9th UNISEC-GLOBAL Virtual Meeting

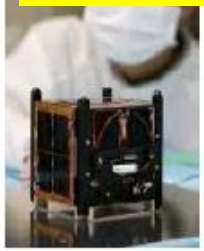
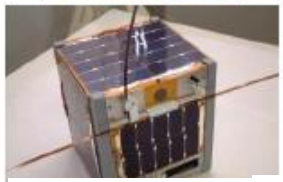
- Opening Remarks -

Tonight main lecture:
Space Weather

… so let us talk about space science and exploration conducted by micro/nano-satellites !

Shinichi Nakasuka
University of Tokyo

Innovative utilizations of Micro/nano/pico satellites(<100kg)

Education

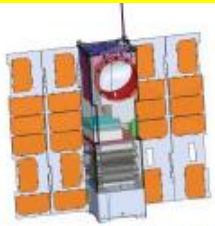
OPUSAT(1U:1kg)
XI-IV(1U:1kg)


Remote sensing

AeroCube(1.5U:2kg)
Dove,Flock(3U:4kg)

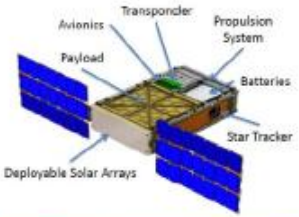

Telescope

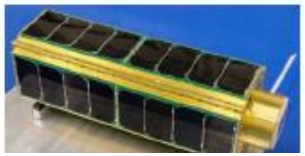
AAReST




Weather

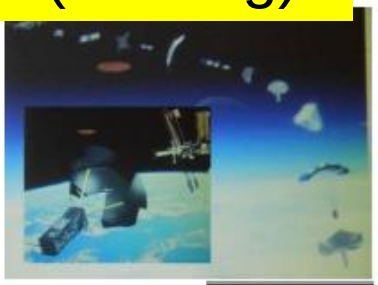
MiRaTA(3U)
MicroMAS(3U)





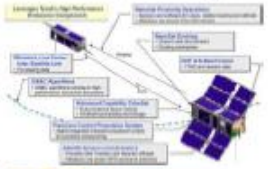
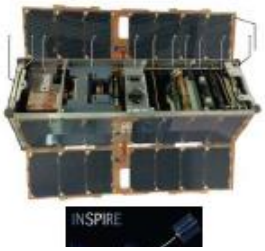
Bio-engineering

BioSentinel計画案(6U)
SPORESAT(3U:5.5kg)



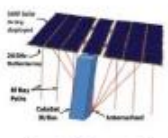
Re-entry

再突入回収(3U)
Sunjammer

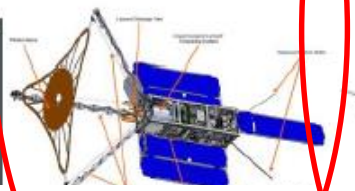
Rendezvous/ docking

INSPIRE(3U)



Communication

高速通信・ISARA(3U)
低速通信・AISSAT-1(6kg)

Space Science

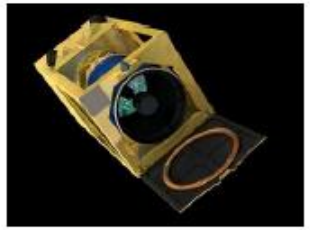
RACE(3U)
FS-7(3U)


Atmosphere

(可視・近赤外)
NEMO-AM(15kg)


Exploration

LWaDi(6U)
CAT(3U)




High Resolution.

SCOUT(50kg)
Skysat(120kg)

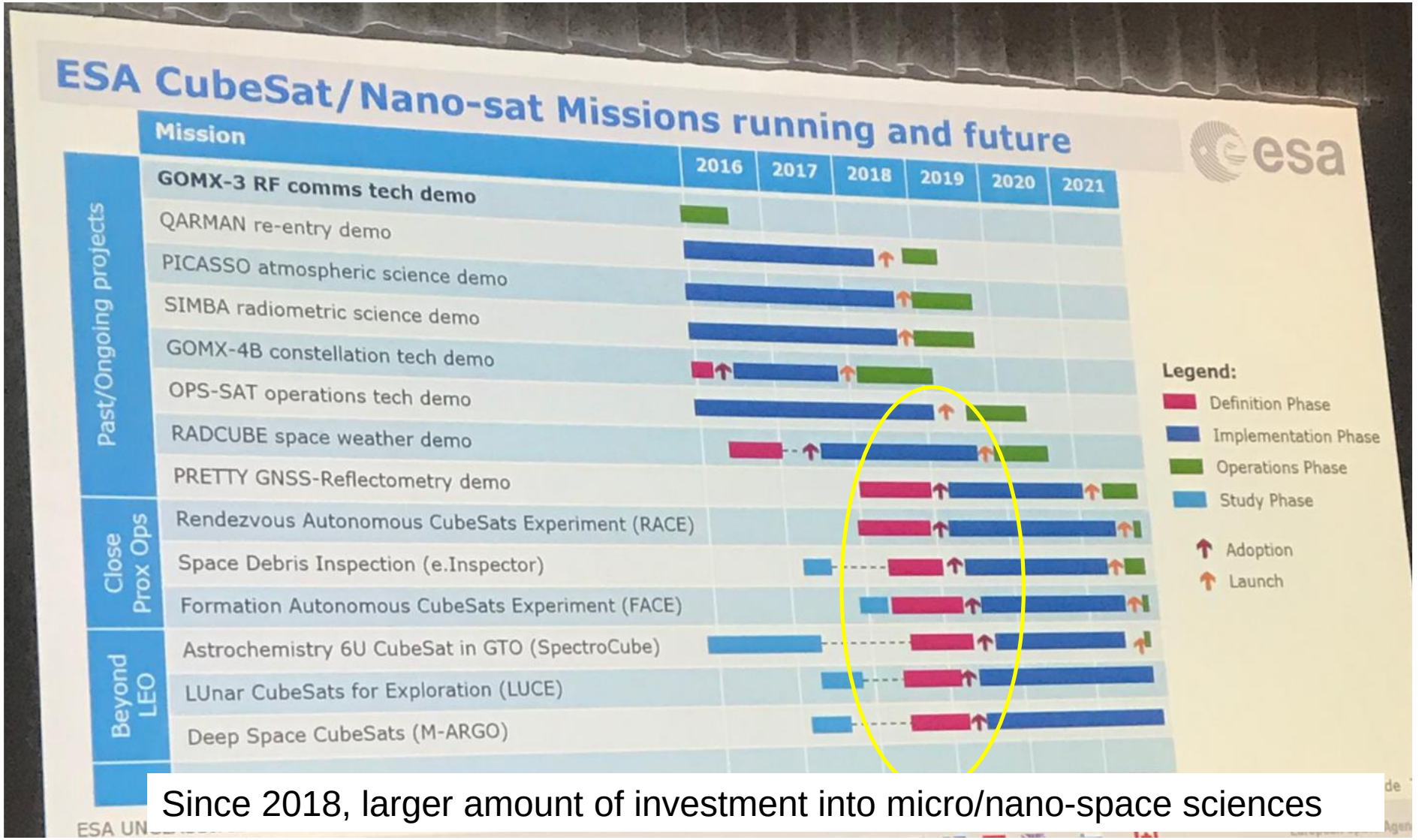
Primarily by university/venture companies, but governmental projects are also appearing, which begin to replace mid-large sized satellites.

Miniaturization of sensors

	Selva* and Krejci, 2012	Freeman 2017	Justification
Atmospheric Chemistry Instruments	Problematic	Feasible	PICASSO, IR sounders
Atmos Temp and Humidity Sounders	Feasible	Feasible	
Cloud Profile and rain radars	Infeasible	Feasible	JPL RainCube Demo
Earth Radiation Budget radiometers	Feasible	Feasible	SERB, RAVAN
Gravity Instruments	Feasible	Feasible	Need a demo mission
Hi-res Optical Imagers	Infeasible	Feasible	Planetlabs
Imaging microwave radars	Infeasible	Feasible	Ka-Band 12U design
Imaging multi-spectral radiometers (Vis/IR)	Problematic	Feasible	AstroDigital
Imaging multi-spectral radiometers (μWave)	Problematic	Feasible	TEMPEST,
Lidars	Infeasible	Feasible	DIAL laser occultation
Lightning Imagers	Feasible	Feasible	
Magnetic Fields			
Multiple directio			
Ocean color inst			
Precision orbit	Feasible	Feasible	CanX-4 and -5
Radar altimeters	Infeasible	Feasible	Bistatic LEO-GEO
Scatterometers	Infeasible	Feasible	GPS refl. (CyGNSS)

By introducing CubeSat as test beds, community are taking large efforts to make their sensors small in order to get in-orbit demonstration opportunity.

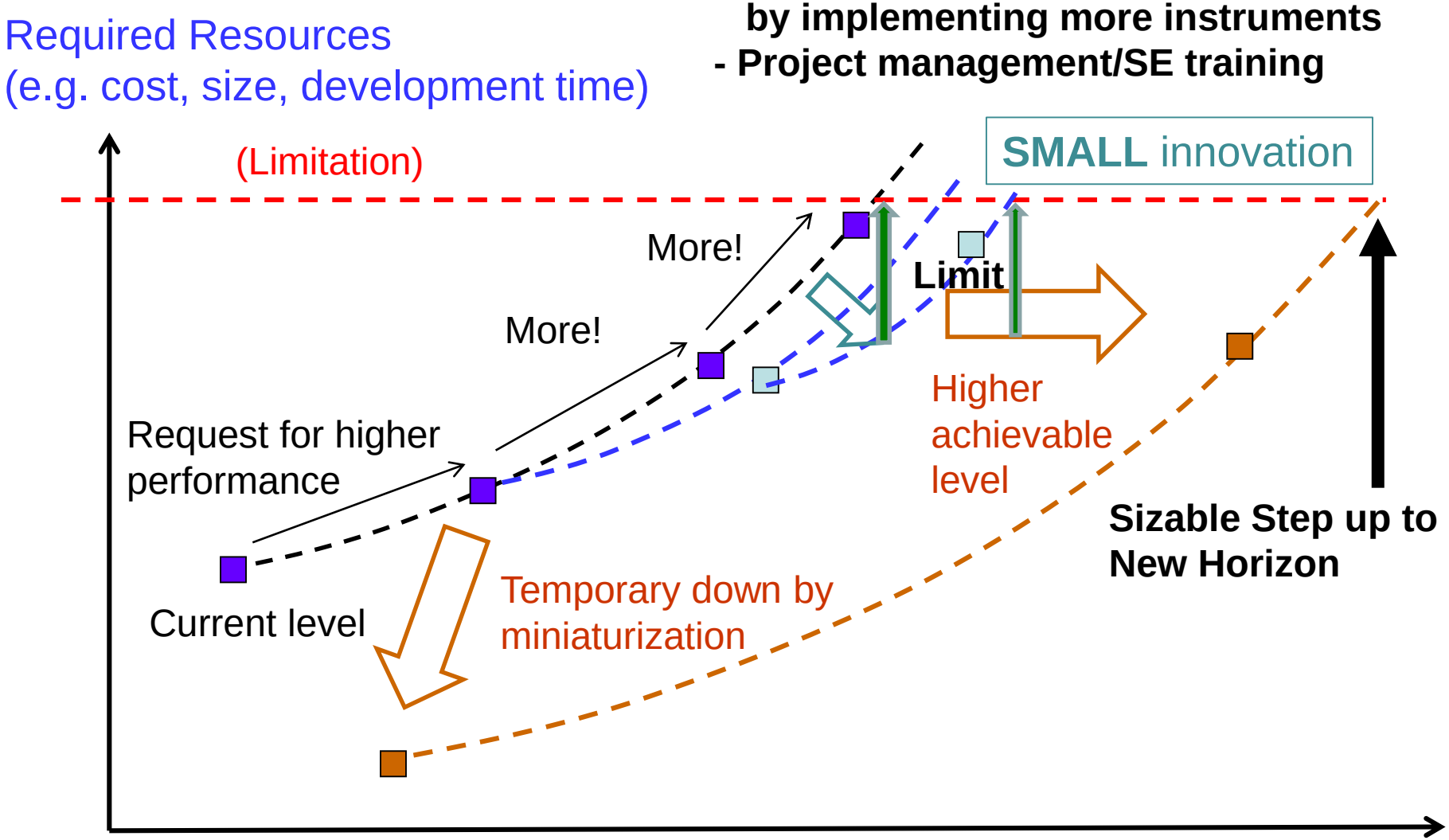
ESA is also moving towards micro/nano-satellites



Since 2018, larger amount of investment into micro/nano-space sciences

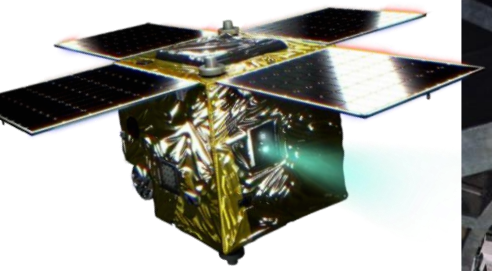
Innovations by Micro/nano-satellites

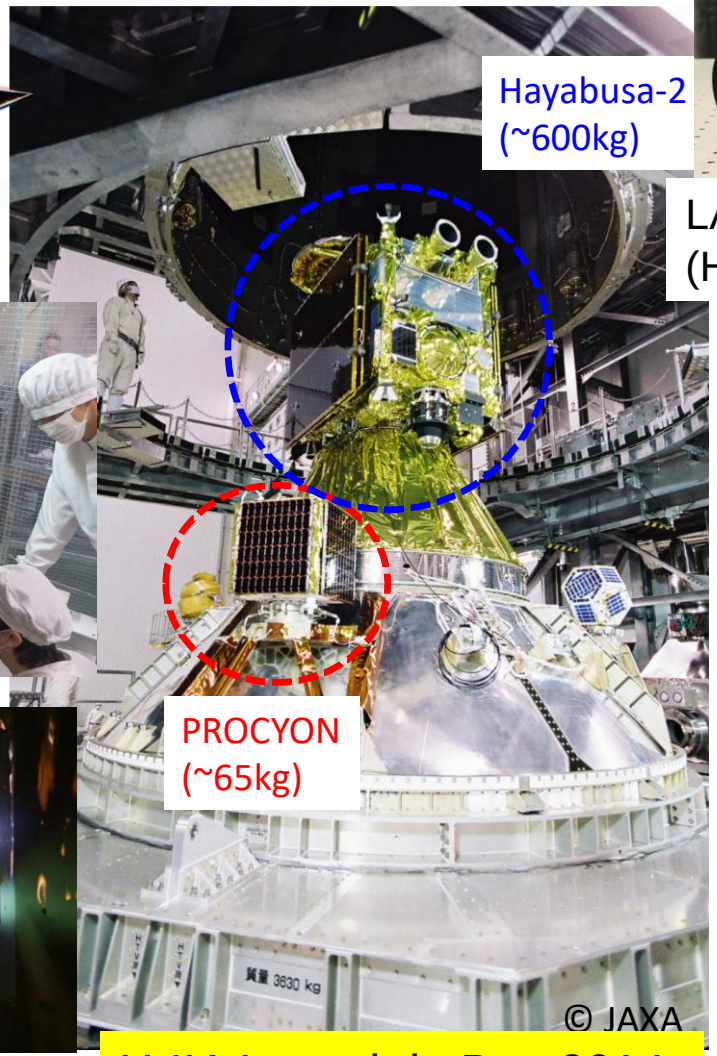
- **More scientific missions**
- **Contribute also to mid-large satellites by implementing more instruments**
- **Project management/SE training**



PROCYON (2014)

- The World First Interplanetary Micro-sat (65kg)
- Joint project with JAXA

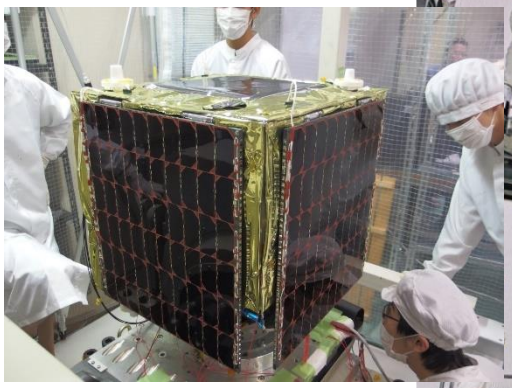


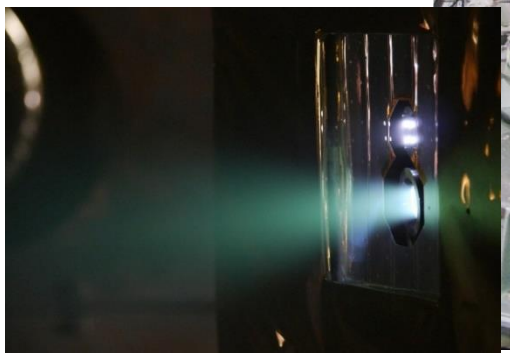


Hayabusa-2
(~600kg)

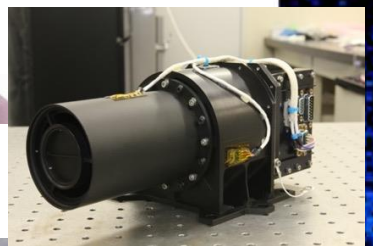
PROCYON
(~65kg)

© JAXA



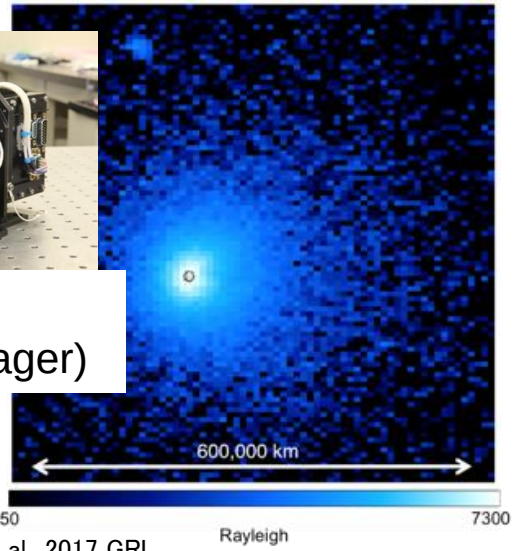


H-IIA Launch in Dec 2014



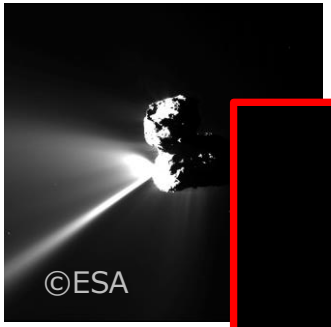
LAICA
(Hydrogen imager)

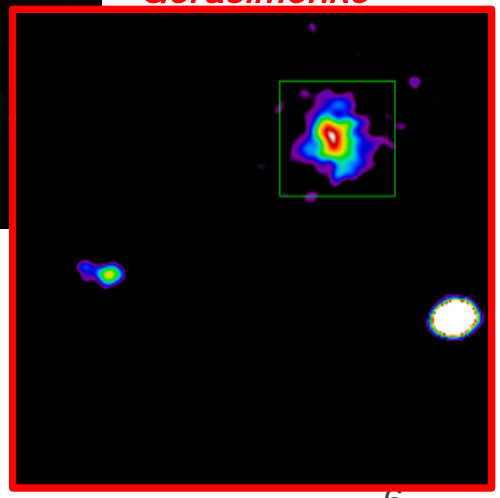
Earth's hydrogen corona



Kameda et al., 2017 GRL

Hydrogen around 67P/Churyumov–Gerasimenko





Shinnaka et al., 2017 AJ

New Technology Demonstrations on PROCYON

Thrusters (RCS)

Manufacturer: The University of Tokyo
Thrust: 22 mN
Specific impulse: 24.5 s
Propellant: Xenon

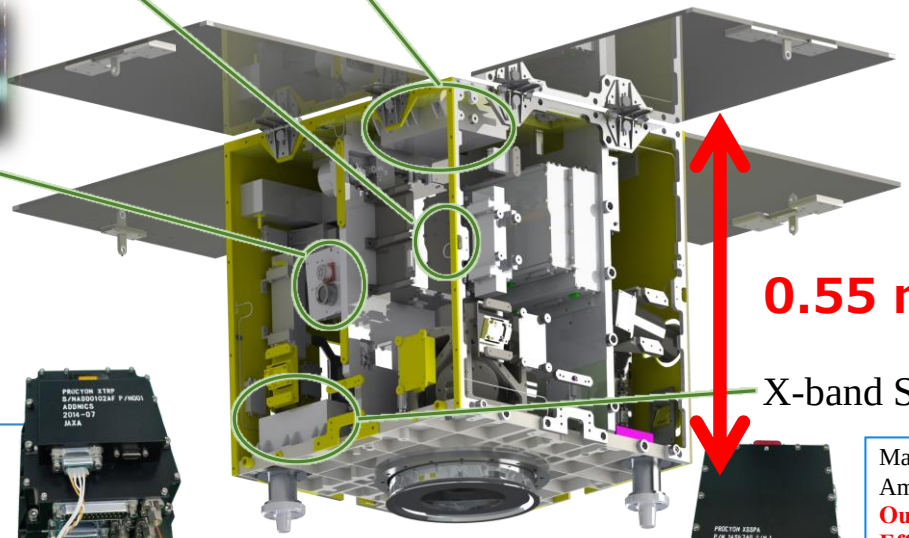
DDOR Tone Generator

Manufacturer: Digital Signal Technologies, inc.
Max. output power: +9 dBm (each tone)
Max. tone width: 86 MHz
Max. sweep width: 7.9 MHz
Sweep time: 2 to 40 min
Alan variance: < 1×10^{-1} (1-100 s),
< 1×10^{-9} (1000 s) (-20 to +60°C)

S/C size: 55cm
S/C mass: 65kg

Ion Thruster

Manufacturer: The University of Tokyo
Thrust: 300 μN
Specific impulse: 1000 s
Propellant: Xenon



0.55 m

X-band Transponder

Manufacturer: Addnics corp.
Max. output power: +17 dBm (tunable)
Receiving level: -150 to -50 dBm
Coherent ratio: 749/880
Modulation: PCM/PSK/PM,
two-way Range & two-way Doppler,
DDOR ($\pm0.5F_0$, $\pm2F_0$)

X-band Solid State Power Amplifier

Manufacturer: Digital Signal Technologies, inc.
Amplification device: GaN HEMT
Output power: 41.85 ± 0.15 dBm
Efficiency: > 32.7 % (Max. 35.1 %) (-20 to +60°C)

RF Output > 15W
Efficiency > 32.7%

Deep Space Navigation/Guidance/Control, Communication was successful during one year deep space operations

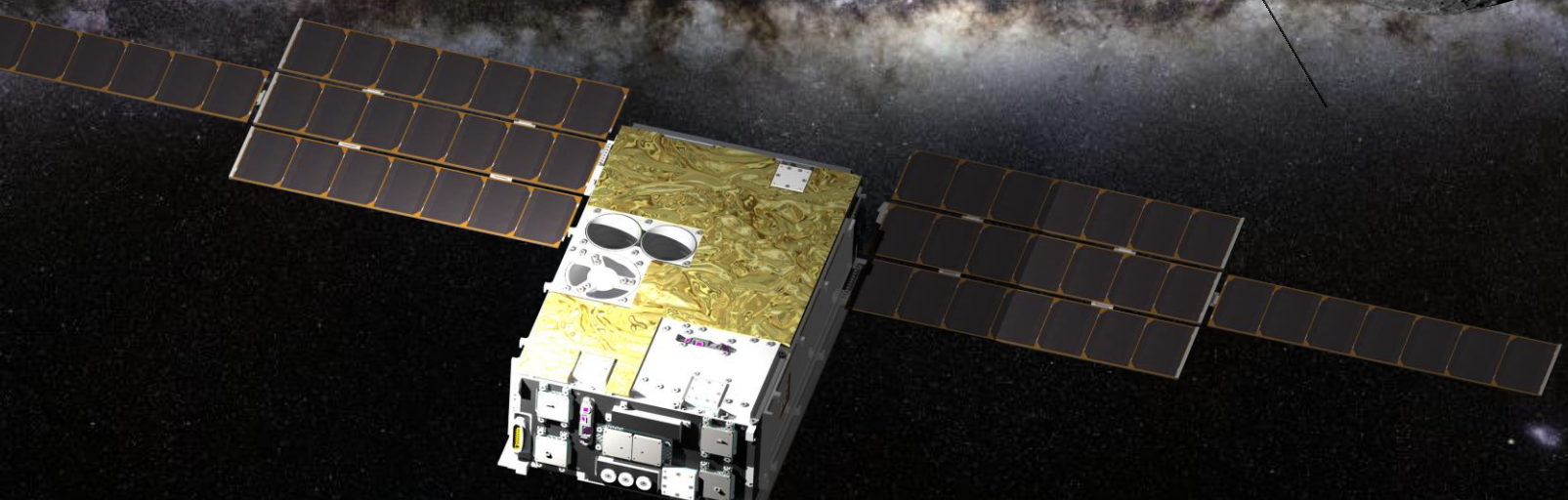
EQUULEUS

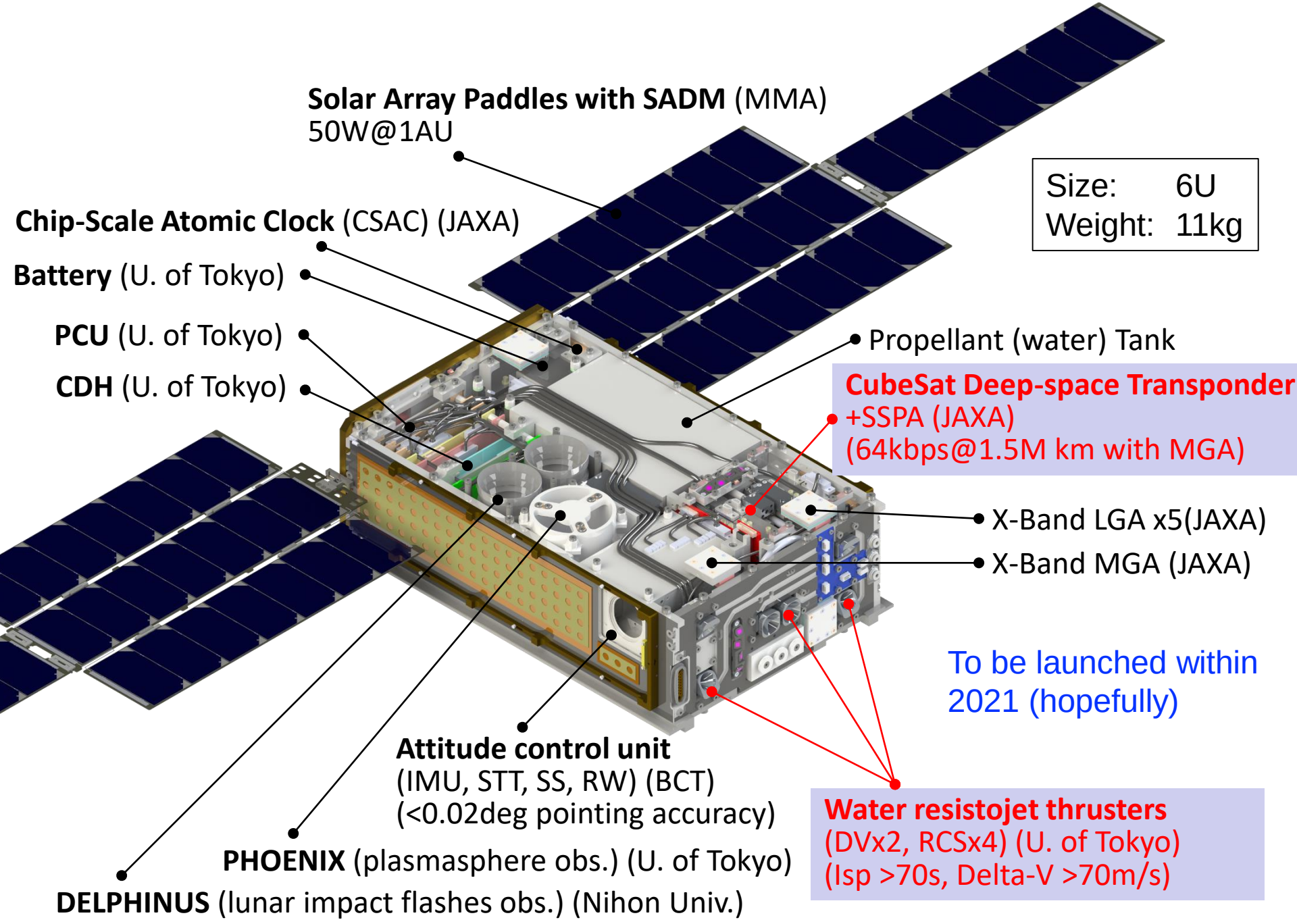
To be The first CubeSat to Lunar Lagrange point

(EQUULEUS = EQUilibriUm Lunar-Earth point 6U Spacecraft)

Missions:

- Low-energy trajectory control demonstration within Sun—Earth—Moon region
- Earth's plasmasphere observation
- Lunar impact flashes observation
- Characterization of dust in the cis-lunar region

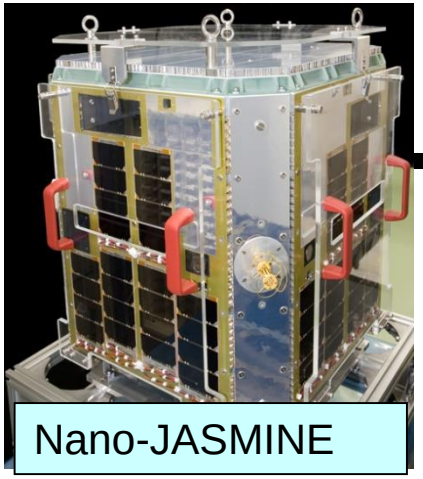



Solar Array Paddles with SADM (MMA)
50W@1AU
Chip-Scale Atomic Clock (CSAC) (JAXA)
Battery (U. of Tokyo)
PCU (U. of Tokyo)
CDH (U. of Tokyo)
Size: 6U
Weight: 11kg
Propellant (water) Tank
CubeSat Deep-space Transponder
+SSPA (JAXA)
(64kbps@1.5M km with MGA)
X-Band LGA x5(JAXA)
X-Band MGA (JAXA)
To be launched within
2021 (hopefully)
Attitude control unit
(IMU, STT, SS, RW) (BCT)
(<0.02deg pointing accuracy)
Water resistojet thrusters
(DVx2, RCSx4) (U. of Tokyo)
(Isp >70s, Delta-V >70m/s)
PHOENIX (plasmasphere obs.) (U. of Tokyo)
DELPHINUS (lunar impact flashes obs.) (Nihon Univ.)

Space Science/Exploration

- Interesting space science/exploration missions by micro/nano-spacecraft are realizable. Tactics include;
  - Do not compete with larger missions by governments
  - Search for niche areas which even small spacecraft can do
  - Concept of daughter spacecraft on governmental mother-ship
- Space science/exploration would be excellent areas to raise the technological level
  - Very unique sensors/equipment/design are frequently required
  - Strong motivation comes from science community side
- Characteristics different from Earth orbiting satellites.
  - Long life time required. Thermal and radiation environment.
  - Communication distance/delay. Laser or RF communication?
  - How to obtain launch opportunity, ground station, etc.?
  - Maneuvers are essentially required. NGC for orbital transfer.

Logic of “order”



Theoretical researchers require this but we relaxed…

10^{-12}

After severe discussions ….

10^{-8} Engineering prof. “We can surely achieve this level.”

10^{-9} “Let us compromise at this point !”

10^{-10} Science professors “This is needed to aim at the top science”

10^{-8}	10^{-9}	10^{-10}
Micro/nano-pathfinder	100-500kg mission	Novel prize class mission
< $ 10 M	< $ 100 M	< $ 300 M

Seeking for “compromise point” is important !

Quick start with “not perfect” but “good enough” missions.

The 7th Mission Idea Contest for Deep Space Science and Exploration with Nano/Micro Satellite

- **Special lectures** are available on the web:
  <http://www.spacemic.net/lecture.html>
  - New challenges for Deep Space Exploration with Micro/nano Satellites
  - Science operations of Space missions
  - Deep Space Exploration and Micro-propulsion System
  - Trajectory Design for Deep Space Exploration Missions
  - Communication for Deep Space Mission with micro/nano Satellites

- **Call for proposals**
  - Abstract Submission Due: **July 7, 2021**
  - Length: 5 pages max
  - Template can be downloaded at the website

- **Eligibility: anybody (student, professional, individual, team, organization)**
- **Final presentation to be held on Nov.13 in Japan or online.**
- **Award**: 1st place, 2nd place, Student prize, other (TBD)

http://www.spacemic.net