Mission Classification and Assurance for University-based Lean Satellite

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University satellite projects in Japan

- UNISEC: University Space Engineering Consortium
- UNISEC-Japan consists of
  - 56 laboratories/groups from 39 universities
  - 805 student members
  - 240 individual members
  - 24 corporate supporters (based on August 2023)
  - alumni members
- UNISEC-Japan members maintain cooperative relationships in conducting practical space development and utilization.

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University satellite projects in Japan

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Lean Satellite

- University satellite is categorized as “Lean Satellite”
  - A satellite that utilizes non-traditional, risk-taking development and management approaches – with the aim to provide the satellite value to the customer and/or the stakeholder at low-cost and with short time to realize the satellite mission[1].
  - Defines small/micro/nano/pico satellites by the philosophy, not by mass/size.
- Lean satellite tolerates a risk, but still needs to achieve the mission success as much as possible
  - “Failure is not an option” nor “Failure is accepted”

- *[1] “Definition and Requirements of Small Satellites Seeking Low-Cost and Fast-Delivery”, Edited by Mengu Cho and Filippo Graziani, International Academy of Astronautics, 2017, Code ISBN/EAN IAA: 978-2-917761-59-5*

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UNISEC's Lean Satellite Mission Assurance Activities

- In 2020, members of UNISEC-Japan utilized the time that suddenly became available due to the pandemic in
  - Remote sessions on lessons learned from university satellite projects in UNISEC (University Space Engineering Consortium) JAPAN in 2020
  - Survey on the lessons learned of mission assurance
    - Sponsored by JAXA
  - Report (439 pages!) on
    - Analysis about the success and failure cases and their causes.
    - Extraction of requirements for mission assurance
    - *Sorry, Japanese only*

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UNISEC's Lean Satellite Mission Assurance Activities

- Following the activities in 2020, in 2021 UNISEC members worked on
  - Mission assurance handbook for university-based lean satellites
    - Further analysis of the failure cause
  - Based on the activities, "Mission Assurance Handbook for the University-built Lean Satellite" was published in March 2022.
  - Currently 3rd version (published in March 2023)

Mission Assurance Handbook for the University-built Lean Satellite

- Target satellite projects at universities and polytechnic-colleges in Japan
  - Not only the first project of the universities, but also the second and later projects
- Summary of points to be kept in mind of faculty members and students to improve the mission success rate
- Organized in the order of project life-cycle
- Published and available online
- Many of the content is still applicable to satellite projects in new space companies and/or non-Japanese organizations

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Handbook download

Use your smartphone and capture the QR code below

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Contents

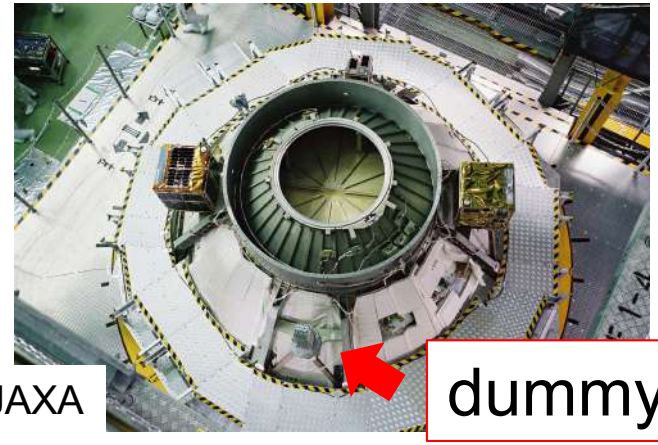
1. Introduction
2. Project management (9)
3. Mission definition (4)
4. Conceptual design (4)
5. Detail design (10)
6. Production (3)
7. Testing (15)
8. Operation (3)
9. Post-operation (3)
10. Sustainability of university satellite program (4)

If you missed the last page

Ordering according to project life-cycle

2.5 Project management (Compliance with safety requirements)

- Non-compliance with the safety requirement may lead to serious delay of the schedule
- In the worst case, the satellite is not launched
  - Dummy mass will go instead of your satellite
- At the end of conceptual design and detailed design, list-up the issues related to safety requirements and confirm with the launch provider
- Agree with the launch provider on the safety requirement verification methods that can be done with **the minimum effort**
  - The safety verification is necessary, but non-value adding activity
  - Do more value-adding activities such as mission assurance



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3.1 Mission definition phase (feasibility)

- **Know the limits** when you define the missions
  - Team talents and skills
  - Budget
- **A professor is not the God**
  - Doesn't know everything to judge the mission feasibility
  - Open mind to suggestion/comments/assistance by others

- 3-axis stabilization from the first satellite?
- High-speed communication by mechanical students?

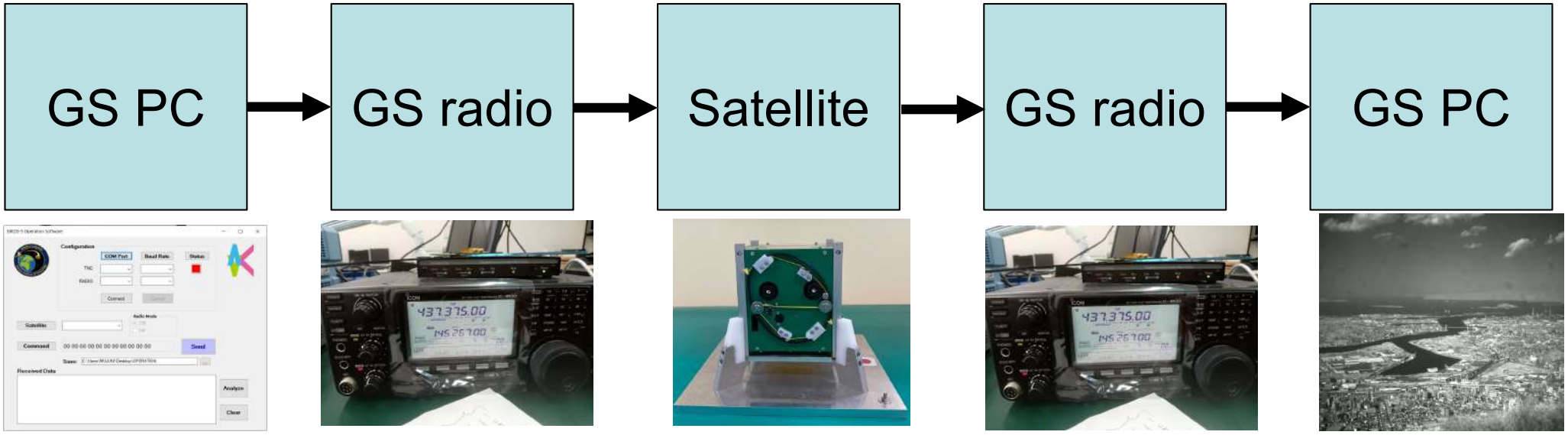
7.1 Testing phase (Electromagnetic Compatibility Test)

- Because of cold launch, EMC with launchers and other satellites are not important
- Live with **self-generated noise**
- Verify that the communication link has enough margin
  - Uplink signal level is much higher than the satellite-generated noise floor
  - Confirm before moving to FM

Sensitivity test for uplink success in a shield box

7.2 Testing phase (End-to-End mission test)

- Verify the basic data flow of the main mission
  - Command uplink
  - Satellite mission
  - Data downlink
  - Confirmation of data on GS PC
- Make the details, after confirming that the basic mission can be done



7.4 Testing phase (System functional test)

- Move to FM assembly as soon as FM components are delivered and start the function tests as an integrated system
- Check the consistency of data sent from the satellite
- Do not move to the environment tests (e.g. vibration, thermal vacuum), before you solve problems

FM system function test

Other mission assurance activities

1. Mission classification
2. CubeSat salon

Mission classification and mission readiness

- For a given mission, stakeholders expect a certain mission success rate
  - More expectation, more funding (or more funding, more expectation)
- Classify satellite missions based on the expected mission success rate
- The technical level maturity of the satellite developer must meet the expected mission success rate
  - “University A has the technical level good enough to do *** mission”
  - “University B is too early to do *** mission”
- Roadmap to raise the mission success rate (i.e., mission readiness) of university lean satellite projects
  - Use the doable mission as an index
  - Stakeholders can trust the developer and provide the funding to do the mission

Mission classification and expected mission success rate

Mission classified		Contents	Expected success rate (%)
7	National security project	Provide data to national security (defense) projects	95
6	Civil project	Provide data to national civil (e.g. weather) projects	90
5	Science	State-of-art science observation and deep space exploration Papers accepted by prestigious journals, e.g. *Nature*.	80
4	Constellation pathfinder	Constellation pathfinder (in-orbit prototype) for space business	70
3	Outsourcing	A satellite built by outsourcing with external funding (a)Outreach purpose (public relations, etc.) (b)Orbit demonstration of technology possessed by companies (mainly manufacturing industries) (c)Orbit demonstration of mission feasibility of a new idea of space application by companies (d)Orbit demonstration of scientific payload requested by science people	60
2	University research	A satellite built for research purpose. The stakeholder is the university itself, no external stakeholder.	50
1	University education	A satellite built for education purpose. The stakeholder is the university itself. The funding is mostly provided by the university alone.	25

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Mission classification and expected mission success rate

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Credit: NRO

https://spaceflightnow.com/news/n1109/19nrodeclassified/

National Geospatial-Intelligence Agency

Cannot fail, but 100% is not expected
Launch may fail anyway

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Mission classification and expected mission success rate

Mission classified		Contents	Expected success rate (%)
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From Asahi Shinbun

Failure of H2A/F6 lost 2 military satellites

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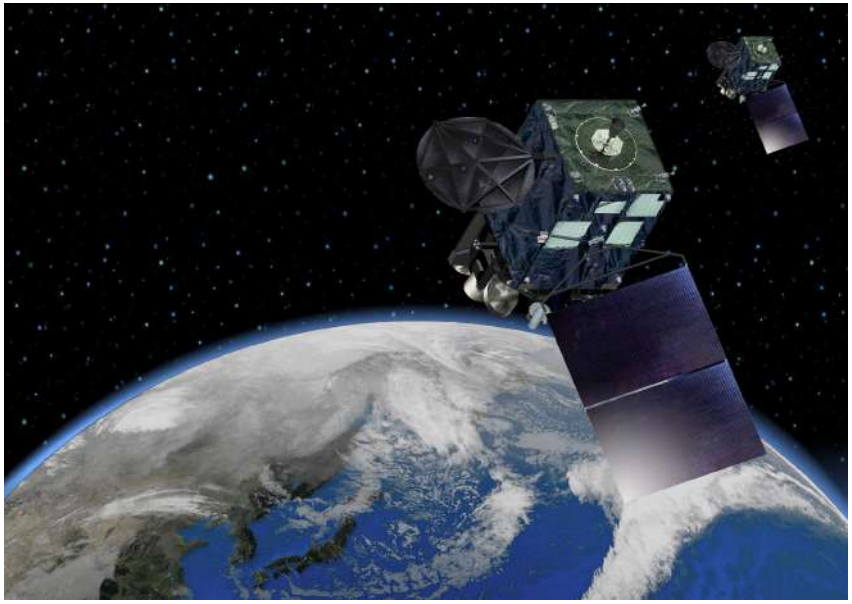
Mission classified		Contents	Expected success rate (%)
6	Civil project	Provide data to national civil (e.g. weather) projects	90



Credit: Japan Meteorological Agency

Important to people on the ground. It may fail.
Redundancy prepared if necessary.

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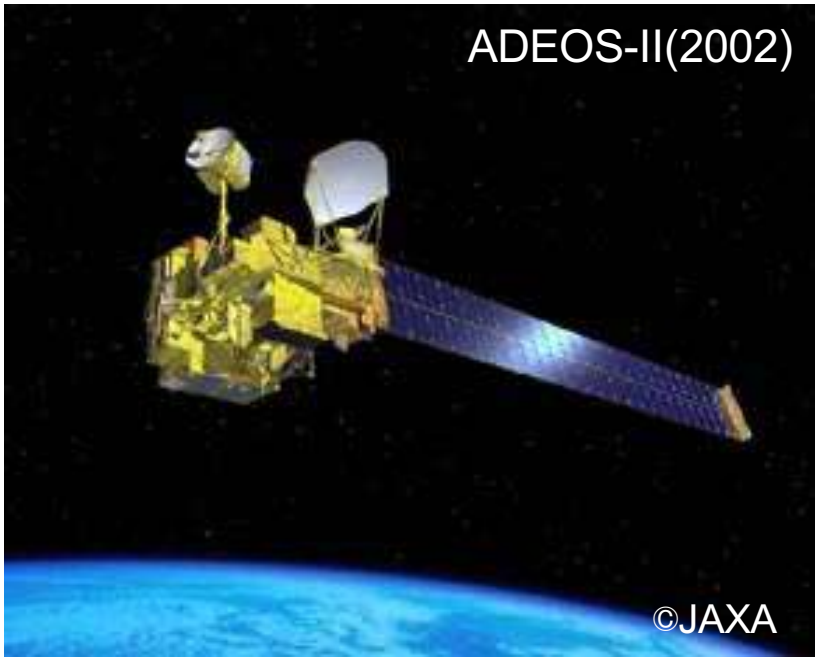

In Japan, 90% success rate since 1995

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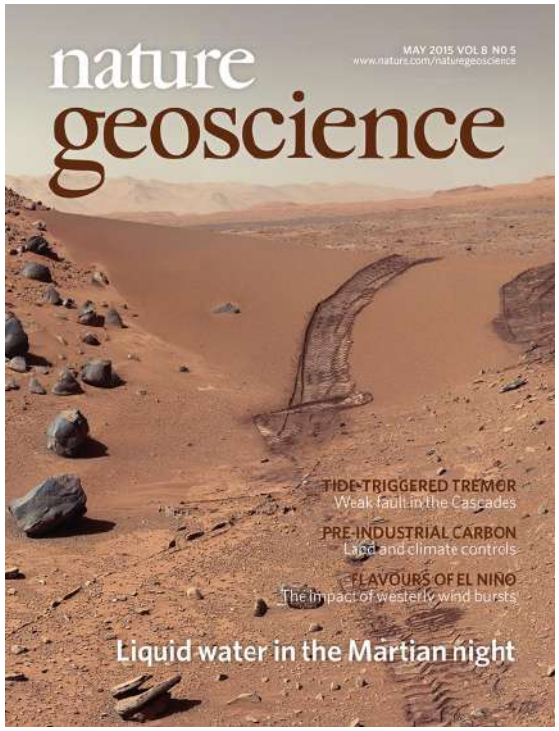

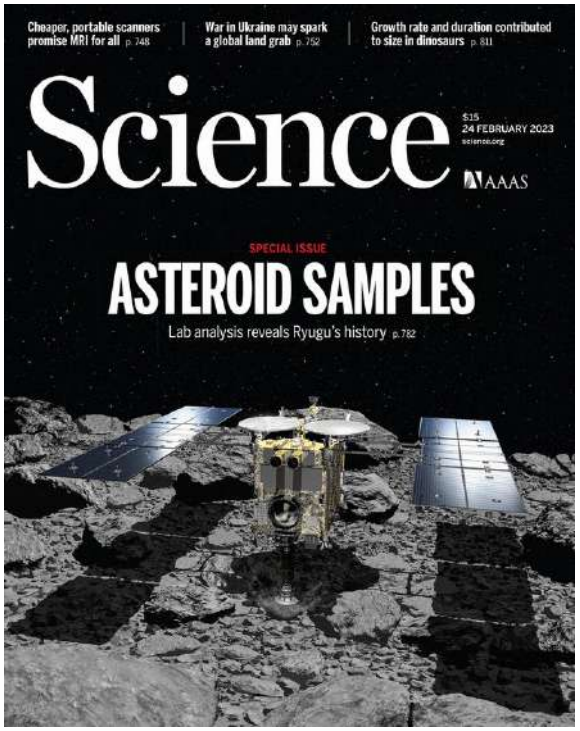

Although they are not on the cover yet, many CubeSat missions are now published in top-ranking journals. Some of them are university satellites.

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Mission classification and expected mission success rate

Mission classified		Contents	Expected success rate (%)
5	Science	State-of-art science observation and deep space exploration Papers accepted by prestigious journals, e.g. *Nature*.	80

In Japan, 84% success rate for national science missions

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Mission classification and expected mission success rate

Mission classified		Contents	Expected success rate (%)
4	Constellation pathfinder	Constellation pathfinder (in-orbit prototype) for space business	70

https://synspective.com/jp/information/2023/strix_alpha_mission_completed/

https://optronics-media.com/news/20141111/27782/

Many constellation pathfinders are built by start-up companies born from university satellites

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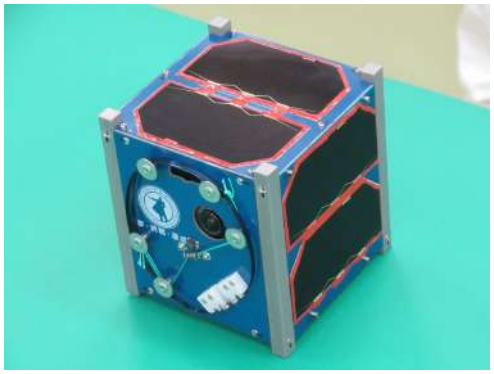
Mission classification and expected mission success rate

Mission classified		Contents	Expected success rate (%)
3	Outsourcing	A satellite built by outsourcing with external funding (a)Outreach purpose (public relations, etc.) (b)Orbit demonstration of technology possessed by companies (mainly manufacturing industries) (c)Orbit demonstration of mission feasibility of a new idea of space application by companies (d)Orbit demonstration of scientific payload requested by science people	60



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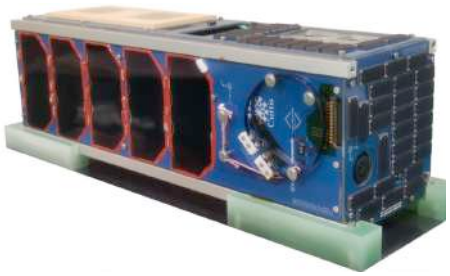

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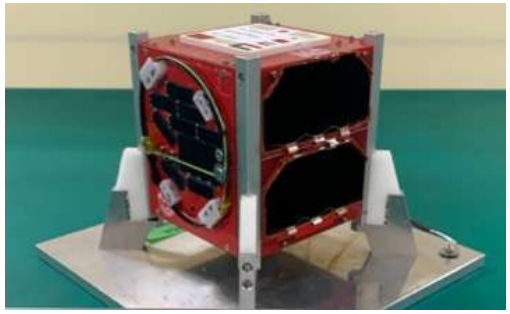

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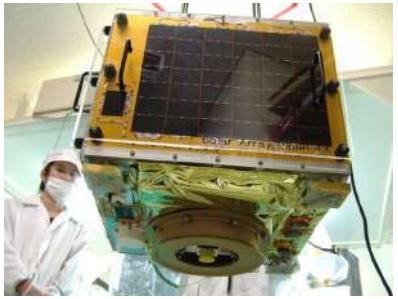

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Many universities do the outsourcing missions.
Some works, but some do not work.

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Mission classification and expected mission success rate

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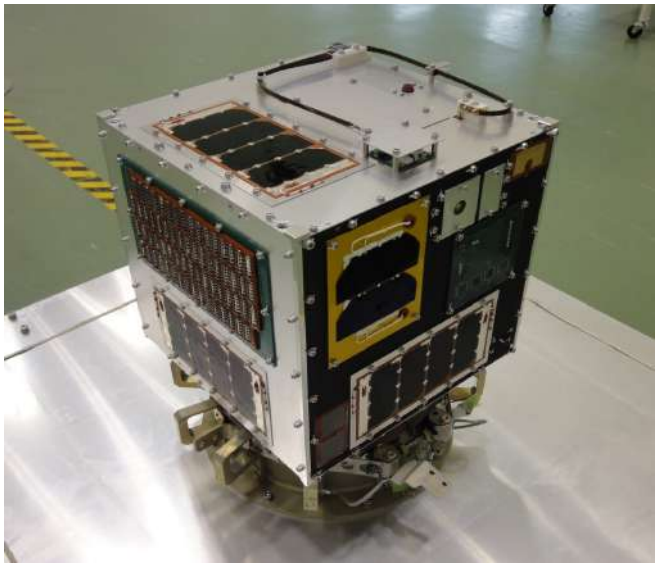
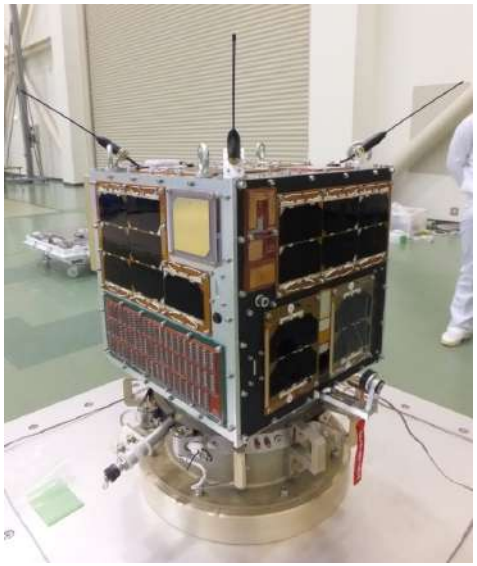
2	University research	A satellite built for research purpose. The stakeholder is the university itself, no external stakeholder.	50





Some works, but some do not work

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Mission classification and expected mission success rate

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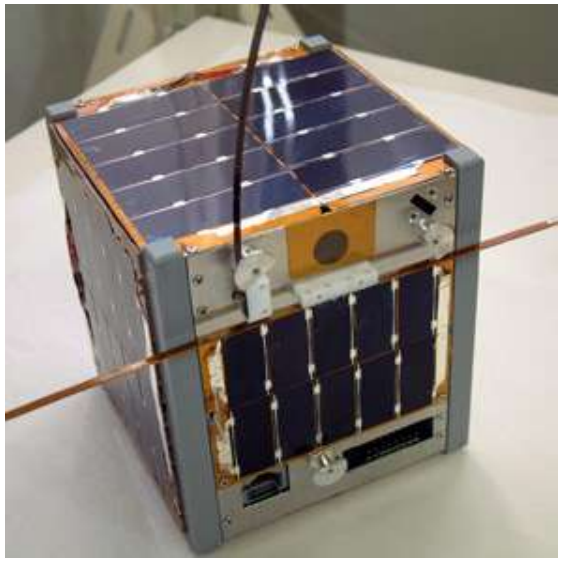
1	University education	A satellite built for education purpose. The stakeholder is the university itself. The funding is mostly provided by the university alone.	25

2002



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Sometimes, it ends up with DoA (Dead-on-Arrival).
However, do not forget that these satellites often work

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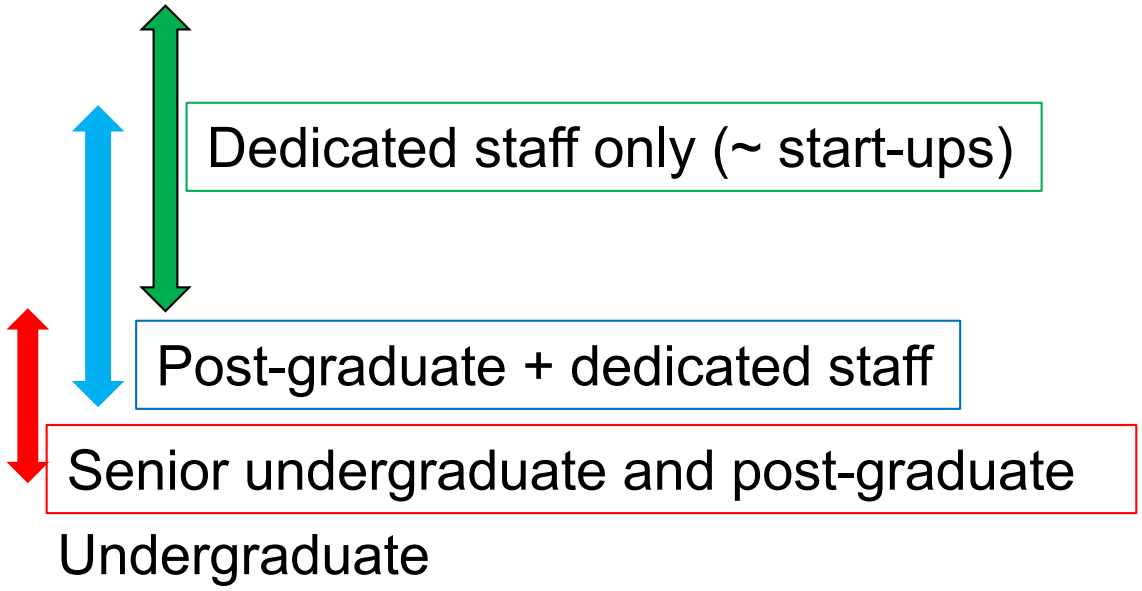
What makes university satellites succeed in their missions?

- Experience
- Motivation
- Budget
- Talent
- Skill
- Facility
- Do rigorous reliability and quality managements contribute to the mission success?
  - Depends on the team levels
    1. Undergraduate
    2. Senior undergraduate and post-graduate
    3. Post-graduate + dedicated staff
    4. Dedicated staff only (similar to start-ups)

Mission classification and university team levels

Mission classified	
7	National security project
6	Civil project
5	Science
4	Constellation pathfinder
3	Outsourcing
2	University research
1	University education



- Rigorous reliability and quality managements based on standard documents work mostly for “dedicated staff only” case.
- Perhaps for “Post-graduate + dedicated staff” case.
- Impossible for the other two

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Normative documents for reliability and quality managements for university satellites?

- Teams need to be educated first
  - Understand the benefits and needs of the documents
- Some (or many) do not stay for the entire project life cycle
  - Difficult to apply the documents consistently
- Textbook and guidelines are more suitable for the teams made of
  1. Undergraduate
  2. Senior undergraduate and post-graduate
- If dedicated staff stay throughout the entire life cycle
  - The benefits and needs of the documents understood already
  - Still needs the resource to educate the other team members
  - Experience dictates what documents should be adopted

Mission classification and university team levels

Mission classified	
7	National security project
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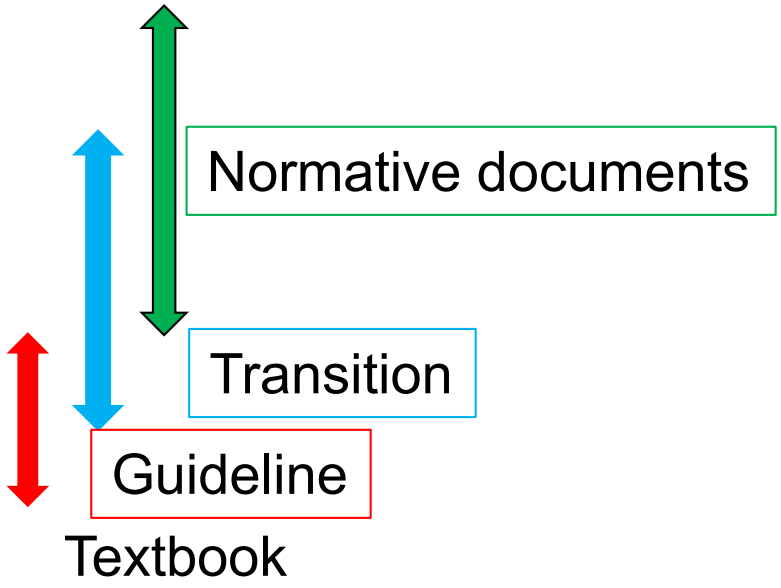

- Normative documents for reliability and quality managements from mission level 3 and higher (when external stakeholders exist)
  - Tailoring of agency adopted documents (e.g. JERG, ECSS, etc.)?
  - Bottom-up approach based on best-practices and lessons learned?

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Reliability and quality managements for lean satellites

- Satellite projects dealt by rigorous reliability and quality managements based on standard documents
  - Small risk tolerance margin
  - One of a kind
  - Involve many people who do not know each other
- Lean satellite projects
  - Large risk tolerance margin
  - Based on flight heritage of previous satellites
  - Small team who know each other
  - Decisions made based on ***experience*** (lessons learned & best practices), not based on documents
- Need to make the individual experiences to the shared ***knowledge***
  - *How do we collect experiences of various small projects?*

CubeSat salon

- Newcomers (university and companies) need helps
- Advices by external reviewers are very effective at the mission definition phase
  - Mission planning
  - Mission feasibility
  - Optimum satellite bus selection for a given mission
  - System lifecycle planning
  - Introduction of helpers and collaborators
- A place to provide consultation for the newcomers
  - A very low barrier for knocking the door
  - *CubeSat Salon*
- **Starting July 2024**

Collect information for guideline and normative documents

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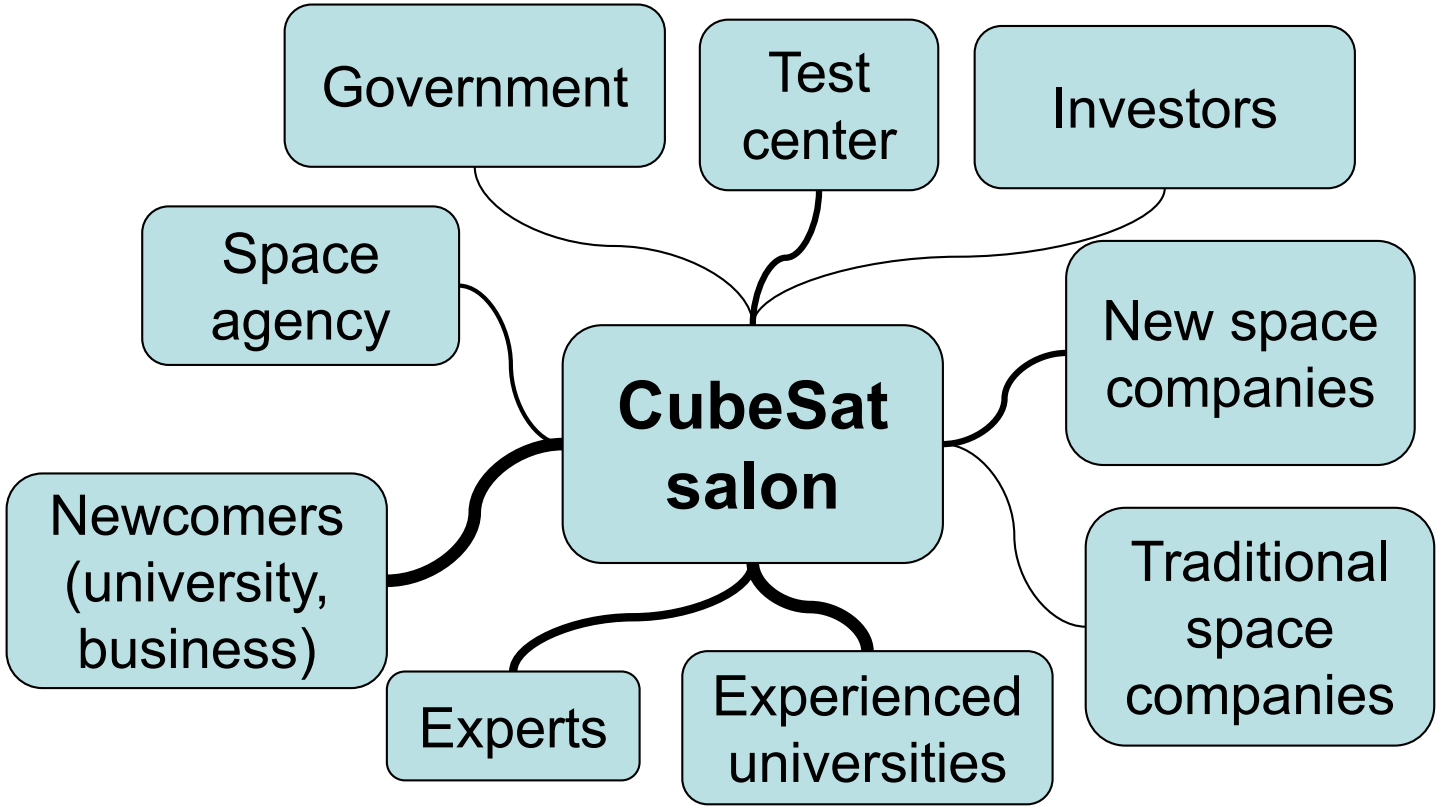
CubeSat salon

- CubeSat salon can play the networking role
  - Connect between company-university, company-company, university-university
  - Introduce universities and facilities that can assist throughout the system lifecycle
  - Sharing of lessons learned
- Assist to persuade the non-space company management to enter the space sector



Conclusion

- Collaboration between UNISEC-Japan and JAXA on mission assurance of university lean satellites with intensions of
  - Human resource development
  - Advancement of lean satellite missions
  - Promotion of new space sectors
  - Possible use of lean satellites for the national space program
    - Needs of standards in near future
- We seek information exchange with other countries, especially agencies, about how to promote the mission assurance of lean satellites

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