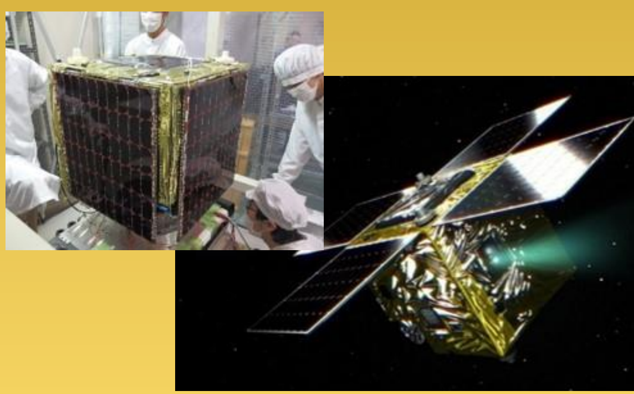
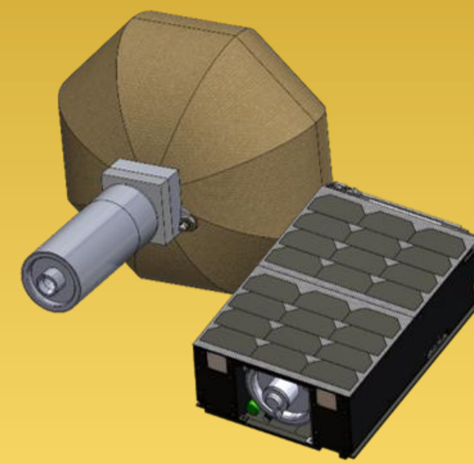
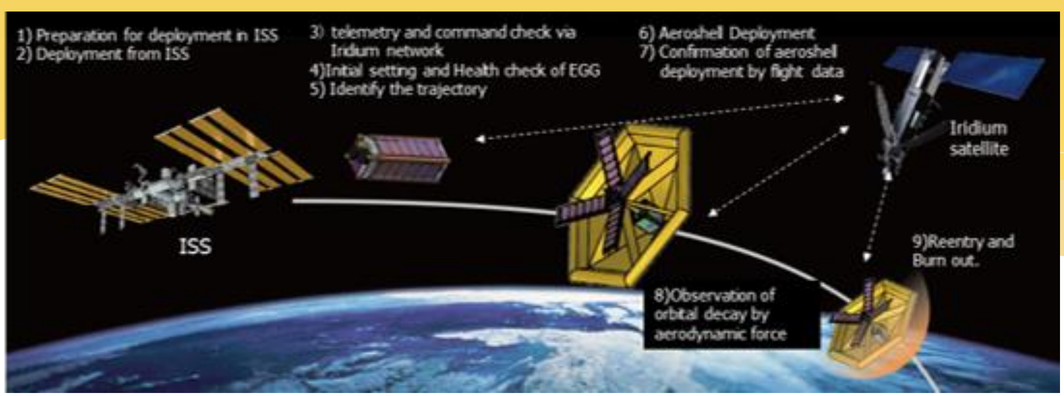
Short Course : Small Satellite

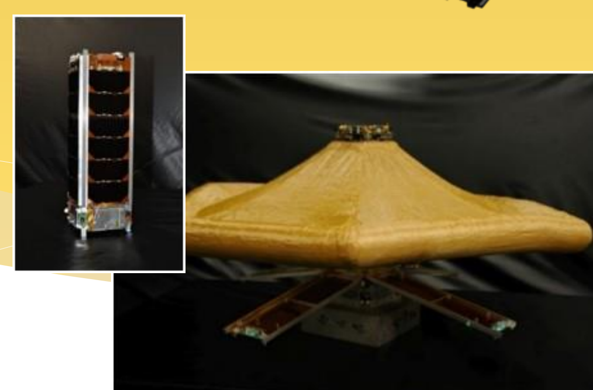
SmallSat Efforts in JAPAN for future planetary exploration.

Kazuhiko Yamada (JAXA/ISAS)









Self introduction

Name: Kazuhiko Yamada
Affiliation : JAXA/ISAS
My major : Atmospheric entry technology

"especially",
deployable membrane aeroshell for atmospheric-entry capsule.

I have led Japanese activity related to the research and development related to deployable aeroshell since I was a student in 2000.

2004 : 1st balloon drop test
2009 : 2nd balloon drop test
2012 : Suborbital reentry demonstration using sounding rocket
2017 : Nanosatellite EGG with deployable aeroshell

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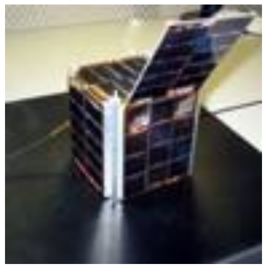
  - Deployable aeroshell for small sat
  - EGG → BEAK → SPUR
- Future vision and Summery
  - New exploration world with small-sat tech.

Start of Small-satellite Era

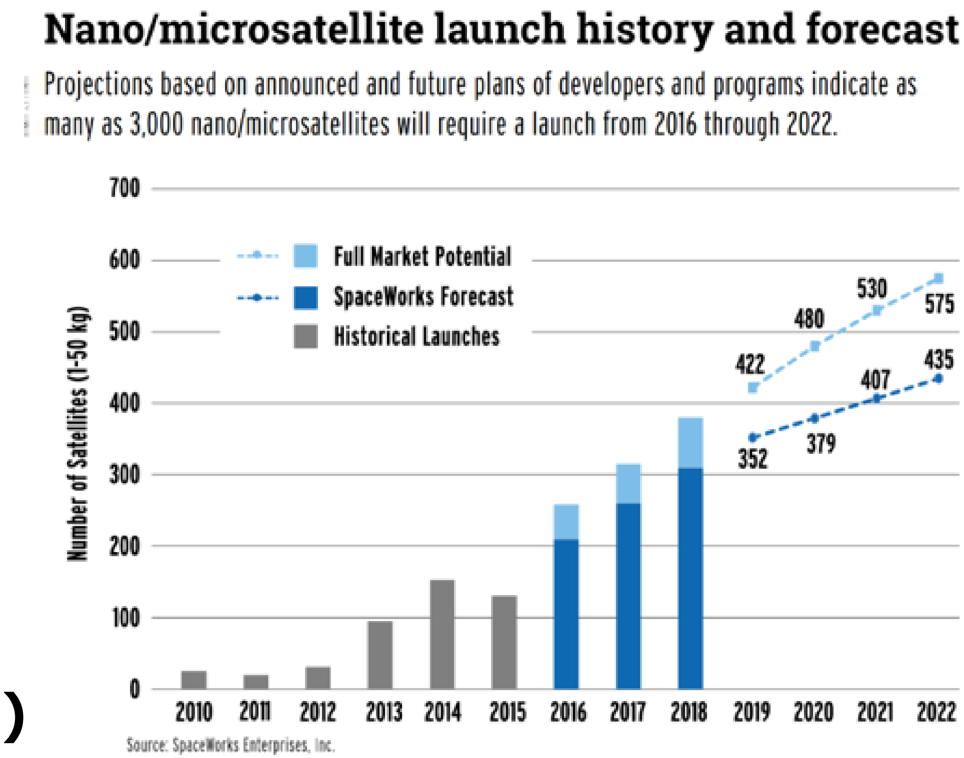
1999 : Cube-sat spec. development

2003 : First launches of 1U-Cubesat s

(From SpaceNews Magazine)



HODOYOSHI series (2014-)

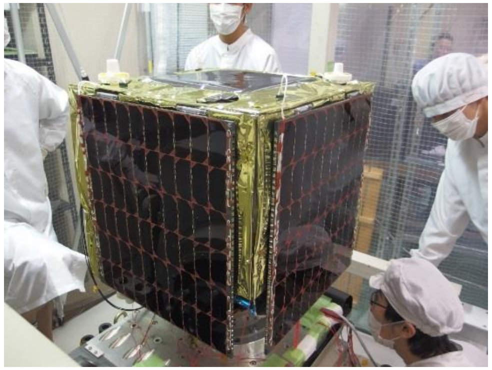


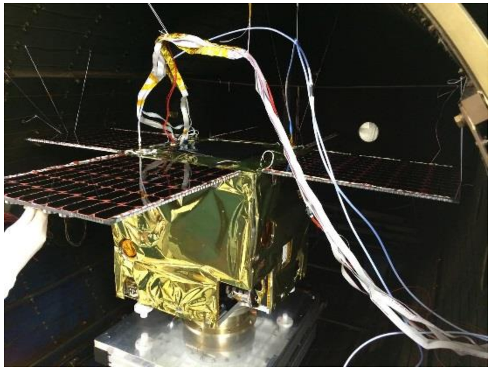
Many small-satellites have been launched and operated in LEO.
It is time to challenge to next field, that is, "planetary exploration"

PROCYON's challenge

PROCYON : The first interplanetary Full-scale Micro-spacecraft

PROCYON was developed by The University of Tokyo with collaboration team of many universities and JAXA/ISAS.





PROCYON spec.

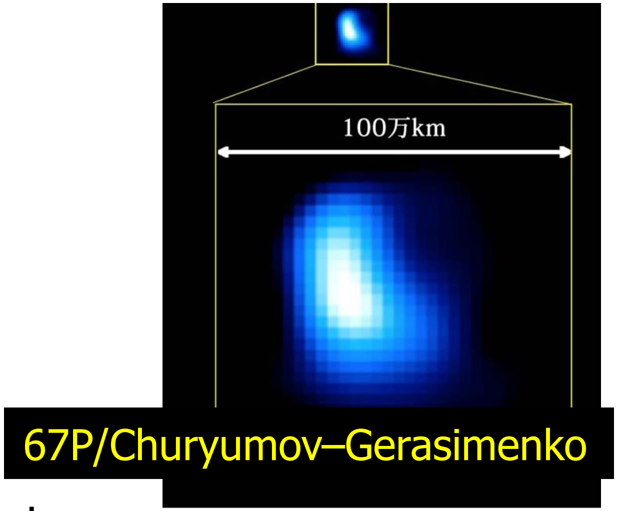
Size:	0.55m x 0.55m x 0.67m + 4 SAPs
Weight:	<70kg (wet), payload(camera) 10kg.
Power	>240W SAP and Li-ion BAT 5.3Ahr
AOCS	4RW and 3-axis FOG, STT, NSAS <0.002deg/s, <0.01deg
Propulsion	Cold gas RCS (22mN, 24s ISP) and Ion propulsion(0.3mN, 1000s ISP) 2.5kg Xenon installed
Communication	X-band, DDOR (HGAx1, MGAx1, uplink LGAx2, downlink LGA x2), >15W

PROCYON was developed in only 14months utilizing the heritage of Cube-sat and HODOYOSHI-series and launched in Dec. 2014.

PROCYON's achievement

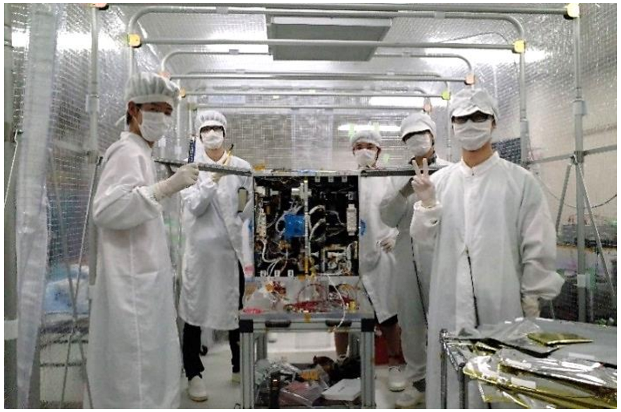
Demonstration of deep space bus system
including deep space communication and trajectory guidance/navigation/control →success!

Scientific mission
(geocorona observation and observation of hydrogen emission around 67P/C-G) →success!



All the mission were successful <u>except for:</u>
- **<u>long-time</u> deep space maneuver** by the ion thruster
- *actual* **asteroid flyby**

Within the very limited development time (14 months) and budget (a few M$), we could **demonstrated the capability** of this class of spacecraft to perform deep space mission by itself and it can be a useful tool of deep space exploration.

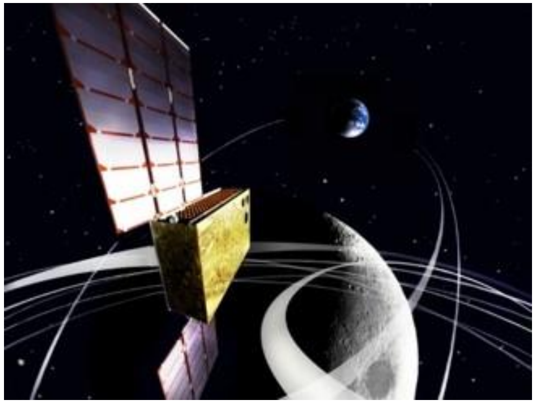


<u>PRYCYON proved technical readiness to deep space exploration by small satellite.</u>

Next Challenges using SLS opportunity

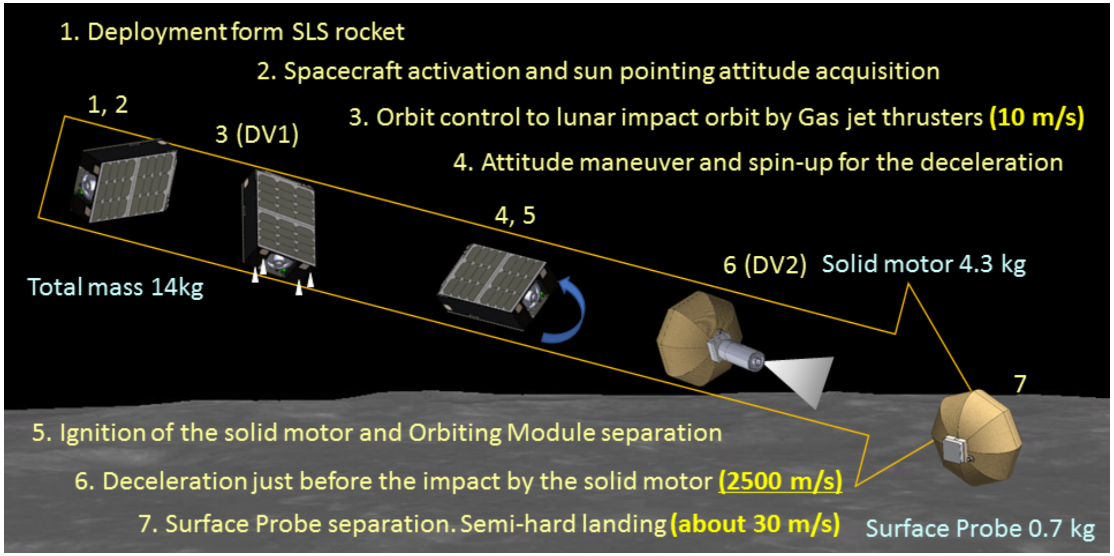
Two Japanese 6U satellites to challenge for planetary exploration are selected and developed as SLS secondary payload.

EQULLEUS & OMOTENASHI



EQULLEUS (EQUilibrium Lunear-Earth point 6U Spacecraft) EQULLEUS have been developed by JAXA and the University of Tokyo. EQULLEUS aims to be the first CubeSat to Lunar Lagrange point using water resistojet thrusters.

OMOTENASHI has been developed by JAXA. OMOTENASHI aims to be the smallest lunar lander in world using retrojet(solid motor), airbag and crushable material.



Overview of EQULLEUS

[Engineering Objective] (primary mission)

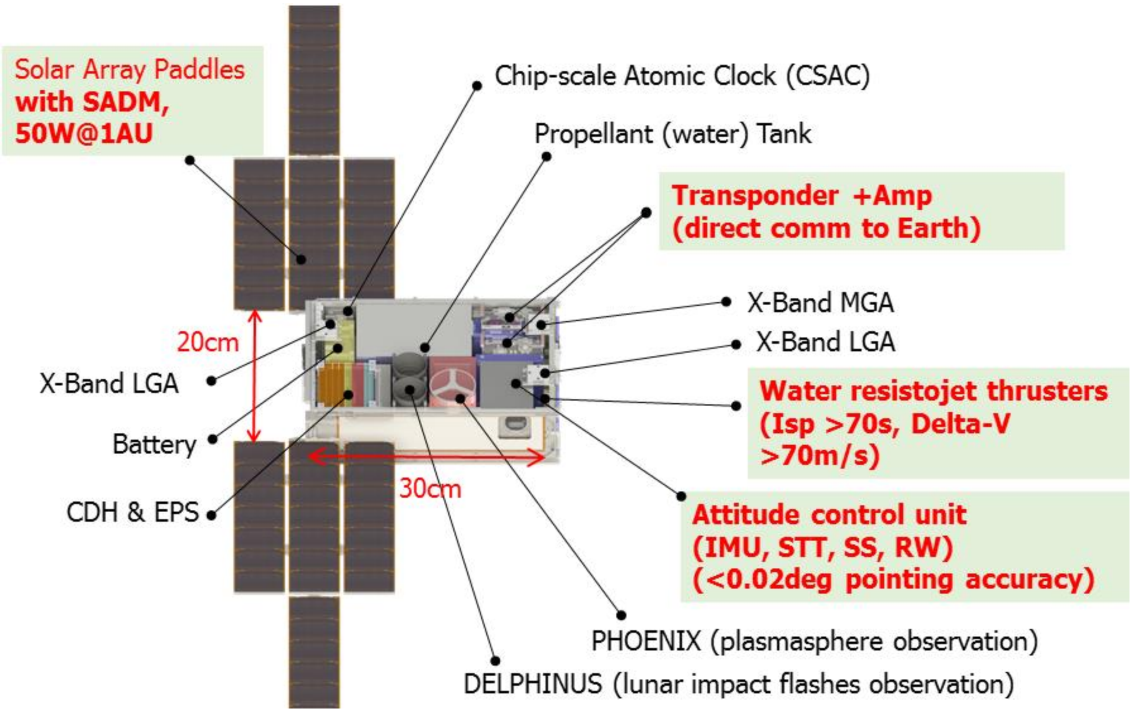
Demonstration of **the trajectory control techniques within the Sun-Earth-Moon region** (<~1.5M km from Earth) by a nano-spacecraft through the flight to the Earth-Moon Lagrange point L2 (EML2)

[Science Objectives]

*Imaging observation of the Earth's plasmasphere

*Lunar impact flash observation

*Dust environment measurement in the cis-lunar region



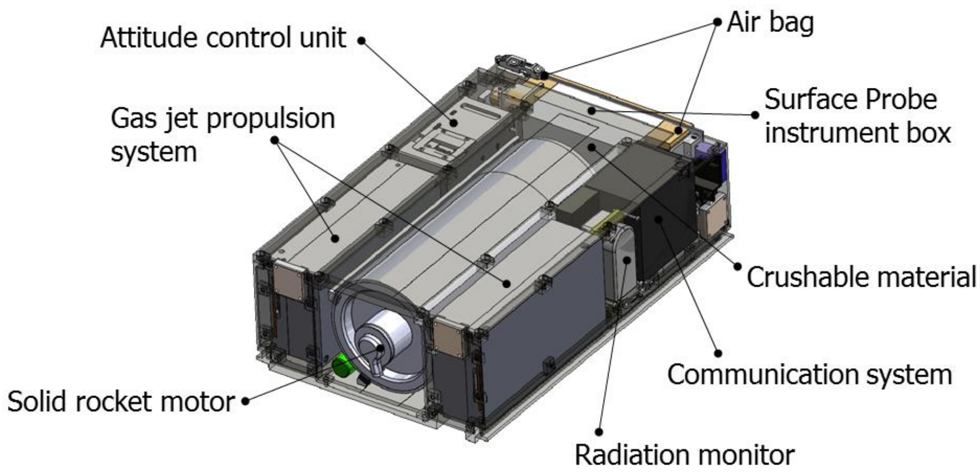
Overview of OMOTENASHI

<Objectives>

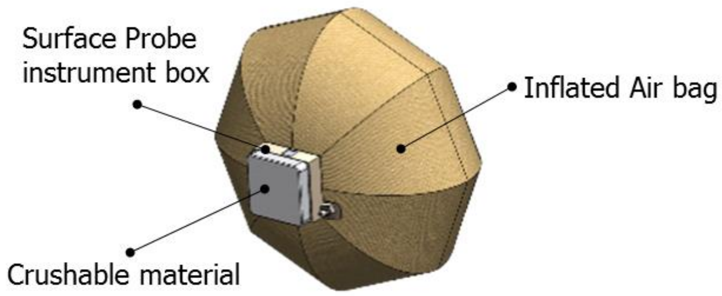
*Development of the smallest lunar lander in the world and demonstrate the feasibility of the hardware for distributed cooperative nano-exploration system. Small landers will enable multi-point exploration which is complementary with large-scale human exploration system.

*Observation of radiation and soil environment of the moon surface by active radiation monitors and touchdown acceleration measurements.

Launch configuration



Landing configuration



What is next step ?

In order to realize an attractive and valuable planetary exploration, “orbiters” and “landers” on a planets with gravity and atmosphere are necessary and indispensable.

Can we realize “orbiters” and “landers” under the restricted resource constraint in small satellite ?

＊**Lander (Entry, Descent, and Landing) technology**

Conventional EDL technique (ablator and parachute) required a large resource, high cost and complex systems.

→ Need innovative technique, like **a deployable aeroshell.**

＊**Orbiter (orbit insertion) technology**

Conventional propulsion technique required a large resource.

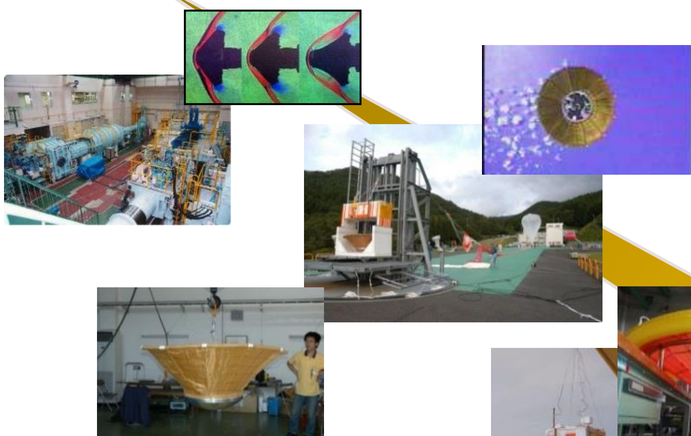
→ Need innovative technique, like **an aerocapture by a drag modulation using deployable aeroshell and jettison.**

“Deployable aeroshell” is the final key technology to enhance a value of planetary exploration by small satellites.

Development of deployable aeroshell

Driven by The University of Tokyo and many Universities and JAXA/ISAS

2000 : fundamental study (wind tunnel test and numerical simulation)



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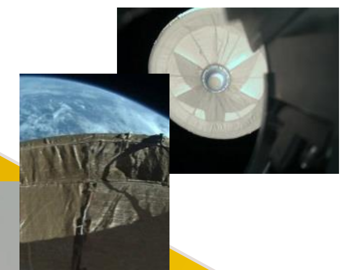
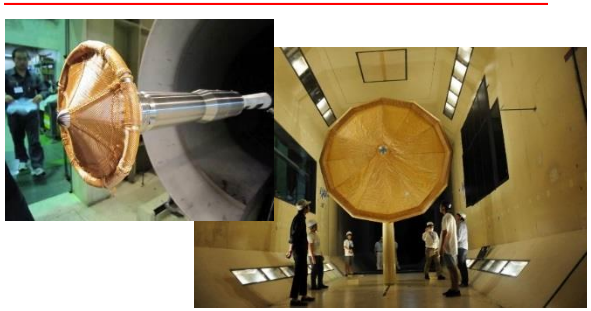


2017 :
Nano satellite EGG
From ISS by JSSOD

2005- :
Hypersonic wind tunnel test
Full scale wind tunnel test



Apply to planetary Exploration by Small sat?

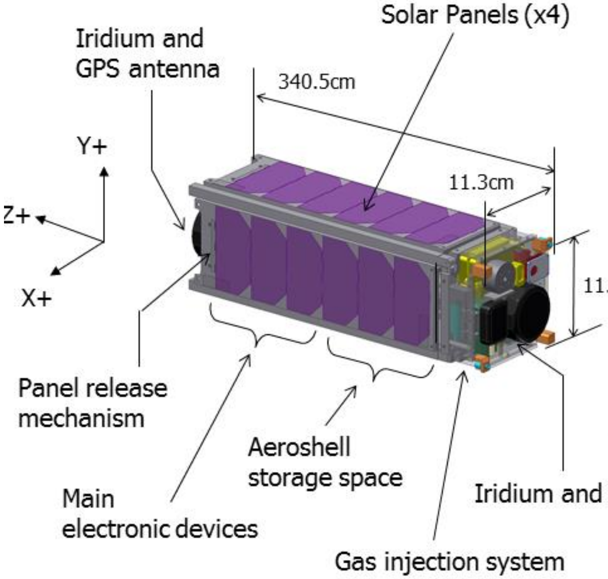
Overview of EGG

"EGG" ~re-Entry satellite with Gossamer aeroshell and GPS/Iridium

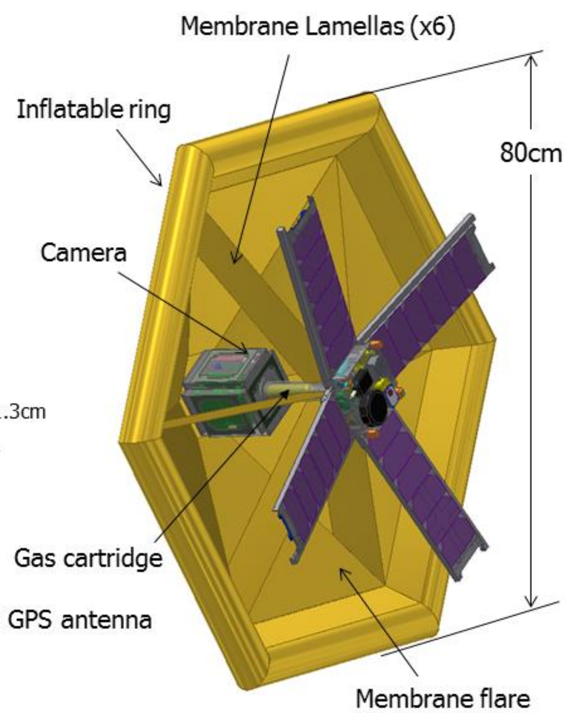
is a 3U-nanosatellite deployed from ISS using JSSOD system equipped in KIBO

<EGG's objective>

To demonstrate indispensable technologies for a future atmospheric-entry flight test of the inflatable aeroshell in Low-Earth-Orbit



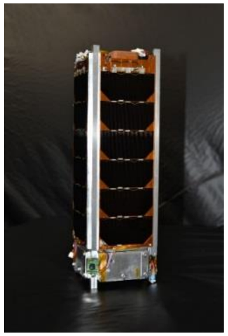
Packed configuration (3U)



Deployed configuration (diameter = 80cm)

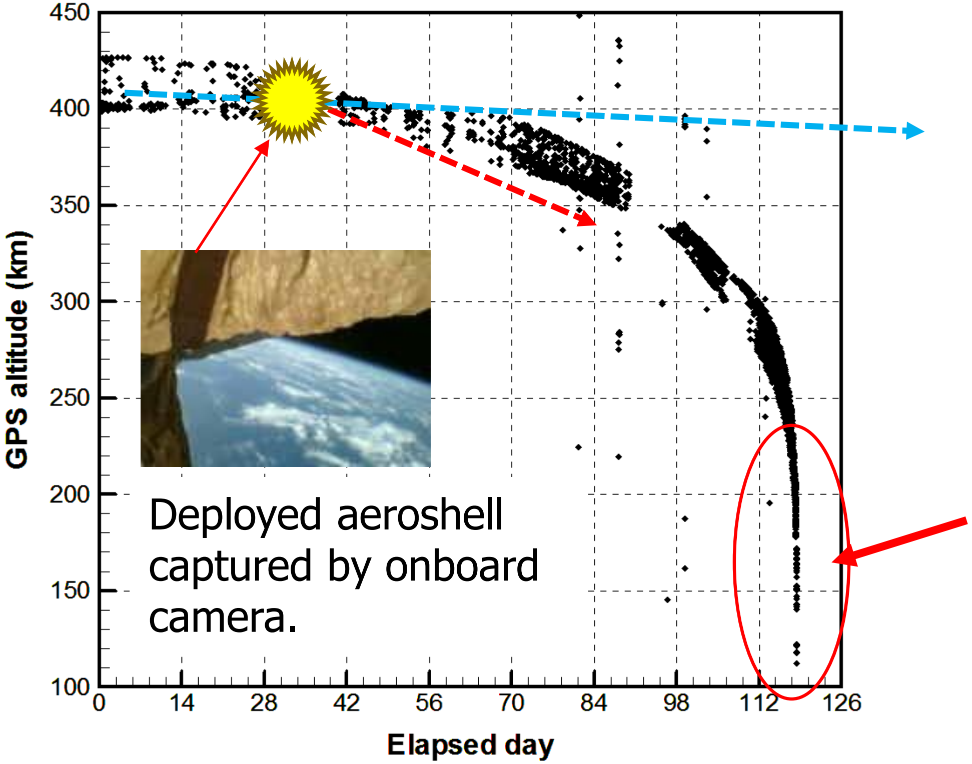
3U-size(10 x 10 x 30cm)

Mass : 4kg



EGG' Achievements and to BEAK

Altitude history acquired by COTS GPS



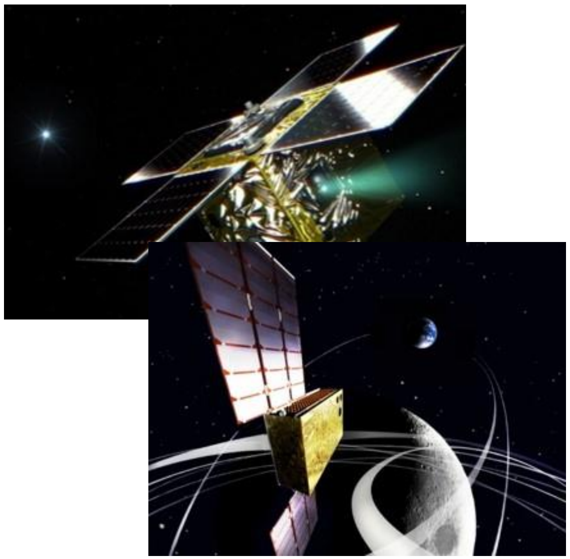
- Demonstration of aeroshell deployment system installed in 3U nanosatellite in LEO.
- COTS GPS receiver (firefly) can identify EGG's position during flight and acquired the orbital decay process of EGG.
- Observation of orbital decay process due to aerodynamic force acting on the deployed aeroshell and reentry phase using Iridium SBD Tele-com system

Next planned demonstrator utilizing EGG's Heritage

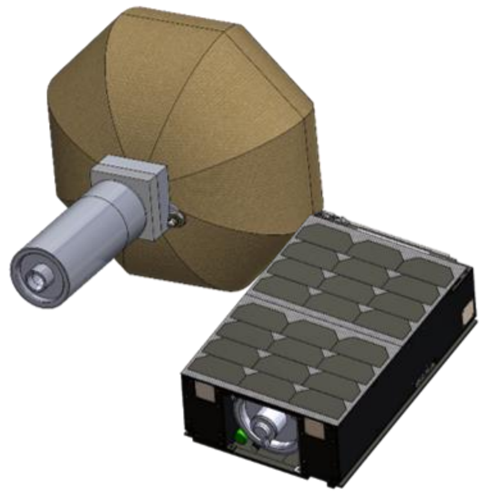
2020: BEAK (*Breakthrough by EGG-derived Aerocapture Kilt Vehicle)*
→ Aero-assisted orbit change of drag moderation will be demonstrated
by a jettison of the deployable aeroshell in Earth's atmospheres.

Future vision

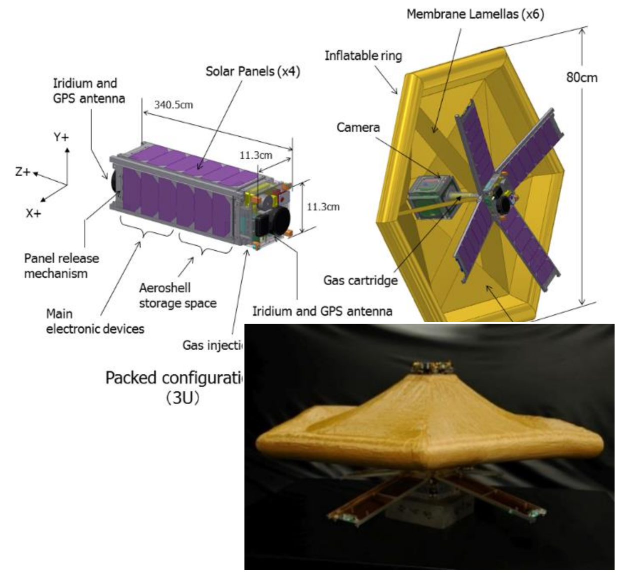
PROCYON & EQUULEUS



OMOTENASHI



EGG & BEAK



*Small sat spacecraft bus system technology
*Orbital maneuver technique with ion thruster and/or water resist jet

*Landing technology (air bag, retrojet, crushable)
*Solid motor technology for small satellite

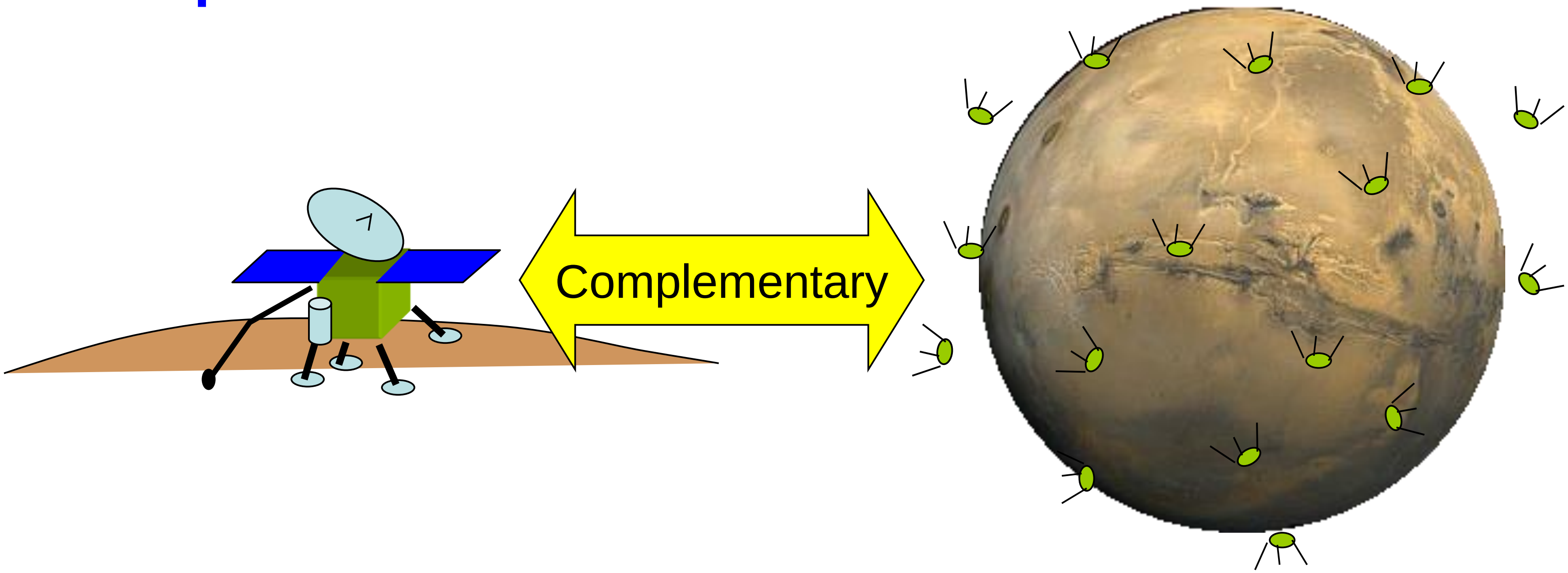
* Deployable aeroshell technique for atmospheric-entry.
* Orbital insertion technique by drag modulation aerocapture

Open a door of planetary exploration by small satellites

Paradigm shift in planetary exploration

Single-Point-Type Exploration

Network-Type Exploration By flock of scattered probes



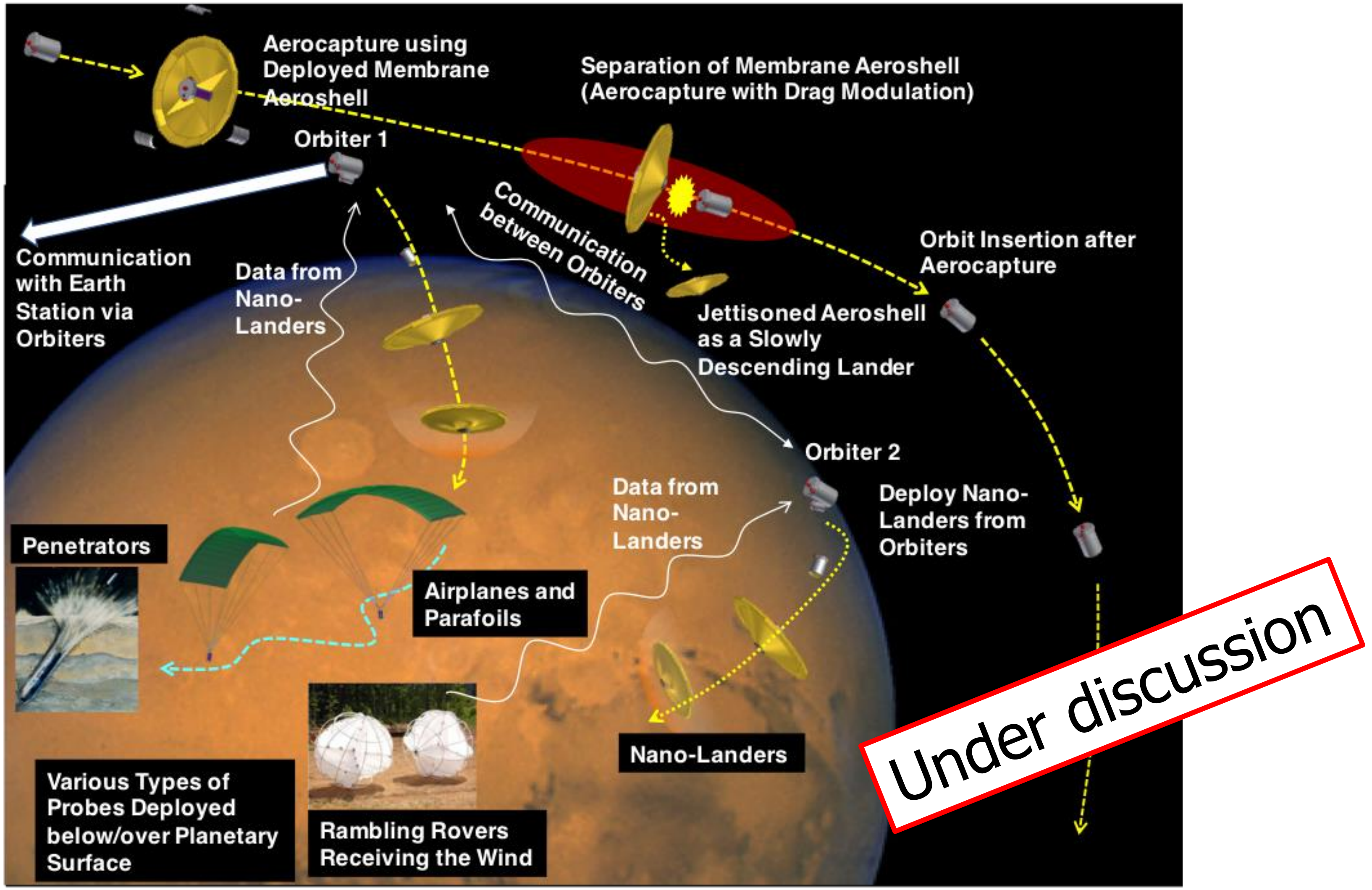
*Detailed and Precise information available
*Mobility is a problem
*Hard to understand as "a SYSTEM of complexity"

Understanding of planet as "a SYSTEM of Complexity" based on synthesis of information obtained by simultaneous and Multipoint observation using a group of spatially dispersed probes.

Small sat and nano-landers technique can realize this network exploration.

Proposed next projects

SPUR Scattered nano Probes Unfolded Reconnaissance



Summery

In Japan, some planetary exploration missions by small satellite-class is active on the heritage the cube-sat, hodoyoshi-sat and ISAS's small flight vehicle experiment (balloon and rocket) technology.

These projects are driven by collaborating with JAXA/ISAS, the University of Tokyo and many universities.

Small satellite technology has a potential as game changer for planetary exploration. For example, it may open a new world, that is, network exploration on the planet by scattered probes.