Science Instruments on Hayabusa follow-on missions

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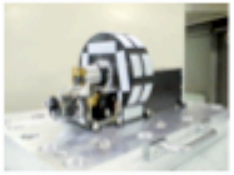
(prepared by Masanao Abe (JAXA))

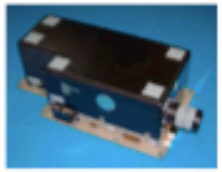
Science instruments under examination

Optical Camera
(6x6 degs, 1000x1000 px, filter)



AMICA

Near Infrared Spectrometer
(0.85 - 2.1 μm → ~3.4μm)

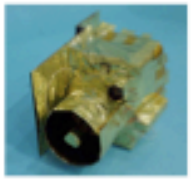


NIRS

X-ray fluorescence Spectrometer
(0.7 - 10 KeV, Δλ=100eV)

XRS

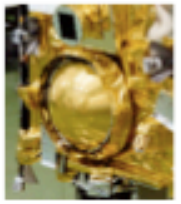
Laser Altimeter
(50m - 50km)



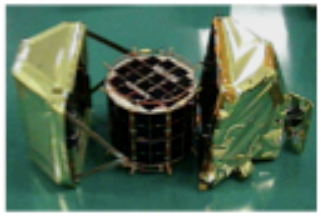
LIDAR

Sampler

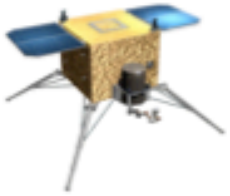
Capsule



Small Rover



Small Lander



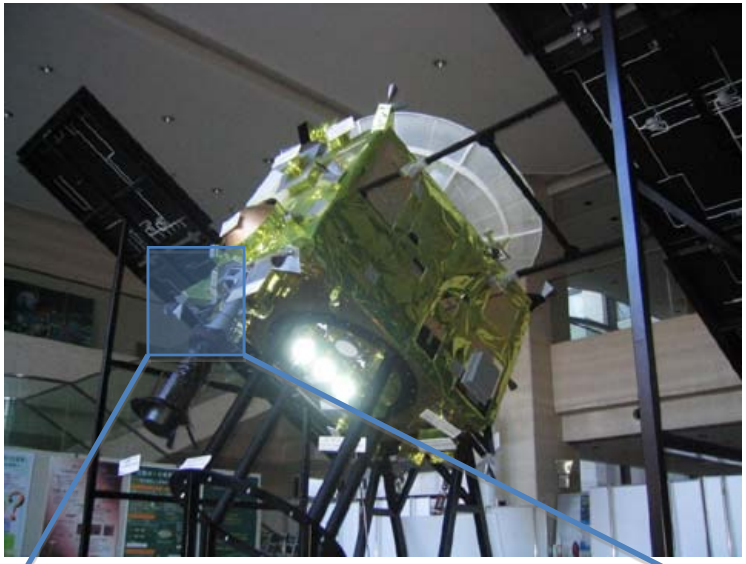
Others

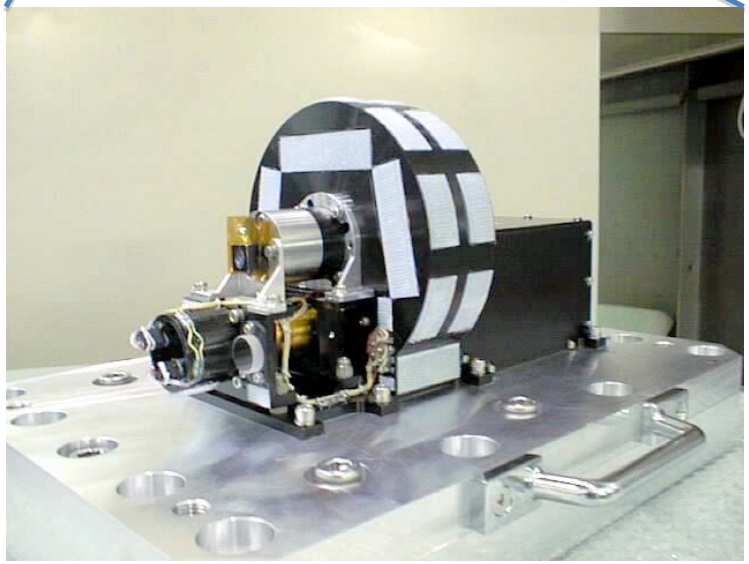
Basic concept of Hayabusa-IF* camera

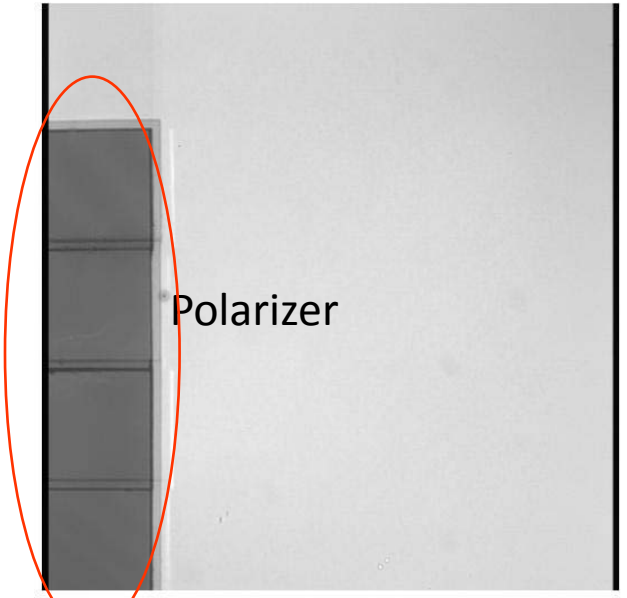
- Use Navigation camera as a scientific imager
- Similar optics and CCD as AMICA, but with minor modifications on
  - Filters
    - ECAS -> special set for C-type
    - Remove ND flter , polarizer on CCD
  - Electronics
    - More flexible and autonomous operation
    - More effective compression
    - Larger onboard storage
    - Onboard data analysis

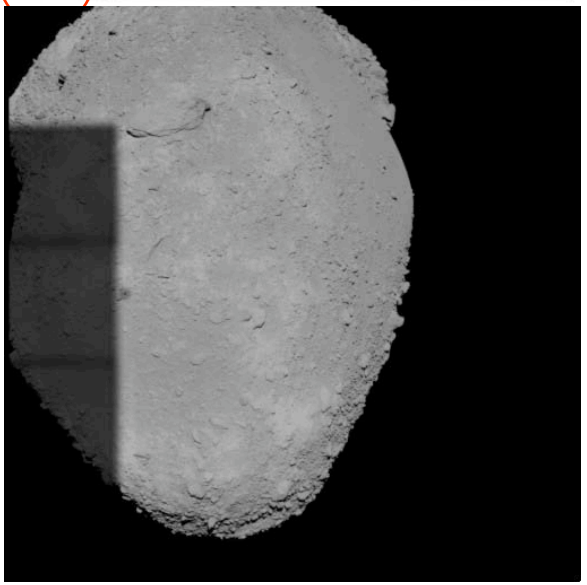
*Hayabusa-IF: Hayabusa Immediate Follow-on mission

AMICA on Hayabysa

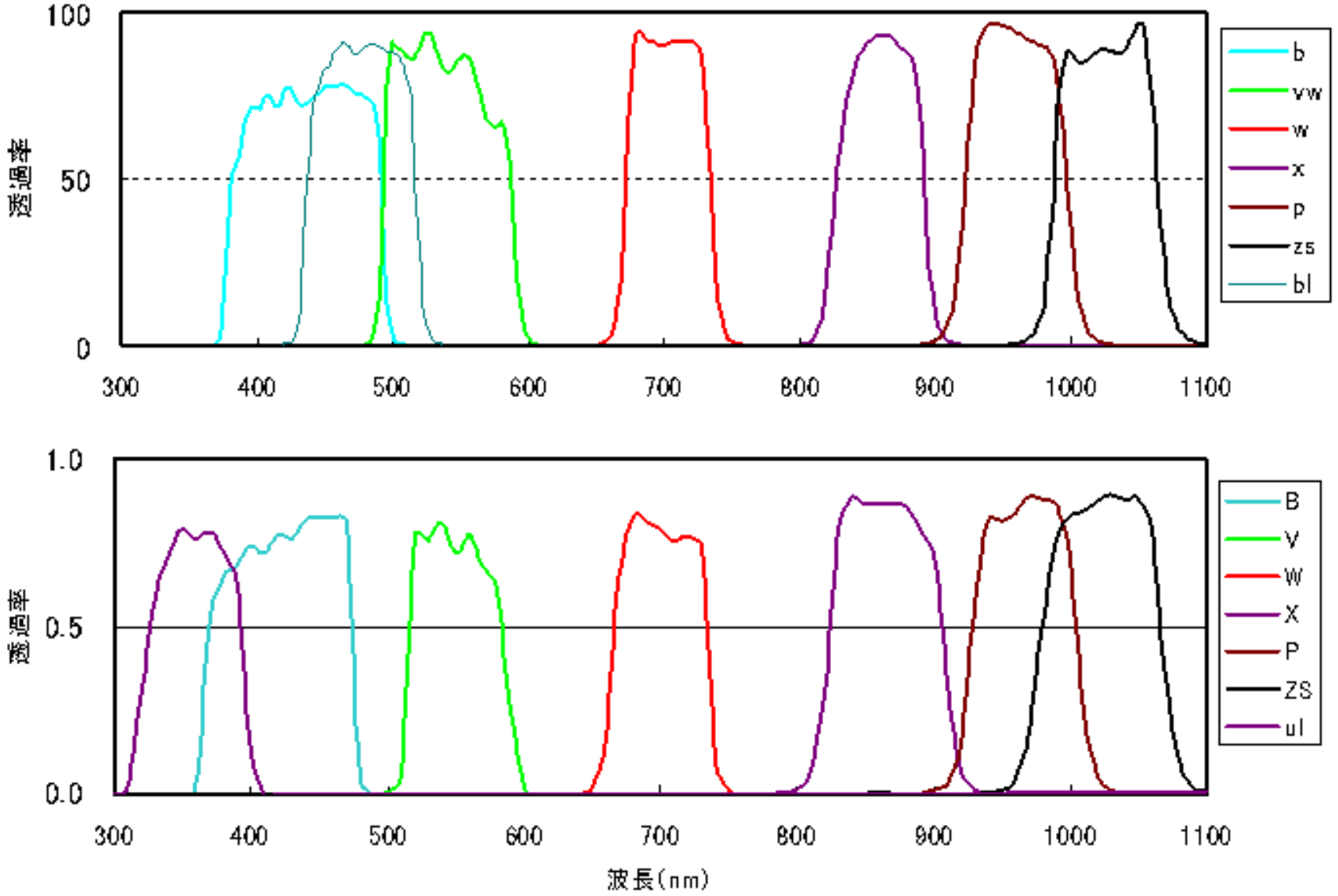








Ground-based ECAS

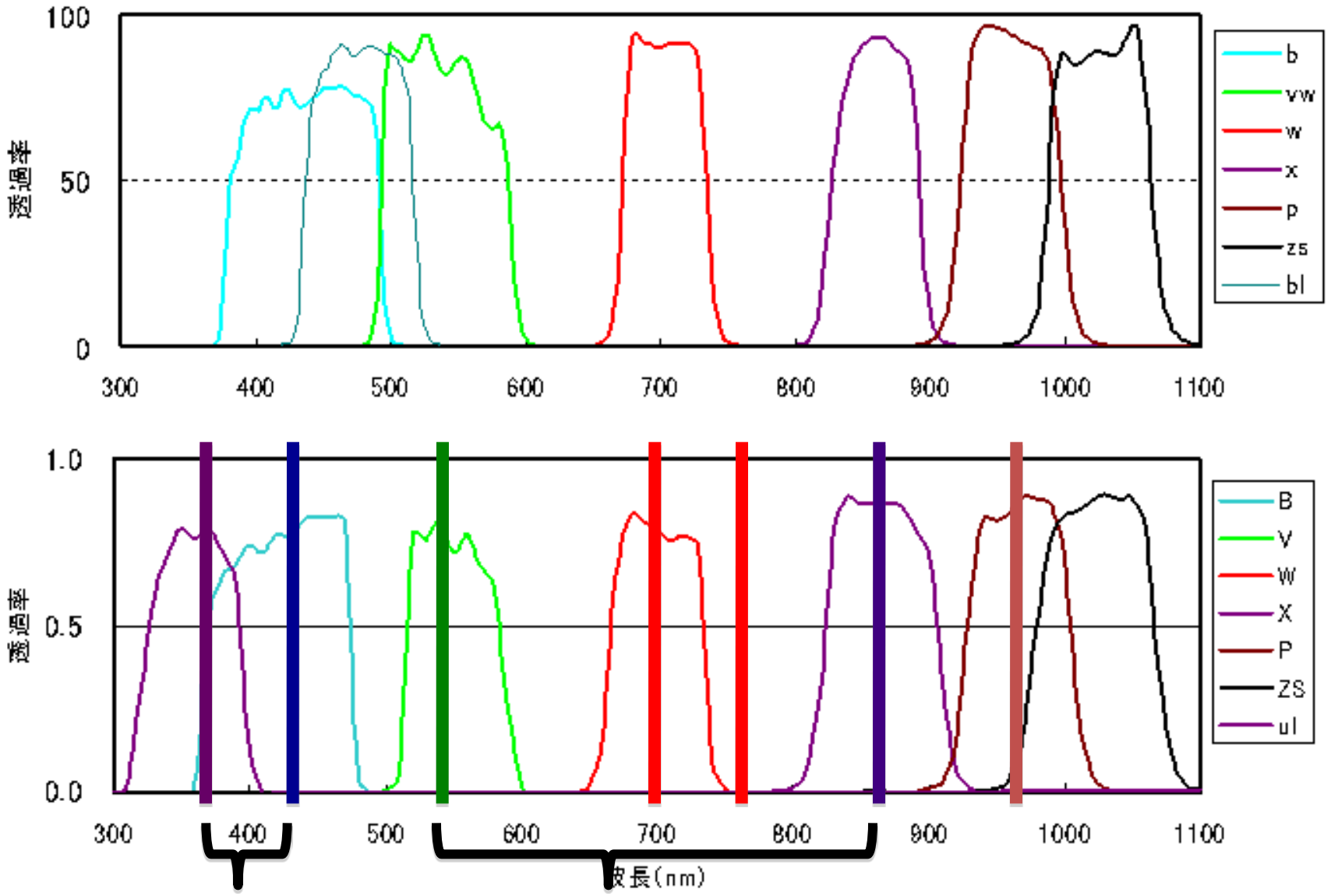


Quasi ECAS filters on AMICA

A new filter set

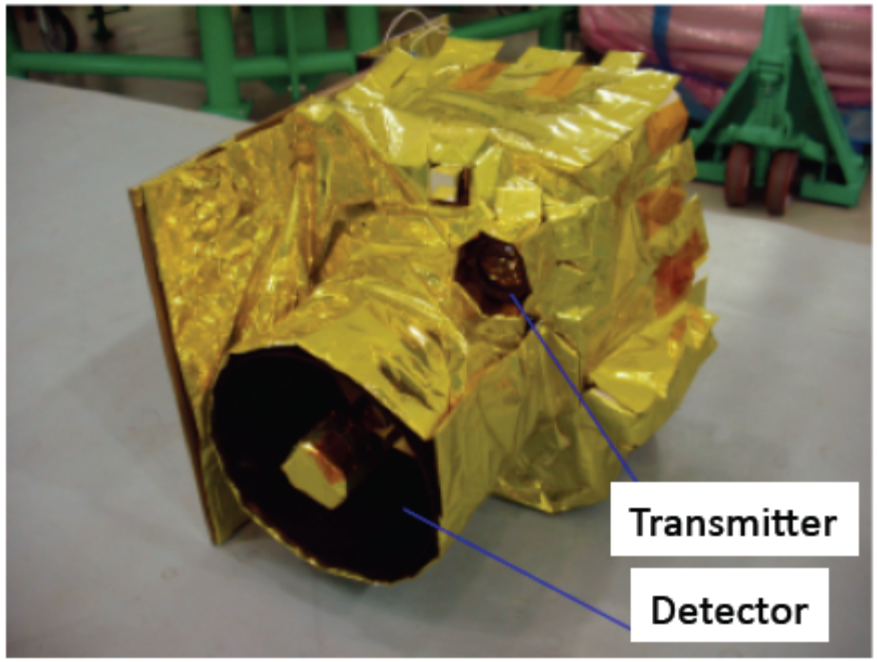
- Narrower band width (5~20 nm)
  - Remove ND filter
  - More accurate colorimetry
- ***UV absorption as a thermal metamorphism indicator?***
- ***Phyllosilicate absorption around 700nm*** (430nm ?)
- Nearby reference bands
- Wide filter for imaging stars and the artificial orbiters (~TM)
- Natural RGB for outreach purpose?
- Several common bands with previous missions? (SSI/Galileo, MSI/NEAR, AMICA/Hayabusa, FC/ Dawn, NAC/Stardust, ??/Rosetta,etc,)

Ground-based ECAS



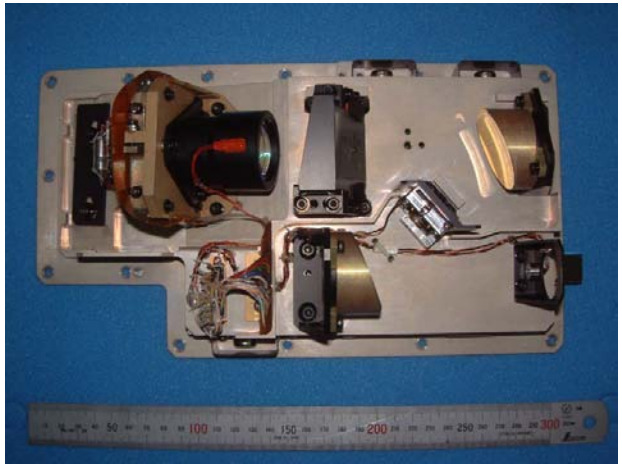
Spec. of LIDAR for Hayabusa

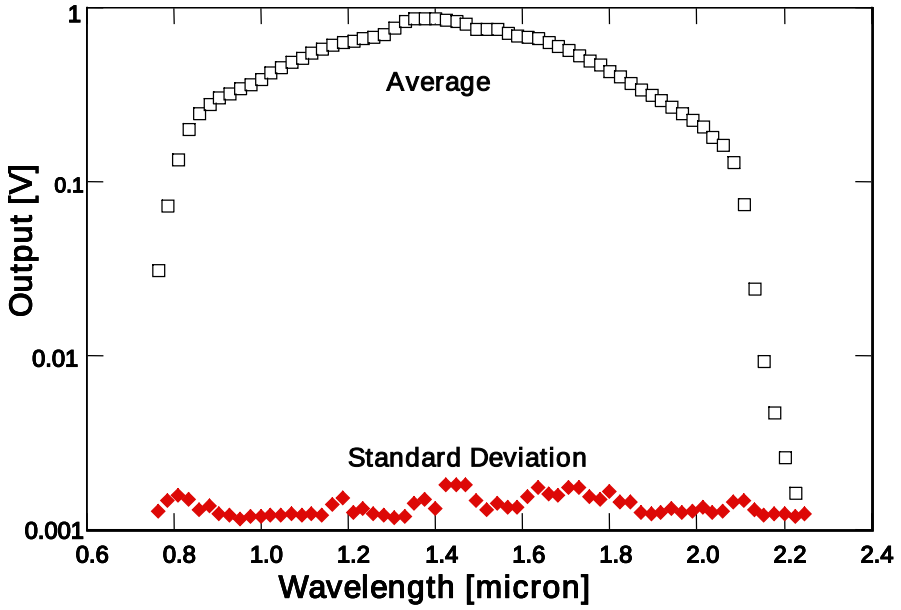
- Range: 50±1 m ~ 50±0.01 km
- Frequency: 1 Hz
- Beam width: 1.7 mrad/ 0.097°
- Weight: 3.7 kg
- Power: 17 W (+ heater)
- Size: 240 x 228 x 250 mm (+ radiator)



Hayabusa NIRS

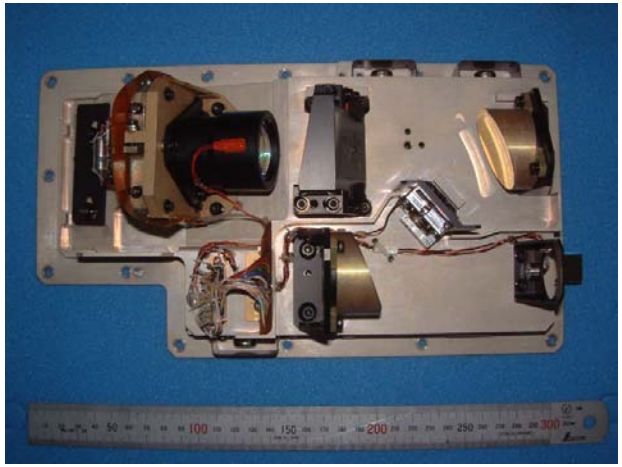
- Wavelength range: 764-2247nm (△λ23.56nm)
- FOV: 0.1x0.1deg(9m@5km distance)
- Detector: InGaAs Liner Array (64channels)
- F value: 1.00
- Effective diameter: 27mm
- Operating temperature: 260K
- A/D resolution (dynamic range) : 14bits

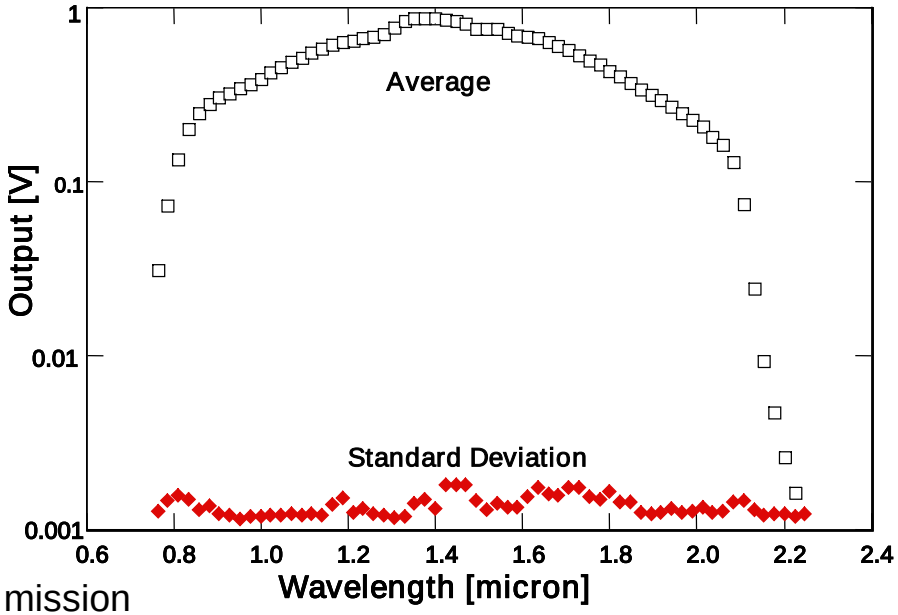




Hayabusa-IF* NIRS

- Wavelength range: 700-2100nm (△λTBD nm)
- FOV: 0.1x0.1deg(9m@5km distance)
- Detector: InGaAs Liner Array (128 channels)
- F-value: 1.00
- Effective diameter: 27mm
- Operating temperature: 260K
- A/D resolution (dynamic range) : 14bits



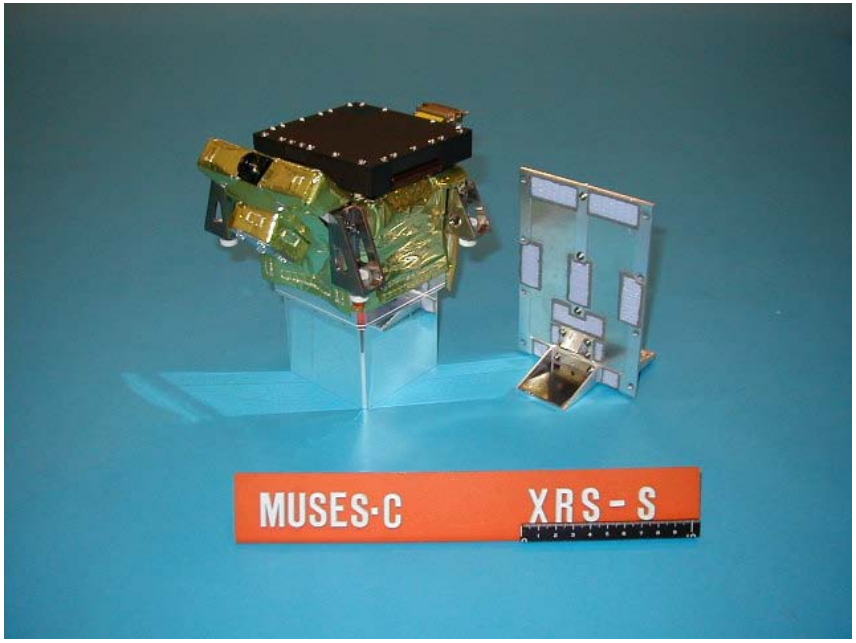


*Hayabusa-IF: Hayabusa Immediate Follow-on mission

Remote XRF Spectrometer

Outline:

- Solar X-ray induced XRF spectrometry
- Determine surface major elemental composition to classify into meteorite types (Mg, Al, Si, S, K, Ca, Ti, Fe, …)
- Possible detection of lighter elements (C, O)
- Evaluate surface processes



Instrumentation:

- Components:
  - Asteroid X-ray detector
  - Solar X-ray monitor (direct, standard sample)
  - Electronics
- Detector: 2D-CCD (TBD)
- Energy Range: 0.2 – 10 KeV
- Energy Resolution: < 200 eV (@5.9KeV)
- Mass: 3 kg
- Power: 15 W
- Operation Temp: -40 ~ +30
- Cooling: Thermoelectric cooler + radiator

Dust Environment Monitor: Description

<Objectives>

(1) Science: Geological Context and Interior

To understand surrounding environment and recent geological activities (if any) of a primitive asteroid or a dormant comet nuclei as definitions of these two categories of small bodies get unclear in recent years

(2) Operational: Mission Safety

To evaluate mission safety for proximity operation around an unexplored, primitive object prior to sampling sequences and to assist sampling site selection

➔ Measurement of positional, elevational, and temporal variations of dust flux in the vicinity of the target body

Dust Environment Monitor: Specifications

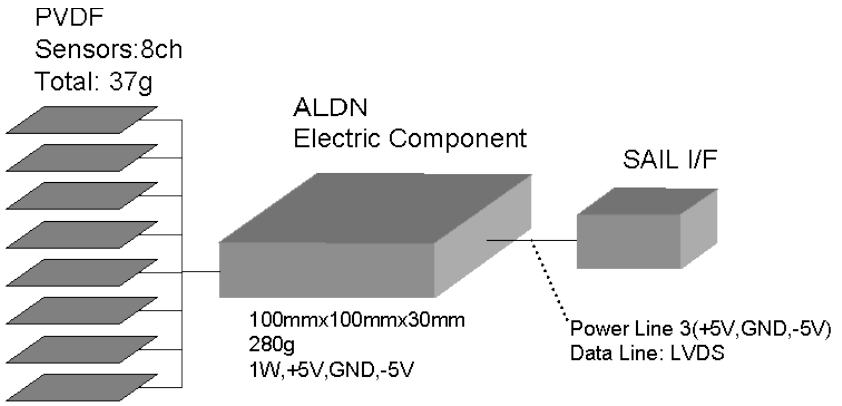
<Engineering Considerations>

- Impact sensors sensitive to low velocity regimes (<100 m/s) are needed; impact-induced plasma detectors are not suitable for this rendezvous mission
- Opportunistic interplanetary flux measurements are also possible for hypervelocity impact sensors (> a few km/s)

<Candidate Sensors>

*** PVDF or/and PZT (Example: ALADDIN FM for IKAROS Mission)**

> Size & Thickness : 100 x 200 mm for 9 micron thickness
> 250 x1000 mm for 20 micron thickness
> Total Detection Area: ~1.2 m^2
> Channels: 8 Ch
> Mass: sensors: ~37 g, electronics: 280 g
> Power: 1W(5V single supply)
> Thermal tolerance: 2 solar
> Detection size limit:>1 micron at >5 km/s
(cf.) 5 mm glass beads at free fall



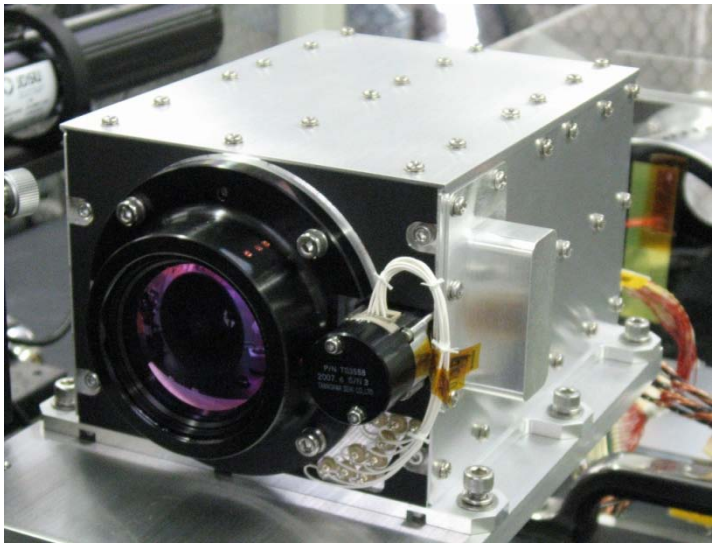
<Optional (Wild) Idea>

- Extra sample collection of freshly ejected dust without touching the surface can be the minimum "safety net" of SR in case of unexpected consequences (e.g., GIADA)

Infrared Camera (1)

- It mounts an uncooled micro-bolometer array (UMBA) for commercial infrared camera.
- It detects thermal emission in a wavelength region 8-12 μm to map the temperature distribution.
- It is relatively small and light in weight.
- It is under development for the Japanese Venus orbiter mission, PLANET-C.

Wavelength region	8 - 12 μm
Field of view	12^o x 12^o
Spatial resolution	0.05^o
Target temperature	220 - 250 K
Pixel size	320 x 240
NETD	0.3 K (at 230 K)
Absolute accuracy	3 K
F-number	1.4
Size	200 x 130 x 110 mm
Weight	3.5 kg
Power consumption	29 W

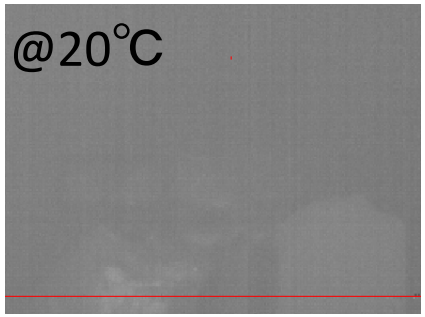


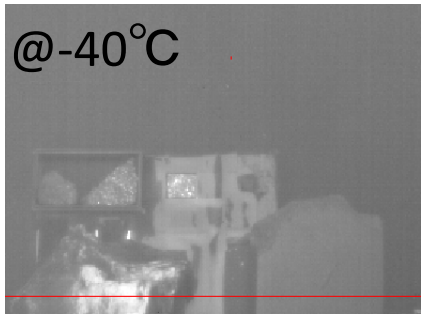
LIR prototype for PLANET-C

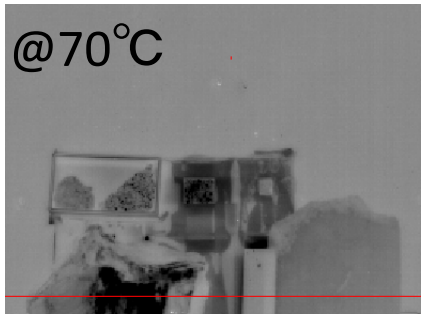
Infrared Camera (2)

Sample Images acquired by LIR

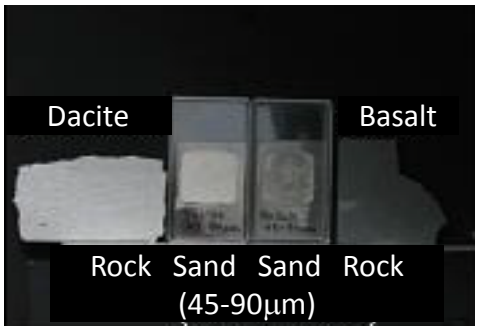
Different kind of rocks and meteorites

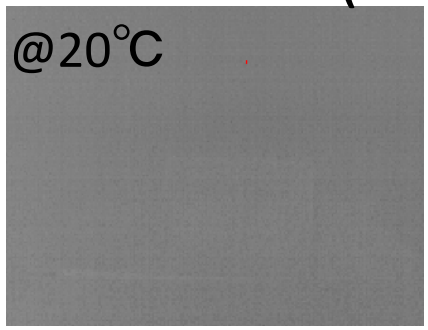


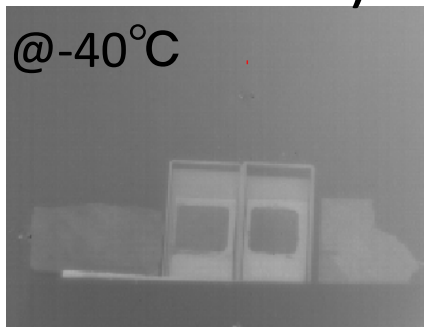


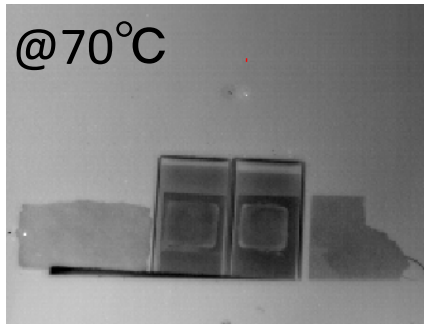


Different state of minerals (rock and sand)



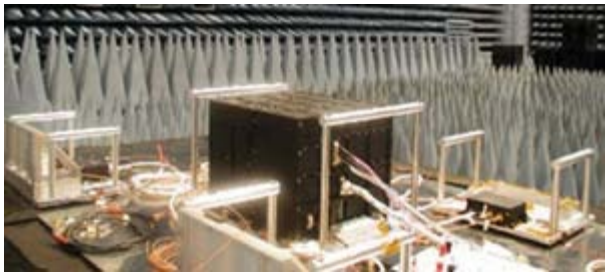






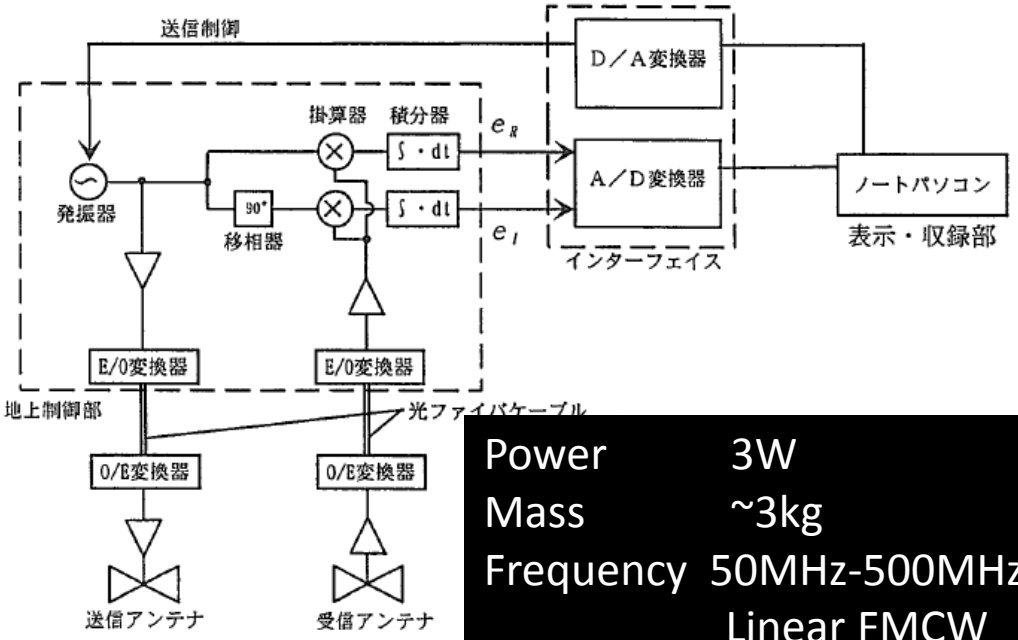
We expect that the distribution of emissivity and thermal inertia on the surface of an asteroid is estimated from LIR observation. It will contribute to identifying a mineral, the size of sand, and porosity of the surface.

SELENE's Lunar Radar Sounder



Specifications	
Mass	23.182kg
Power	56.7W
Sounder obs.	
SDR frequency	5MHz (main freq.)
Radiation Power	800W
Pulse width	200 micro sec
Modulation	10kHz/micro sec
Sounding depth	5km
Natural plasma wave obs.	
Frequency	10Hz - 30MHz
Telemetry speed	
High speed	492kbps
Low speed	176kbps

Moderately modified version of this instrument is now under discussion for future Japanese missions, such as a Europa mission, a Mars lander/rover, and a Lunar lander/rover



Power	3W
Mass	~3kg
Frequency	50MHz-500MHz Linear FMCW
Resoution	10cm
Penetration	10m

Mothership Science Instruments

• Vis Camera	R. Nakamura
• LIDAR	N. Hirata
• Vis - NIR Spectrometer	M. Abe
• Remote XRF Spectrometer	T. Okada
• Dust Environment Monitor	H. Yano
• Infrared Camera	Fukuhara
• Radar	H. Miyamoto
• Gravity Measurements	T. Iwata

Science Payload Ideas onboard the Mothership

Instruments	Themes	Development Priority	Heritage (Japan)	Heritage (Europe)	TRL
Nav Camera-1 ONC-T	Geology	Nominal	Hayabusa	Rosetta	8-9
Nav Camera-2 ONC-W1	Morphology	Nominal	Hayabusa	Rosetta	8-9
Nav Camera-3 ONC-W2	Morphology	Nominal	Hayabusa	Rosetta	8-9
LIDAR	Geology, Interior	Primary	Hayabusa	Bepi-Colombo	4-9
Multi-band Imager (VIS)	Geology	Primary	Kaguya, Hayabusa	Bepi-Colombo	4-9
Multi-band Imager (IR)	Geology	Nominal	Kaguya	-	9
High Resolution Camera	Geology	Primary	Kaguya	Rosetta	8-9
Monitor Cameras	Environment	Nominal	Kaguya	-	9
Thermal IR Camera	Geology	Nominal	Planet-C	Bepi-Colombo	4-6
UV Camera	Environment	Optional	Planet-C	Rosetta, Bepi-Colombo	4-8
VIS Spectrometer	Minerals	Nominal	Kaguya	Rosetta, Mars Express	8-9
NIR Spectrometer	Minerals	Primary	Kaguya, Hayabusa	Rosetta, Mars Express	8-9
MIR(3μm) Spectrometer	Minerals	Primary	R&D	Rosetta, Mars Express	4-8
X-ray Spectrometer	Elements	Nominal	Kaguya, Hayabusa	SMART-1, Bepi-Colombo	4-9
Gamma-ray Spectrometer	Elements	Optional	Kaguya	Bepi-Colombo	4-9
Secondary Ion Mass Spectrometer	Elements	Optional	R&D	Philae	4-8
Slow Dust Impact Monitor	Environment	Nominal	IKAROS, BepiColombo	Giotto, Galileo, Ulysses, Cassini, Rosetta	4-9
Solar Flare Monitor	Environment	Nominal	R&D	-	4
Ground Penetration Radar	Interior	Optional	Kaguya, R&D	Rosetta, Mars Express, MRO	4-9

End