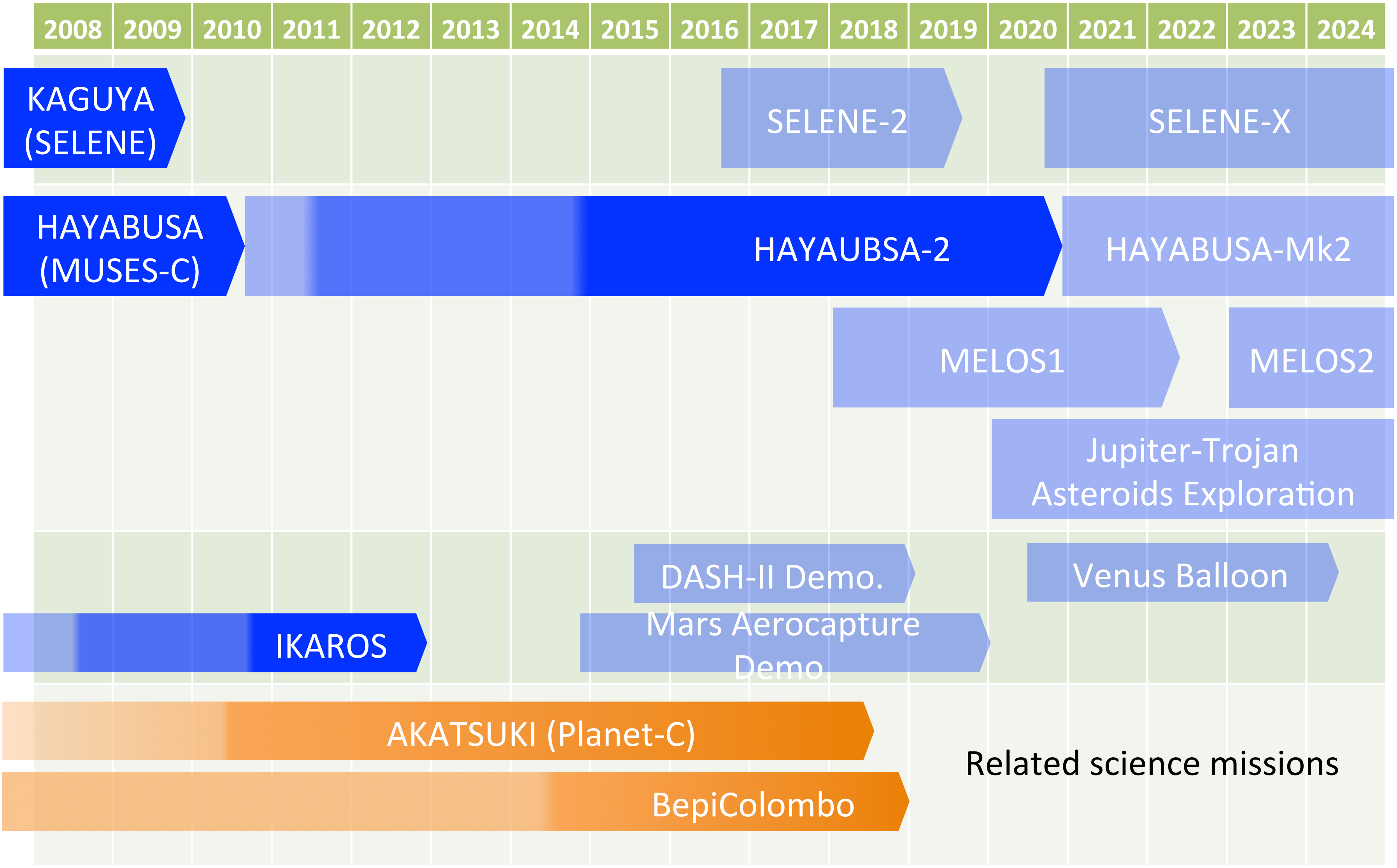
9th International Planetary Probe Workshop
Toulouse, France
June 2012

An Overview of Japan's Planetary Probe Mission Planning

K. Fujita
JAXA Space Exploration Center
Japan Aerospace Exploration Agency

JAXA's Planetary Exploration Mission Roadmap

Overview of scheduled and proposed missions



HAYABUSA-2 (1/5)

■ Primitive body exploration program proposed in JAXA

03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	…	future

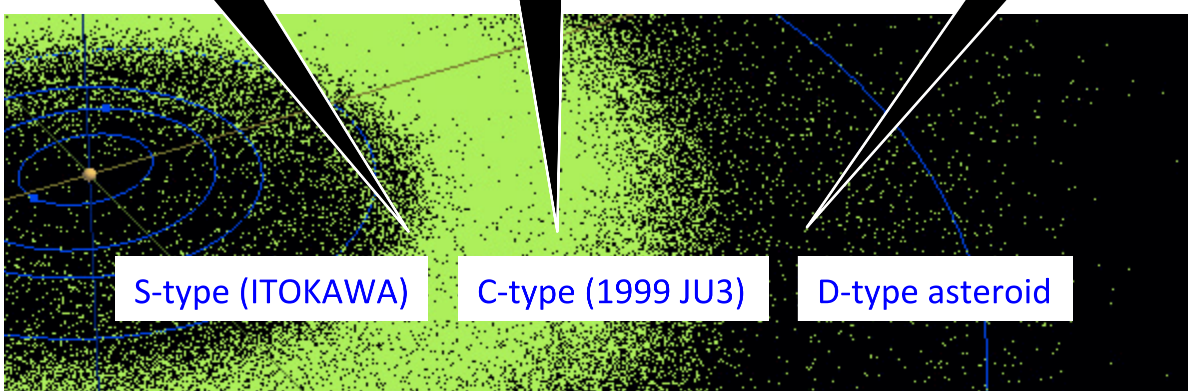
HAYABUSA

HAYABUSA-2

HAYABUSA-Mk2

Propelled by ion engines

Propelled by Solar Power Sail



Sample return from more primitive asteroids located at a further distance, using higher technologies

HAYABUSA-2 (2/5)

Purpose of HAYABUSA-2

1. **Science**

   To answer “Where did we come from?”

   - ☐ The origin and evolution of the solar system
   - ☐ The original material of life
   - ☐ The origin of the water of the ocean

2. **Engineering**

   To develop original and unique technologies for exploration of solar system

   - ☐ New technology used for Hayabusa → more reliable and robust
   - ☐ New challenges : ex) impactor, small rover, …

3. **Exploration**

   To extend the area that human being can reach

   - ☐ Return trip
   - ☐ Space-guard, Resources, Research for manned missions, etc.

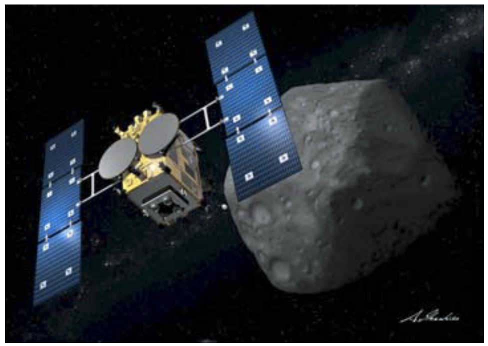
Reproduced from
“The Hayabusa2 Mission of JAXA”
COSPAR Planetary Protection Colloquium 2012
Alpbach, Austria, 31 May 2012

HAYABUSA-2 (3/5)

Mission Outline

Launch

Dec.2014 (or 2015)



Arrival at 1999 JU3

June 2018

HAYABUSA-2 observes 1999 U3, releases small rovers and a lander, and executes multiple samplings

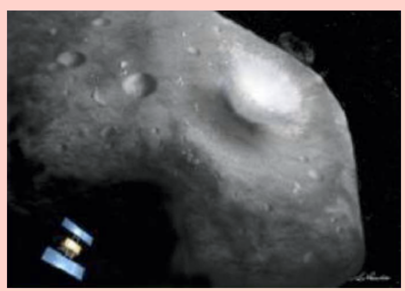
Earth return

Dec.2020

New experiments

2019

HAYABUSA 2 carries an impactor

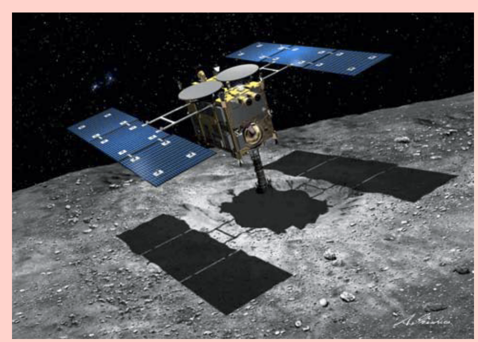


The impactor collides with 1999 JU3

Samples not weathered by cosmic radiation will be collected from a newly created crater

Departure

Dec.2019



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HAYABUSA-2 (4/5)

Mission instruments

Payloads	Specifications
Multiband Imager (ONC-T)	Wavelength: 0.4 – 1.0 µm, FOV: 5.7 deg x 5.7 deg, Pixel Number: 1024 x 1024 px filter (ul, b, v, w, x, p, Wide) (Heritage of Hayabusa)
Near IR Spectrometer (NIRS3)	Wavelength: 1.8 – 3.2 µm, FOV: 0.1 deg x 0.1 deg (Heritage of Hayabusa, but 3µm range is new)
Thermal IR Imager (TIR)	Wavelength: 8 – 12 µm, FOV: 12 deg x 16 deg, Pixel Number: 320 x 240 px (Heritage of Akatsuki)
Laser Altimeter (LIDAR)	Measurement Range: 30 m – 25 km (Heritage of Hayabusa)
Sampler	Minor modifications from Hayabusa-1 (Heritage of Hayabusa)
Small Carry-on Impactor (SCI)	Small system released form the spacecraft to form an artificial crater on the surface (New)
Separation Camera (DCAM)	Small, detached camera to watch operation of Small Carry-on Impactor (Heritage of Ikaros)
Small Rover (MINERVA II-1, II-2)	Similar to MINERVA of Hayabusa-1 (possible payload: Cameras, thermometers) (Heritage of Hayabusa)
Small Rover (MASCOT)	Supplied from DLR & CNES MicrOmega, MAG, CAM, MARA

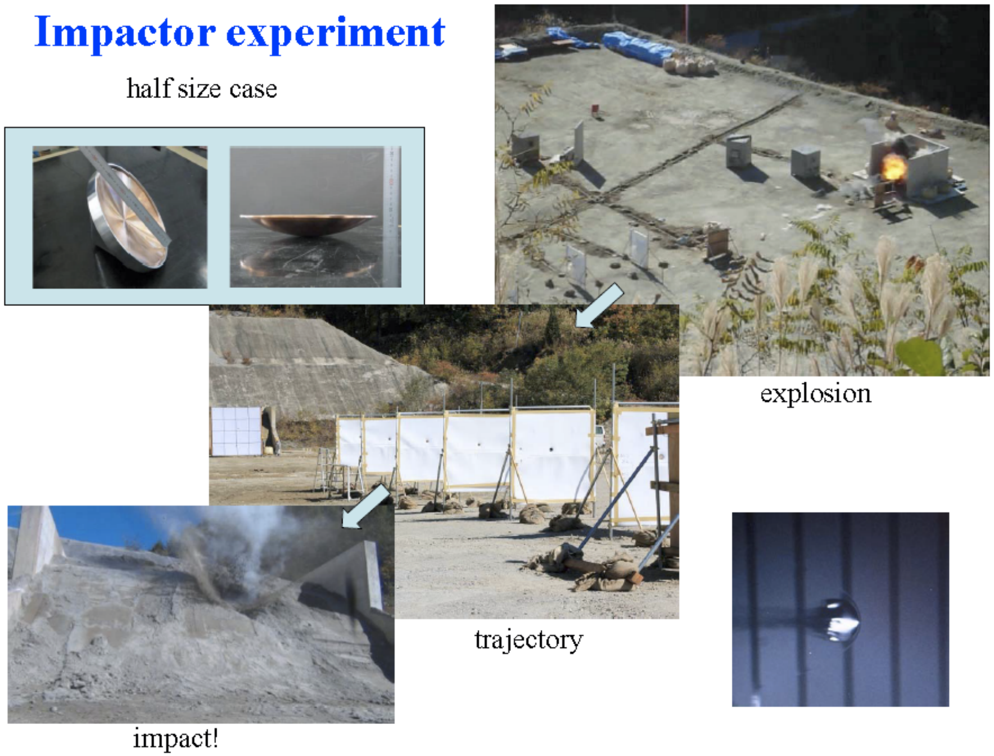
Taken from
"The Hayabusa2 Mission of JAXA"
COSPAR Planetary Protection Colloquium 2012
Alpbach, Austria, 31 May 2012

HAYABUSA-2 (5/5)

■ Current Status

Date	Events
May 2011	Phase-B started
Jul. 2011	Phase-C started
Mar. 2012	CDR completed
Present	Phase-D Manufacture is going on
Jan. 2013- Apr. 2013	1st I/F test will be done
Oct. 2013- Sep. 2014	FM test will be conducted
Dec. 2014	Phase-E / Launch
Dec. 2015	Earth swing-by
Jun. 2018	Arrival at 1999 JU3
Dec. 2019	Departure from 1999 JU3
Dec. 2020	Return to earth

■ EM test results



Taken from
“The Hayabusa2 Mission of JAXA”
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SELENE-2 (1/4)

■ Lunar exploration strategy proposed at JAXA

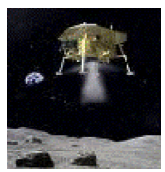
07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	… future

KAGUYA → SELENE-2 → SELENE-X

- Robotic lunar exploration

KAGUYA (SELENE) : Orbiter for global remote sensing

SELENE-2 : Lander for in-situ observation

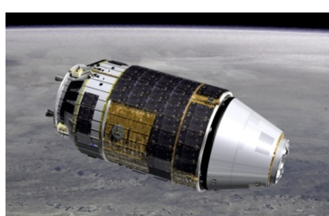


SELENE-X : Next generation Landing mission

Science exploration & moon utilization by Japanese astronauts

- Human lunar exploration

With operation & utilization of ISS & HTV, fundamental technologies for human exploration will be gained



Reproduced from "JAPANESE MOON LANDER SELENE-2 AS A ROBOTIC PRECURSOR MISSION" GLEX-2012.03.1.7x12702

SELENE-2 (2/4)

Purpose of SELENE-2

- Demonstration of technologies required for future planetary explorations
- Scientific research and utilizablity examination by in-situ sensing
- International contribution & collaboration

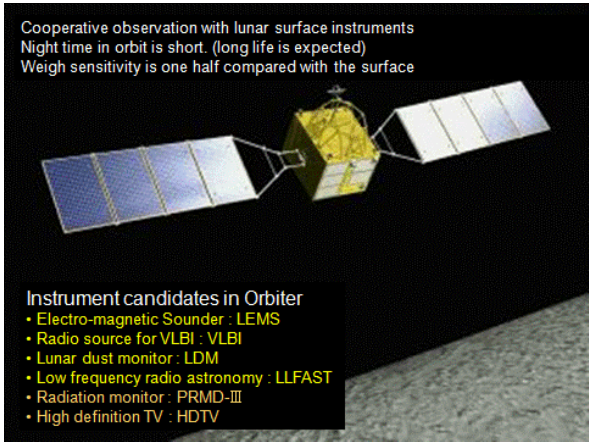
	Kaguya (SELENE)	SELENE-2	SELENE-X	Remaining objectives
Technology development	Lunar orbit insertion Communication relay	Soft landing Surface mobility Night survival with a few watts.	Large-scale lander Return technology Night survival with hundreds watts.	Manned spacecraft Life support system
Planetary science	Remote sensing observation of surface material, global terrain, gravity field, magnetic filed, etc.	In-situ observation of geology and geophysics on the near side.	In-situ observation of geology and geophysics on the polar region and sample and return	Sample and return from other interesting area including far side Seismometer network
Investigation for future lunar utilization	Remote sensing observation of sunlit/shadow, material resources, etc.	Observation of radiation environment, surface soil mechanics.	Demonstration of lunar observatory Detailed observation of polar region	In-situ resource utilization
International collaboration	Date exchange	Payload co-development.	System level collaboration	Program level collaboration
Public interest and outreach	High definition TV from the orbit. (Earth rise)	High definition TV from the surface.	What else?	Astronauts activity

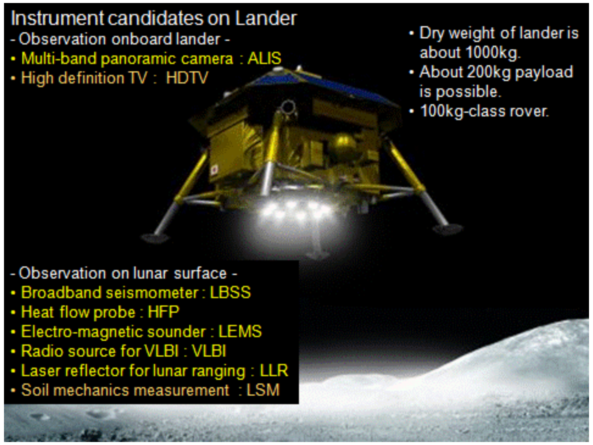
Taken from
"JAPANESE MOON LANDER SELENE-2 AS A ROBOTIC PRECURSOR MISSION"
GLEX-2012.03.1.7x12702

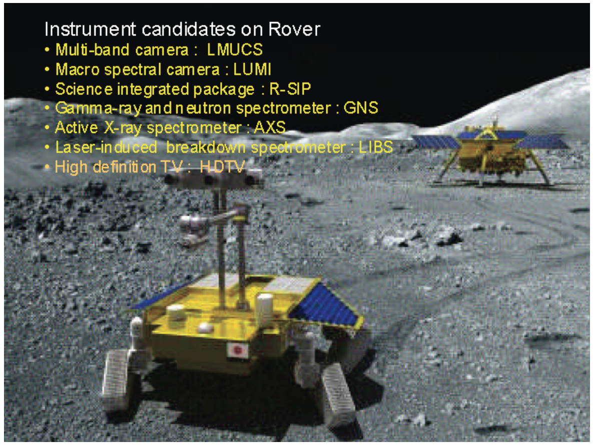
SELENE-2 (3/4)

Taken from
"JAPANESE MOON LANDER SELENE-2 AS A ROBOTIC PRECURSOR MISSION"
GLEX-2012.03.1.7x12702

■ System configuration







Item	Specification (TBD)
Spacecraft configuration	Orbiter, Lander and Rover
Mass	Orbiter: 700 kg (Dry) Lander: 1,000 kg (Dry) Rover: 100 kg
Power	500 W (lander)
Mission instruments	Model payloads are selected.
Mission Duration	Two weeks for lander and rover A few month for geophysical obeservation
Launcher	H-IIA Rocket
Launch site	Tanegashima Space Center
Launch date	2017 (TBD)
Landing area	TBD (near side, middle latitude)

Orbiter	Bus system		600 kg
	Mission payload		100
	Fuel		2400
	Total		3100
Lander	Bus system		700
	Mission payload		200
	Rover	Bus system	90
		Mission payload	10
		Total	100
	Fuel		1700
	Total		2700
Total			5800

SELENE-2 (4/4)

Current status

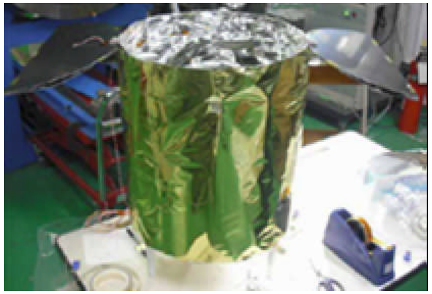
- Proposed schedule

Date	Events
Jun. 2007	MDR completed Phase-A started
Sep. 2010	ΔMDR completed
Present	Frontloading studies are going on
Aug. 2012	SSR
Oct. 2012	RFP
May 2013	SDR
Apr. 2013	Phase-B starts
2017	Launch

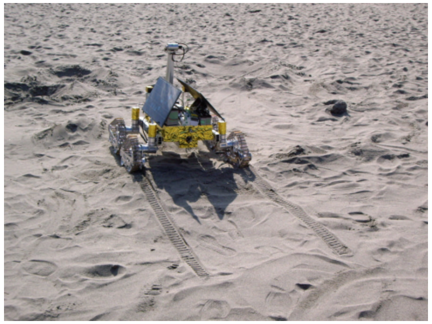
- Frontloading studies

Drop test of landing legs

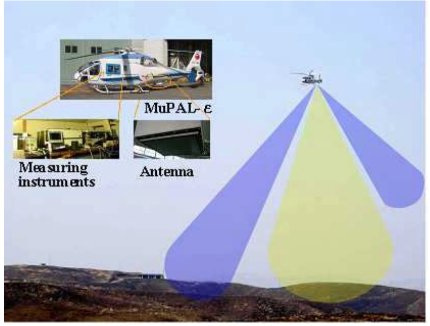
A prototype of nigh survival unit



Field test of a rover in Nakatajima Beach, Japan



Field test of a BBM landing radar over Mt. Aso, Japan



MELOS (1/4)

- MELOS = Mars Exploration with Lander-Orbiter Synergy
- Purpose

1. **Science**

   To answer "How is the climate of Mars determined?" "Why is the present climate of Mars as it is?" "Life on Mars?"

   - The mechanism of global material recycling in the presence of dusts, water, and trace gases
   - The sign of life

2. **Engineering**

   To demonstrate technologies required for future planetary explorations

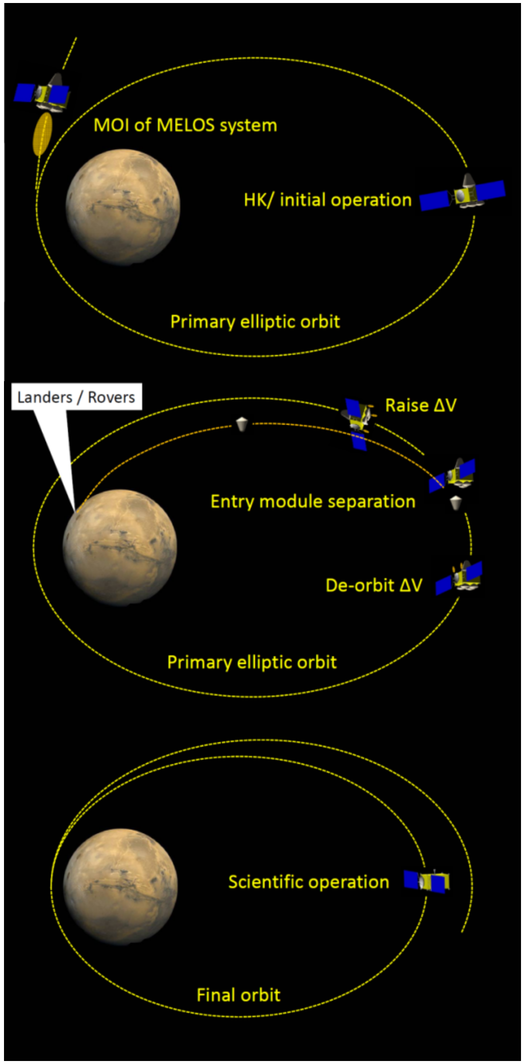
   - The EDL technology for guided entry and reliable landing
   - The surface exploration technology with considerable mobility

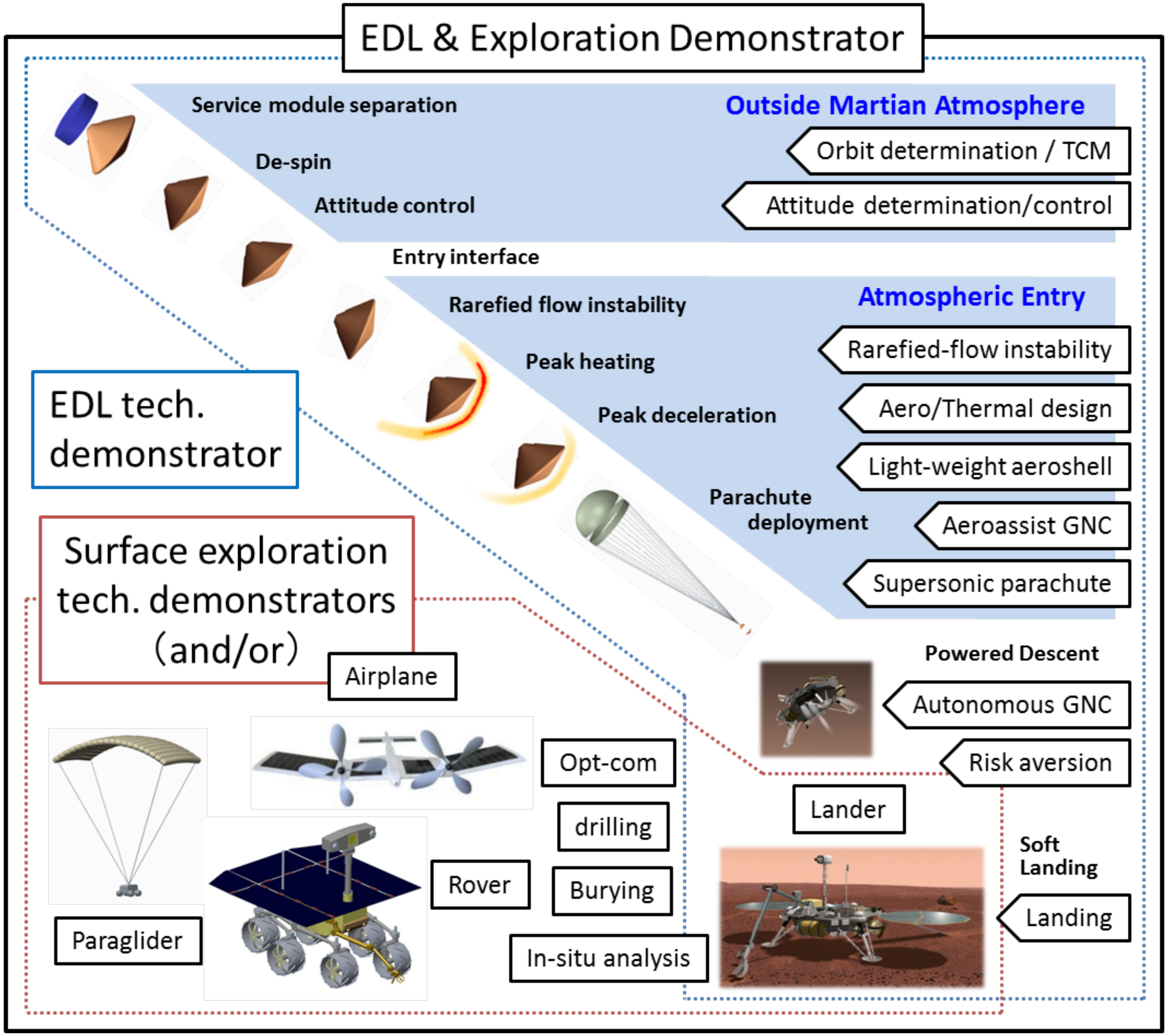
3. **Exploration**

   To extend the area that Nipponese can reach (political purpose)

MELOS (2/4)

■ Fundamental mission scenario

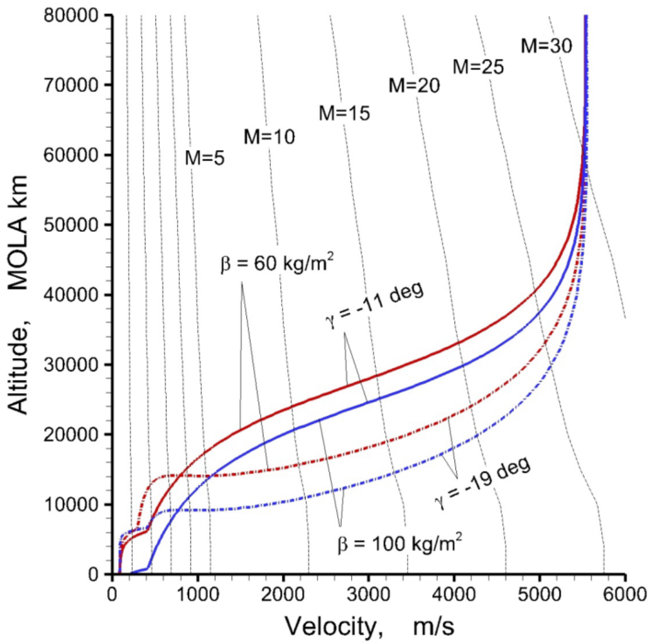


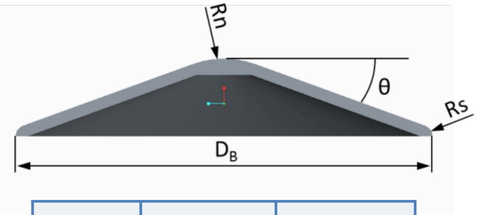


MELOS (3/4)

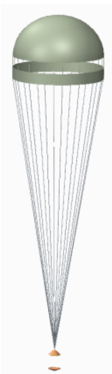
Conceptual design for minimum-size EDL demonstrator

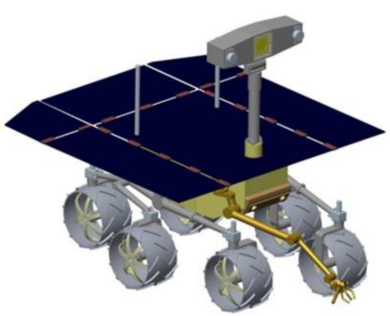
- Launch in 2018, V_{inf} = 2.962 km/s
- Landing point = +2.0 MOLA altitude km / south hemisphere
- Landing subsystem = 45-kg rover only
- Mission payload = Life search & weather monitoring package (10 kg in total)





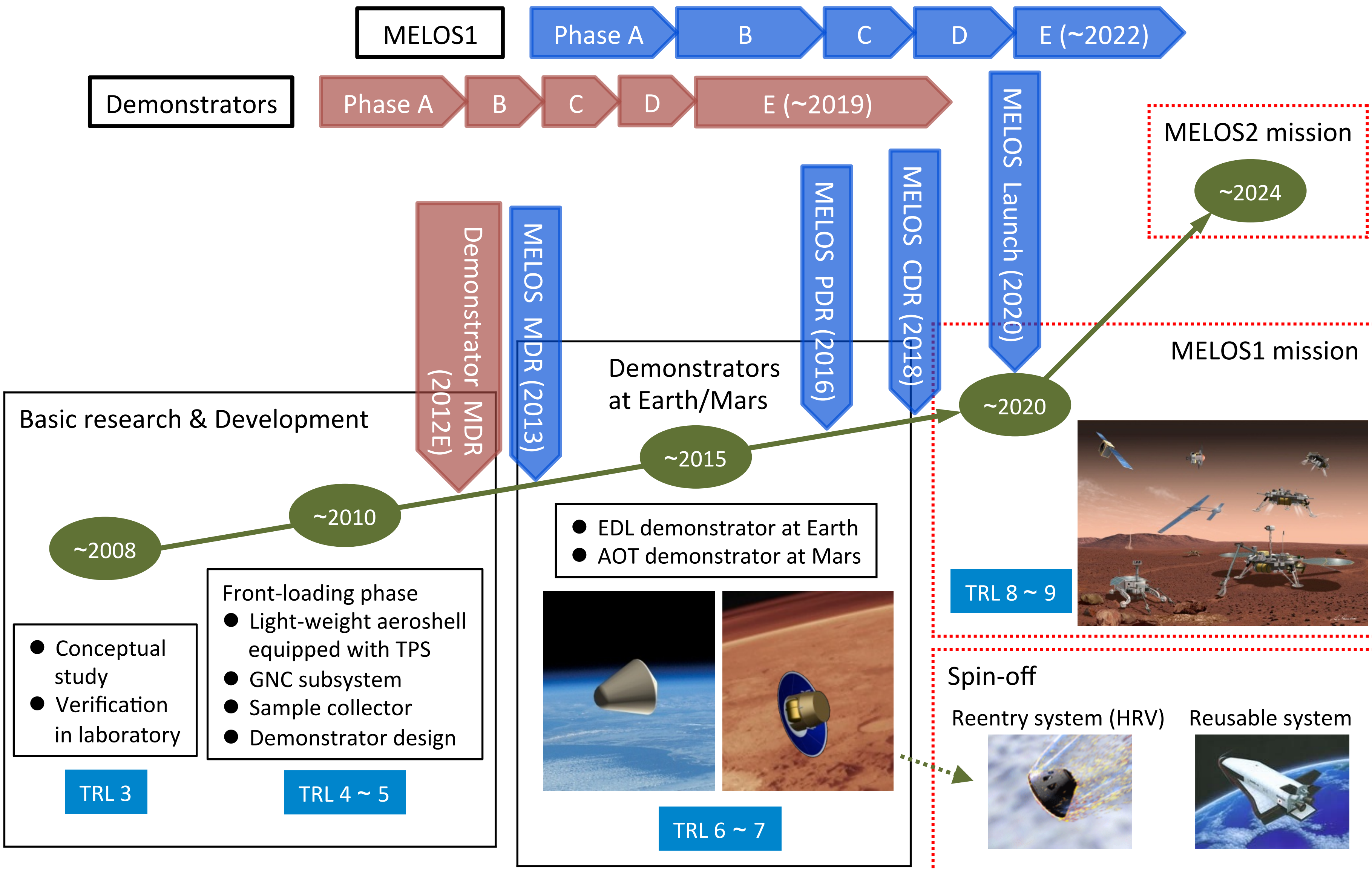
D_B	2.225	m
β	60	Kg/m²
γ	-19	°
α_{trim}	-13	°
L/D	0.2	





Component	Mass (kg)	
Service module	80	
Parachute	15	
Aft-aeroshell	30	
Landing module	113	
Propulsion		52
AOCS		19
Power supply		22
Structure		20
Rover	45	
Rover bus		35
Mission inst.		10
Fore-aeroshell	35	
Margin	35	
Total	353	

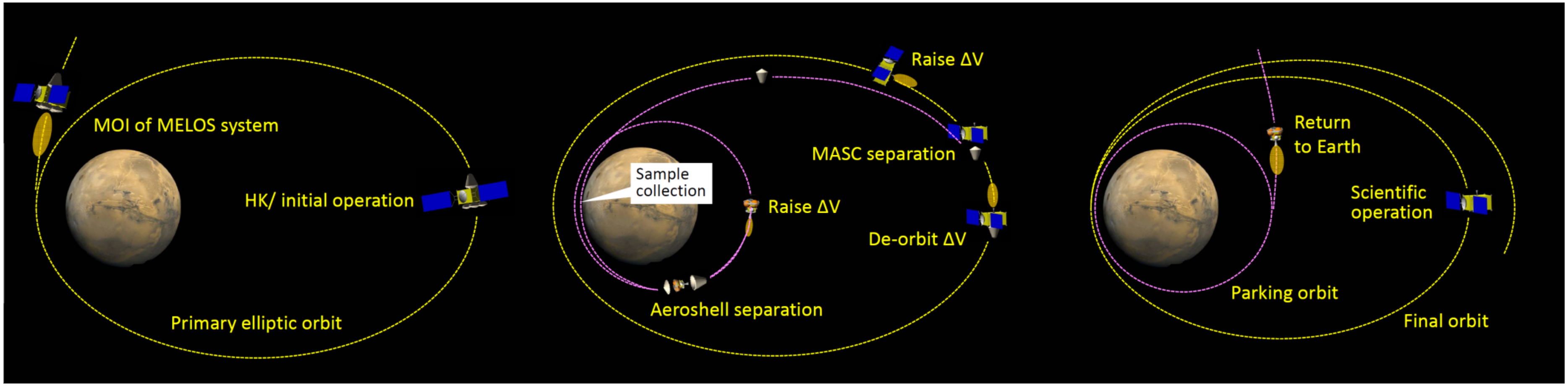
MELOS (4/4)


MELOS1
Phase A
B
C
D
E (~2022)
Demonstrators
Phase A
B
C
D
E (~2019)
Demonstrator MDR (2012E)
MELOS MDR (2013)
MELOS PDR (2016)
MELOS CDR (2018)
MELOS Launch (2020)
MELOS2 mission
~2024
MELOS1 mission
~2020
Demonstrators at Earth/Mars
~2015
Basic research & Development
~2010
~2008
EDL demonstrator at Earth
AOT demonstrator at Mars
Front-loading phase
Light-weight aeroshell equipped with TPS
GNC subsystem
Sample collector
Demonstrator design
Conceptual study
Verification in laboratory
TRL 3
TRL 4 ~ 5
TRL 6 ~ 7
TRL 8 ~ 9
Spin-off
Reentry system (HRV)
Reusable system

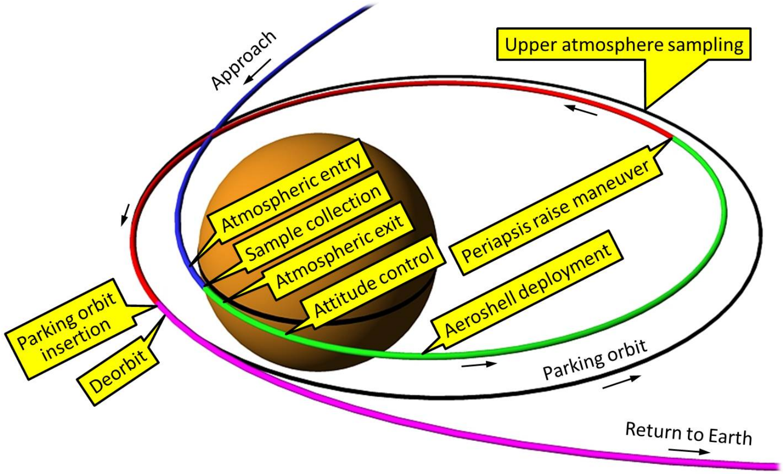
MASC (1/4)

MASC = Mars Aeroflyby Sample Collection

- Similar concept of SCIM proposed to Mars Scout Mission
- Collect Martian dust & atmosphere sample and return to earth without landing



Altitude (km)	Dust fluence for V = 4 km/s (count/cm².sec)			
	0.5–1.5 µm	1.5–2.5 µm	2.5–3.5 µm	1–10 µm
45	0.05	0.04	0.02	0.23
40	4	3	1.4	16
35	56	48	23	252
30	367	312	148	1650
25	1331	1129	536	5984
20	3526	2991	1420	15849

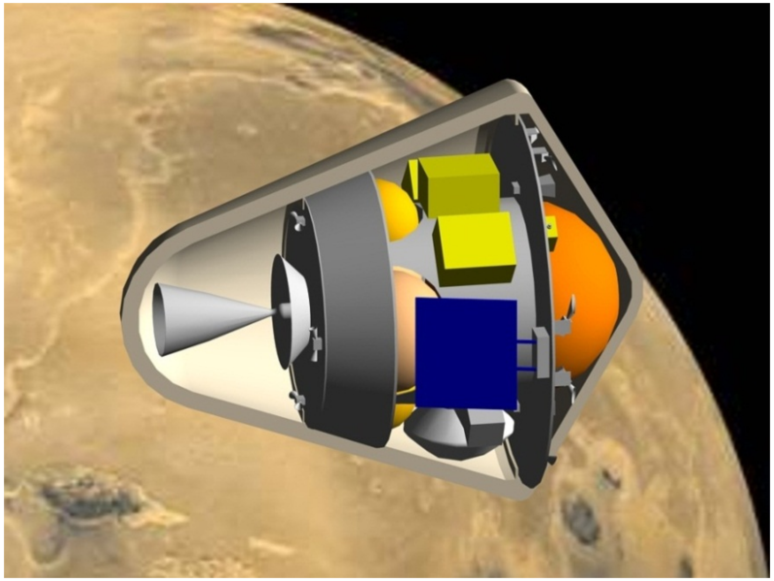


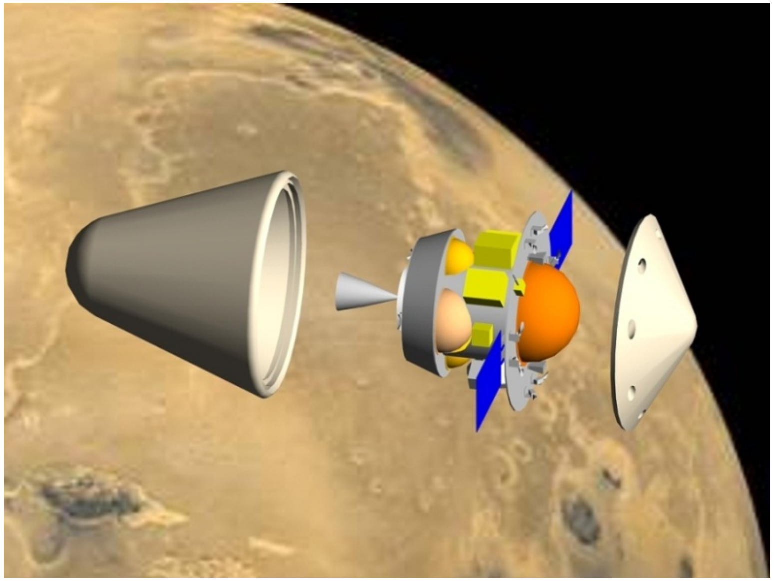
MASC (2/4)

Conceptual system design

- Conducted based on the latest status of subsystem development, and on heritages of HAYABUSA sample return system
- Further reduction of system mass may be realized by introducing new instruments

Total mass	593				
Orbit insertion subsystem		175			
Aeroshell			133		
RCS (dry)			15		
Hydrazine (fuel)			15		
MON-3 (oxidizer)			12		
Orbiter subsystem		358			
OME propellant for departure			190		
Hydrazine (fuel)				105	
MON-3 (oxidizer)				85	
Earth return subsystem			168		
OME (dry)				48	
Hydrazine (fuel)				15	
Structure				35	
Sampler				10	
Electronics				44	
Earth reentry capsule				16	
Margin		60			

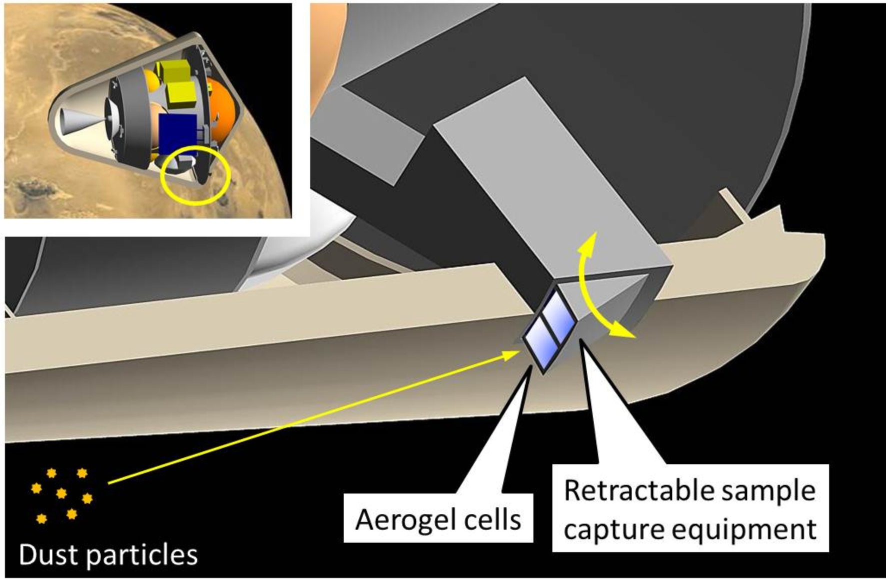




MASC (3/4)

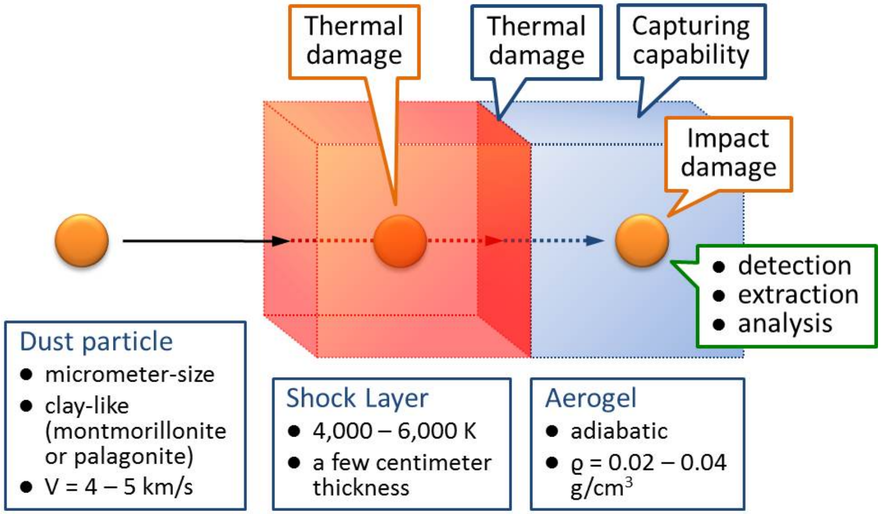
Dust Sampler Design

- Retractable samplers (currently 2) are exposed for a few seconds
- Samplers are located near aeroshell base to reduce heat transfer rate
- Silica aerogel is used for capturing sample particles (like STARDUST)
- Aerogel cells are transported to the reentry capsule inside MASC



Key issues

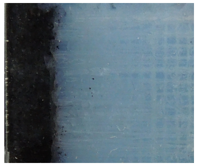
1. Damages inflicted on dust particles by high-temperature shock layer
2. Damages inflicted on aerogel exposed to high-temperature shock layer
3. Dust capturing capabilities of aerogel
4. damages inflicted on dust particles by impingement
5. capabilities of detecting & extracting dust samples stuck in the aerogel



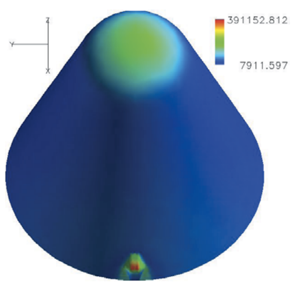
MASC (4/4)

Current status of frontloading studies

- Development of Non-Ablative Light-weight Aeroshell (NALT)
- Detailed estimation of flight environments
- Bus design update
- Development of dust sampler
  - ☐ Trajectory & heat transfer analysis of sample dust particles
  - ☐ Arcjet heating test campaigns
  - ☐ Dust capturing test
  - ☐ Detection / extraction / analysis capability test

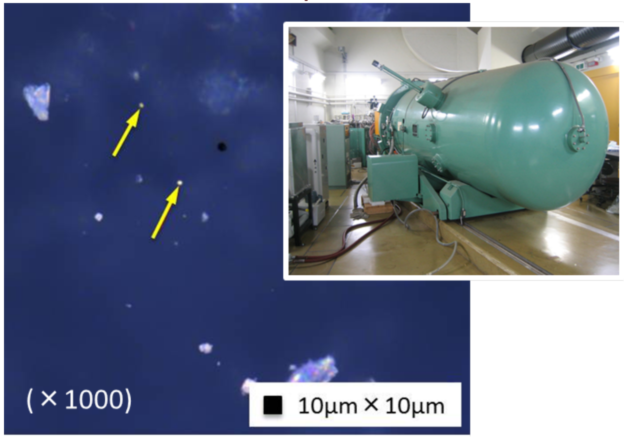


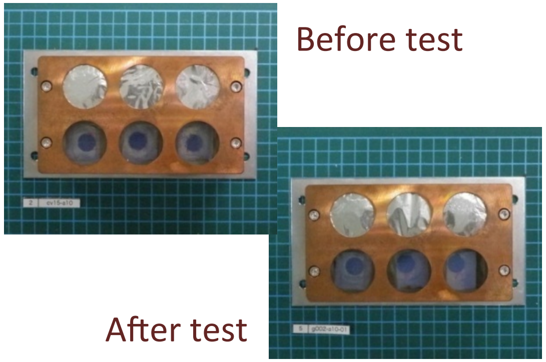
CA-SA 2-layered aerogel for higher heat-resistance



- Trajectory analysis of particles
- Optimization of collector location by means of CFD

VdG dust capture tests

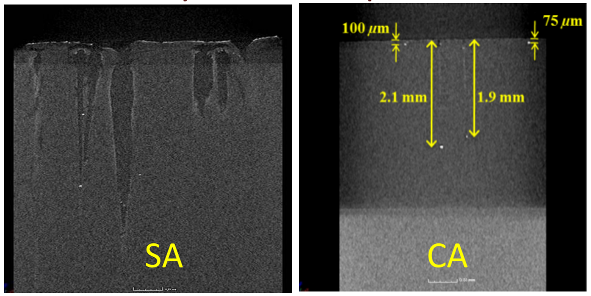




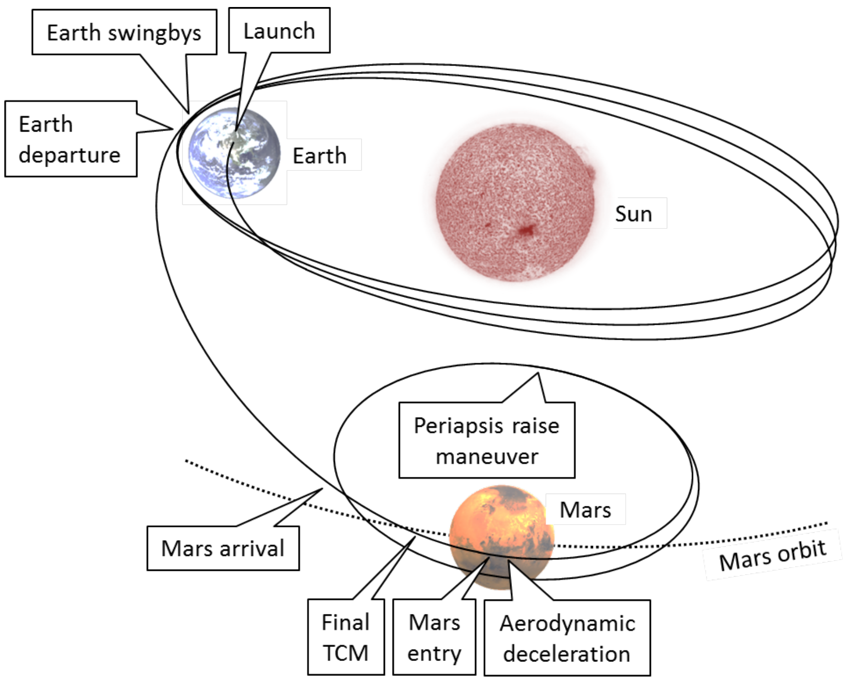
Before test

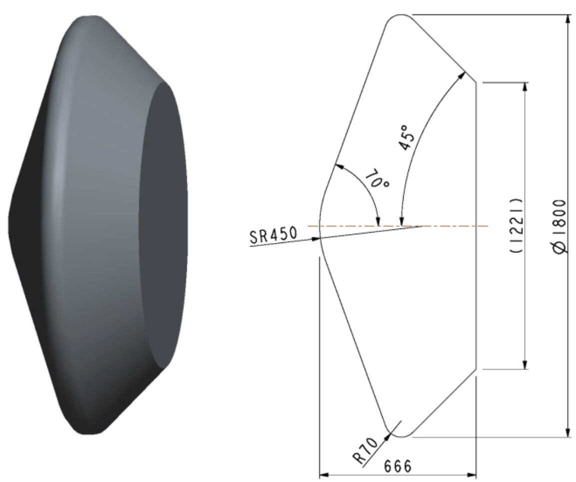
After test

Micro X-ray CT for sample extraction



Mars Aerocapture Demonstrator (1/3)





Purpose

- Proposed as a low-cost, quickly-developed, small-sized demonstration mission
- Demonstration of aerocapture technique
  - Accurate orbit determination & TCM
  - Aeroassist guidance & navigation
  - Ultra-light-weight aeroshell equipped with TPS

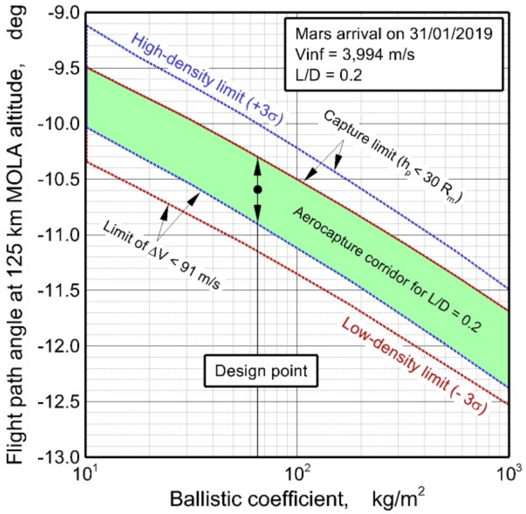
Mission overview (case study)

- A small-sized simple bus system
  - Launched as a piggyback of an appropriate main spacecraft for a deep-space mission
  - Total wet mass = 240 kg at earth departure
  - Orbit adjustment by earth swingbys
  - Mars arrival with V_{inf} ~ 4 km/s
- Aerocapture subsystem
  - Aeroshell weight ~ 40 kg
  - Post aerocapture ΔV < 100 m/s
  - Aerocapture corridor : $\Delta\gamma < 0.2^{o}$
  - Lifting aeroshell with L/D ~ 0.2
  - Final orbit apoapsis alt. = 300 km ~ 30 Rm

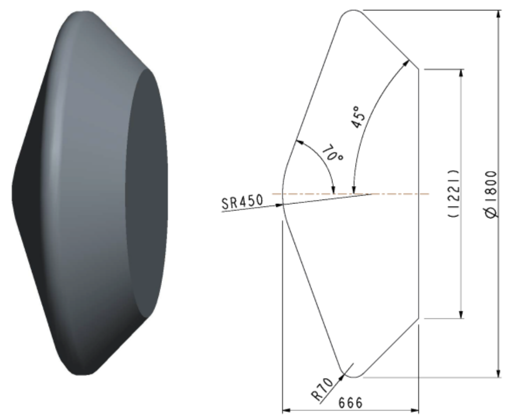
Mars Aerocapture Demonstrator (2/3)

Feasibility assessment

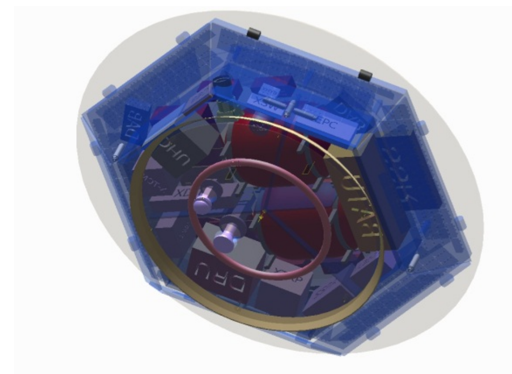
- Aerocapture corridors



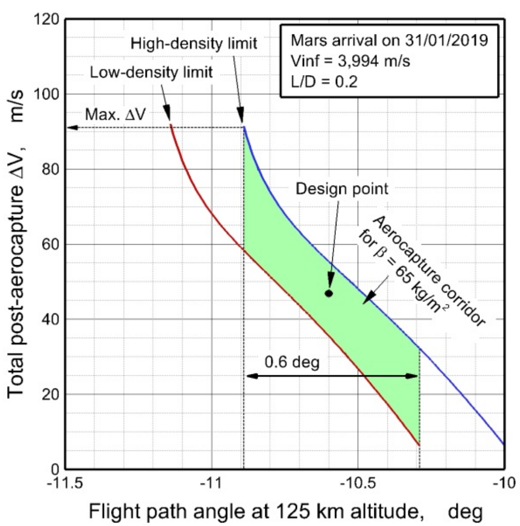
- Design of aeroshell

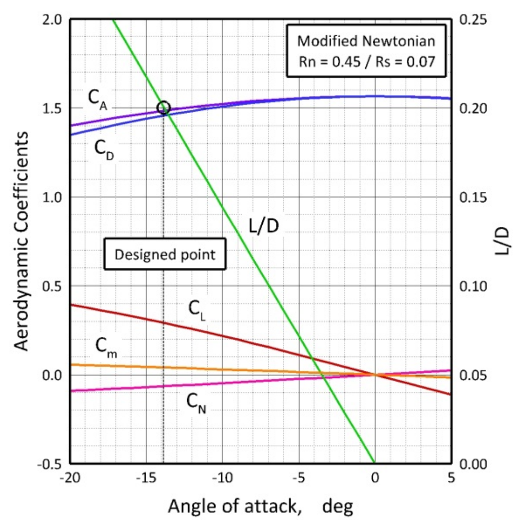


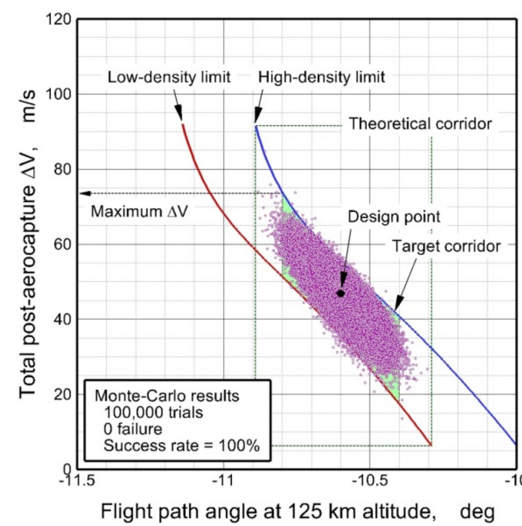
- System design
- Operation planning



- Verification



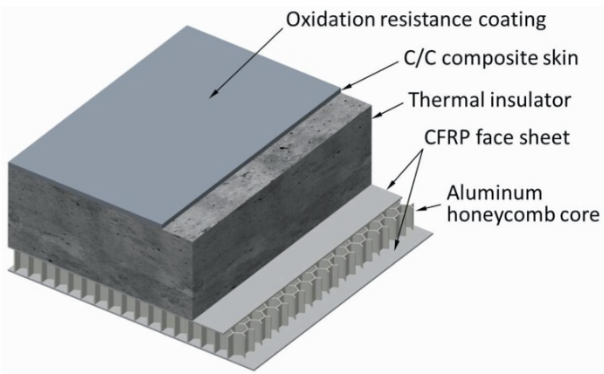


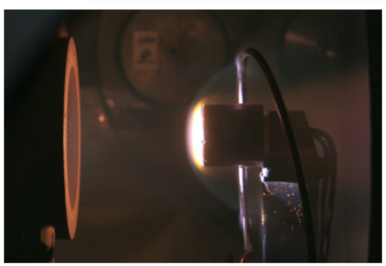


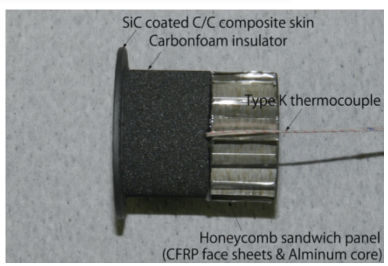
Mars Aerocapture Demonstrator (3/3)

■ Frontloading R & D (common activities for Mars missions)

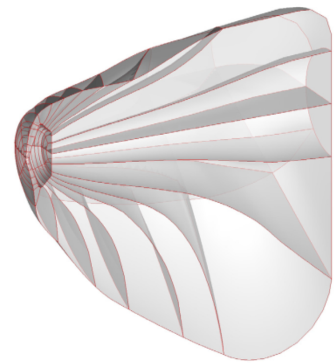
- Ultra-light-weight aeroshell
  - ☐ Light-weight ablator (ρ ~ 0.3 g/cc)
  - ☐ Non-ablative Lightweight TPS (NALT)

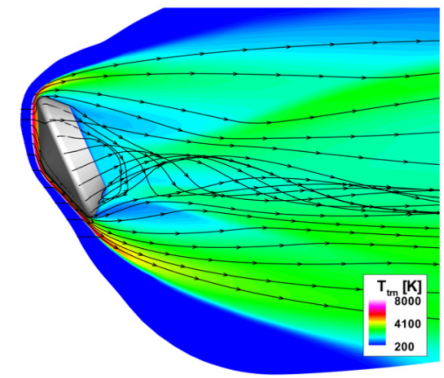


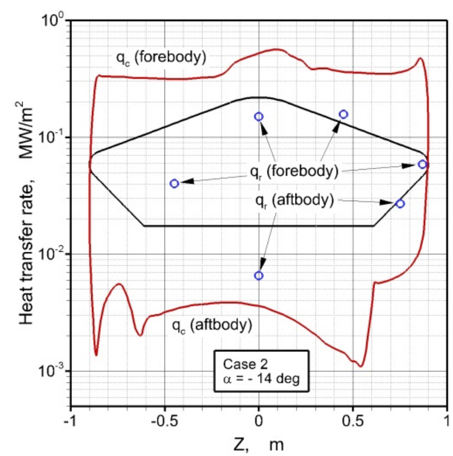


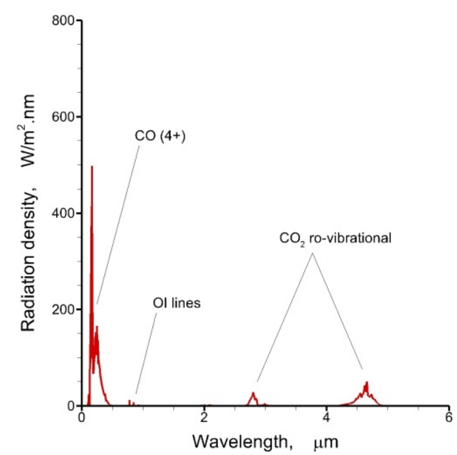


- Improvement of accuracy in predicting flight environments
  - ☐ 3D CFD & verification by experiments
  - ☐ VUV to IR radiation model

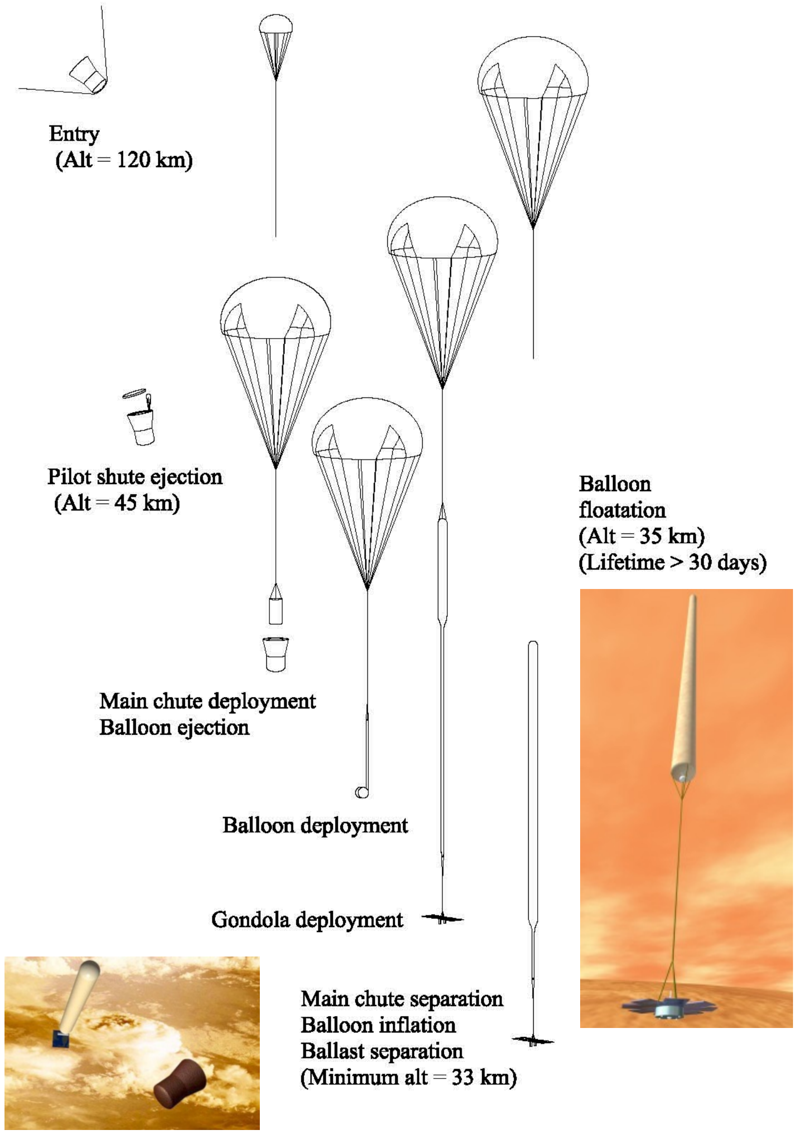








Venus Balloon (1/2)



Purpose

- Proposed as a low-cost, quickly-developed, small-sized demonstration mission
- Scientific aspect : in-situ sensing of Venus
  - Long-term observation under clouds (alt. 35-40 km < VEGAs flight altitudes)
  - Mechanism of strong equatorial winds (super-rotation), N-S circulation, observation of aerosol…
- Engineering aspect
  - High temperature electronics, planetary balloon technology, entry probe technology, VLBI,…

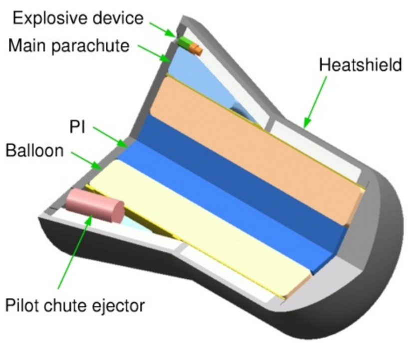
Mission overview

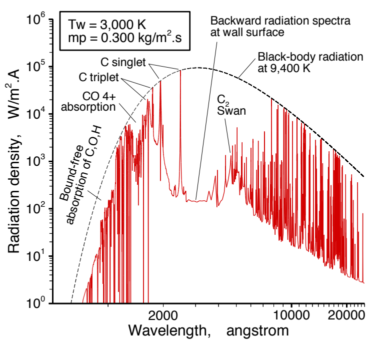
- A small-sized simple bus system
  - Total mass = 160 kg at arrival
  - Direct entry of a 35-kg capsule (V~11km/s)
  - Bus system flyby (or VOI by aerocapture)
- A long-term super-pressure balloon
  - Lifetime > 30 days
  - Inflated & maintained by using water vapor pressure
  - Total mass = 10 kg

Venus Balloon (2/2)

Current status of feasibility assessment

- Conceptual design of entry system
  - Radiation-coupled flowfield analysis (2006)
  - Trajectory-based TPS design (2007)

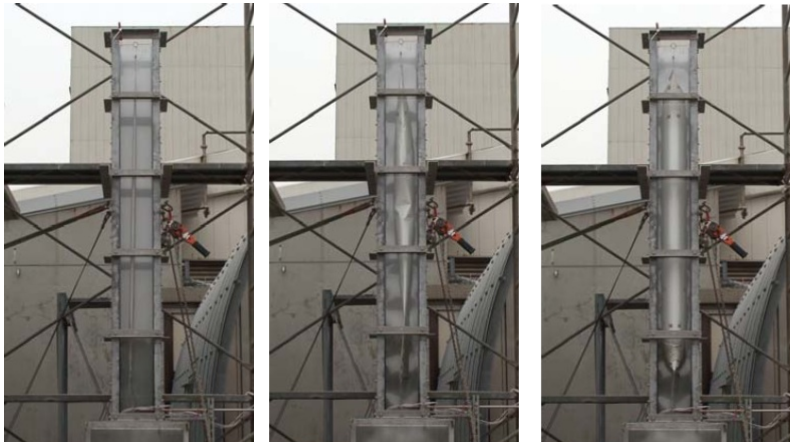




Components		Weight (kg)
TPS	Nose Side Aft body	6.3 5.8 5.1
Structure		3.2
Mortar		0.7
Pilot chute		0.4
Main chute		1.1
Bus electronics		2.0
Battery		0.4
Payload	Balloon Gondola	7.8 2.2
Total		**35.0**

- Conceptual study of VOI by aerocapture
  - Drag-modulation aerocapture sub-system analysis (2008)

- Balloon inflation demonstration (2007)
  - Vertical low-speed hi-temp. WT (~150^{o}C)
  - 0.16x1.88 m test balloons



Summary

- An overview of Japan's planetary probe mission planning is presented from a scheduled mission (HAYABUSA-2) to concept-level researches
- In the next mid-term program, JSPEC concentrates its effort on success of HAYABUSA-2, and initiation of SELENE-2 mission
- In the preliminary feasibility studies, technically challenging missions such as Mars aerocapture, MASC, and Venus balloon have been entertained
- Because of limited budget and resources, JAXA is looking for chances for international collaboration/cooperation for deep space missions