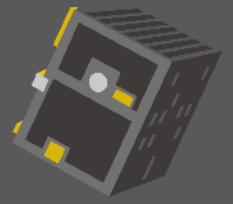

Lessons Learned and Mission Assurance of Small Satellite Development in JAXA's "Innovative Satellite Technology Demonstration Program"

June 25, 2024

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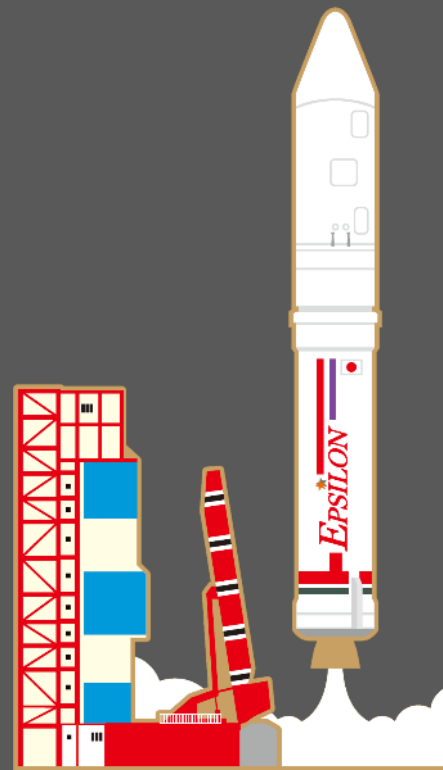
Research and Development Directorate, JAXA

革新
INNOVATIVE
SATELLITE TECHNOLOGY
DEMONSTRATION PROGRAM



Innovative Satellite Technology Demonstration Program

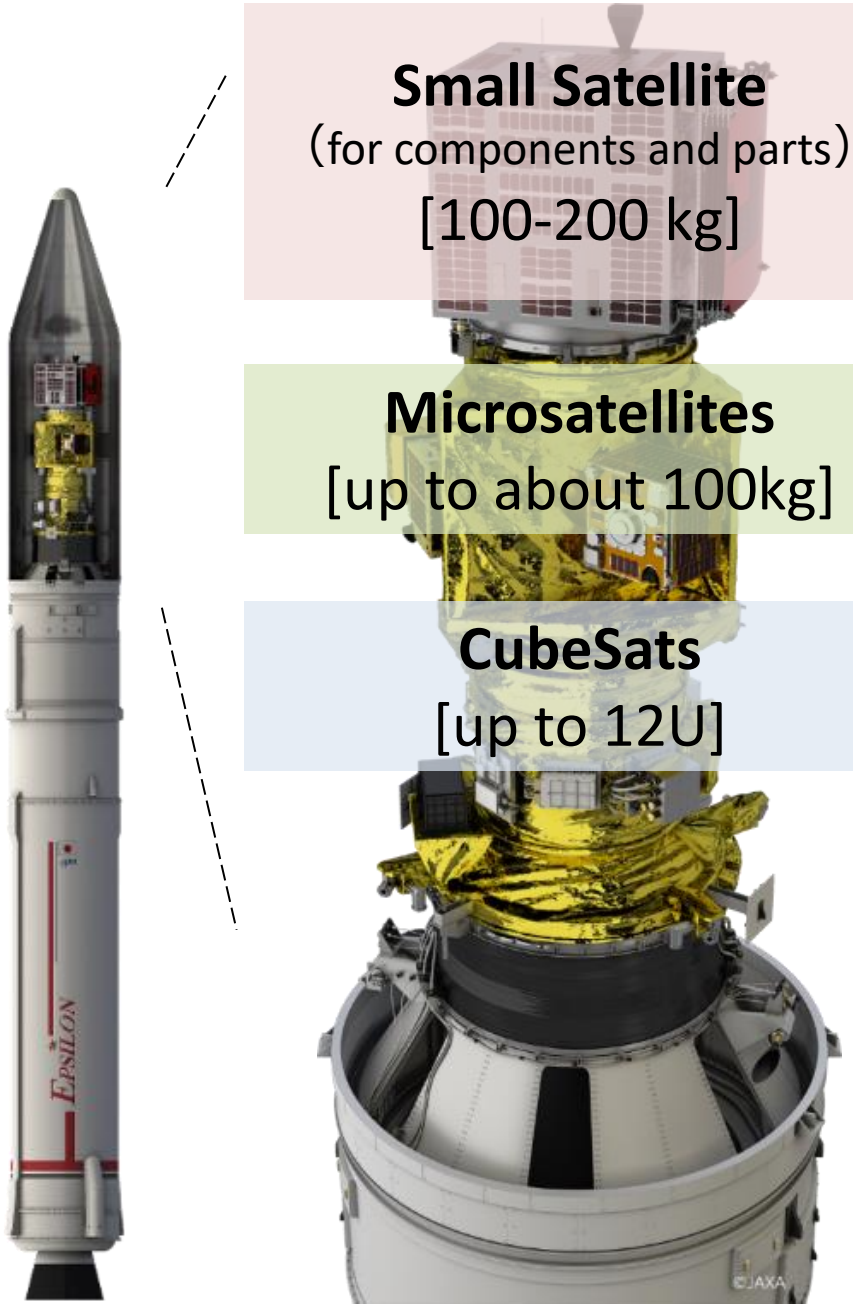
- This program provides Japanese universities, research institutes, and private companies with **on-orbit demonstration opportunities** to strengthen international competitiveness, revitalize the space industry, promote business, and develop human resources.

  ** The demonstration missions are targeted at domestic organizations.*

- Continuous demonstration missions are planned, **once every two years**.

Features

- Demonstration under this program covers from satellite systems (Microsatellites and CubeSats) to components.
- **Component alone can be demonstrated** by JAXA-developed small satellite.
- Technology that have had **few on-orbit demonstration opportunities** (ex. satellite propulsion systems, deployment mechanisms, and individual parts), **can be demonstrated**.



Small Satellite
(for components and parts)
[100-200 kg]

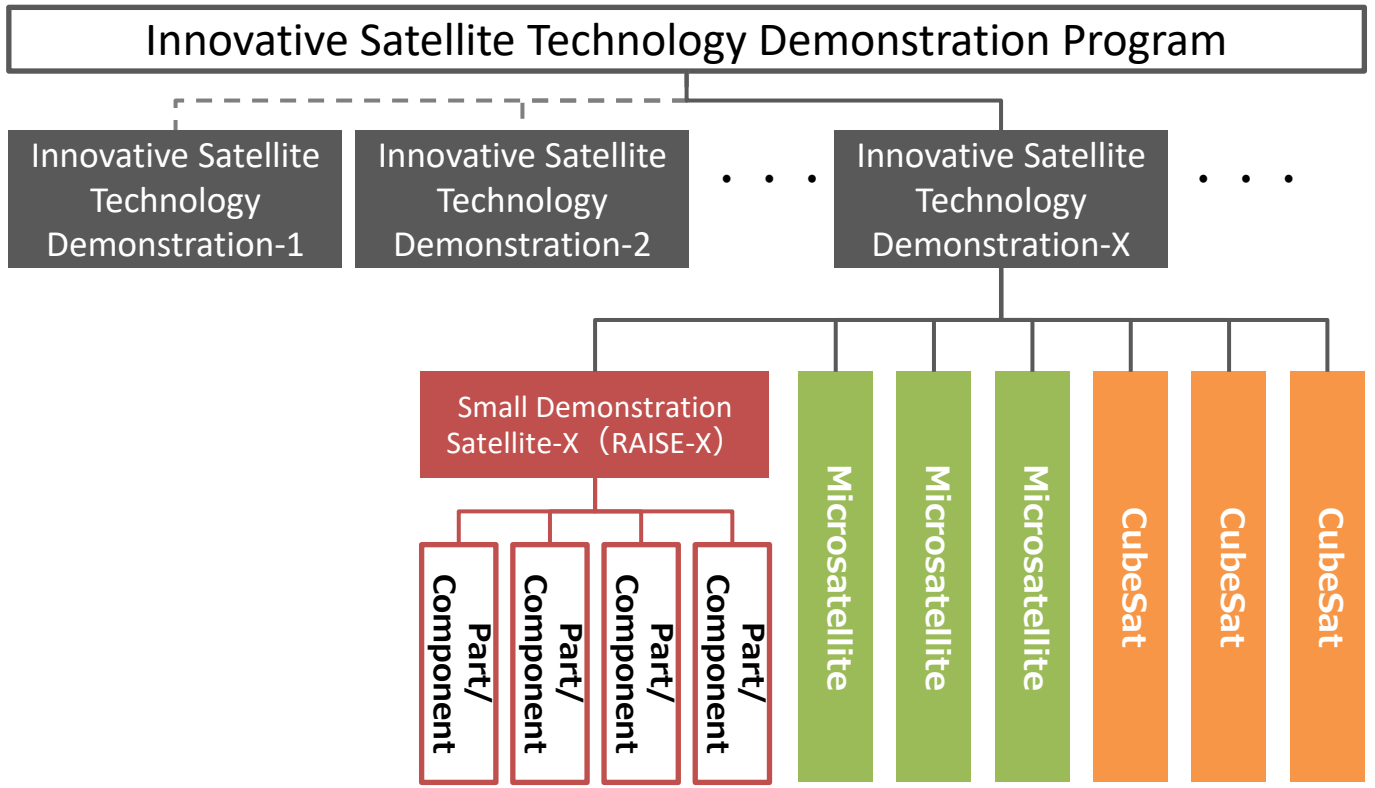
Microsatellites
[up to about 100kg]

CubeSats
[up to 12U]

Demonstration Missions

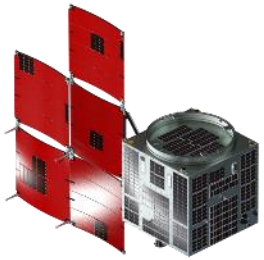
Various demonstration opportunity is available.

- Parts (electronic and machine parts, etc.) and components
- Microsatellite [up to about 100kg]
- CubeSat [up to 12U]

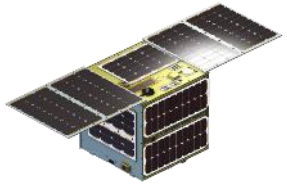


Innovative Satellite Technology Demonstration-1

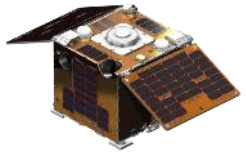
- 7 satellites (13 demonstration themes in total).
- Launch on January 18, 2019, by Epsilon Launch Vehicle No.4.



RAPIS-1
(JAXA)

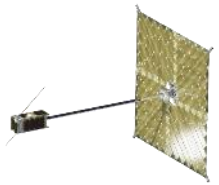


MicroDragon
(Keio University)



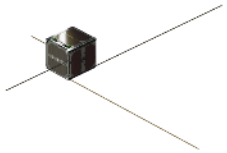
RISESAT
(Tohoku University)

ALE-1
(ALE Co., Ltd.)



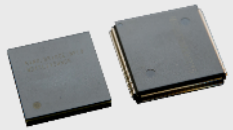
OrigamiSat-1
(Tokyo Institute of Technology)

Aoba VELOX-IV
(Kyushu Institute of Technology)

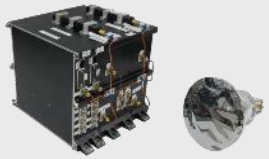


NEXUS
(Nihon University)

Microsatellites | **CubeSats**



NBFPGA
(NEC Corporation)



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Keio University
/Tokyo University / ISAS

HXTX/XMGA
(Keio University)

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GPRCS
(Japan Space Systems)

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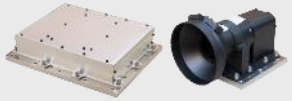
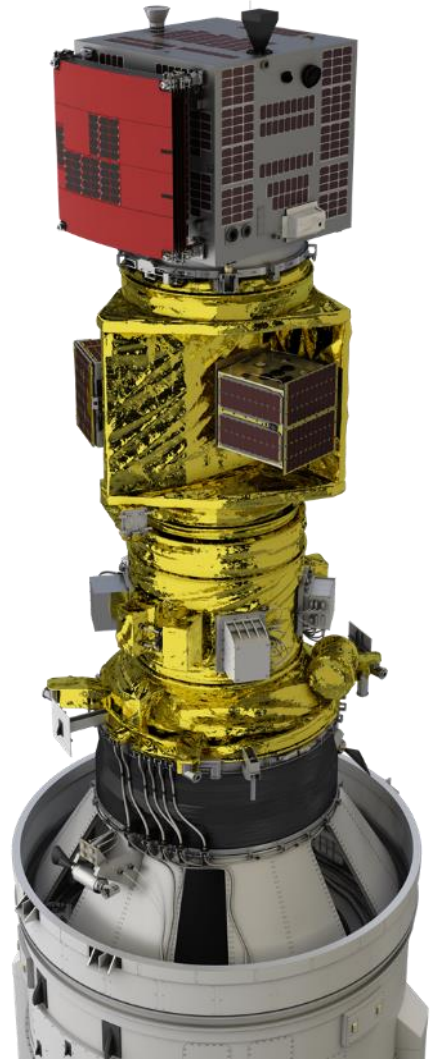
SPM
(Japan Space Systems)



DLAS
(Tokyo Institute of Technology)

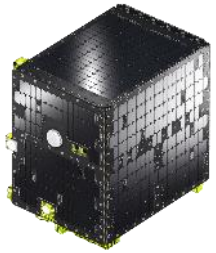
TMSAP
(JAXA)

Fireant
(Chubu University)

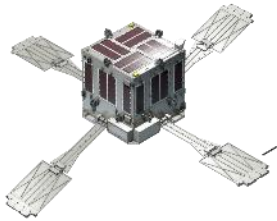


Innovative Satellite Technology Demonstration-2

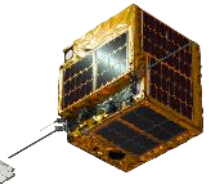
- 9 satellites (14 demonstration themes in total).
- Launch on November 9, 2021, by Epsilon Launch Vehicle No.5.



RAISE-2
(JAXA)



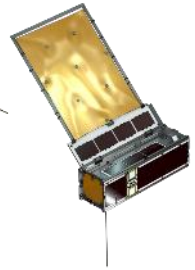
HIBARI
(Tokyo Institute of Technology)



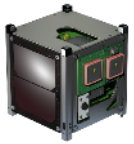
Z-Sat
(MHI)

DRUMS
(KHI)

TeikyoSat-4
(Teikyo University)

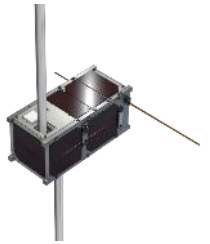


ASTERIS
(Chiba Institute of Technology)



ARICA
(Aoyama Gakuin University)

NanoDragon
(Meisei Electric Co., Ltd.)

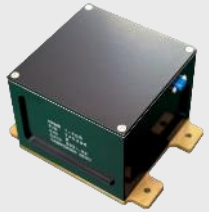


KOSEN-1
(National Institute of Technology, Kochi College)

Microsatellites

CubeSats

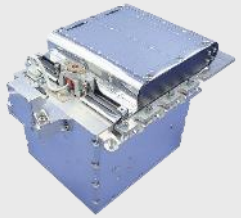
SPR
(Sony Semiconductor Solutions Corporation)



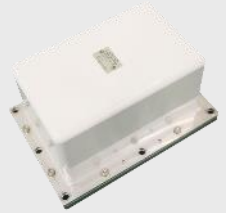
I-FOG
(Tamagawa Seiki Co.)

ASC
(Amanogi, Corp.)

3D-ANT
(Mitsubishi Electric Corporation)



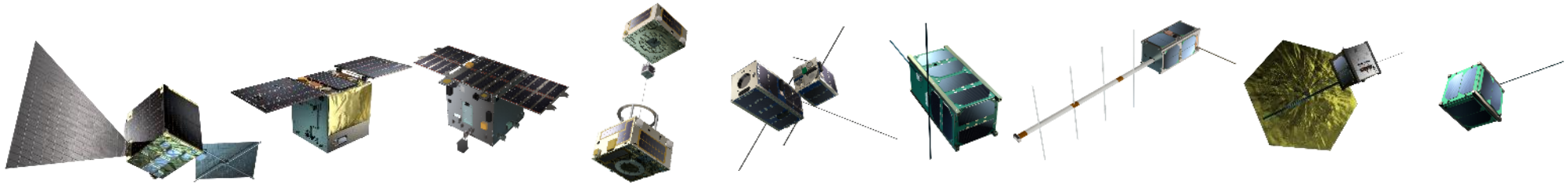
ATCD
(Tohoku University)



MARIN
(JAXA)

Innovative Satellite Technology Demonstration-3

- 9 satellites (15 demonstration themes in total).
- RAISE-3 and 5 CubeSats were launched by Epsilon Launch Vehicle No.6 on October 12, 2022, but failed to inject into orbit.
- KOYOH launched on December 2, 2023. Launches of PETREL & STARS-X are being coordinated.



RAISE-3 (JAXA)
KOYOH (Kanazawa University)
PETREL (Tokyo Institute of Technology)
STARS-X (Shizuoka University)
MAGNARO (Nagoya University)
MITSUBA (Kyushu Institute of Technology)
KOSEN-2 (National Institute of Technology (KOSEN), Yonago College)
WASEDA-SAT-ZERO (Waseda University)
FSI-SAT (Future Science Institute)

Microsatellites | **CubeSats**

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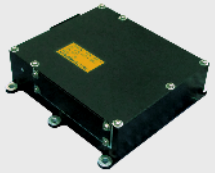
LEOMI (Nippon Telegraph and Telephone Corporation)

© NEC Space Technology, Ltd.

SDRX (NEC Space Technology, Ltd.)



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GEMINI (Mitsubishi Electric Corporation)

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KIR (Pale Blue Inc.)

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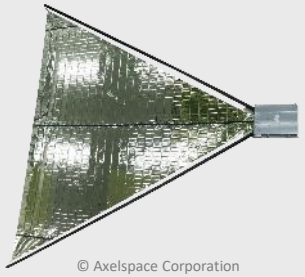

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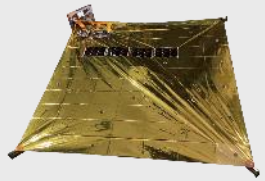
D-SAIL (Axelspace Corporation)



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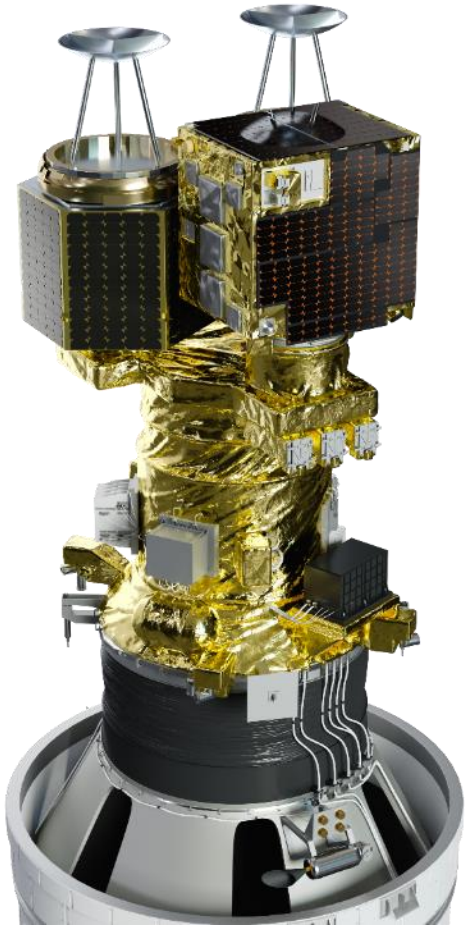
HELIOS (SAKASE ADTECH CO., LTD.)



Innovative Satellite Technology Demonstration-4

- 9 satellites (16 demonstration themes in total).
- Rechallenge demonstration missions of “Innovative Satellite Technology Demonstration-3” and new missions were selected.
- Under developing. Scheduled for launch in JFY2025.

Oct. 2015：
Call for Missions

Jul. 2018：
Call for Missions

Jan. 2019：
Launch

Feb. 2020：
Call for Missions

Nov. 2021：
Launch

Jun. 2022：
Call for Missions

Oct. 2022：
Launch

Innovative Satellite Technology Demonstration-1

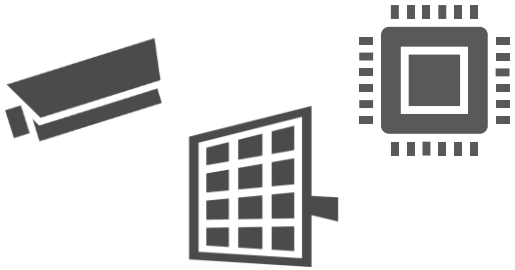
Innovative Satellite Technology Demonstration-2

Innovative Satellite Technology Demonstration-3

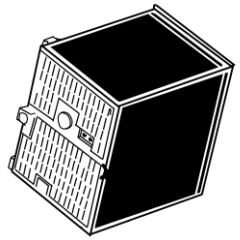
Innovative Satellite Technology Demonstration-4

Small satellites as a demonstration platform

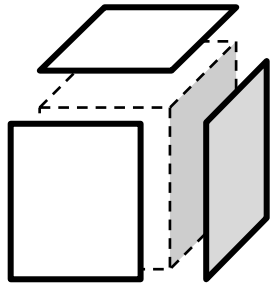
- are developed by JAXA.
- mount demonstration mission components.
- perform in-orbit experiments of each demonstration mission.
- provide experimental data to the mission component users.



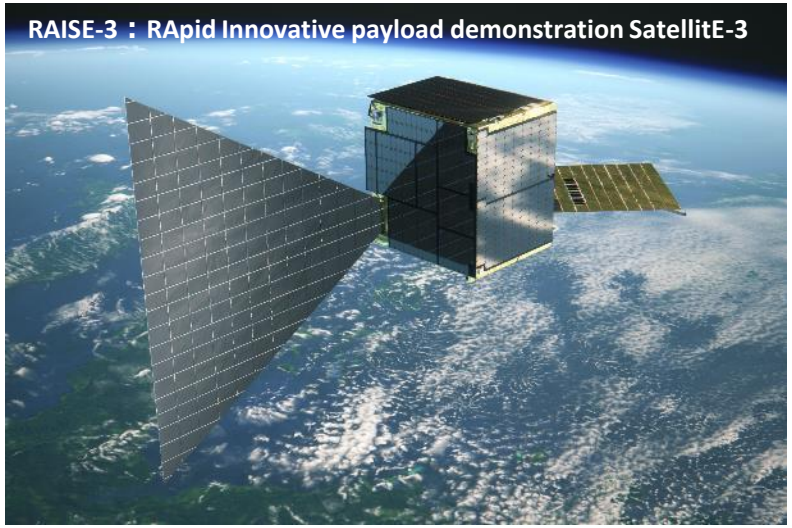
Mission component users



JAXA

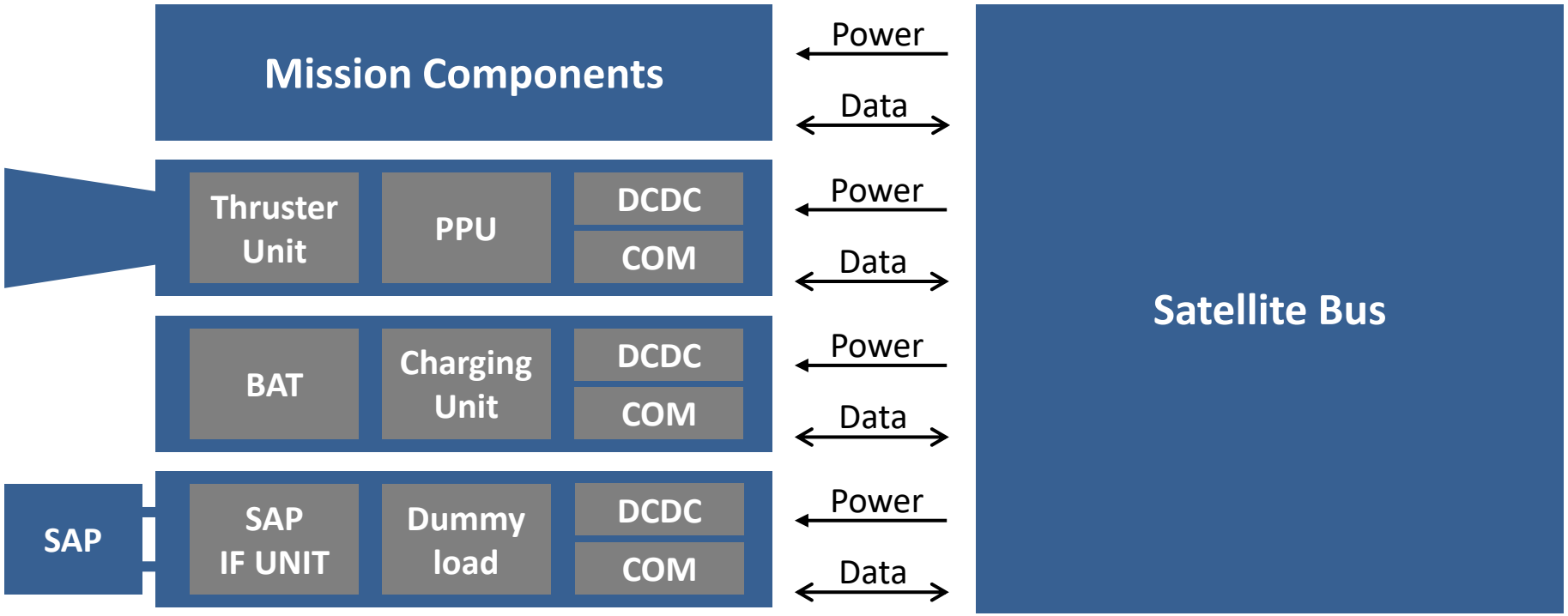


Satellite manufacturer



Mission interface

- To prevent loss of system functions due to failure of any mission component, the satellite bus and mission components are separated as little as possible.
- Equipment for the operation or monitoring the mission component must be prepared by the users to eliminate complex coordination and ensure independence.
- The above policy is nominal, but the interface can be adjusted if needed.



* Blocks are just example.

Characteristics of small satellite development in this program

1. **Multi-mission**
   6-8 demonstration missions (components or parts) in total for each satellite.

2. **Little experience**
   Demonstration mission users are newcomers to the space industry.
   They have little knowledge/experience in the space field.

3. **Short-term development**
   The development period is very short.
   (The budget is relatively small so that the human resources are limited.)

4. **Specific difficulties (in the development of small satellites)**
   The development methods and appropriate standards for small satellites have not been fully established yet in JAXA.

Mission component users

JAXA & Satellite manufacturer

From the next page, Lessons Learned (LL) and Misson Assurance (MA) according to these 4 characteristics.

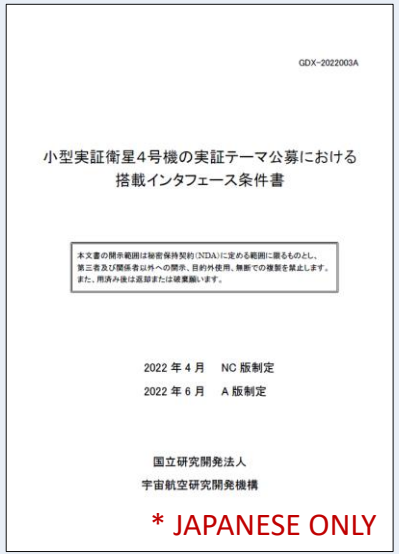
1. Multi-Mission

LL

- In this program, project may start with the mission component design and requirements not yet determined, and requirements may be added or clarified during the development process.
- Because multiple components are mounted, even small changes of requirements led to design or verification rework and schedule delays.

MA

- We provide an “Information document of interface design” that summarizes the interface specifications at the time of public recruitment of missions.
  - Applicants can check the specifications in advance, and we can reduce risk.
  - We can reduce the effort of interface adjustment after mission selection.
  - Specifications that deviate from the conditions can be proposed. (*Disadvantage in study on mountability needs to be allowed.)
- It is also important that each demonstration mission user understand in advance that this satellite has multi-mission and cannot reflect all requests.


GDX-2022003A

小型実証衛星４号機の実証テーマ公募における
搭載インタフェース条件書

本文書の開示範囲は秘密保持契約（NDA）に定める範囲に限るものとし、第三者及び関係者以外への開示、目的外使用、無断での複製を禁止します。また、用済み後は返却または破棄願います。

2022 年 4 月　NC 版制定
2022 年 6 月　A 版制定

国立研究開発法人
宇宙航空研究開発機構

* JAPANESE ONLY

Examples of interface conditions

【Mass/Size】

		Category SS	Category S	Category M	Category L
Mass (kg)		≦1.5	≦3.0	≦4.0	≦6.0
Size (mm)	1	≦100×100×150	≦100×150×150	≦150×150×150	≦250×250×250
	2	≦90×100×100	≦90×100×200	≦90×100×300	–

【Electrical power interface】 (*including grounding policy, overcurrent protection policy, etc.)

Selectable from ＋5V, ＋12V, ＋23～34V(unstable)

【Data interface】

Selectable from LVDS, RS422, SpaceWire. Analog telemetry is PA only.

【Mechanical interface】

Mounting screws, connector configuration, surface roughness/flatness, thermal design etc.

2. Little experience

LL

- Demonstration mission users had little experience in space component development and did not know the development flow and the points of concern.
- If JAXA is not aware of that, coordination may not go well.

MA

- We respond in various ways depending on the user.
  - In the case of new users, we contact them frequently (about once a week) and give them lectures on testing and design methods.
  - However, while users are responsible for the development of each mission component, if JAXA gives a lot of advice, the responsibility becomes ambiguous, and it may be taken as excessive demands, which is difficult to deal with.

- We established the “Guideline for demonstration missions”.
  - … is reflecting the concerns and questions commonly held by past demonstration users and the interface conflicts that are likely to occur.
  - … describes the overall flow of satellite development and operation, including experimental operations in orbit, and the process of interface adjustment.
    (Understanding the overall flow is the most important thing in the development.)
  - …also describes the points to keep in mind when designing interfaces and attempts to prevent interface discrepancies.

2. Little experience

MA

Guideline for demonstration missions

No.	Contents
1	Premise – Multi-mission. – Resources will be shared with others.
2	Related & reference documents
3	Overview of this program
4	Overview of development and operation of small satellites in this program – What to do for each phase of development – Basic knowledge on visible passes of operation, command types, etc.
5	Overview of interface adjustment – Adjustment contents at each development phase – Work description and precautions in on-orbit operation
6	Things to keep in mind – Extracted from past lessons learned – About device design and interface adjustment
7	PR matters
8	Terms & Abbreviations

【ex.】

Design assuming verification

- RF components:
  Terminating resistor need to be attachable to antenna end from outside the satellite.
- Satellite propulsion systems/deployment mechanisms:
  Desirable to enable verification without actual movement by setting command parameters.

Sequence counter

- Desirable to include a sequence counter in the component telemetry to discriminate problems in system tests and on-orbit operations.

Firmware update

- Desirable that the uploaded data is not lost even when the device is turned off because the amount of data transmission is large and to be uplinked over multiple passes.

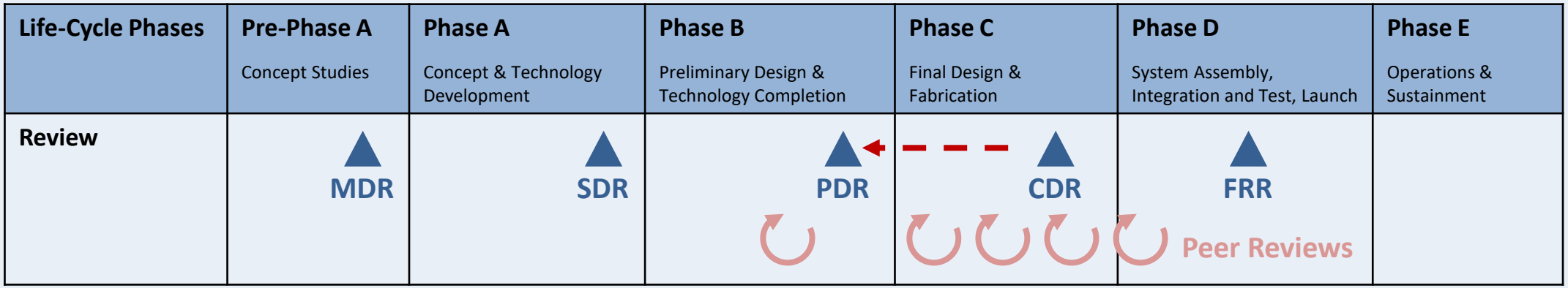
3. Short-term development

LL

- Because of a short-term development (especially the long lead time for purchased equipment), it is necessary to procure EM and FM component at the same time and conduct some tests in parallel.
- It was difficult to reflect in FM any defects found in EM testing or any points raised at the CDR, resulting in a large amount of rework.

MA

- Early confirmation of concept of operations
  - Firming up the final operation details is effective in preventing rework.
  - We create a concept of operations at the mission definition stage and finalize it before the start of the project.
  - Demonstration mission users are required to present an operational plan at the application stage.
- Reconsideration of development process
  - During the short-term development, additional tests and re-verification based on indications from review can have a significant impact on the schedule.
  - We conduct peer reviews frequently and timely to prevent rework and verification omissions.
    * Currently undergoing trials in the development of RAISE-4!



4. Specific difficulties

LL

- Catalog components for small satellites often have characteristics that are not listed in the specification sheet.
- It is difficult to install redundant component on small satellites with limited resources, and reliability must be improved with limited resources.

MA

- Things to check when using catalog components
  - It is important to thoroughly investigate usage conditions on other satellites and understand the characteristics of the component through test.
- Ensuring functional redundancy:
  Function of the malfunctioning component is replaced by functions of software and/or other components.
  - Angular velocity rates are estimated based on star tracker information when a gyro sensor fails.
  - Orbit position information is estimated by internal propagation of the attitude control system when the GPS receiver fails.
  - Magnetic field is estimated using GPS position information and a magnetic field model when a magnetic sensor fails.
    etc.
- We are also developing the handbook on small satellite system design in this program for satellite system manufacturer.

For the future

User collaboration

- The program involves a wide variety of users, and collaboration among users is important.
- “CubeSat salon” with an advisory function for new users is planned to be operated this year.
  (The trial will be conducted as a joint research project between Kyushu Institute of Technology and JAXA.)
  - It would be very beneficial for satellite system development if the community could share information on the operating status and characteristics of devices used in orbit.
  - However, it is difficult to disclose information related to defects, and the issue is how to gather such information.

https://unisec.jp/cubesatsalon <JAPANESE ONLY>

Guidelines and standards for small satellites

- Brush up the guidelines so that they can be published on our website in the future.
- A handbook for satellite system manufacturers is also under consideration.
  (Both are only Japanese.)

Thank you for your kind attention.

Summary

- This program provides on-orbit demonstration opportunities.

- We developed/are developing the small satellites to demonstrate components.
  - There are difficulties in developing small satellites, and we are working to improve mission assurance by applying Lessons Learned.
  - There are still challenges: the development methods and appropriate standards for small satellites have not been fully established yet in JAXA.

革新 INNOVATIVE SATELLITE TECHNOLOGY DEMONSTRATION PROGRAM