Demonstration and Experiment of Space Technology for INterplanetary voYage

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Solar System Sciences using DESTINY

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Abstract

DESTINY (Demonstration and Experiment of Space Technology for INterplanetary voYage) is a Japanese candidate mission using small scientific satellite (SSS) standard bus launched by Epsilon Launch Vehicle. We are proposing three steps of phase I to III. The final purpose of DESTINY series is to carry payload mass of 200 kg to the deep space between Venus and Mars using improved Epsilon Launch Vehicle with low cost. We present the possible instruments and model missions for solar system sciences and space astronomy in the DESTINY series.

At the first step (Ph.-I), DESTINY aims to demonstrate new technologies of μ20 large scale ion engine, ultra light-mass solar panel, *etc*.. It also plans to observe using scientific instruments with the mass of up to about 10 kg during transfer and Halo orbit of sun to earth Lagrangian point L1 or L2. Potential scientific objects between the near earth orbit and L1 or L2 halo orbits cover wide fields of solar system sciences and space astronomies.

Observations of plasma and energetic particles from the space at around the distance of the Moon are effective to elucidate whole the structure of terrestrial magnetosphere. As one of candidate scientific instruments, X-ray Telescope will make imaging of the solar wind charge exchange (SWCX) with a full coverage from the distance of the Moon and the first full imaging for the magneto-sheath, cusp, and magnetopause. Ultraviolet Telescope will observe the Lyman Alpha emission from the geocorona and M-type star with planetary system. ENA (Energetic Neutral Atom) Camera will provide a side-view of the dynamical magnetosphere.

DESTINY is considered to be useful for the pilot observations for future infrared, gamma-ray, and cosmic-ray space astronomical telescope. It is probable to observe and monitor Near Earth Objects (NEO), inter-planetary and inter-stellar dust. Dust Analyser and High Vision Camera will provide physical parameters and chemical features. These instruments would observe one of the most unusual asteroids 3200 Phaethon which has dust tails.

Applied missions of DESTINY will be able to go to deep space with higher mass of payloads, so that the research fields will be spread. Using the Epsilon Launch Vehicle, it will convey instruments of up to 50 kg to the space between Venus and Mars. Ultraviolet Telescope with the larger size will observe the absorption lines from the extra-solar planets such as "hot Jupiter" and "super earth", and Infrared Telescope settled on the orbit of outside the ecliptic plane will observe the cosmic background radiation.

DESTINY launched by the improved launch vehicle with the power of M-V rocket will carry payloads of up to 200 kg into the orbit of Venus and Mars. In this phase, climate observations of Venus using two orbiter, and dust-transport mechanism observation of Mars with the combination of Martian airplane and stationary satellite will be realised.

Background of DESTINY

Abstract from the roadmap for space sciences and explorations
「宇宙科学・探査ロードマップ（宇宙政策委員会 宇宙科学・探査部会 資料）」から

宇宙科学の目標: …	Themes of space sciences: …

↓ **to realize these in a limited budget.** ↓

低コスト・高頻度な宇宙科学ミッション イプシロンロケットの高度化	- low cost, frequent missions - Advances of Epsilon Rocket

↓ **concrete process** ↓

探査機の小型化・高度化	Smaller and advanced bus

⇒ We proposed DESTINY to realize these flows.

To be examined:

- cost evaluation to customize to each mission

- scientific values

Trade-off of confidential vs. DESTINY bus

An example for going to Mars

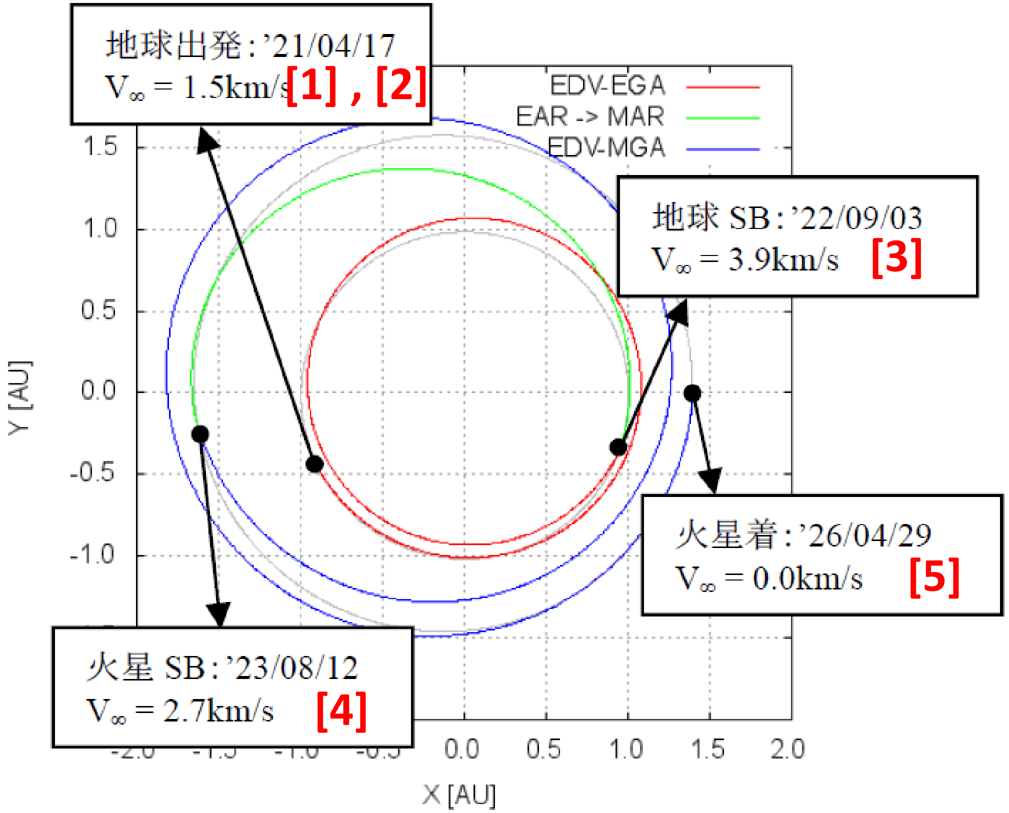
[1] Launch:
- directly injected to arrive Moon
- swing-by at Moon

[2] EDV-EGA(Electric ΔV Earth Gravity Assist):
- accelerated by Ion engine

[3] Transferring for Mars :
- swing-by at Earth

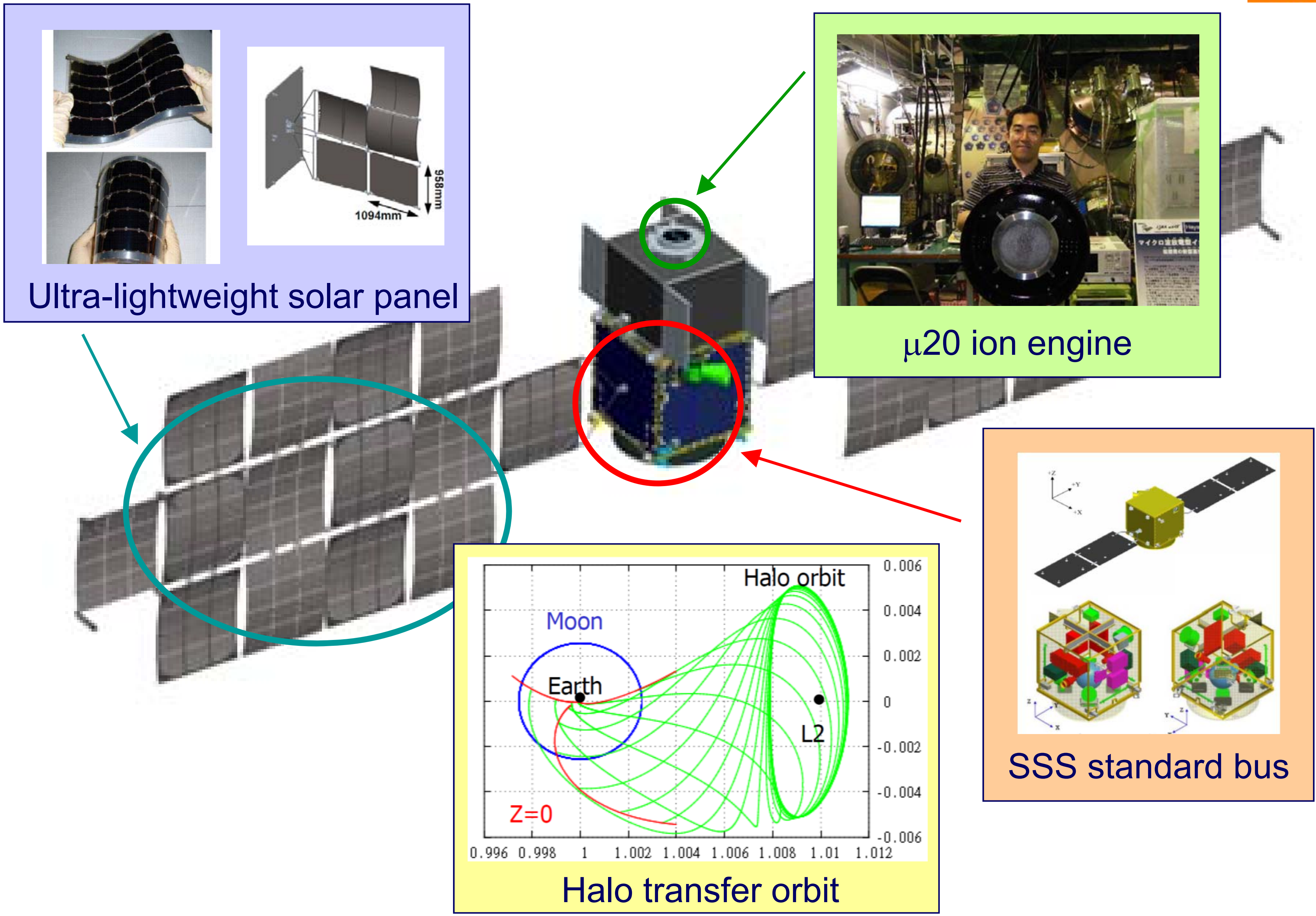
[4] EDV-MGA(Electric ΔV Mars Gravity Assist):
- swing-by at Mars

[5] Mars Injection:
- arriving at Martian Hill sphere
- decelerated by Ion engine to move to lower altitude

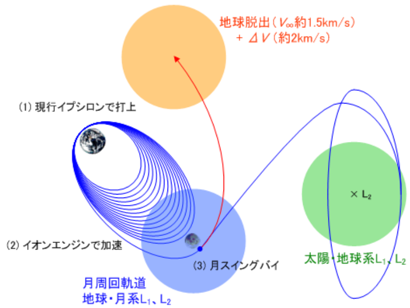


	conventional	DESTINY
M (payload)	△~30 kg	◎~200 kg
Δτ (arrival)	◎shorter	△2~3yr longer
Δτ (developing)	△~5yr	◎~3yr
opportunity	△launch / 4yr	◎launch / 2yr

Key advanced technologies



DESTINY demonstration and applied phase

<table>
<tr><th rowspan="2">Phase</th><th rowspan="2">Demonstration:
I</th><th colspan="2">applied mission</th></tr>
<tr><th>II (Category-A)</th><th>III (Category-B)</th></tr>
<tr><td>rocket
+
orbit</td><td colspan="2">
Epsilon Rocket
with 4th kick stage

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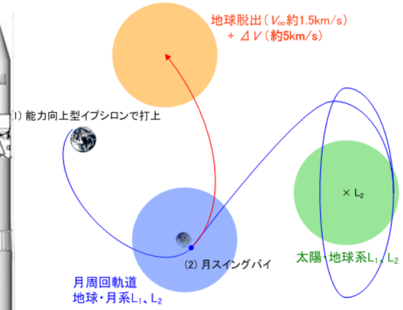

improved Epsilon
Rocket (M−V class)</td></tr>
<tr><td>$M_{payload}$</td><td>**10 kg**</td><td>**50 kg**</td><td>**200 kg**</td></tr>
<tr><td>site</td><td>**Sun-Earth L2 or L1**
(+option)</td><td>Near Earth to
Mars/Venus fly-by
(ΔV_{max} **2 km/s**)</td><td>Near Earth to
Mars/Venus orbit
(ΔV_{max} **5 km/s**)</td></tr>
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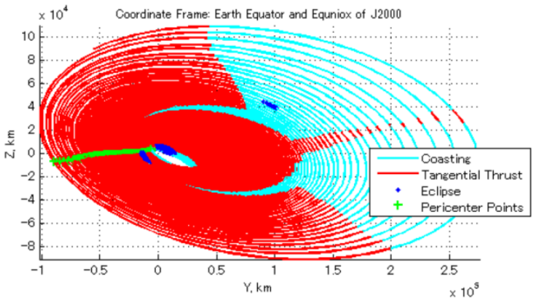
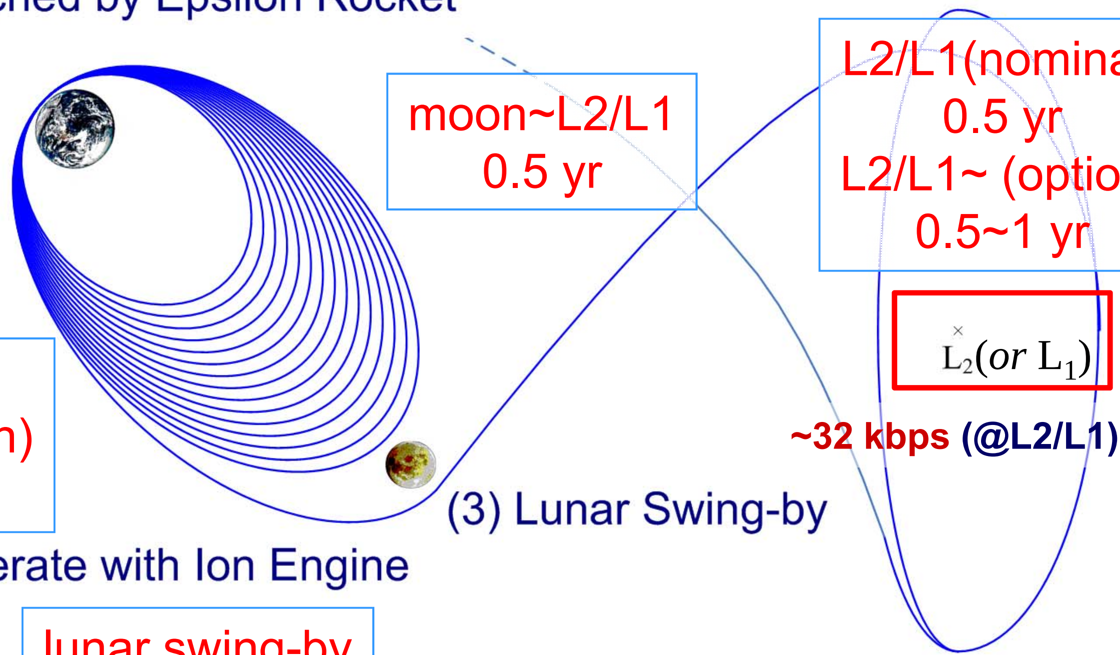
Mission profile of DESTINY Demonstrator

■: ion engine stops
= observation periods

(1) Launched by Epsilon Rocket

(4) Injected into L_2 Halo Orbit





spiral phase
(launch ~ moon)
1.5 yr

~32 kbps (@L2/L1)

(3) Lunar Swing-by

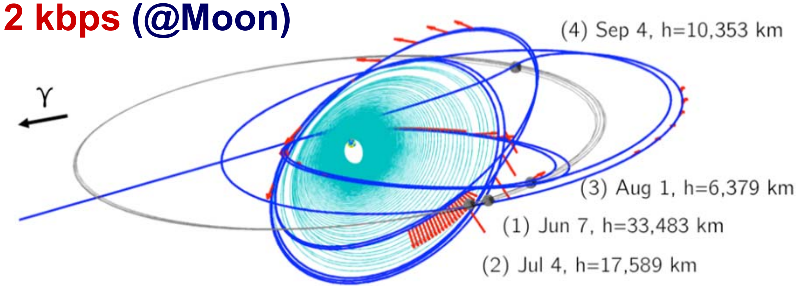
total dose ; 100 krad
(electron; 1mm-Al)

(2) Accelerate with Ion Engine

lunar swing-by
3 month

(5) Escape from L_2 Halo Orbit
option: another L, NEO, *etc*.

~512 kbps (@Moon)



Candidate scientific instruments

instruments	main targets	mass [kg]	Site（† option）
1) X-ray telescope	SWCX: Solar Wind Charge eXchange	10.0	NE-L1
2) Small UV telescope	Lyα line from Geocorona	2.2	NE-L1
3) UV telescope	Lyα from M-type star-planetary system	8.7	L2
4) ENA camera	ENA: Energetic Neutral Atom, ion particles	7.0	NE-L1
5) Dust analyzer	interstellar/interplanetary dust, meteoroid	5.0	Moon-L2, NEO†
6)High vision camera	meteoroid, Near Earth Objects (NEO)	4.0	
7) Thermal IR imager	impact flash on the lunar surface	0.8	Moon
8) Small telescope	orbit determination of NEOs	10 *	L1
9) Polarimetry	scattering of the zodiacal light	10 *	L2 or L1
10) γ / cosmic-ray detector	back ground radiation	10 *	L2

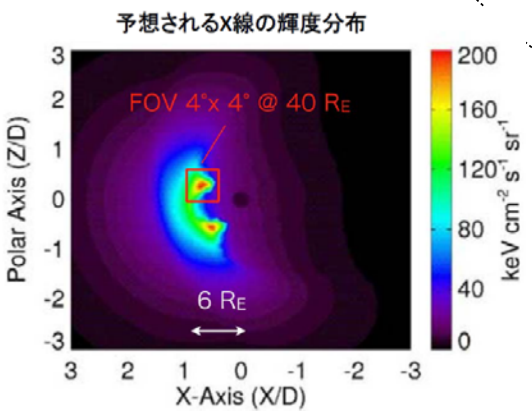
* tentative values

Ph.-I: X-ray Telescope

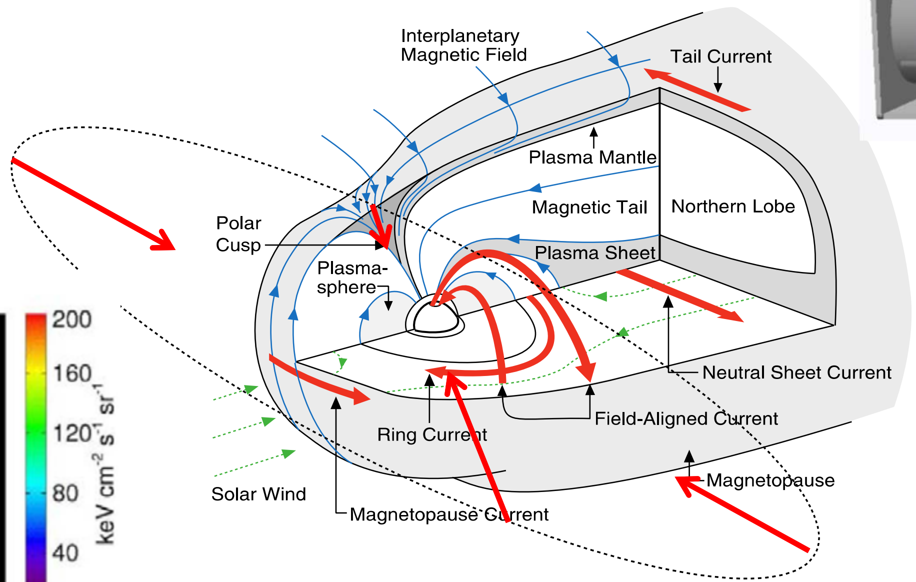
Ezoe + DESTINY

- **Imaging of SWCX (Solar Wind Charge eXchange)**
  - The first **full coverage imaging** of Magnetosheath, Cusp, Magnetopause from the distance of Moon (*cf*. Suzaku on LEO)
  - Validation for the future small and light-weighted X-ray telescope
- Requirements: positioning < 1 arc-min/min, data rate: 30 kbps, 1 GB / 3 day.

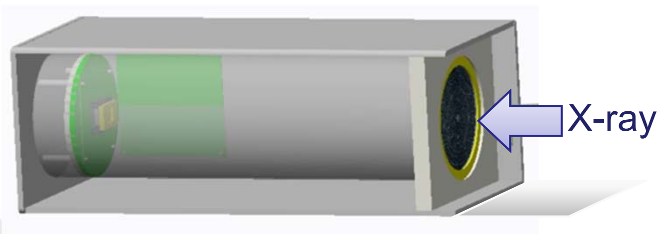
Expected X-ray structure



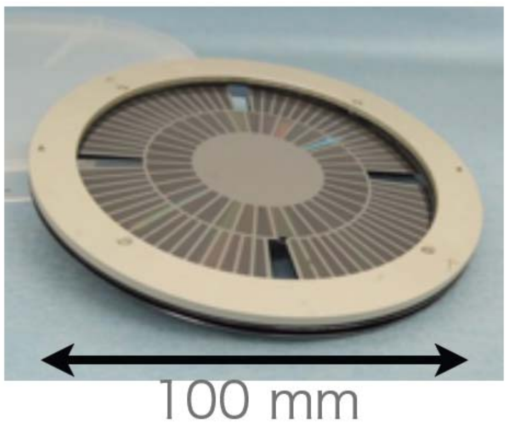
Robertson, *et* al. (2009)



Concept of observation orbit



Over view of the telescope



Prototype of Wolter type I

Ph.-I: Ultraviolet Telescope

Kameda +

- **UV observation for geocorona**
  - **Lyα line** from Geocorona by **4 cmϕ** effective aperture telescope improved from LAICA on PROCYON
  - Simultaneous observations with X-ray telescope.
- **UV observation for extrasolar planets**
  - Lyα line from M-type star with planetary system by **8 cmϕ** EA telescope.
  - ⇒ O_2 detection for "extrasolar earth" survey by several tens-cmϕ to 1 mϕ telescope in the future (2020s).

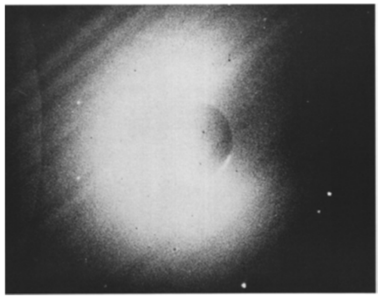
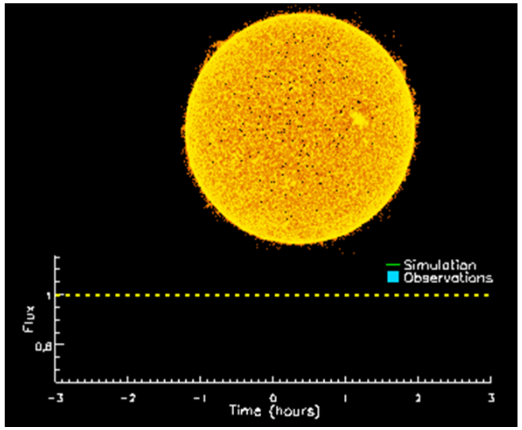
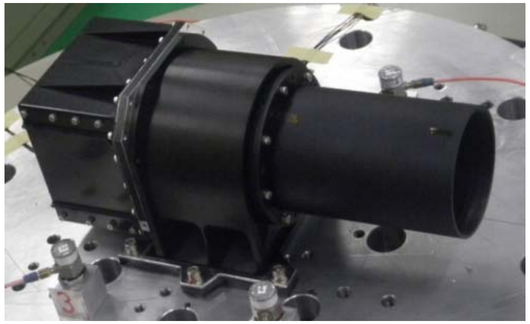


Image of geocorona
（Carruthers+, 1976）



Disturbance by terrestrial hydrogen
（http://www2.iap.fr/exoplanetes/index_en.html）



LAICA on PROCYON

Ph.-I: ENA camera (DENI)

Keika, Brandt +

◆ **ENA: Energetic Neutral Atom, and ion particles**

- "side-view" of the dynamical magnetosphere in <u>one</u> instrument

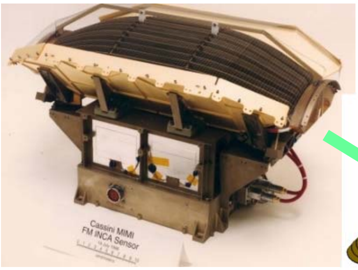
  * Plasma heating and transport from magnetotail to inner magnetosphere

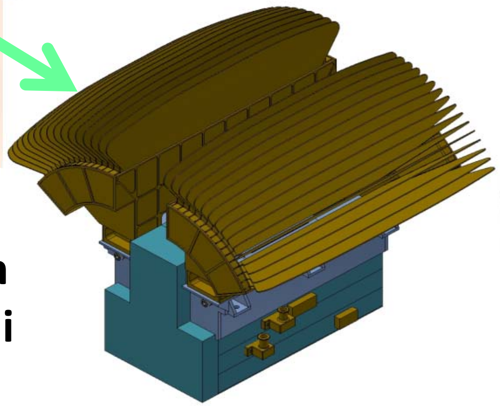
  * Ion outflow from polar ionospheres

  * Changes in magnetopause location

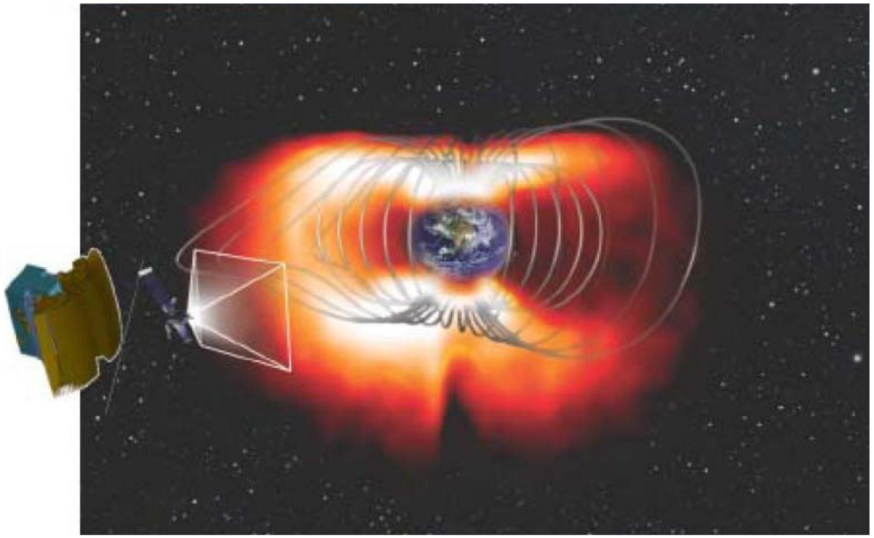
  -> the first composite movies of how Earth's global magnetosphere changes in the solar wind

➢ Requirements: data rate: 500 kbps max, ~5 GB/day max > own recorder





improved from INCA on Cassini



field of view

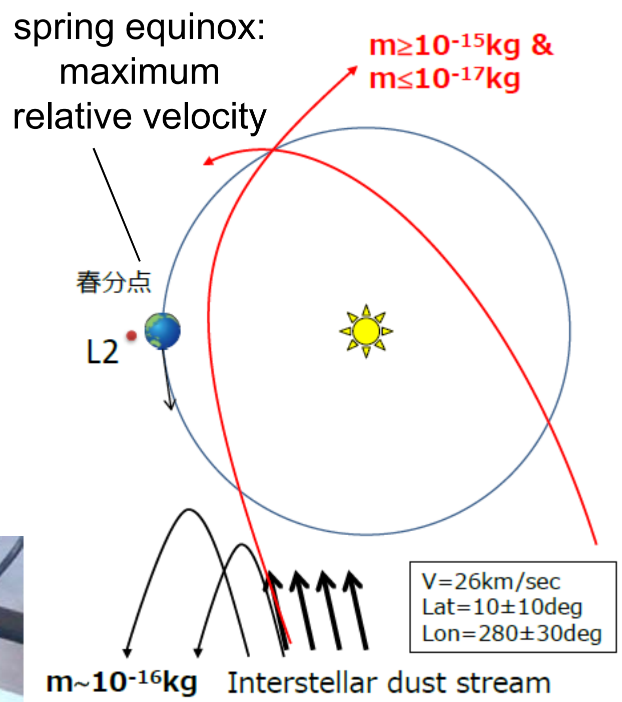
Ph.-I: Dust Analyzer & High Vision Camera

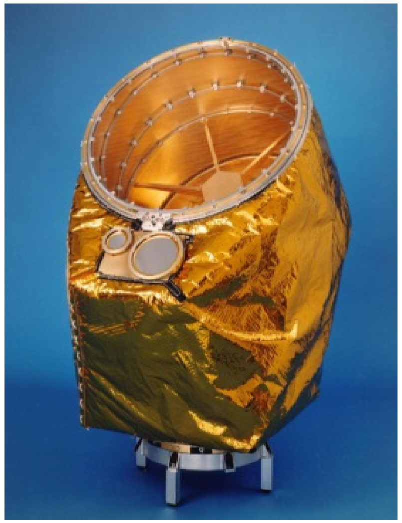
Arai + DESTINY

◆ Observation for interstellar dust
- physical parameters (size, density, ...), chemical features (metallic & organic composition, ...)
- observation from L2

● elucidating for the original material of solar system and life.

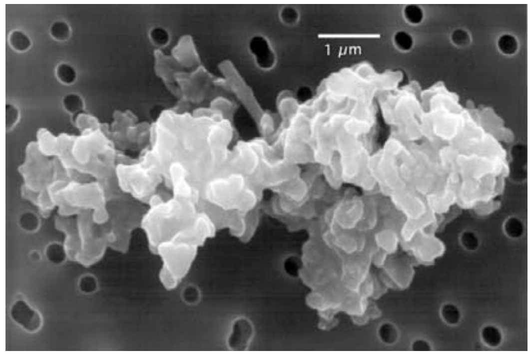
➢ adjustment of the launch window to observe around spring equinox





CDA on Cassini-Huygens

COMETSS on ISS
developed by Chiba Inst. Tech.



Model missions of DESTINY applied phase

Phase	applied mission	
	II	III
rocket	Epsilon Rocket with 4th kick stage	improved Epsilon Rocket (M-V class)
$M_{payload}$	50 kg	200 kg
site	Near Earth to Mars/Venus fly-by	Near Earth to Mars/Venus orbit
model mission (PIs)	* Integrated Imaging of Geo-plasma (Ezoe, Keika, Kameda) * Asteroid Phaethon Fly-by (Arai) * UV observation for extrasolar planets (Kameda) * Cosmic background radiation observation from the outer space of ecliptic plane (Matsuura) * collisional experiments on asteroids (Arakawa)	* Venusian climate observation by two orbiters (Imamura) * Martian dust observation by orbiter & airplane (Ogohara, Oyama) * Sample return from multiple asteroids (Saiki) * Sample return of cosmic and inter-planetary dust (Tachibana)

Ph.–II: Terrestrial and NEO observations

DESTINY

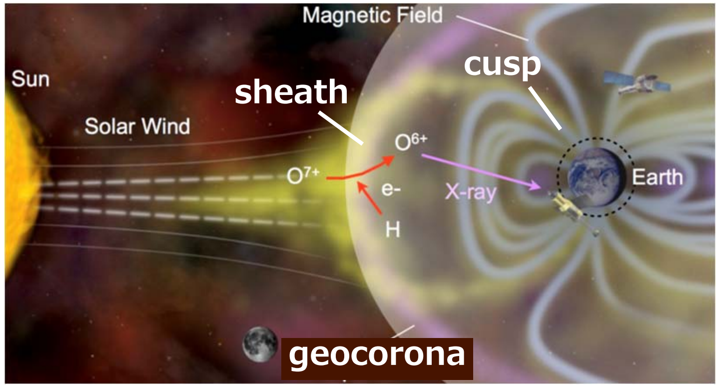
Integrated Imaging of geoplasma

(Ezoe, Kameda, Keika +)

(1) Full coverage imaging of geo-plasma

(2) X-ray telescope, UV-telescope, ENA Camera

(3) candidate orbits: Near Earth (~8 RE), moon (~60 RE), Earth-Moon L1, etc.



structure of magnetospheric plasma

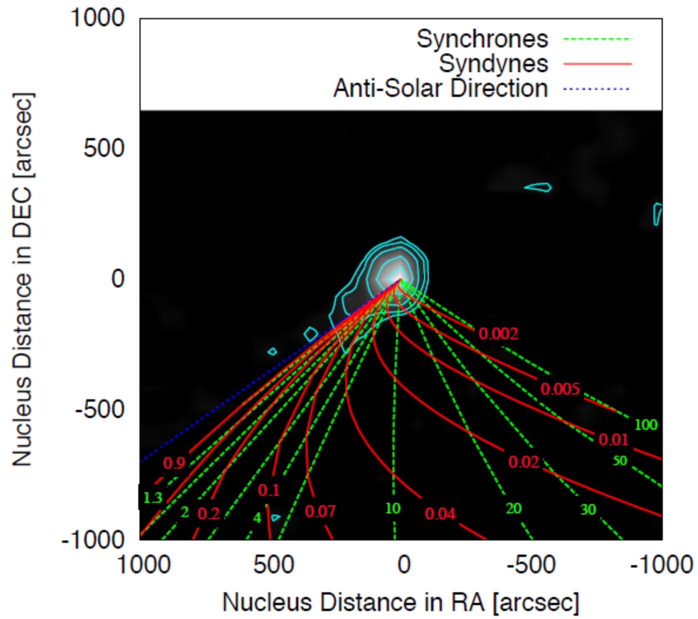
Asteroid "Phaethon" fly-by (Arai +)

(1) Fly-by for the comet-asteroid transition object with a large inclination

(2) Dust analyzer, High vision camera, Near infrared spectrometer, Multi-band camera, Thermal infrared imager

(3) Observing at the cross point Earth and Phaethon orbits

(4) option: multi-fly-by for the segment asteroid 2005UD and 1999YC



Asteroid Phaethon with cometary tail

Ph.–II: Deep Space Telescopes

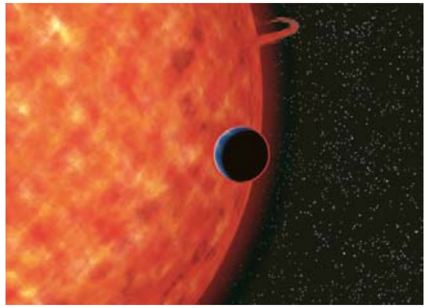
UV observation for extrasolar planets (Kameda +)

(1) extrasolar planets from the outer space of geocorona

(2) 30 cmϕ ultraviolet Cassegrain telescope

(3) Transit method observation of Lyα lines from extrasolar planets

(4) orbit: >30 R_E or Sun-Earth L2



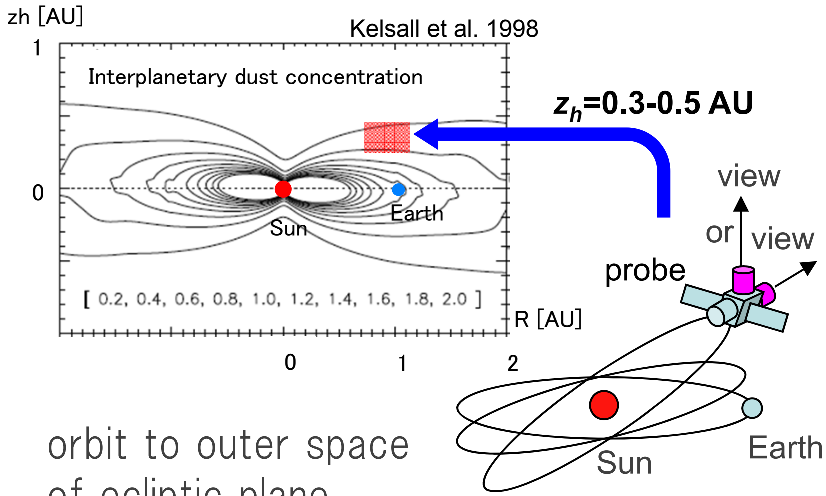
Imagination of GJ3470b (© NAOJ)

Cosmic background radiation observation from the outer space of ecliptic plane (Matsuura +)

(1) The first deep space observatory to elucidate the cosmic evolution and inter planetary dust

(2) 10 cmϕ near infrared offset Gregorian telescope, 0.6-1.7 μm

(3) orbit: z_h =0.3-0.5 AU



orbit to outer space of ecliptic plane

Ph.-III: Venusian climate observation by two orbiters

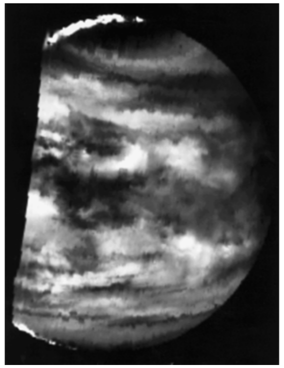
(Imamura +)

(1) 3-dimensional precise observation for atmospheric composition of Venus using two Venusian orbiters

(2) Mother Orbiter: 25,000-400 km, i = 40˚
Daughter Orbiter (50 kg): 175,000-400 km, i = 40˚

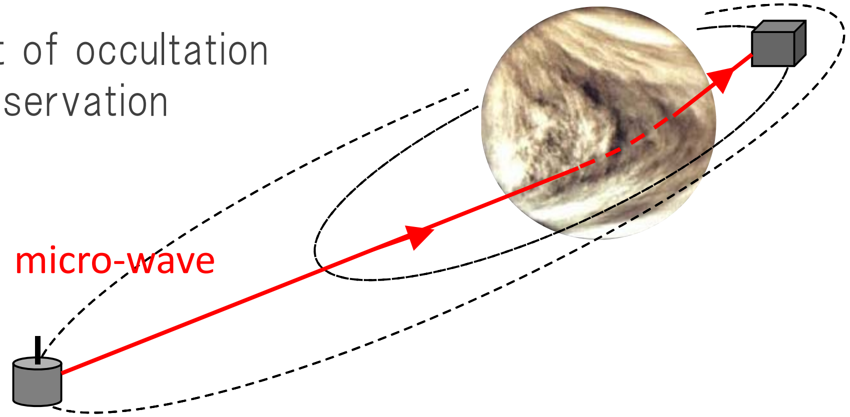
(3) Occultation observation of microwave transmitted from the USO on Daughter Orbiter, 4-way Doppler measurements relayed between ground station and two orbiters

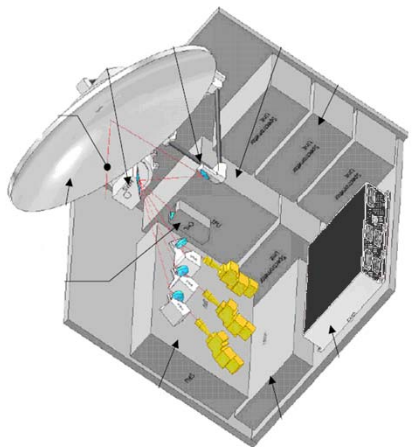
(4) sub-mm sounder, UV-VL, NIR, MIR cameras



NIR image of Venusian night side

Concept of occultation observation





sub−mm sounder

Ph.-III: Martian dust observation by orbiter & airplane

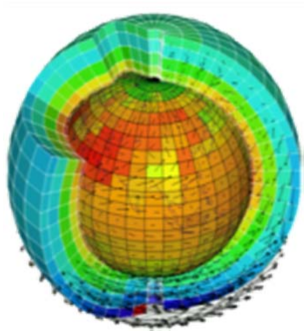
(Ogohara +)

(1) Combination of steady observation from an orbiter and in-situ observation from an aerial probe to elucidate the transport mechanism of Martian dust

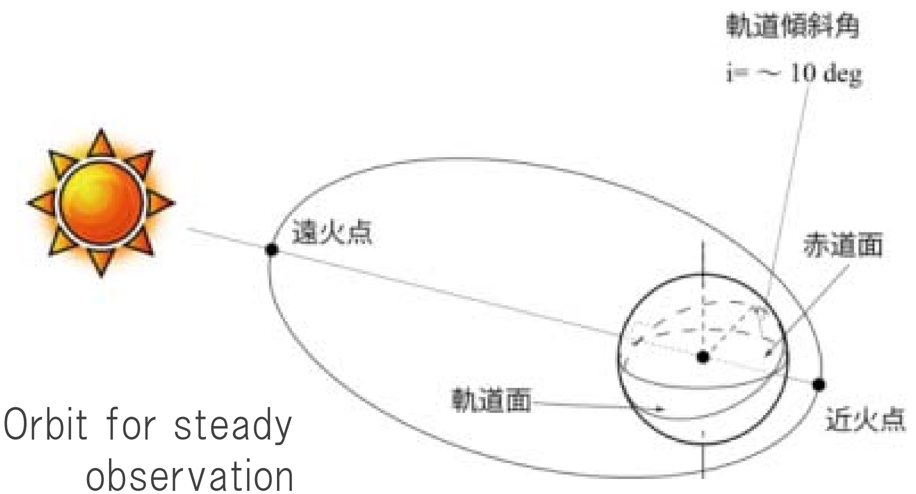
(2) Orbiter: areo-stationary orbit or 6.45Rm-450 km, i = 10˚
Airplane: range 100km, duration 30 min., separated from an entry capsule (100 kg) to observe dust storm

(3) VL polarization camera (SIMPLER), telecamera (NAC), sub-mm sounder (FIRE), MIR camera (LIR), USO on Orbiter

(4) Thermometer, barometer, particle counter, pyrheliometer on Airplane



3D-image of Martian atmosphere



Orbit for steady observation

Martian aerial probe
* 2.5m x 2.0m x 0.5m
* 5 kg

Summary

Phase	Demonstration: I	applied mission	
		II	III
$M_{payload}$	**10 kg**	50 kg	200 kg
site	**Sun-Earth L2 or L1** (+option)	Near Earth to Mars/Venus fly-by	Near Earth to Mars/Venus orbit
mission concept	limited instruments under constraints	Explorations and observations from near Earth to asteroids	Explorations and observations from near Earth to Venusian / Martian orbits

Main interface for instruments on Demonstrator (Ph. I)

- mass ; 10 kg
- electric pwr. ; (not strict during the stop of ion engine)
- orbit ; near Earth (spiral) – moon (fly-by) – transfer – L2 or L1 (Halo) + option (*ex.* NEO, another L)
- pointing ; 1 arc-min
- data rate ; ~32 kbps（@ L2 / L1）, ~512 kbps（@moon）、2 Gbyte