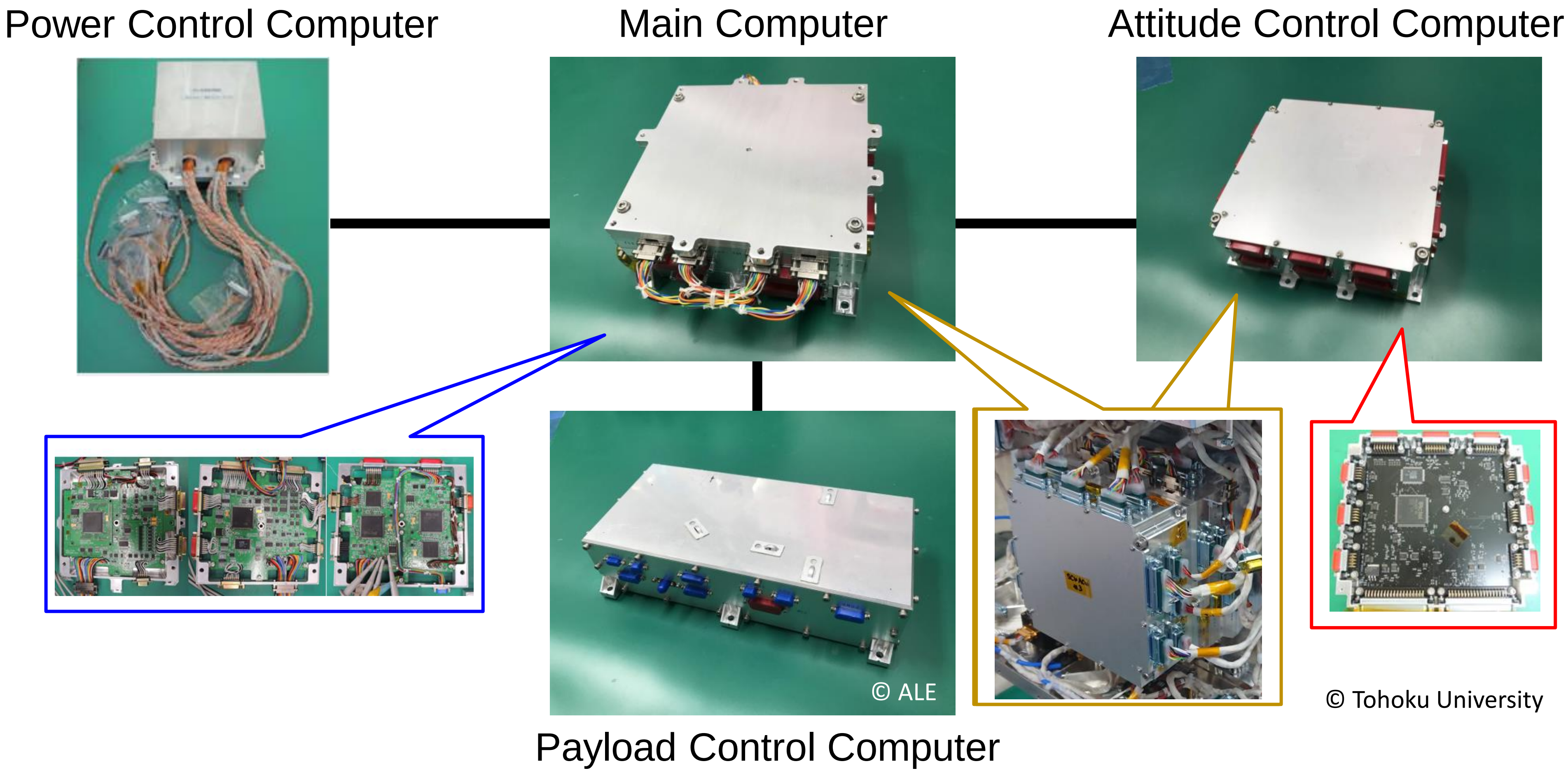
System Interface

3.2. Satellite System Block Diagram

- System architecture can be described using a system block diagram. Satellite components can be generally categorized into subsystems according to their functionalities.
- Each interface needs to be specified, controlled, integrated, and tested for the system integration.

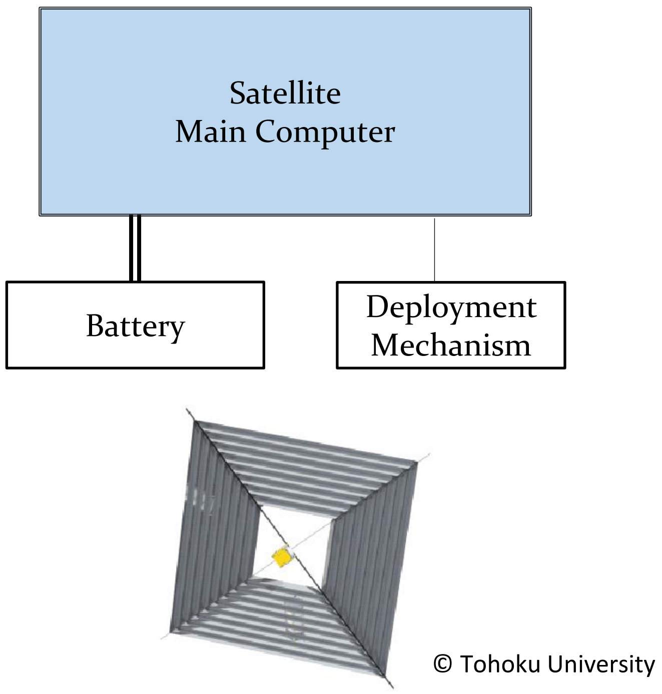


Example of On-board Computers (Micro-satellite RISESAT)

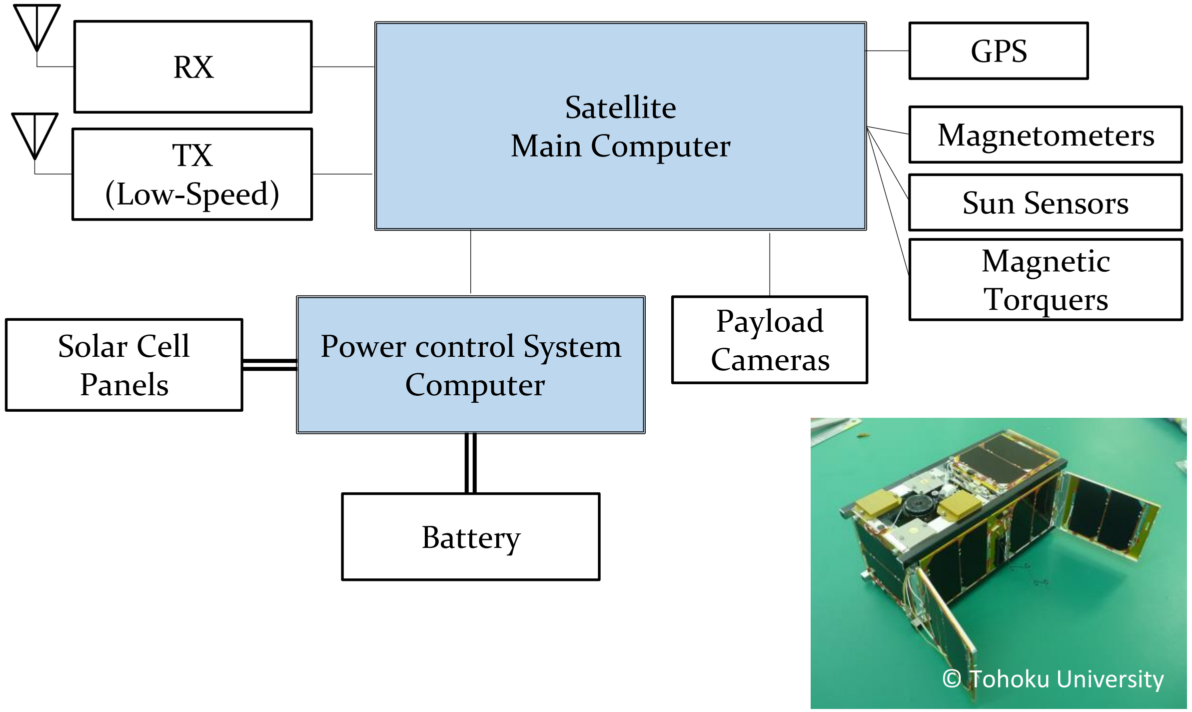


3.4. Electrical Configuration Design

- Satellite system architecture reflects the complexity of the system, and depends on the mission objectives and requirements.
- Fulfilling the mission requirements with minimum component configuration is important to achieve a high system reliability.



Implementation example of 1U CubeSat FREEDOM



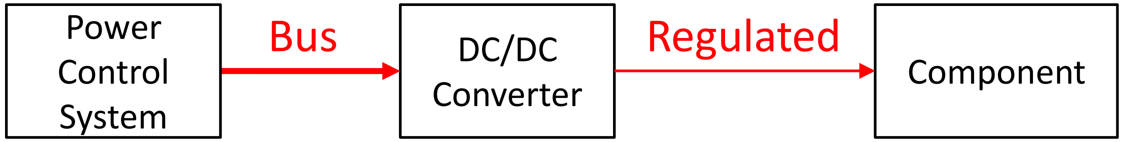
CubeSat system with payload camera and coarse attitude control system

3.5. Electrical Interface

Types of electrical interface can be classified as follows:

Power supply interface

- Unregulated/Bus: Satellite bus voltage, which fluctuates depending on the state of charge (SOC) of the battery.
- Regulated: Voltages-regulated power supply through DC/DC converters, such as 3.3V, 5V, 12, 28V, etc.



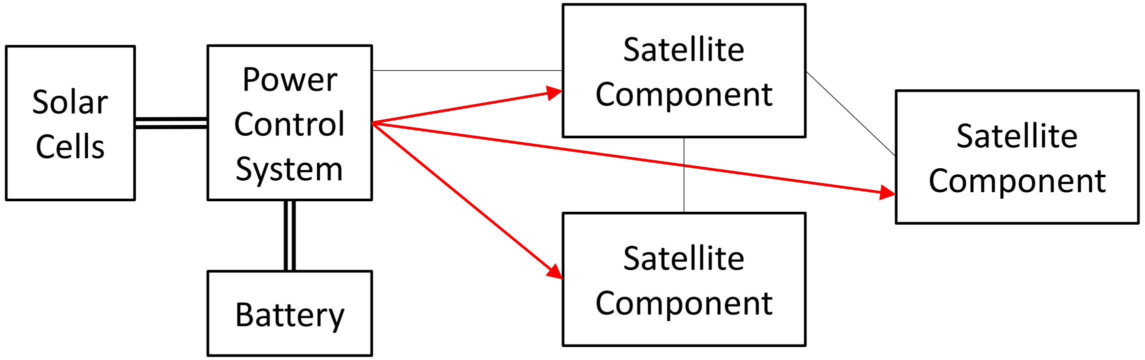
Signal interface

- Analog signal
  - Active analog: voltage output from analog sensors, voltage output from powered devices.
  - Passive analog: thermistors (power is supplied from outside to measure the value)
- Digital signal
  - Discrete signal: ON/OFF status of mechanical switches, status of electrical circuits, etc.
  - Synchronous Serial: Communication interface with dedicated clock signals, suitable for high-speed communication.
  - Asynchronous Serial: Communication interface without dedicated clock signals, suitable for low-speed communication with less cables.
- Radio Frequency
  - Communication between satellite and ground station. Require international radio frequency coordination (before launch), and license.
  - Communication between satellites, between components inside a satellite, etc.

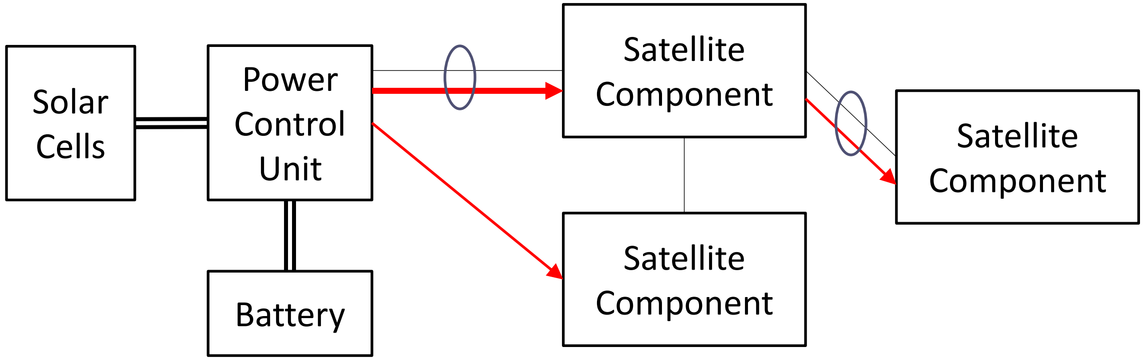
3. CubeSat System Interface

3.6. Power Distribution Method

- Power distribution from the power control system to satellite components can be direct or in-direct, mainly depending on the configuration of the mechanical integration of the satellite electrical components.
- Harness system becomes simpler when the power supply lines and signal lines can be combined into a harness assembly between two devices.
- For a relatively bigger satellite system, hub configuration becomes more efficient.
- The voltage of unregulated power supply lines is usually higher than the regulated voltage, and hence, more efficient in power distribution over a long harness.
- Attention needs to be paid that a long harness causes a considerable voltage drop, and also that a high current flow generates noticeable magnetic fields which causes disturbance to the satellite attitude stability.



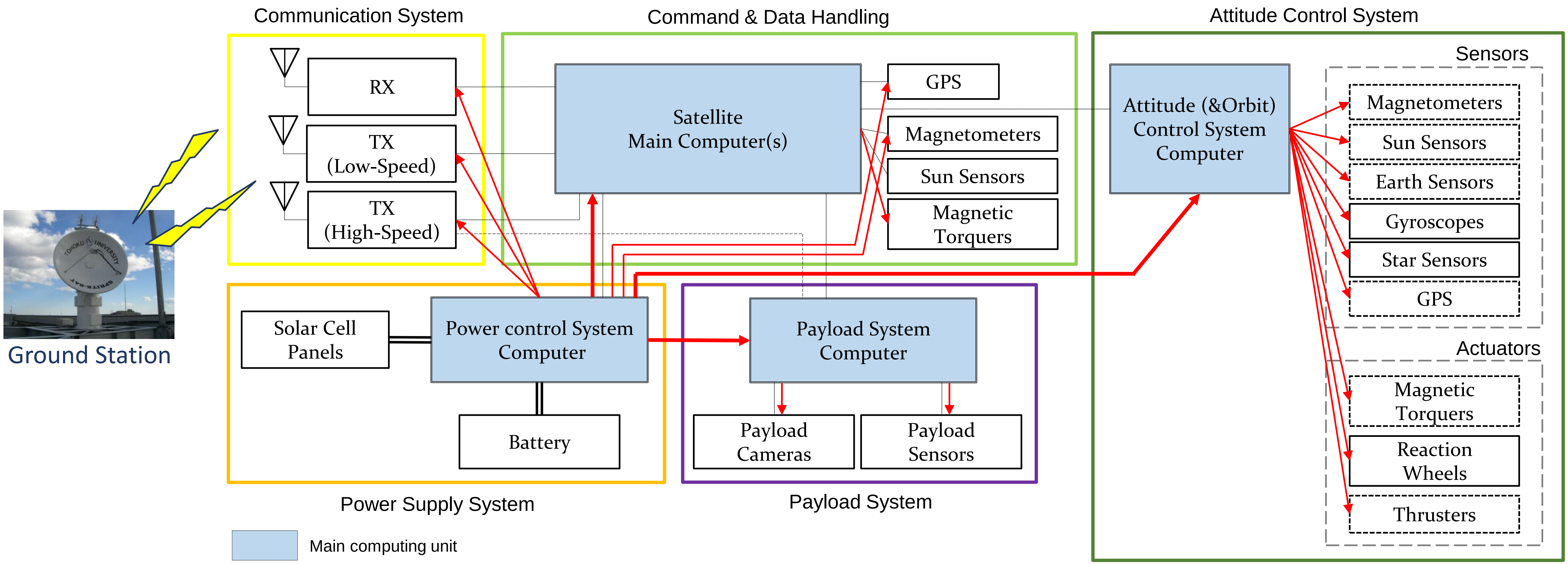
Point-to-Point Star Configuration



Hub Configuration

3.7. Power Distribution Architecture

- Power distribution architecture shall be carefully designed especially for small space systems in order to reduce the system complexity, number of components, harness, mass, size, volume, and power inefficiency.



3.8. Communication Interface

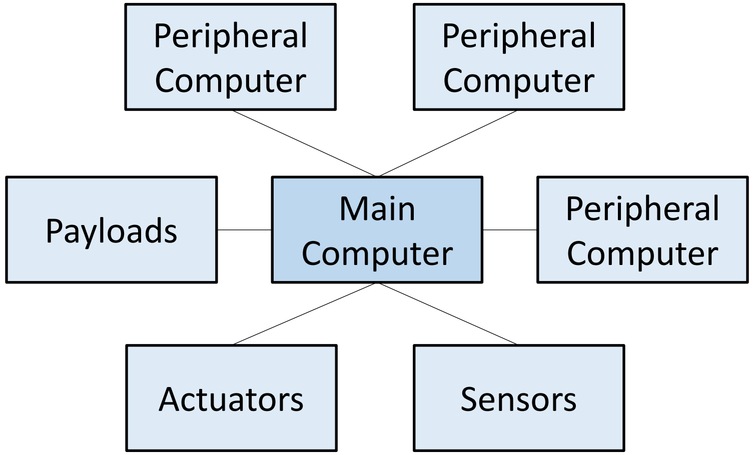
- There are several types of signal interfaces commonly applied to satellite systems.

Interface Name	Signal Lines	Clock	Topology	Protocol
RS-232C	Single End	Asynchronous	Point-to-Point	UART
RS-422	Differential	Asynchronous	Point-to-Point	UART
RS-485	Differential	Asynchronous	BUS	UART
SPI	Single End	Synchronous	BUS	SPI
I^2C	Single End	Synchronous	BUS	I^2C
USB	Differential	Asynchronous	BUS	USB
SpaceWire	Differential	Asynchronous	Point-to-Point	SpaceWire
Ethernet	Differential	Asynchronous	Point-to-Point	Ethernet

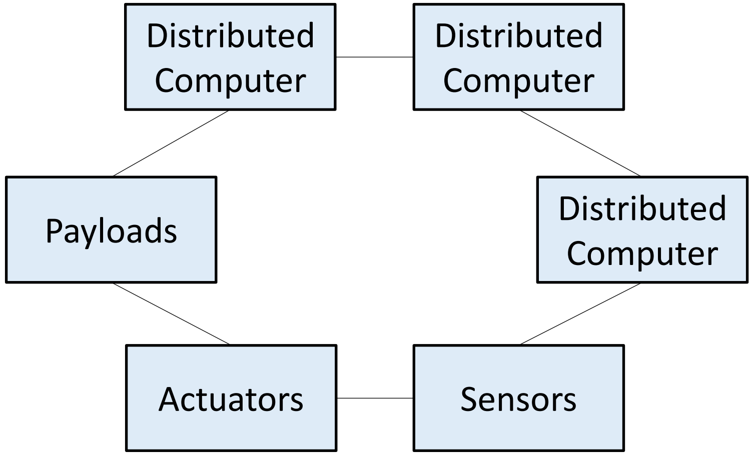
Physical Layer	Voltage
TTL (Transistor-Transistor Logic)	3.3V / 5V
LVDS (Low Voltage Differential Signal)	3.3V

3.9. Computer Network Architecture

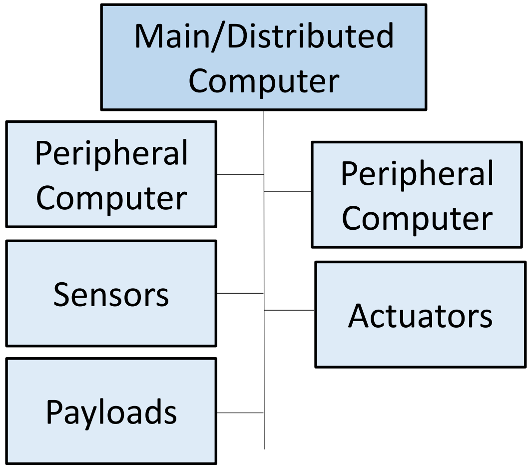
- The computer network architecture shall be carefully designed for developing a computer system for satellites.
- There are several different computer network architectures as below:



Centralized (Star) Architecture



Ring Architecture

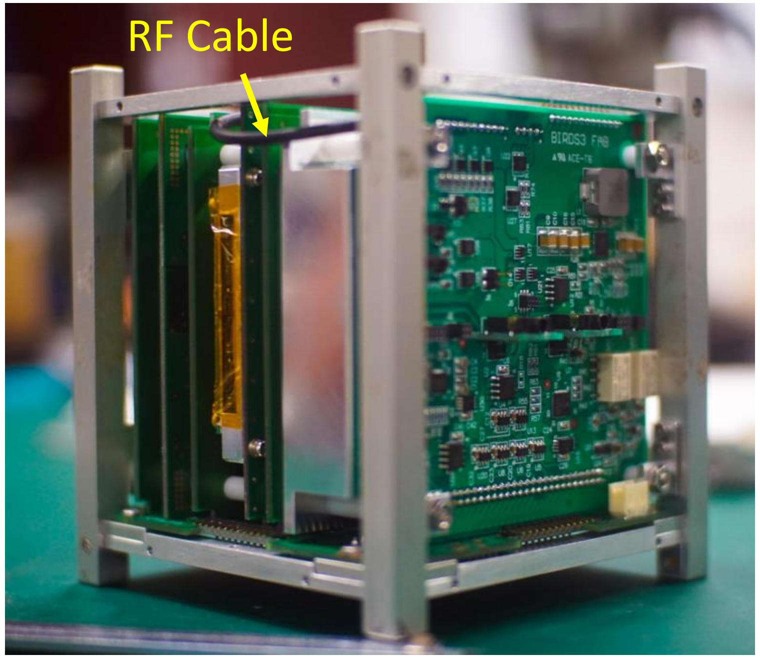


Bus Architecture

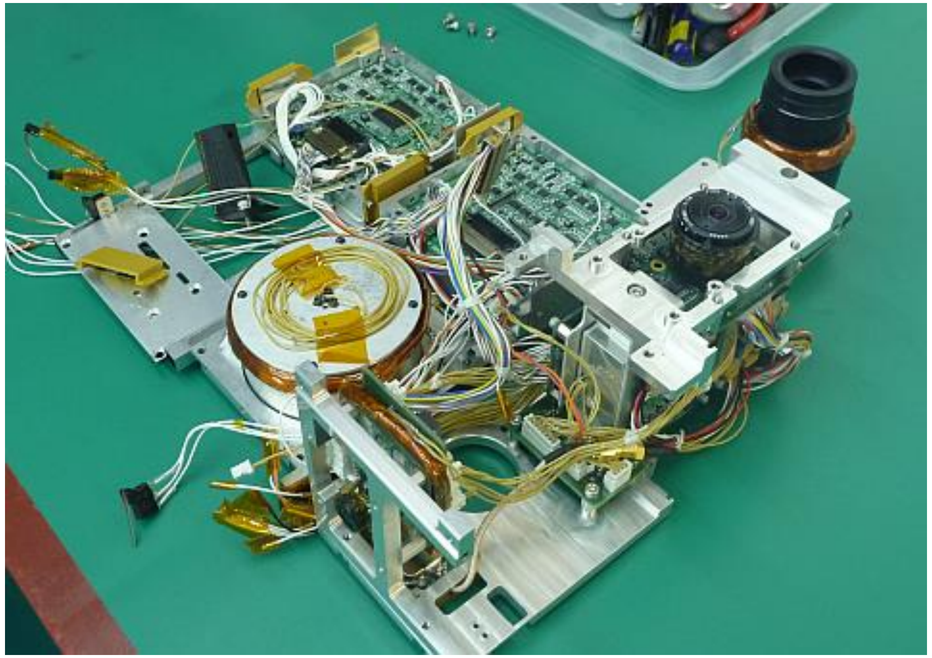
Architecture	Centralized (Star) Architecture	Ring Architecture	Bus Architecture
Merits	High integrity, direct interface only Less influence of unit failure	Smaller wiring harness Easy to add new node	Smaller wiring harness Easy to add new node
Demerits	Point-to-Point connection Large wiring harness	More influence of unit failure Low communication throughput	Interface needs to be compatible Low communication throughput

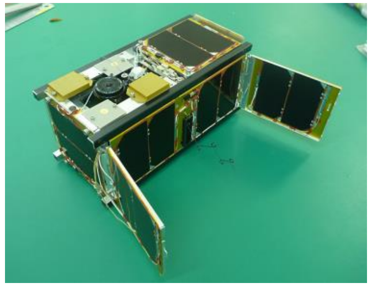
3.10. Radio Frequency interface

- Radio Frequency interface needs a special point-to-point harness connection.
- RF connectors are relatively big and RF cables are relatively thick due to the shielding materials.
- Point-to-Point connection requires harness wiring, which consumes space inside the satellite, and mass budget.
- Harness wiring needs special attention for the accessibility and integration procedure.



1U CubeSat © Kyutech

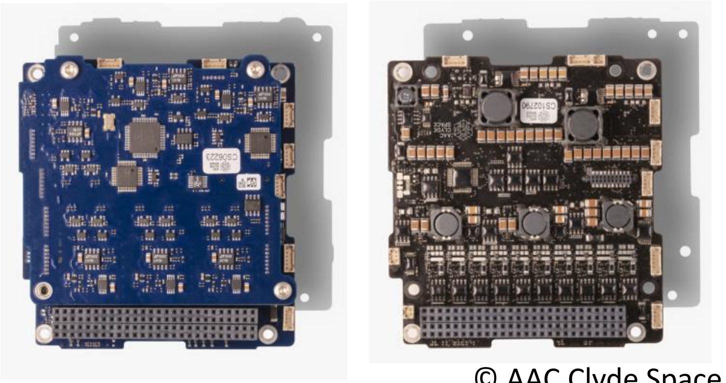




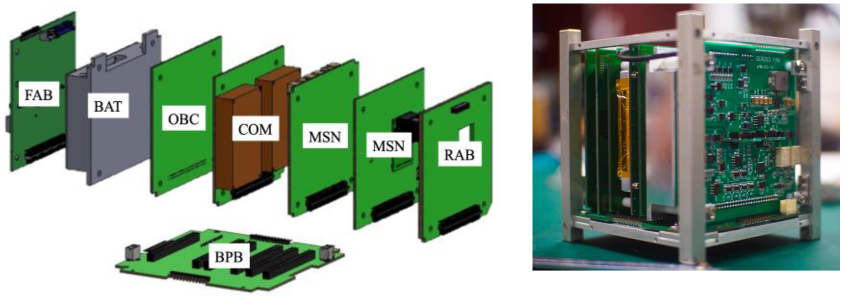
2U CubeSat RAIKO © Tohoku University

3.11. Mechanical and Electrical Interface Standardization

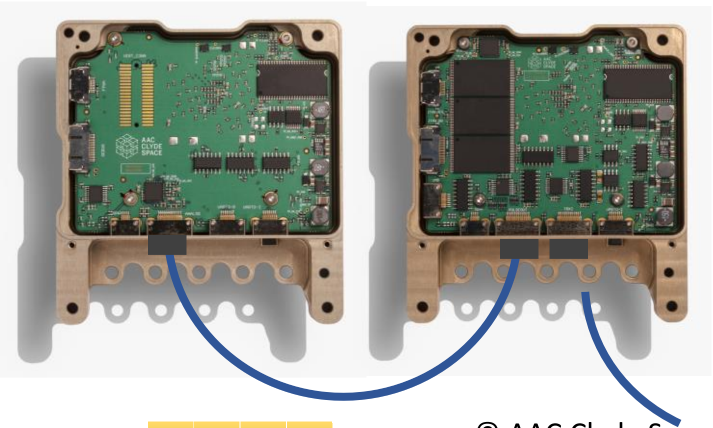
- Three major ways of mechanical and electrical integration: PC-104 Style, Backplane Style, and Point-to-Point.
- The scope of the standards include mechanical interfaces, connectors, types of signals, and pin assignments.



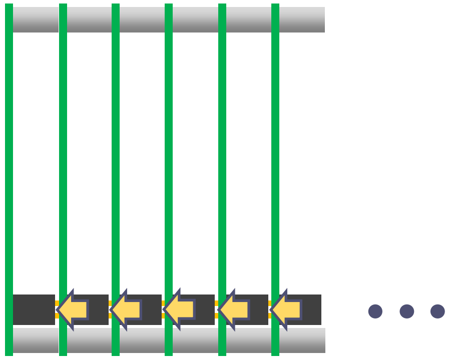
© AAC Clyde Space



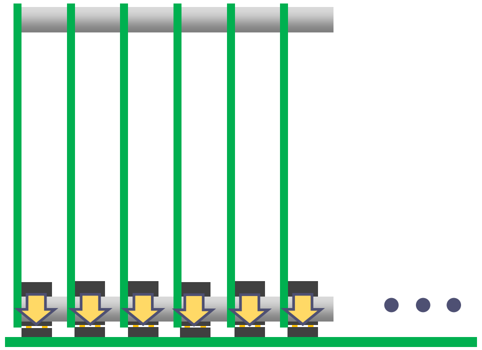
© Kyutech



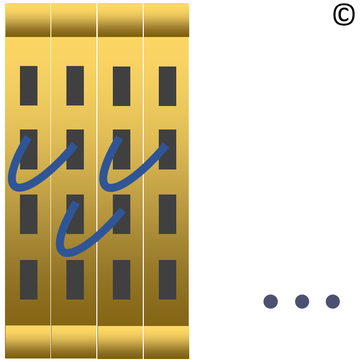
© AAC Clyde Space



PC-104 Style



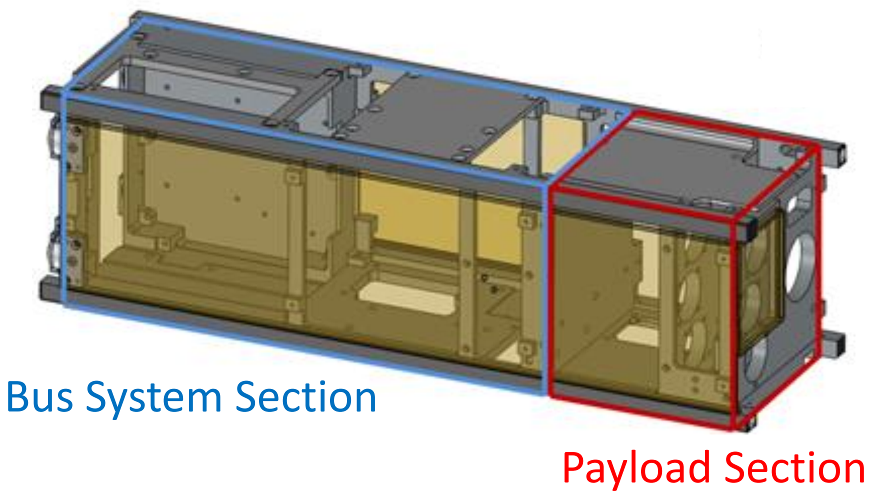
Backplane Style

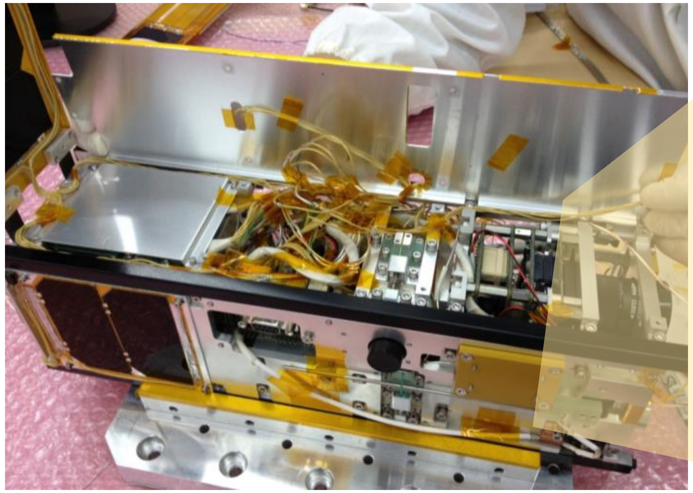


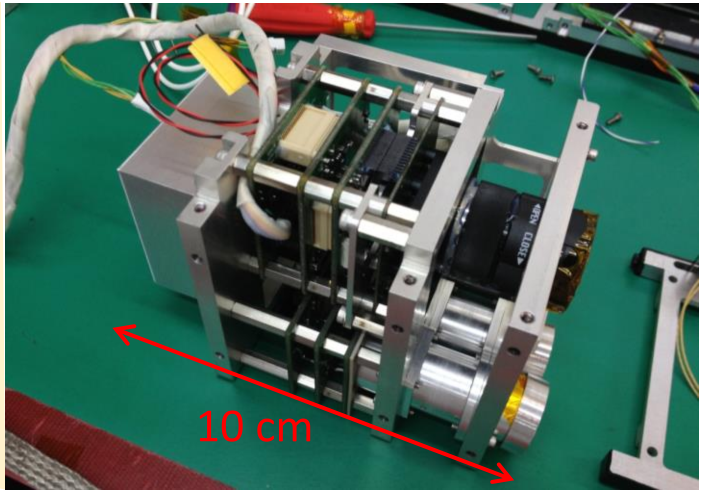
Point-to-Pont

3.12. Payload Interface

- Payload instruments usually tend to have custom interfaces with a combination of different types of electrical interfaces.
- Due to the limitation of mechanical envelope and maintainability, payload instruments need to be assembled as a unit by defining the mechanical, electrical, and thermal interfaces very clearly.
- Payload instruments related with radio frequency measurements are equipped with large antennas, which needs to be held down during the launch and deployed in orbit.







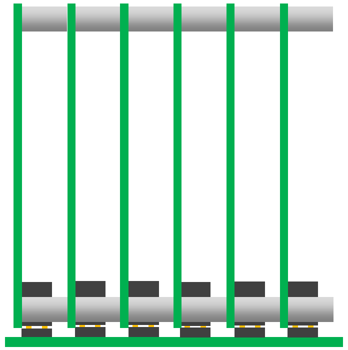
3U CubeSat S-CUBE © Chiba Institute of Technology / Tohoku University

4. CubeSat System Integration

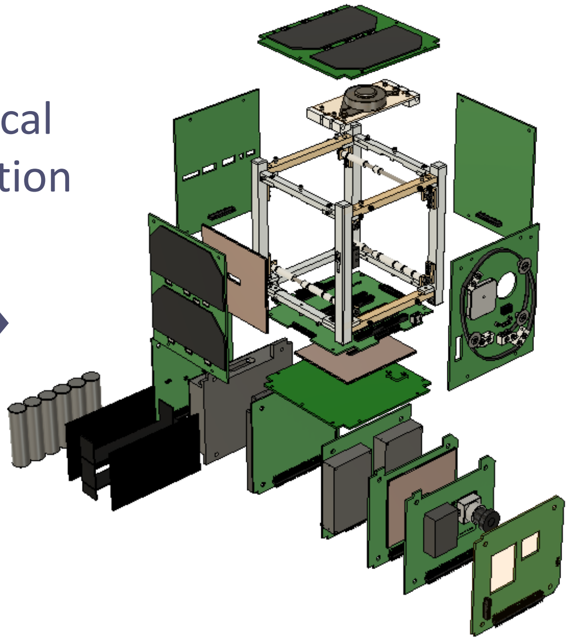
4. CubeSat System Integration

4.1. CubeSat Integration Process Overview

- Thanks to worldwide CubeSat interface standardization efforts, the mechanical and electrical systems of CubeSats can be integrated in a very dense manner to a limited mechanical envelope.
- System design and integration shall be planned in the way that the resources for the payload can be maximized, especially such as the mass, envelope, and power.
- CubeSats need to be assembled to fulfil the tolerance requirements of mechanical dimensions to fit in the pod.

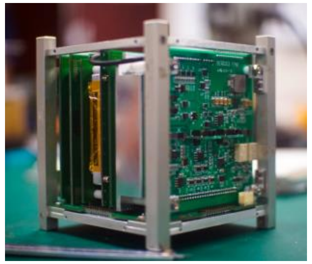


Electrical Integration



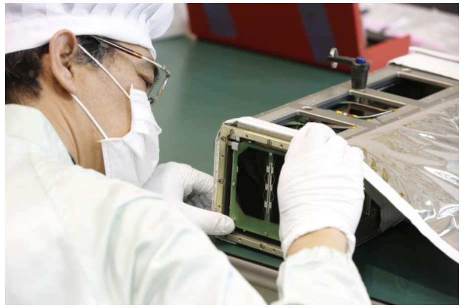
© Kyutech

Mechanical Integration



© Kyutech

Assembly into Release Pod

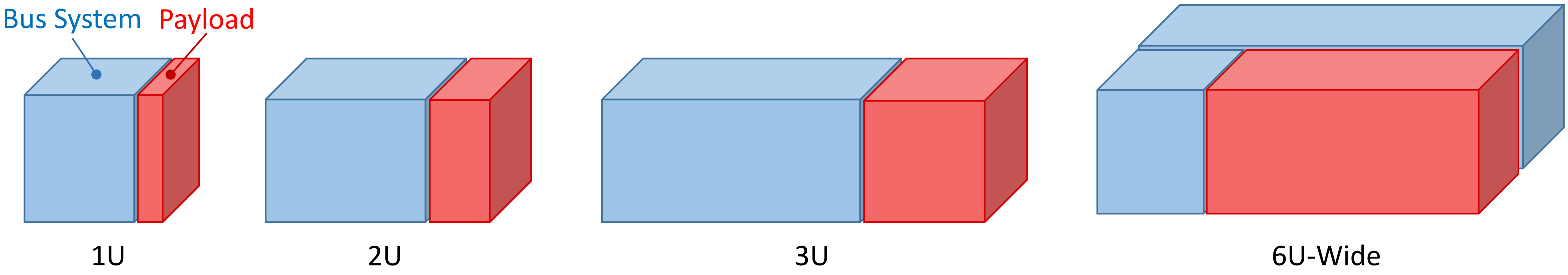


© JAXA

4. CubeSat System Integration

4.2. Relationship of Payload and Bus System

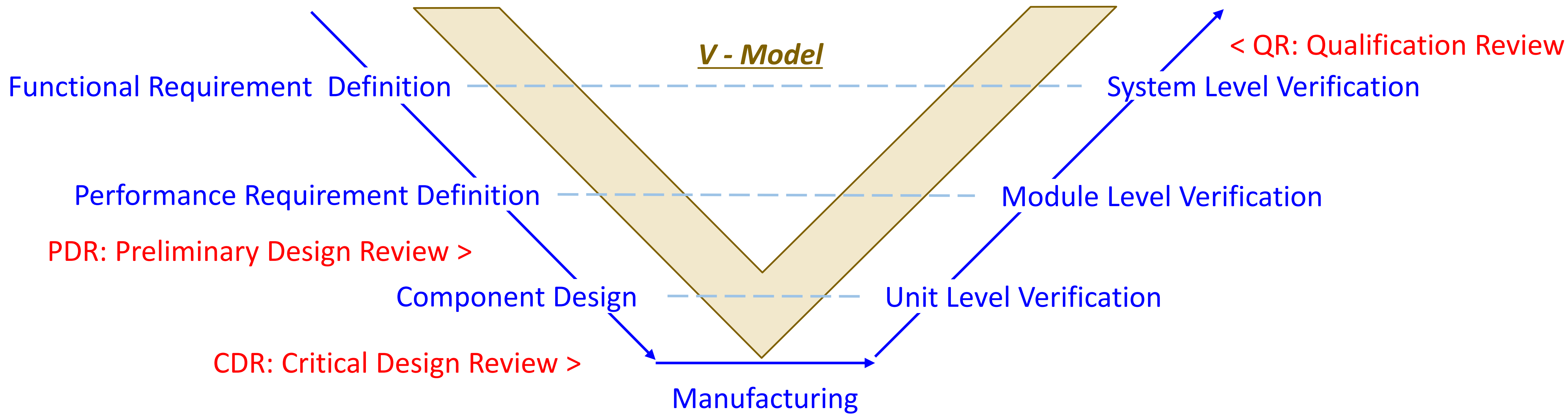
- The size of the CubeSat for each mission shall be carefully selected based on the difficulty level of the mission objective and the complexity of the requirements on payload instruments.
- Larger, high-performance bus systems will be required for high-level missions.
  - Higher power generation, storage, and consumption capability => Large solar panels and more battery capacity
  - Higher data processing capability, more memory storage, higher communication throughput.
  - Accurate attitude determination and control capability.
- The larger and the more complex the system is, the more effort will be required for the system integration.
- It is recommended that the interface between the payload and bus system is clearly defined so that they can be developed in parallel to shorten the development and verification time schedule.



4. CubeSat System Integration

4.3. Development and Verification of Satellite Components

- The requirements of the satellite components shall be defined and driven from the mission objectives and mission requirements. Component requirements include functional requirements, performance requirements, constraints, etc., both for the related hardware and software.
- Requirements shall be detailed by a preliminary design review, and component design shall be defined by a critical design review. Components shall be verified in a “bottom-up” manner, followed by a qualification review.



4. CubeSat System Integration

4.4. Hardware and Software Development and Verification Process

- Software functionalities shall be analyzed as the first step and functional requirements shall be identified.
- Functions can be classified into some functional groups which are implemented as a software unit for the component.
- Development schedules and progress of each hardware and software element shall be managed, and the order of their integration and verification shall be defined in order to control the development schedule.
- Unit tests can be at any level and any kind, in order to ensure that the components fulfill the requirements.
- Identification of verification items is critically important for the mission success. *Need experience!*

<u>Functional Analysis</u>

- Function 1 – Command Processing
- Function 2 – Housekeeping
  - Function 2.1 – Temp. Measurement
  - Function 2.2 – Heater Control
- Function 3 – Image acquisition
- Function 3A – Image processing
- etc…

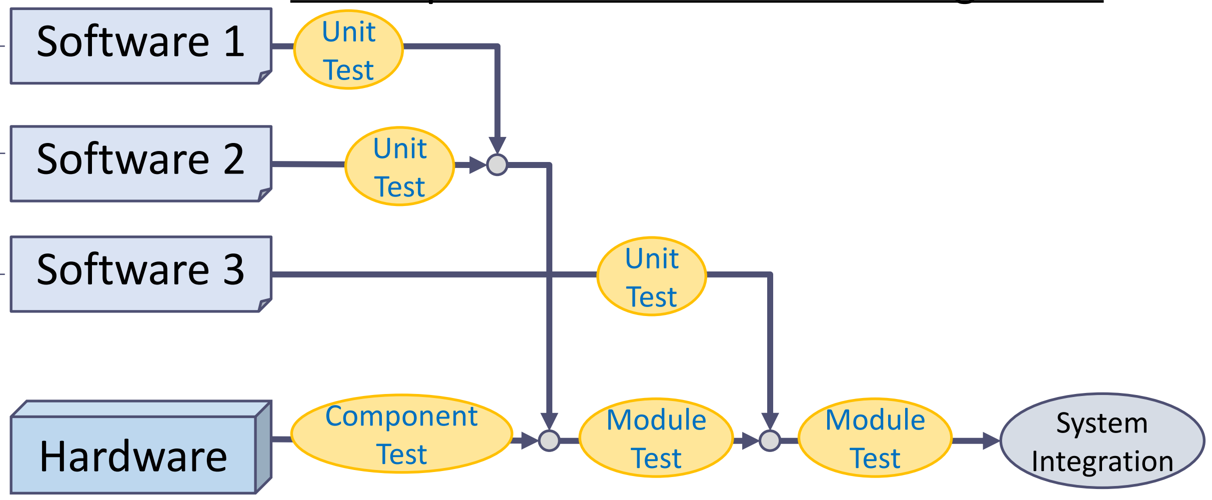
<u>Function Grouping</u>

- Function Group 1
- Function Group 2
- Function Group 3

<u>Hardware Selection</u>

Make or Buy

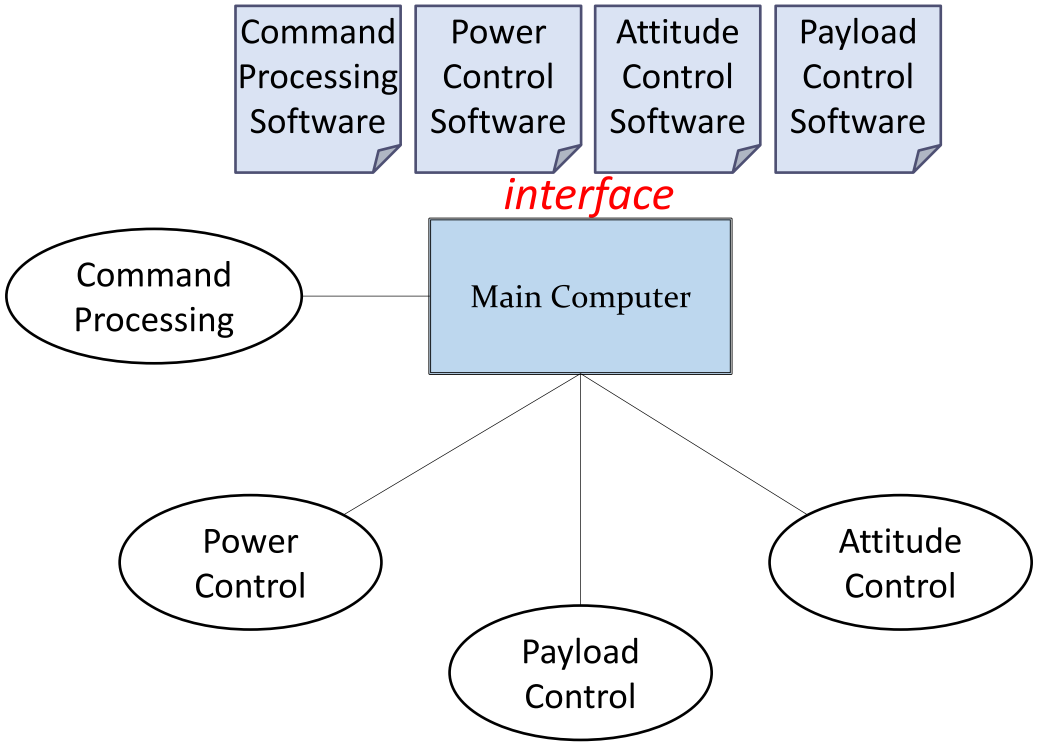
<u>Development & Verification Management</u>



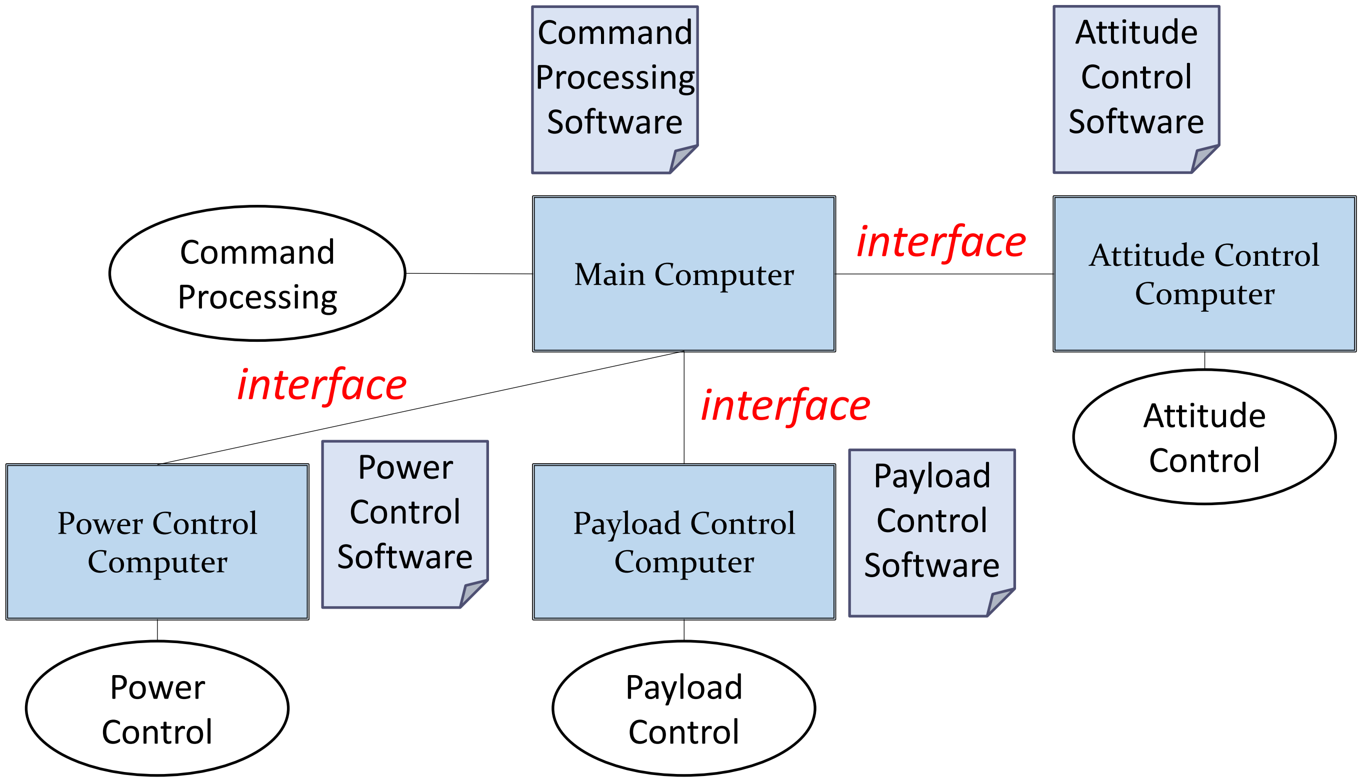
4. CubeSat System Integration

4.5. Computer Architecture and Software Configuration

- Single computer architecture can realize a high degree of system integration with minimum hardware configuration. However, software development of each functional block depends on each other and tends to take more time than the distributed architectures, which enables parallel and independent development of each functional block.



Centralized Single Computer

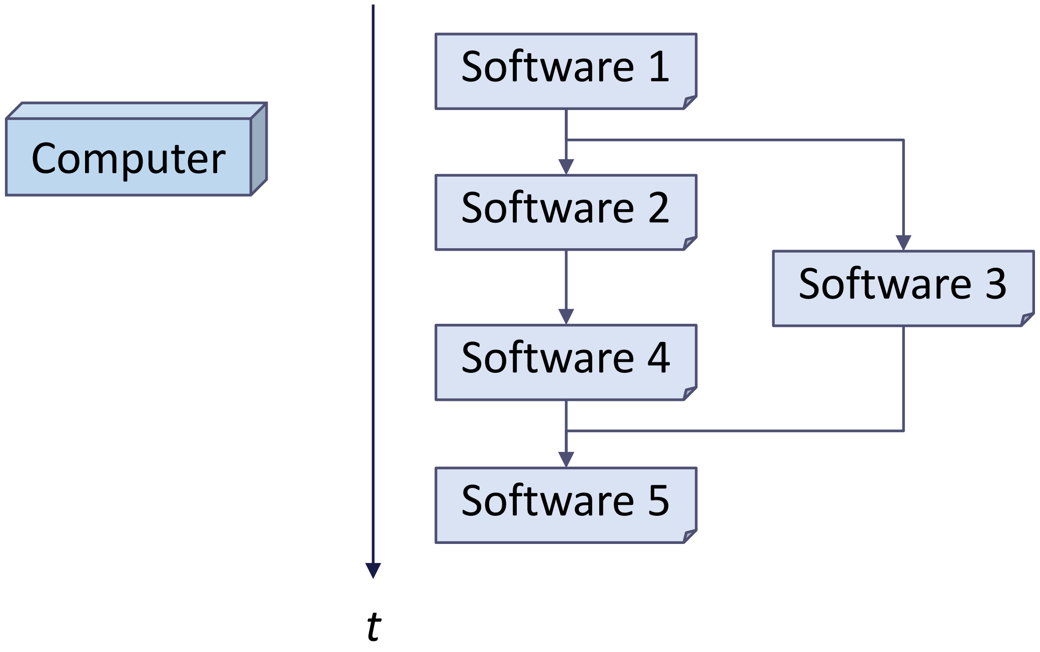


Distributed Computers

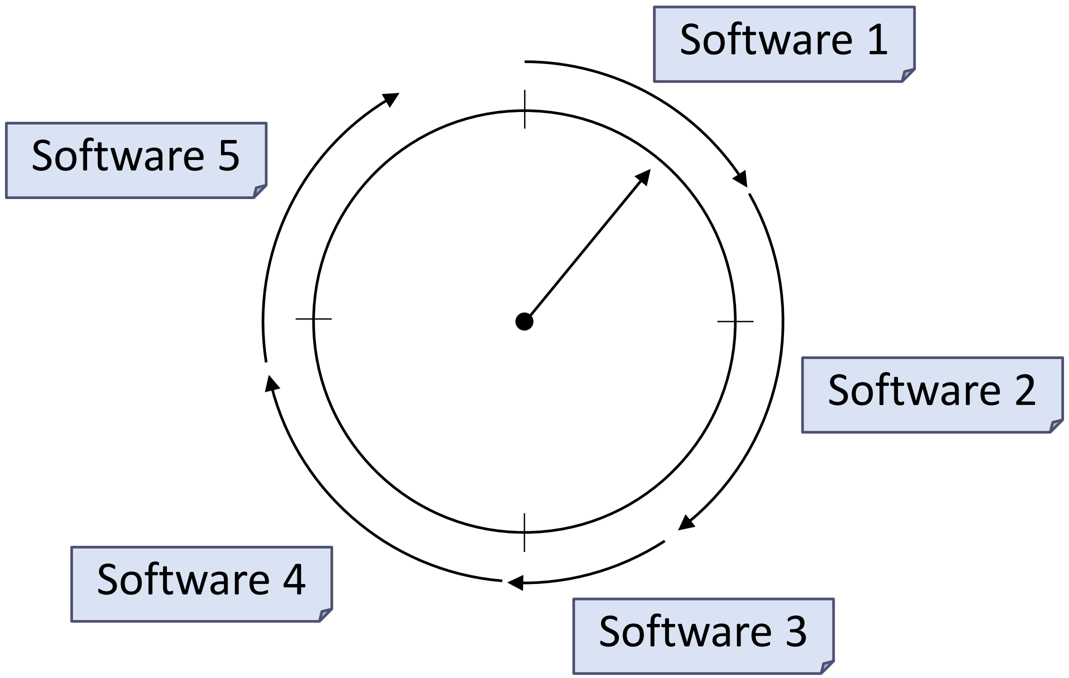
4.6. Software Integration

- Software units to be implemented and executed in a computer shall be integrated into a single piece of on-board software, paying attention to their execution order and logical relationships in between.
- The time period required for each of these software tasks shall be controlled so that the on-board computer can execute all the required tasks in the pre-defined required time period, periodically.

Software Execution

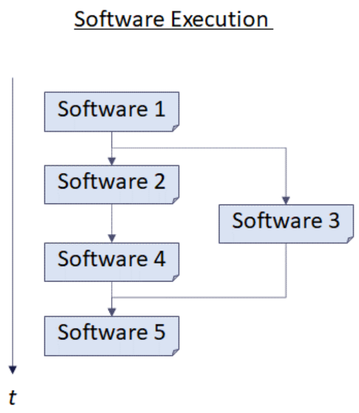


Periodical Execution

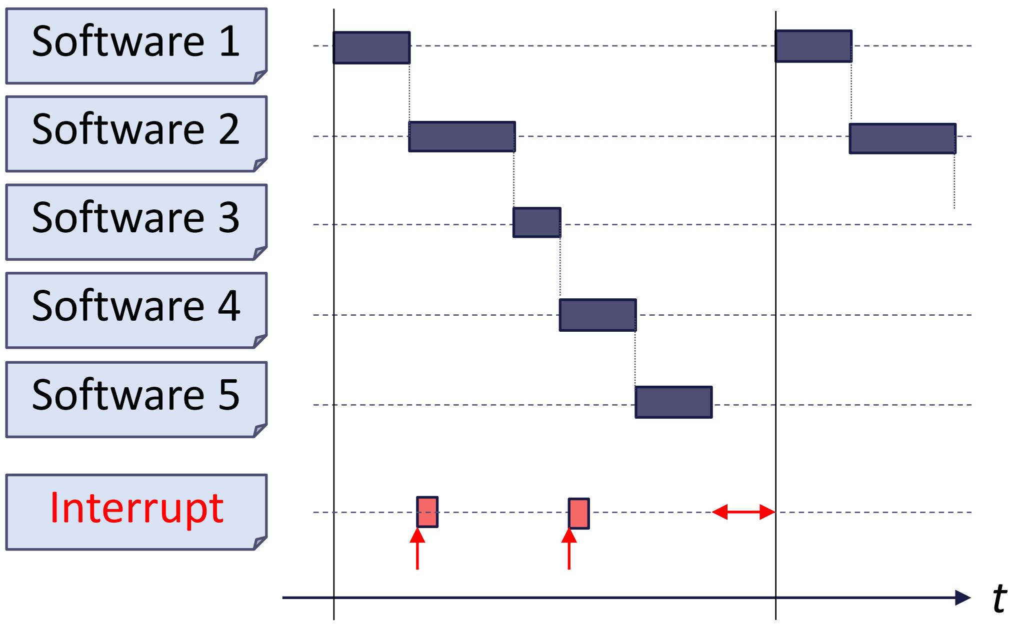


4.7. Software Operating System

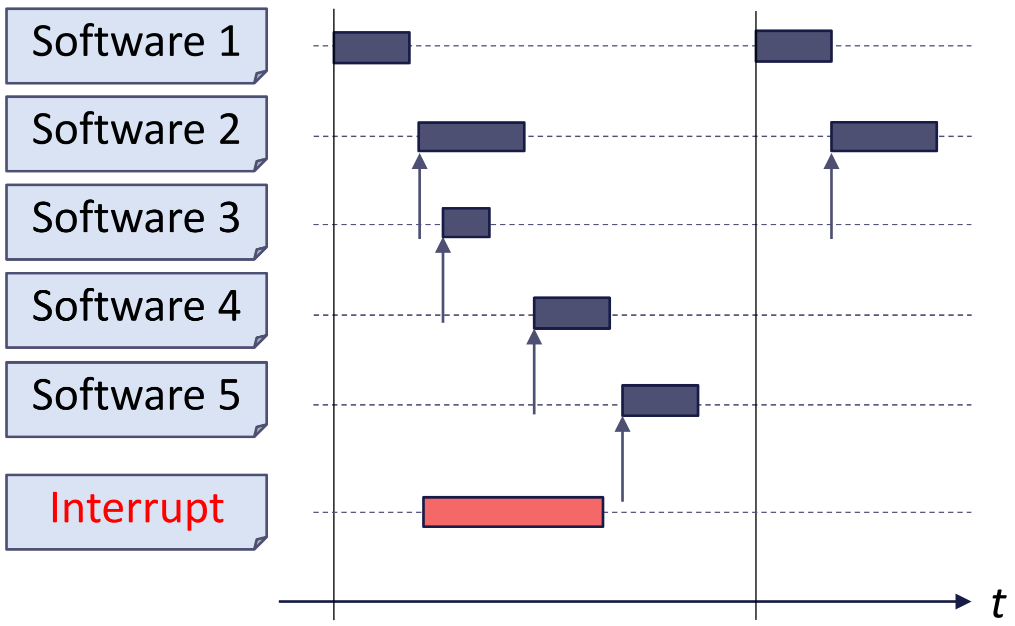
- Software can be implemented either in a "bare-metal" way or using a Real-Time Operating System (RTOS).
- Relatively high-performance computers can utilize RTOS due to its overhead.
- Bare-metal implementation requires more precise tuning of the timing by the programmer.
- RTOS enables precise timing control of the execution and ease of parallel execution of more than one software units.



Bare-Metal Implementation



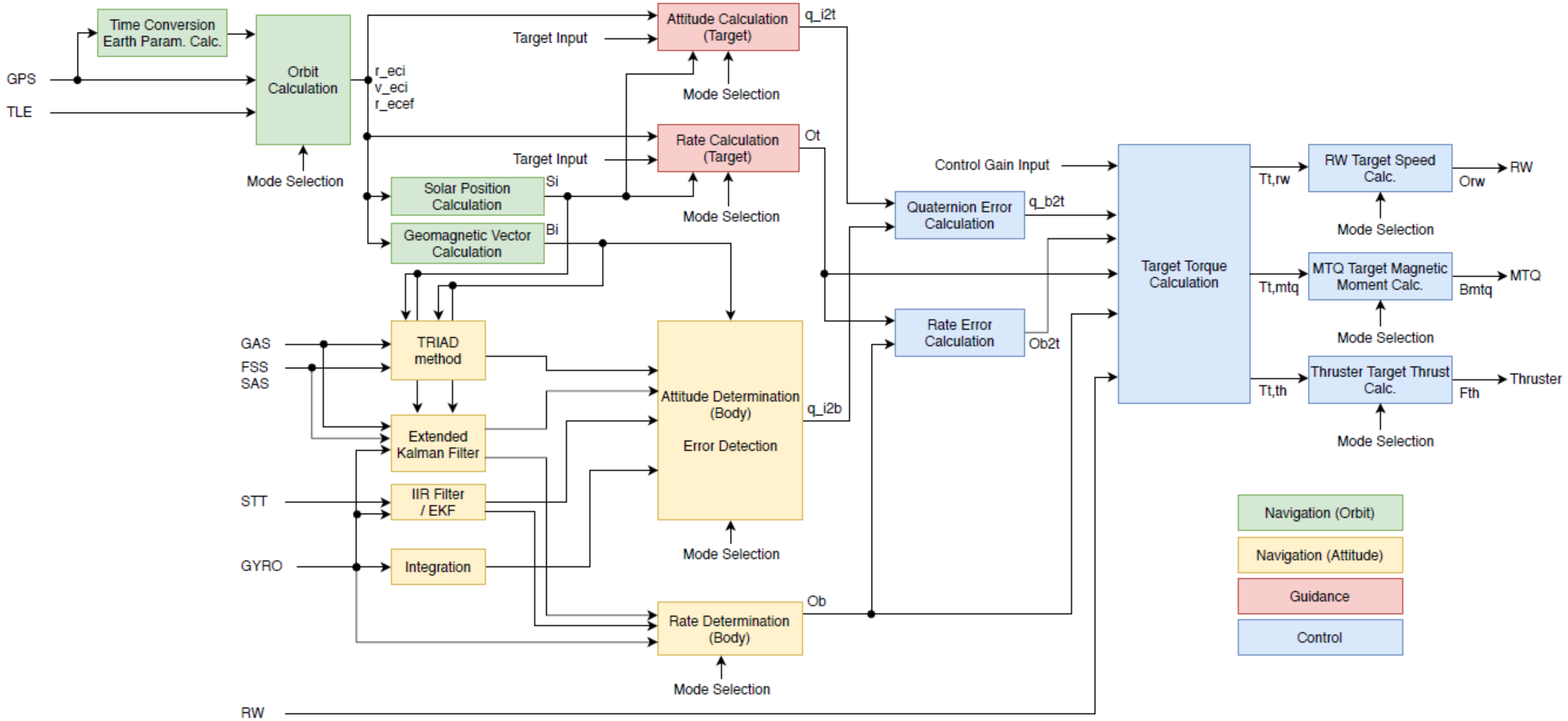
Real-Time Operating System Implementation



4.8. Attitude Determination and Control Software Implementation

- Attitude determination and control software processes includes software functional groups, such as guidance, navigation, and control, and their careful implementation to achieve high-precision attitude control.

Attitude Determination and Control Software Process

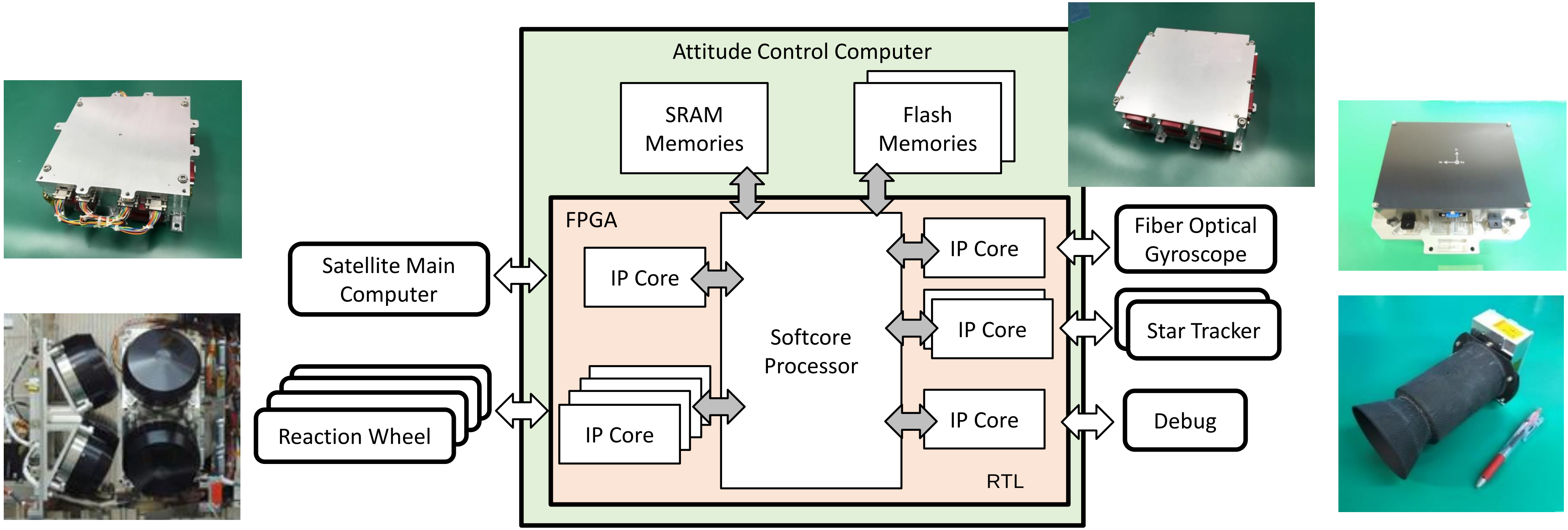


4. CubeSat System Integration

4.9. System Integration through System-on-a-Chip Implementation

- A computer system can be constructed through a System-on-a-Chip (SoC) design approach. Recent advanced of FPGA (Field-Programmable Gate Array) technology allows you to implement CPU and custom peripheral interface logics inside a single FPGA chip.
- Large number of peripheral components can be connected to the computer.

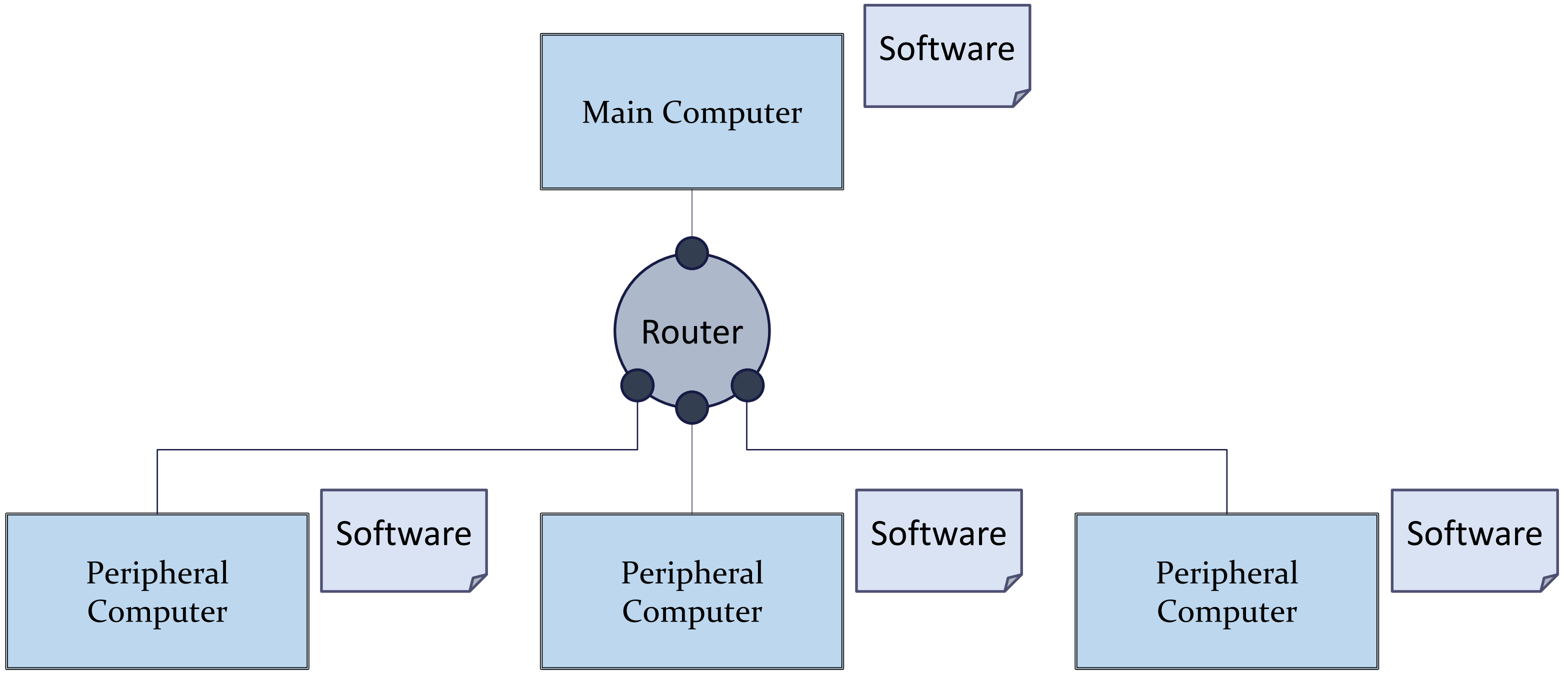
System-on-a-Chip Design Approach – An example of Micro-satellite (RISESAT) Attitude Control System



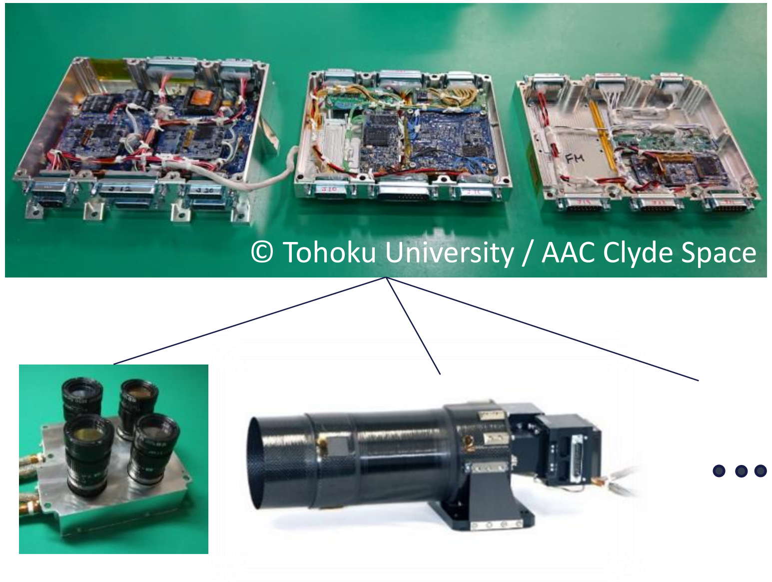
4.10. System Integration through Plug-and-Play

- Standardization of hardware and software can realize satellite system integration through Plug-and-Play (PnP).
- There are several PnP standards suggested for several types of interfaces, such as I^2C, USB, SpaceWire, etc.
- Through PnP technology, one can minimize the system integration effort and maximize reusability.

Plug-and-Play Architecture



PnP Computer of Micro-satellite RISESAT

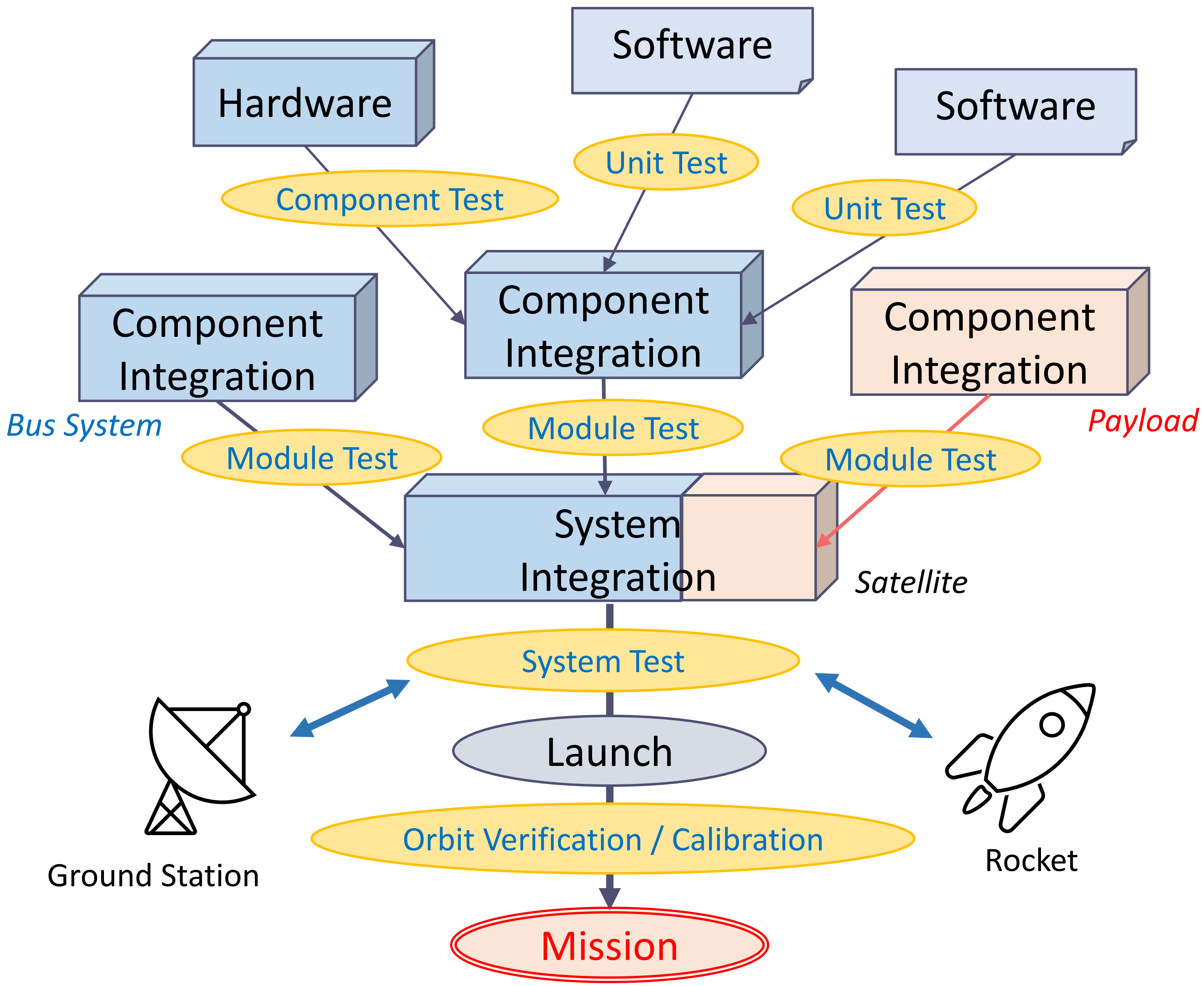


Ocean Observation Camera

Multi-spectral Camera

4.11. Satellite System Integration and Testing

- Satellite system integration takes place in a bottom-up manner, starting from the hardware and software integration of each component, integration between components, and integration between the bus system and payload.
- Assembly and testing shall be conducted in each integration test. This activity is sometimes referred as Assembly, Integration, and Test (AIT).
- The scope of the system level testing shall include testing together with the ground stations and launch vehicles, or its interfaces.
- Satellite hardware and software functionalities shall be tested and calibrated even after the launch, in order to ensure that the satellite can fulfil the mission requirements.



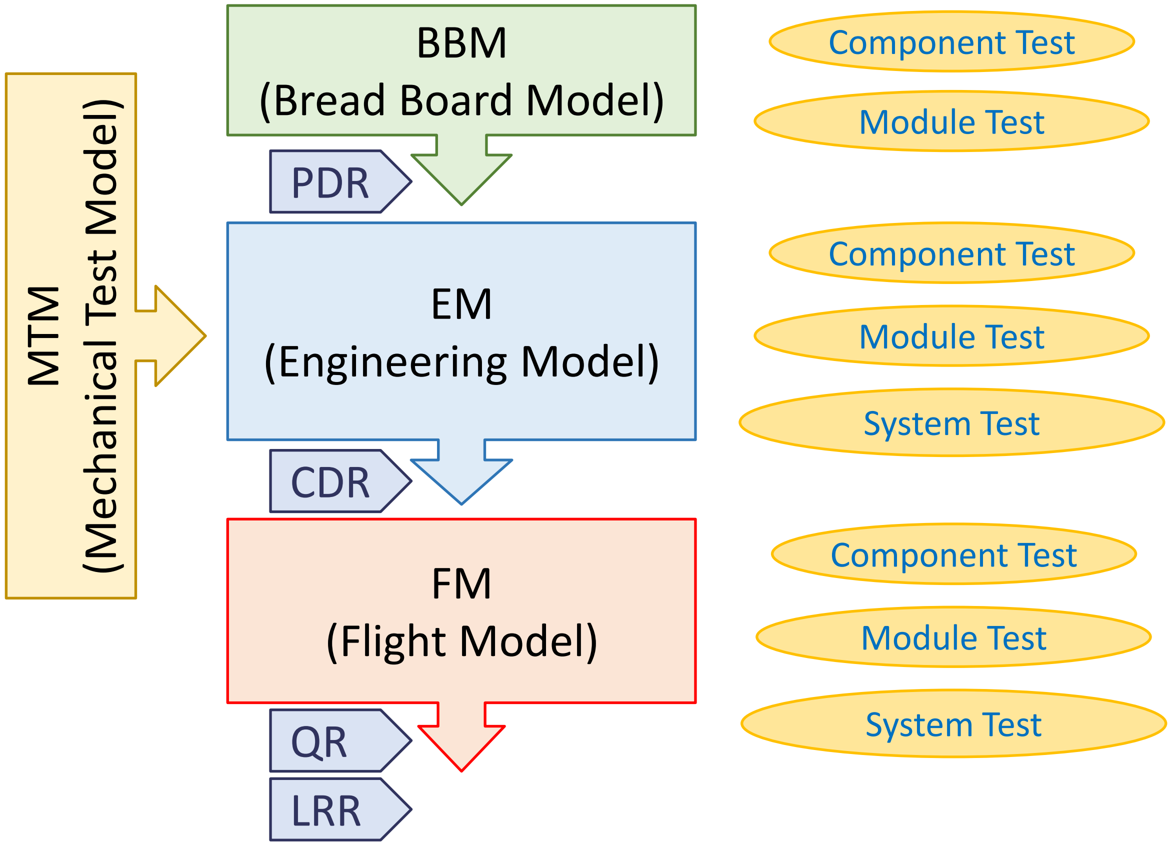
5. CubeSat Functional Verification

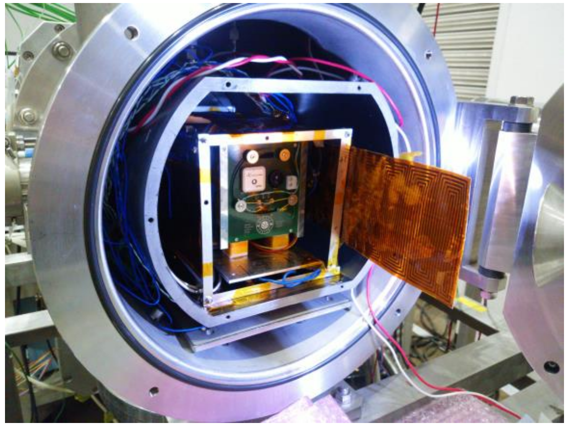
5. CubeSat Functional Verification

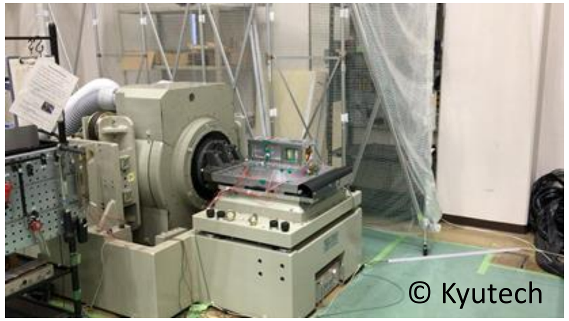
5.1. Verification Process

- Verification processes of a satellite can start from the Bread Board Model (BBM) concept verification.
- Detailed design solution of the satellite is verified using Engineering Model (EM).
- Flight Model (FM) is manufactured based on the verified design through EM, and minimum required tests are applied to obtain qualification for the launch.
- Sometimes a mechanical test model is utilized before the manufacturing of the structure of the EM.

Satellite Verification Process



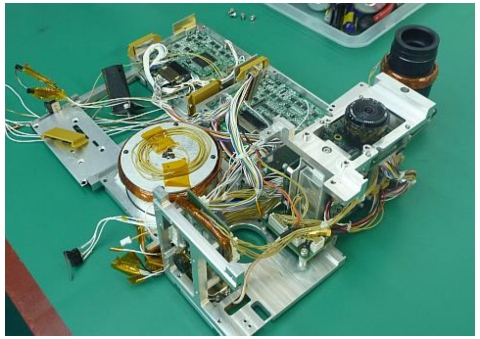


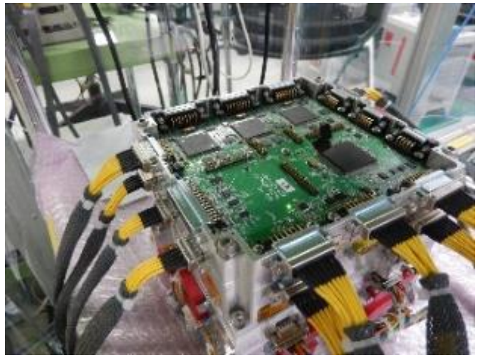


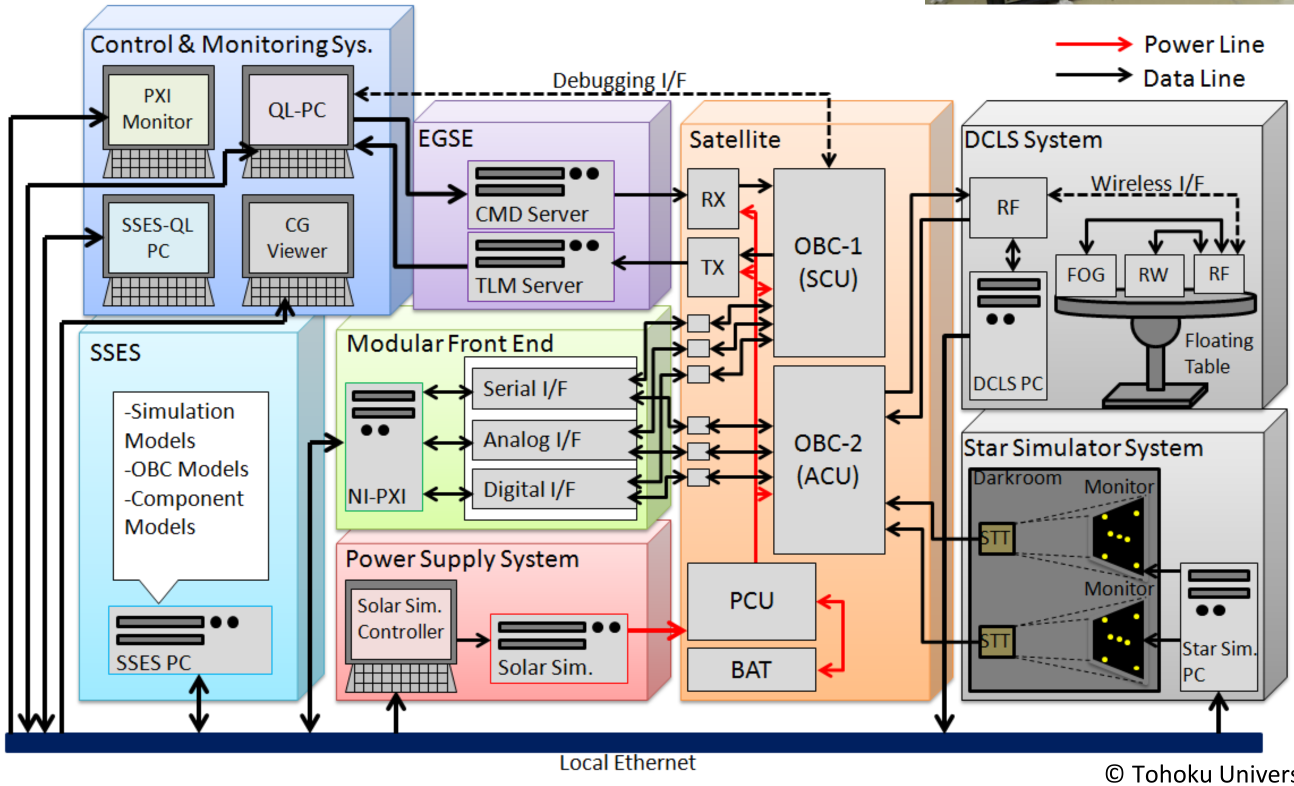
© Kyutech

5.2. Electrical Testing

- Ground testing facilities are required to conduct tests of electrical functionalities of the satellite components and satellite system.
- Software-based simulators are utilized for hardware-in-the-loop tests in real-time in order to verify the correct functionalities of on-board software running on the actual flight hardware.



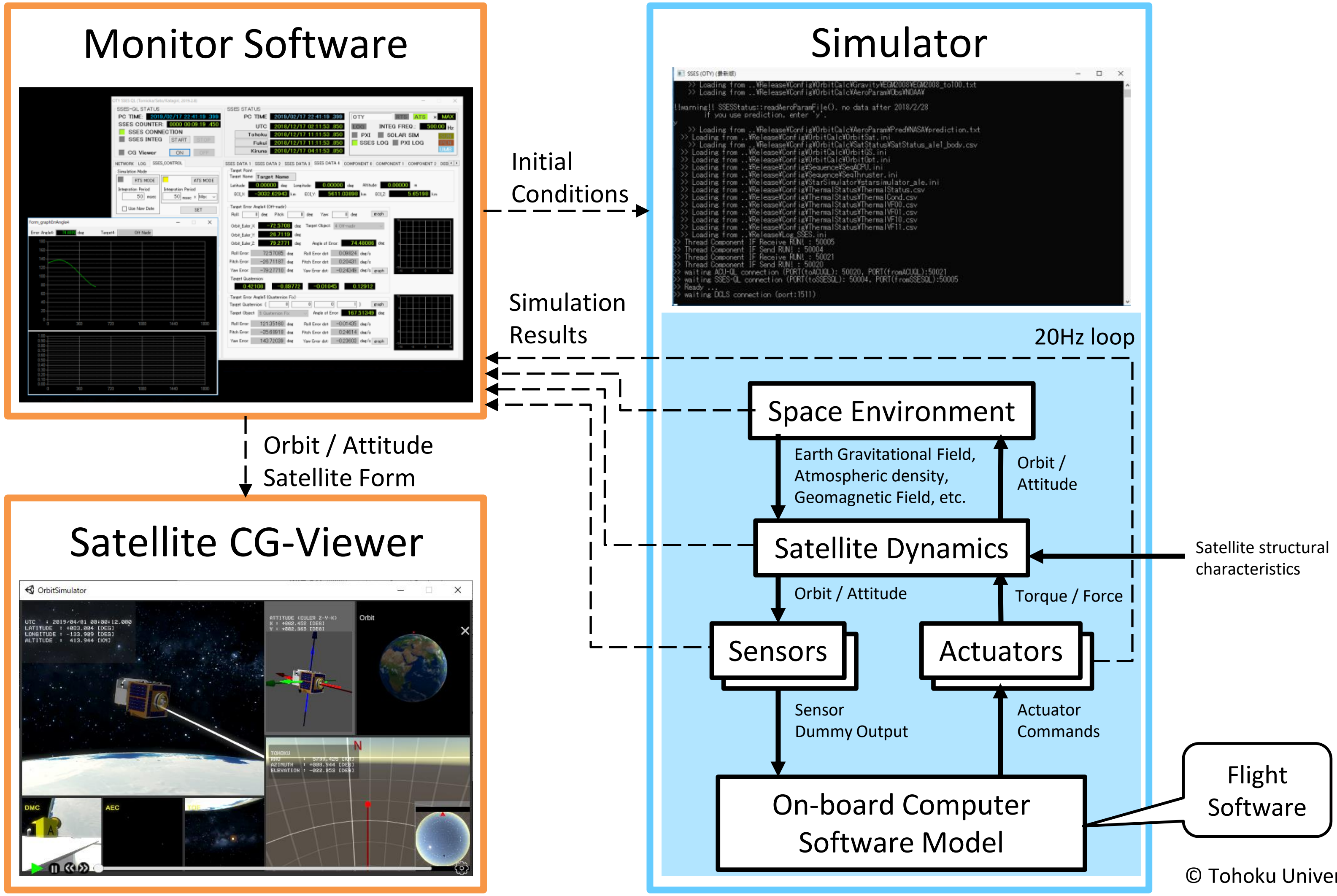




© Tohoku University

5.3. Software Simulation

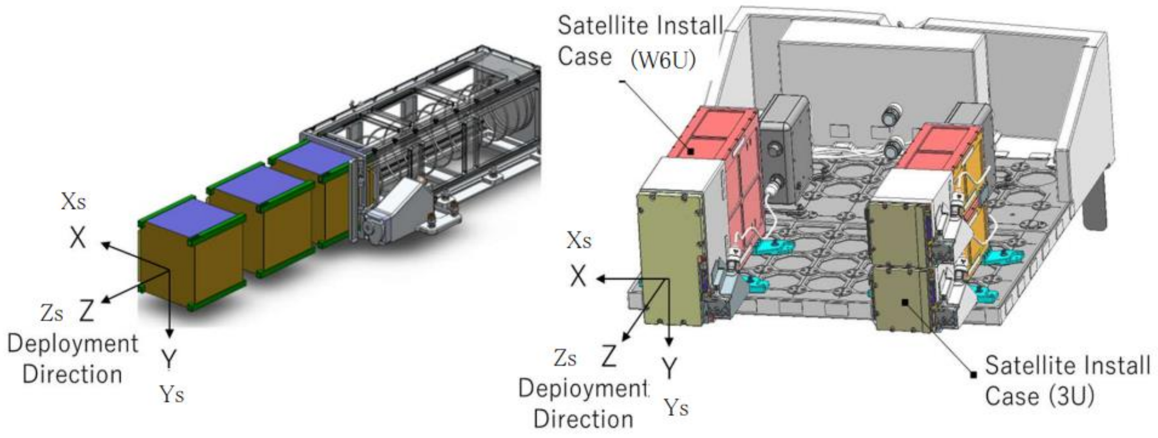
- Full software simulators are very useful for the simulation of the satellite's orbital and attitude behavior.
- The simulation process can be accelerated to conduct a large number of simulation trials.
- On-board software can be developed using this kind of simulation, software development, and verification environment.



5. CubeSat Functional Verification

5.4. Fit Check

- “Fit check” is a one of the most important tests of a CubeSat. A CubeSat’s mechanical and electrical compatibilities are tested using a mechanical Fit Check model of the CubeSat deployment pod.
- The manufacturing and integration of the mechanical system shall fulfill the mechanical requirements posed on CubeSats, such as dimension tolerance, surface accuracy, contact of mechanical switches, etc.
- Not only the structural design, but also the satellite integration process, shall be planned in the way that the satellite assembly and integration process is reproducible.
- It is very important that the assembly, integration and test results are carefully recorded in documents.



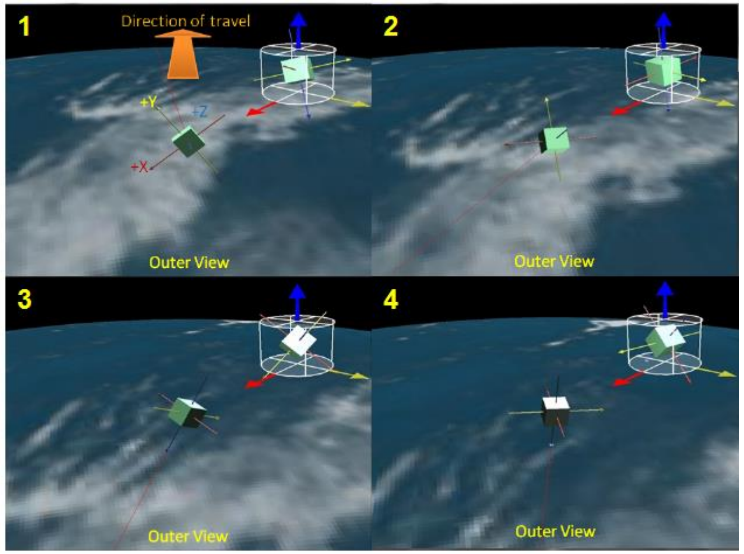
© JAXA

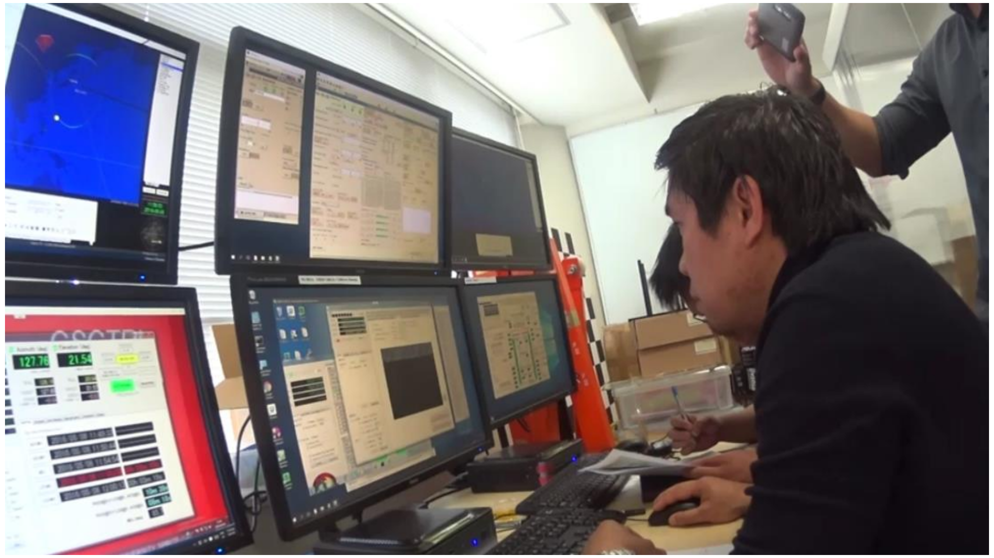
© JAXA

5. CubeSat Functional Verification

5.5. Operation Training

- Operational training shall be started at an early stage of the satellite development, so that the verified software and procedure can be reflected to the flight software.
- Ground station software and on-board software shall be developed and tested in parallel.
- Satellite operation planning skills shall be established within the team using the environment.
- Mission lifetime of a satellite is limited, and hence, effective operation of the satellite is indispensable in order to ensure a secure operation of the satellite and to obtain maximum achievements.





6. CubeSat Project Management

6. CubeSat Project Management

6.1. Hands-on Space Engineering Education

<u>Space Education through Small Satellite Projects</u>

Project members and students experience:

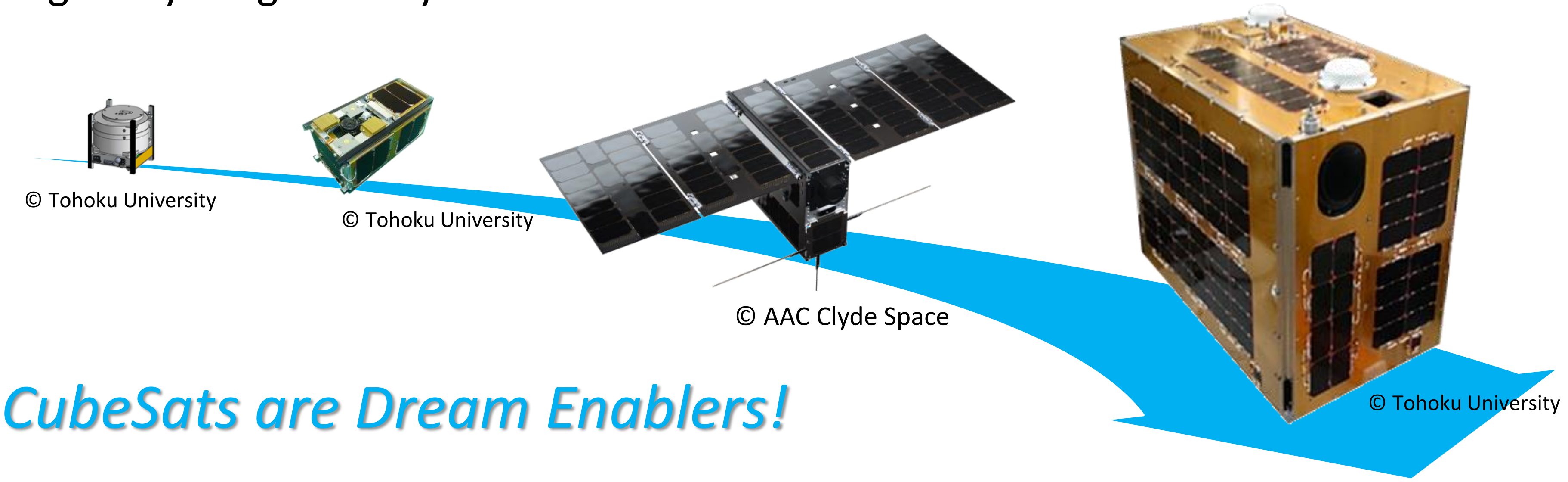
- Mission Analysis
- System Design
- System Development
- Component Procurement
- Component Development
- System Integration
- On-board Software / Algorithm Development
- Ground Verification
- Ground Environmental Test
- Safety Design, Safety Review
- Satellite Delivery and Launch
- Ground Station Installation
- Satellite Operation, Instrument Calibration
- Satellite Data Analysis

© Tohoku University

6.2. Stepwise Development of CubeSats and Beyond

"Start small, go big!"

- Recently, CubeSats have become a major game-changer in the world.
- Thanks to the technological advancement of small satellites, CubeSats are no longer for education only, but for actual space development and utilization.
- Achievements obtained from smaller CubeSats can be directly applied to larger satellites for even more advanced missions.
- 1U CubeSats bring everything within your reach!



CubeSats are Dream Enablers!

6.3. UNISEC Space Engineering Education Activities

University Space Engineering Consortium

6.4. International Space Engineering Education Opportunities

KiboCUBE

- JAXA/UNOOSA program
- Provide opportunities for educational and research institutions from developing economies and economies in transition which are United Nations Member States.

BIRDS Program

- Kyushu Institute of Technology (Kyutech)
- CubeSat development, hands-on training, education, academic program.

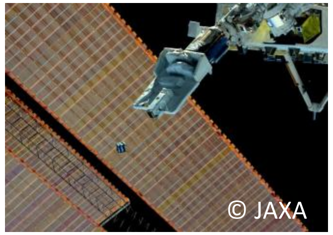
RWASAT-1

- University of Tokyo
- CubeSat development, hands-on training, education.

Micro-Satellite Program

- Tohoku University and Hokkaido University
- 50-kg-class Earth observation micro-satellite projects
- Hands-on activities, education, academic program.
- Establishment of Asia Micro-satellite Consortium (AMC).

JAXA and Japanese Universities have strong collaborative relationships.



© JAXA

© Kyutech

© University of Tokyo/Arkedge Space/RURA

© JAXA

6. CubeSat Project Management

6.5. Worldwide CubeSat Community

- Thanks to the standardized specifications and interfaces of CubeSats, educational and research institutions can share their experiences, engineering skills, on-board components, software, launch opportunities and even their missions!
- By benefitting from each other in the worldwide CubeSat community, one can rely on some of the already established technologies and can realize quick and secure access to space.
- CubeSats can be enabling tools for future space exploration for new engineering and scientific findings, affecting many areas of life on Earth.
- CubeSats can also be one of the future business markets for the nations involved.

7. Conclusion

7. Conclusion

- System engineering processes of CubeSats are introduced, step-wise development activities and review processes are described. The definition of satellite subsystems, as well as relationships of the payload and bus system is explained.
- CubeSat-related standards are introduced, launch opportunities and available mechanical form factors are described.
- CubeSat system interface was introduced in terms of electrical interconnections between satellite components, system block diagrams, system configuration design, power distributions, communications, and mechanical interfaces.
- System integration and verification processes, as well as their engineering aspects, were described both in hardware and software aspects. Some related advanced topics were introduced, such as System-on-a-chip design method and Plug-and-Play system integration method.
- CubeSat functional verification method was introduced. Topics such as environmental testing, electrical functional verification, fit check with the deployment pod, and operation training were discussed.
- Important aspects of CubeSat project management in terms of system integration and capacity building were discussed.

- CubeSats, are now ***changing the game of space development*** and utilization through their low-cost rapid development characteristics, which are based on standardized specifications and interfaces.
- CubeSats are ***the best platform*** for getting started with space development and utilization, and KiboCUBE Academy facilitates access to space for becoming spacefaring nations.

Thank you very much.

[Disclaimer]
The views and opinions expressed in this presentation are those of the authors and do not necessarily reflect those of the United Nations.