Circum-Martian Dust Monitor with a large detection area

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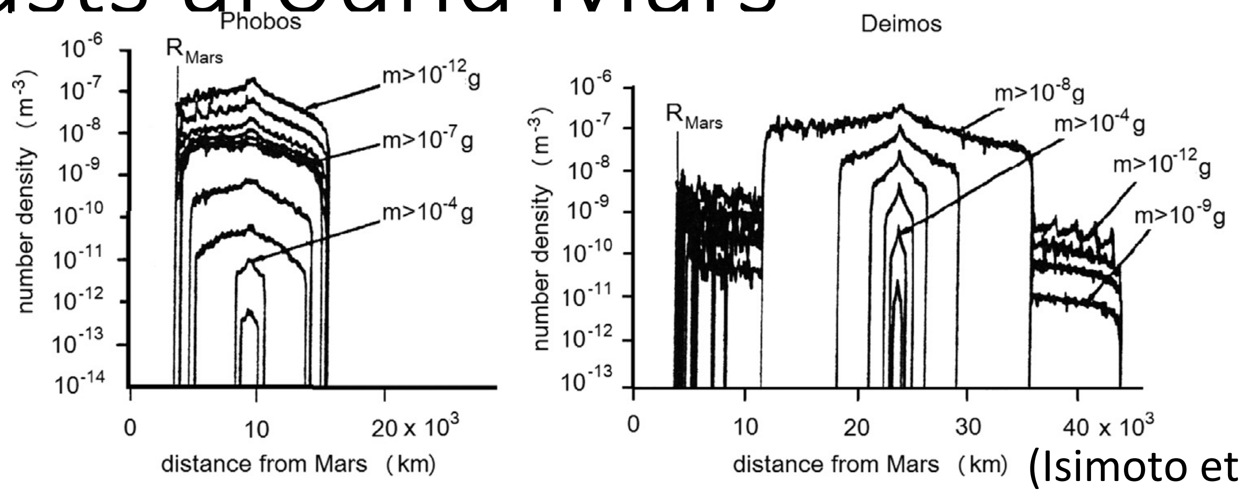
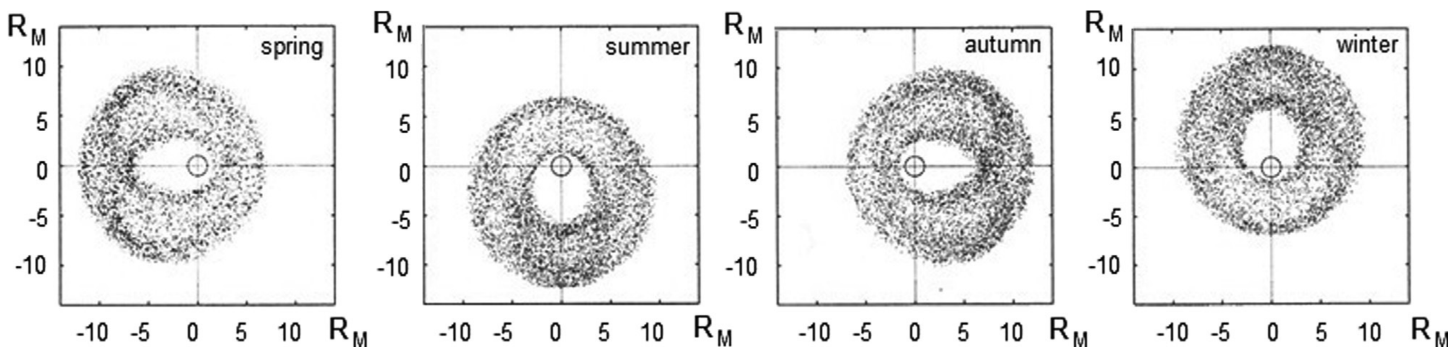
In this presentation

- Introduction new type of dust sensor, which has a large detection area, $1m^2$, for large size dust particle, > 10μm.
- Advertisement of Japanese Mission to Martian satellites, planning to bring a dust sensor to discover dusts of Martian dust rings.

Previous theoretical studies on dusts around Mars



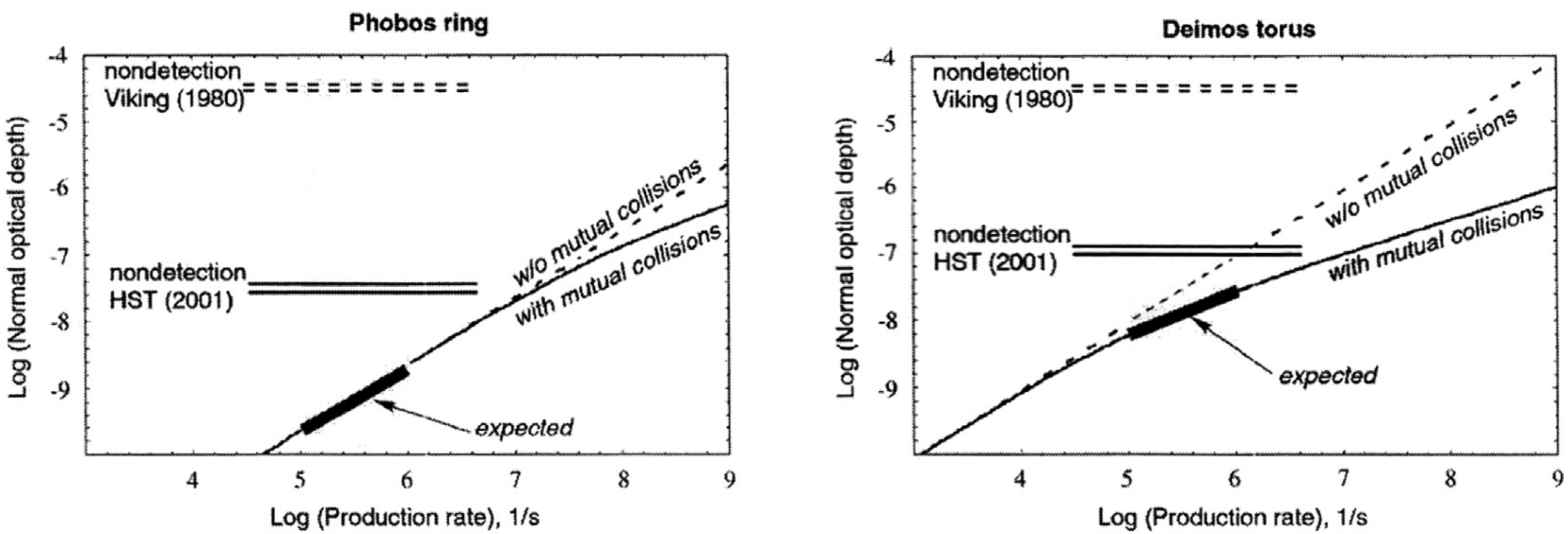
(Isimoto et al.,1997)



Krivov and Hamilton (1997)

A Large detection area is necessary.

Previous observational studies on dusts around Mars: Optical

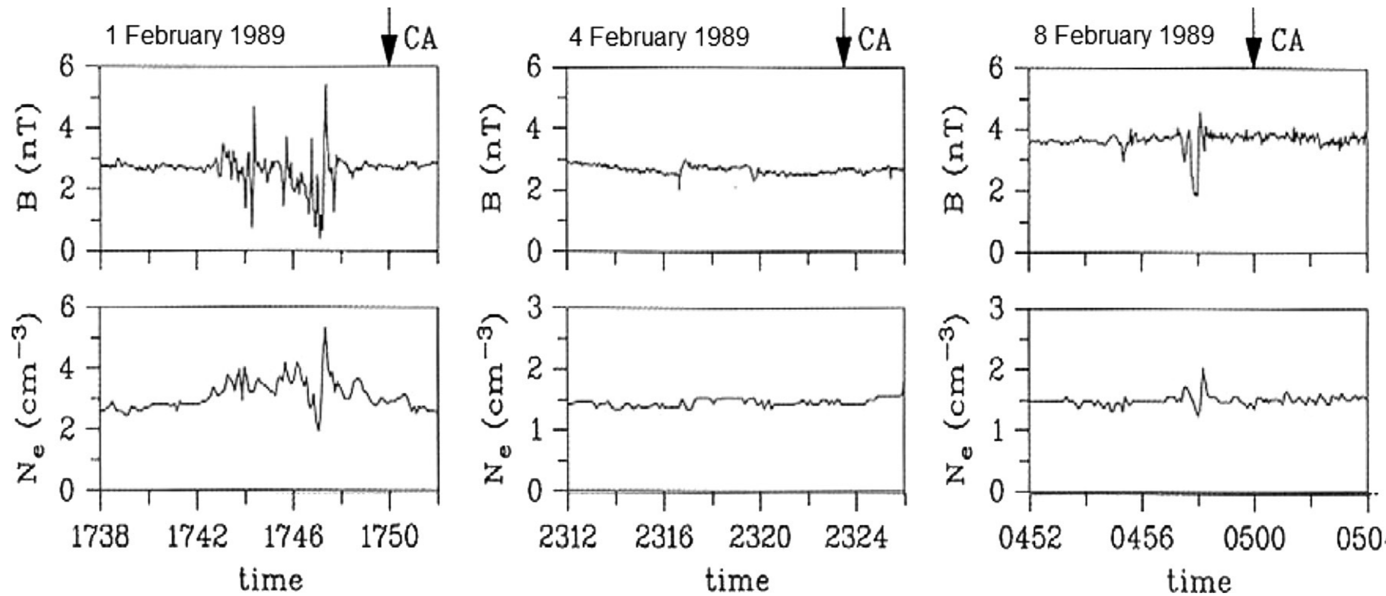


(Krivovetal.,2006)

Optical observation in the past missions:

- Imagery analysis by Viking1, Duxbury and Ocampo (1988),
- Imagery analysis by HST, Showalter et al. 2006

Previous observational studies on dusts around Mars: Solar wind

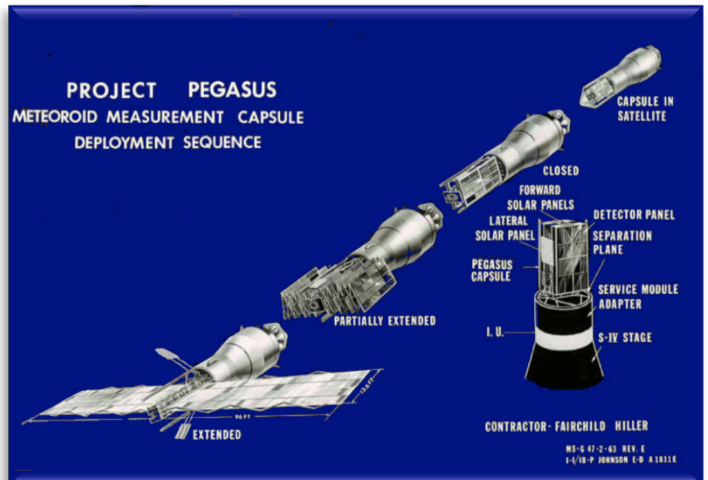


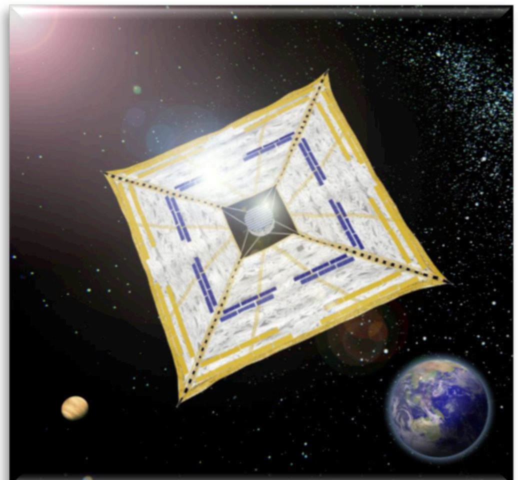
(Dubinin et al.,1990)

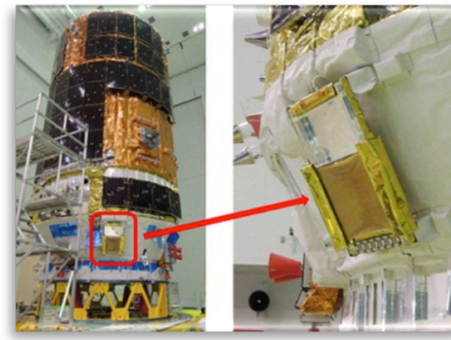
Indirect observation through solar wind disturbance

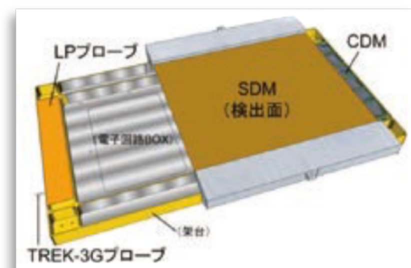
- Disturbance in solar wind plasma and magnetic field by Phobos-2
- Gas ring might be related to dust ring

For direct observation, we need a large area for Mars dust rings





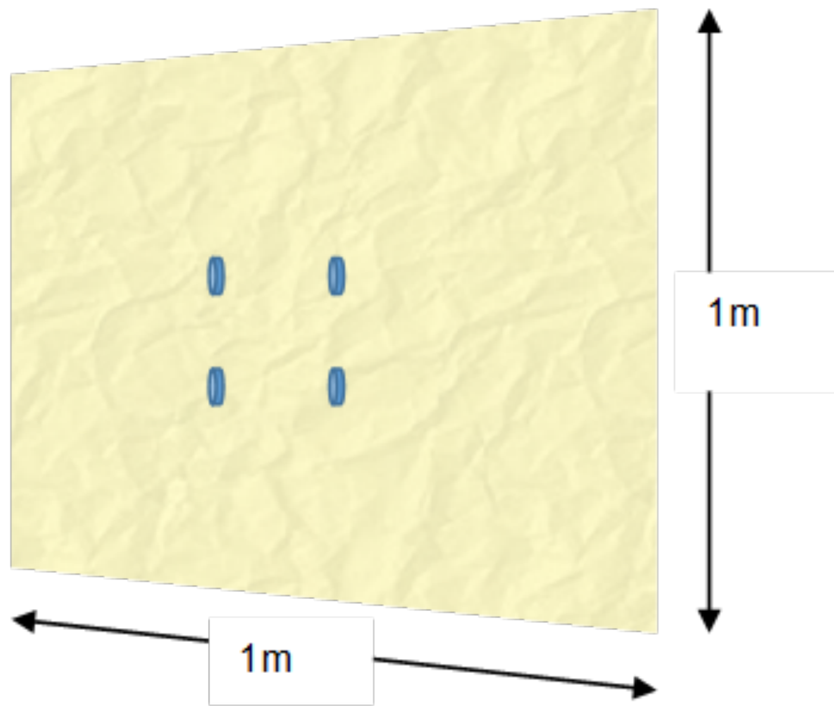




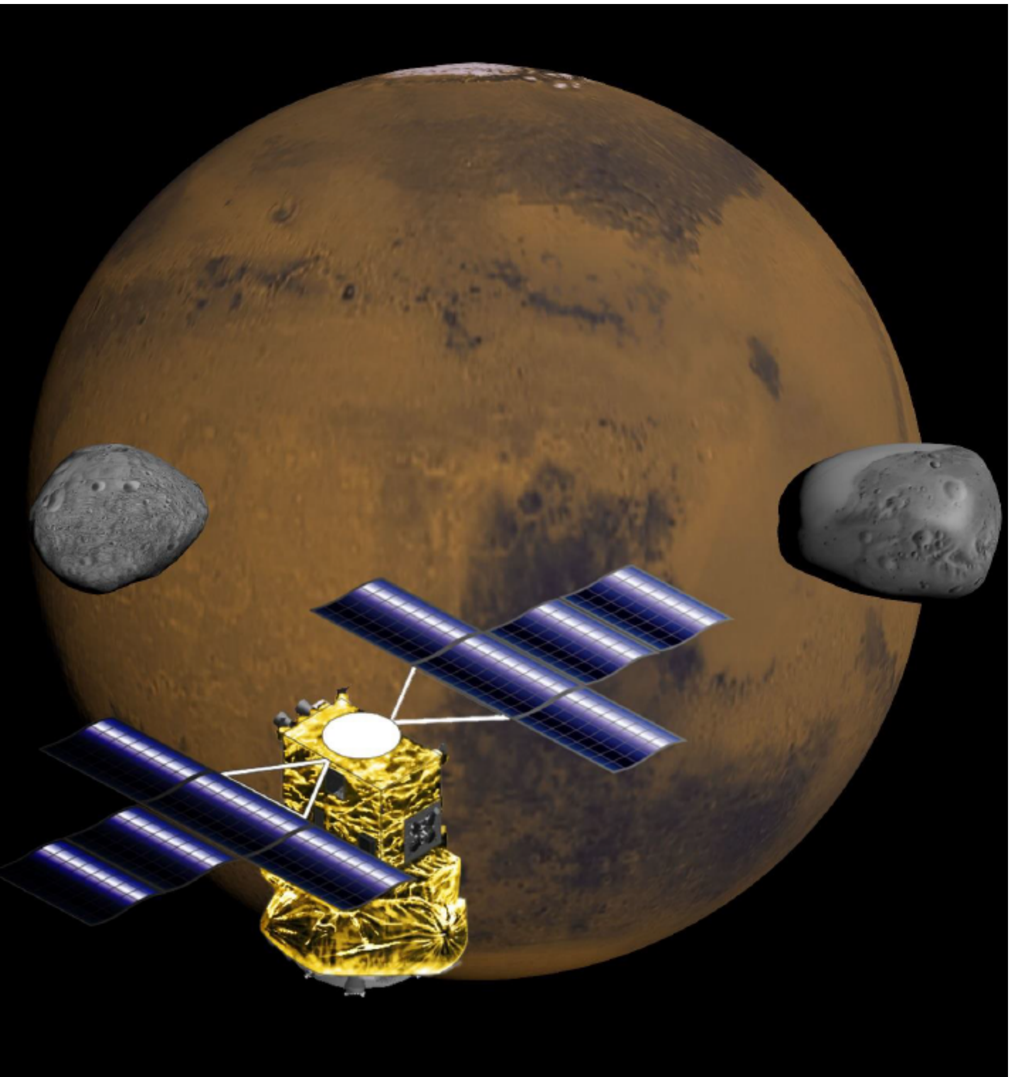
- Pegasus: Penetration measurement, 200m^2, pre-Apollo era
- ALADN: Penetration measurement made of PVDF, ~30cmx30cm
- SDM: Penetration measurement, Space debris detection, ~30cmx40cm, for > 100μm particles

Sensor, proposed in this study

- Sizes of target dust particles: 10- 20μm
- $1m^2$ detection area is needed, to find the increase in dust flux from the surrounding environment (interplanetary dust)
- Dust observation of Martian rings cannot be "main mission". The requirement to spacecraft system has to be minimized.

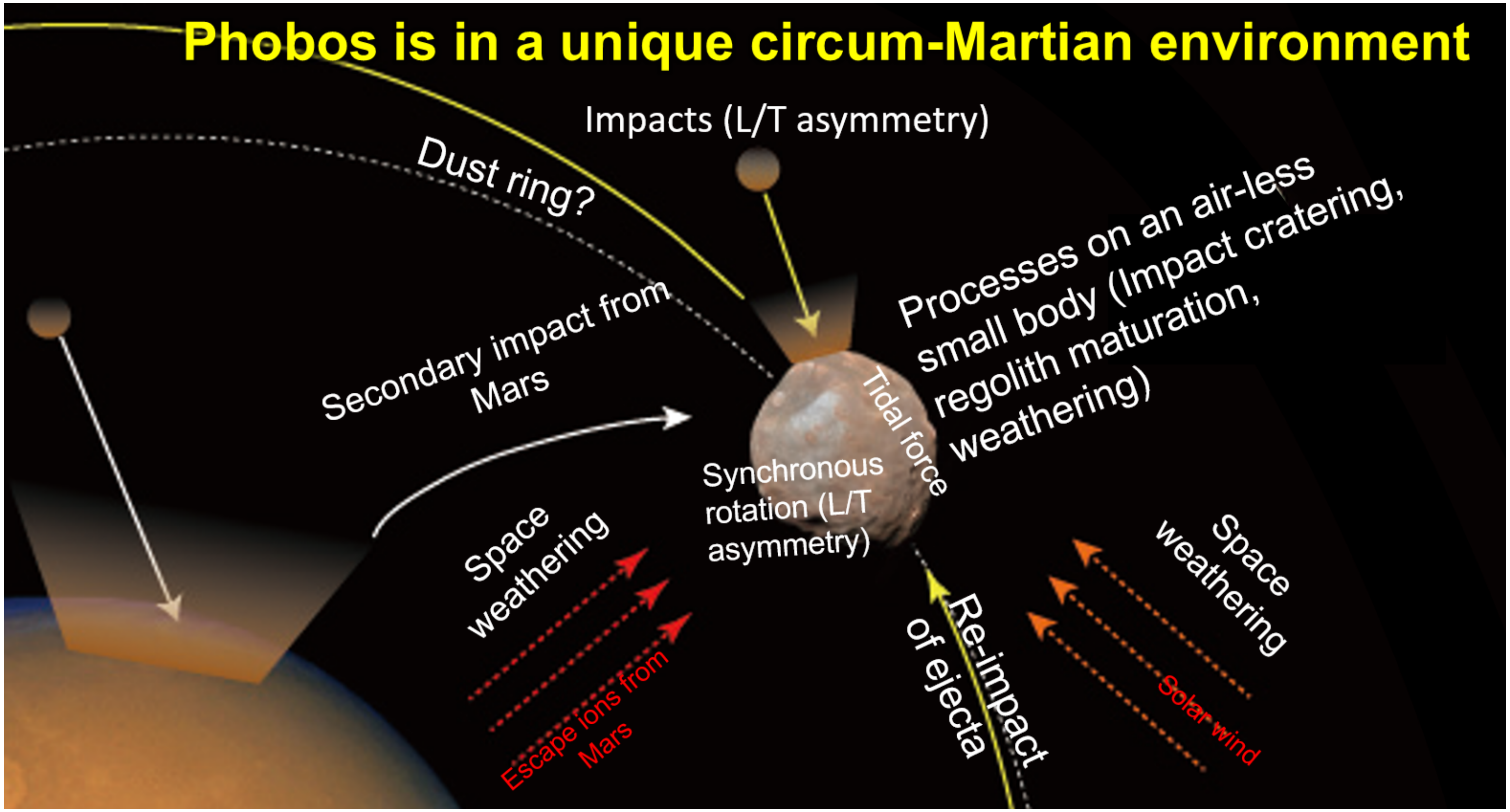


Martian Moons Explorer (MMX)

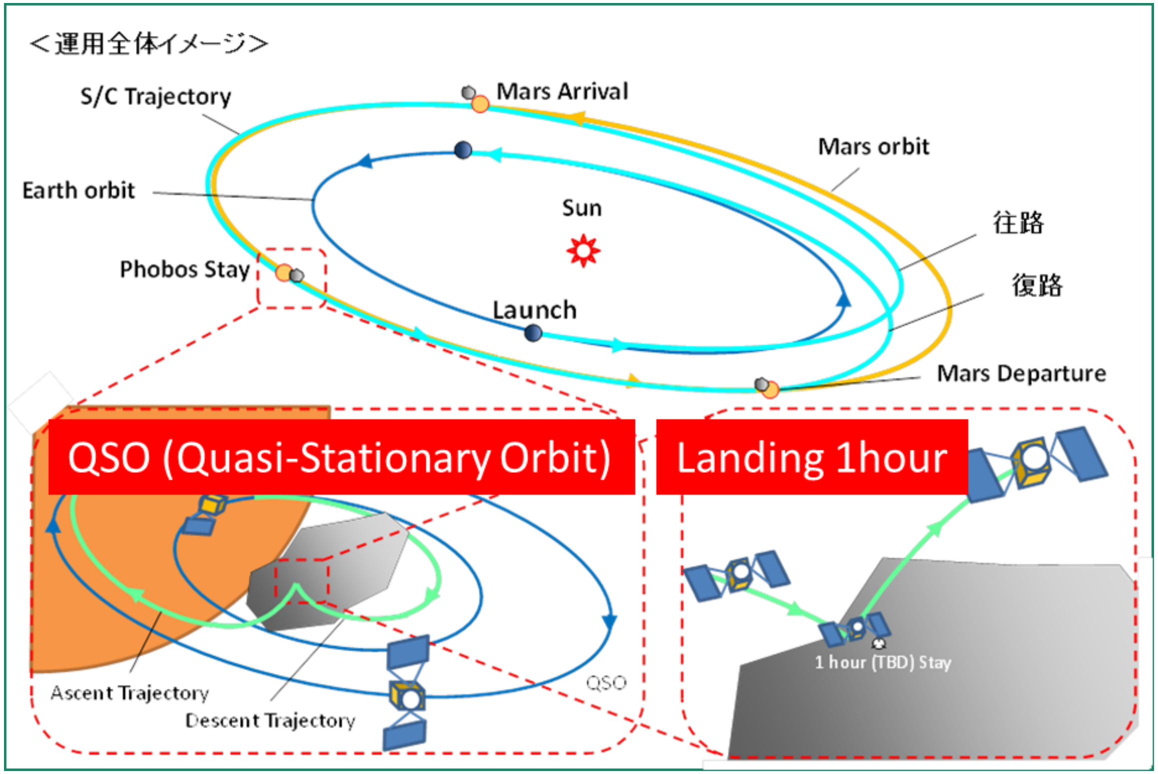


- A mission planed by JAXA performing:
  - in-situ observation of Phobos and Deimos
  - sample return from Phobos
- Mission objectives are:
  - to clarify whether if the moons are captured or formed in situ after a giant impact
  - to understand circum-Mars environment
  - to exploit astronautics and exploration capabilities

To understand circum-Mars environment



MMX, Martian Moons Explorer

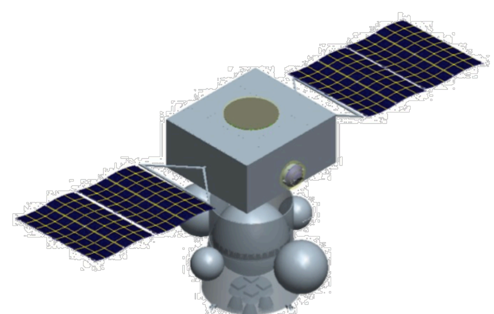


Time frame of MMX

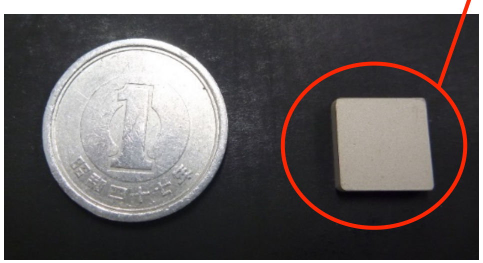
Launch	Aug, 2022 (2024)
Mars Arrival	July, 2023
Mars Departure	May, 2026
Earth Arrival	April, 2027

2 years delayed

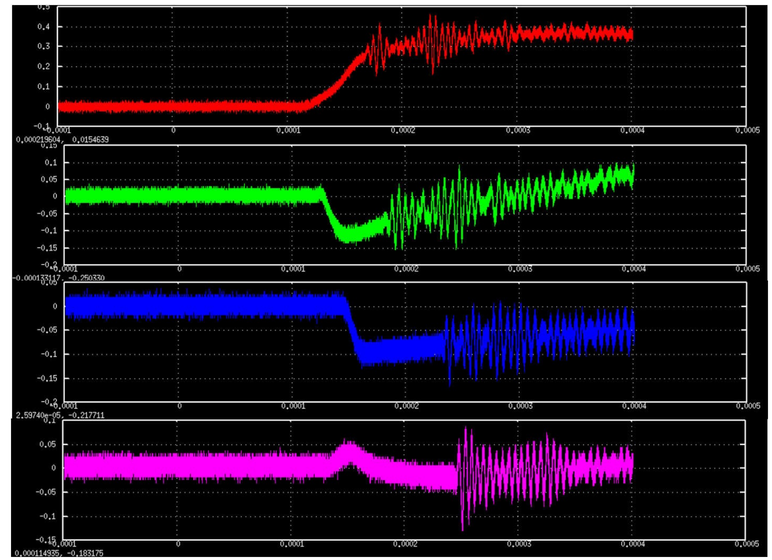
Launch Mass : 3000kg
Three stages system.
Return module: 1050kg
Exploration module: 150kg
Propulsion module: 1800kg
Mission Duration : 5 years



Back to dust instrument: Penetration measurement, but new approach

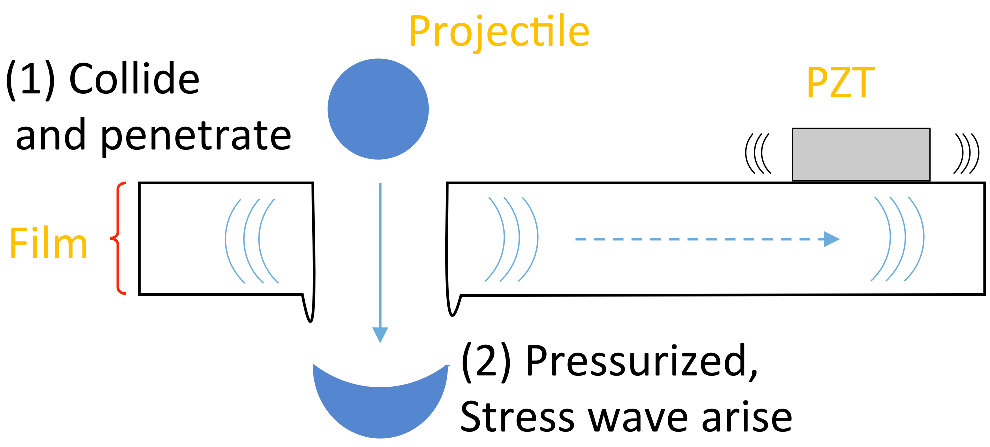


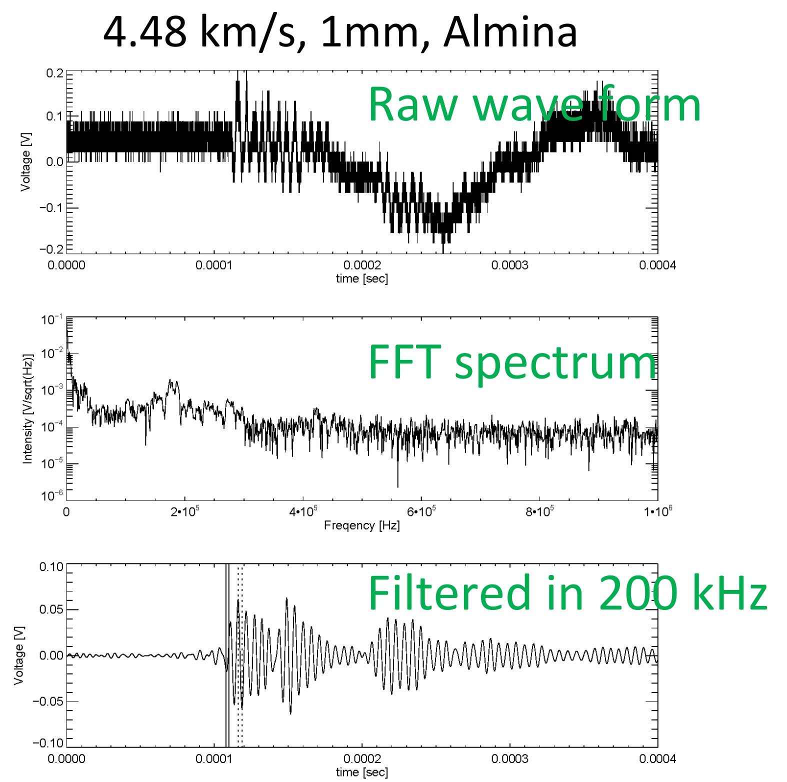
25μm polyimide film as the outermost layer of MLI + piezolelectric PZT element



Single projectile (steel/Almina) ranging of 300μm~3mm is shot by impact guns, collide in 4 – 5 km/s. The PZT sensor pick up stress waves in the film and outputs electric signal so that is readable without amplifier.

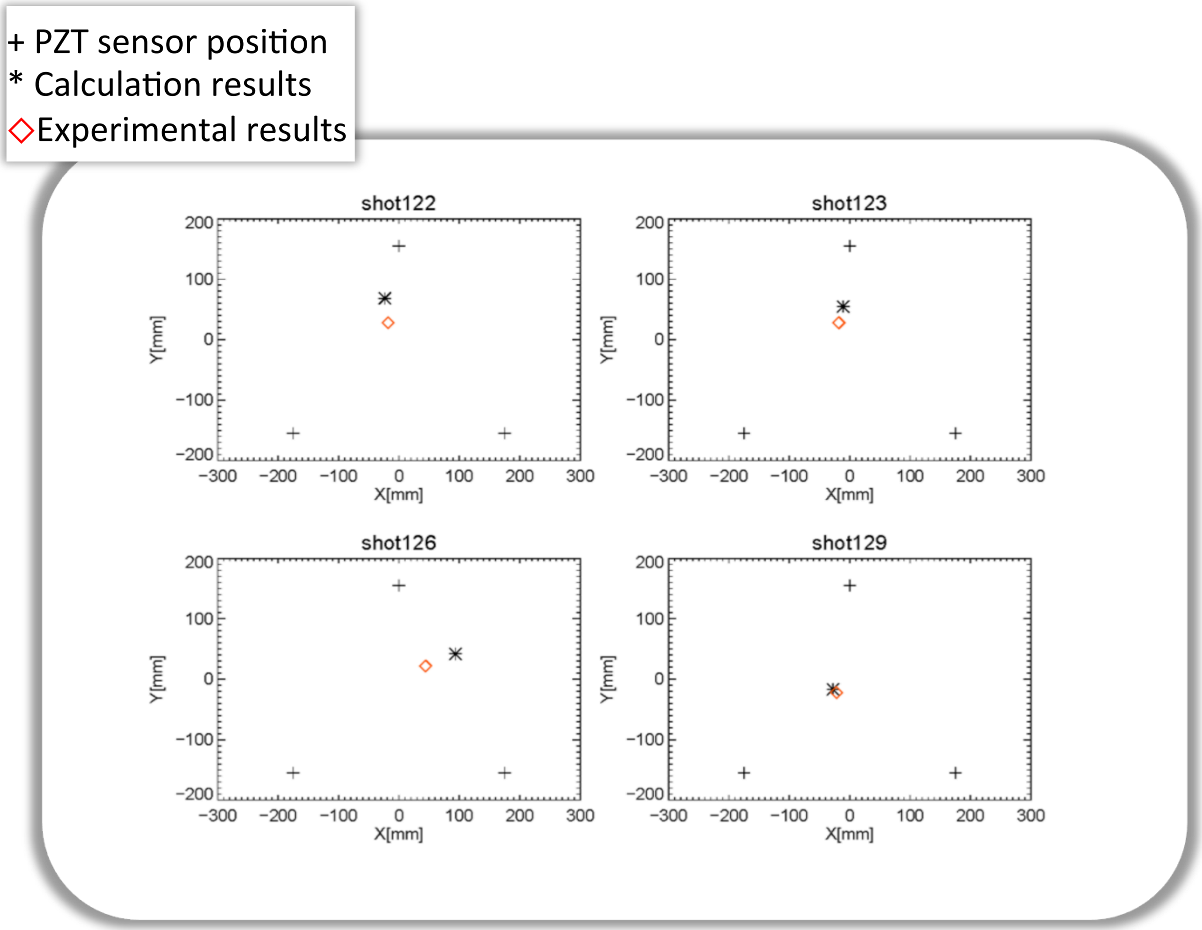
Penetration measurement by acoustic wave detection





(1) When an incident dust particle hits on the film and penetrate, stress waves arise in the film and propagate away from the penetration points.
(2) When the stress waves reaches a tip of PZT sensor and some of them transfer to the piezoelectric sensor, oscillation is induced in the sensor.
(3) The oscillation is converted to electric signal which is read out by the following electronics.

Penetration positioning



- Speed of the stress wave in the film is about 2.1 km/s.
- Time-difference-of-arrival algorithm can derive source position of the stress waves from arrival times of stress wave signals at three different location.

Results of positioning perforation.
Estimation accuracy is about 1 cm.

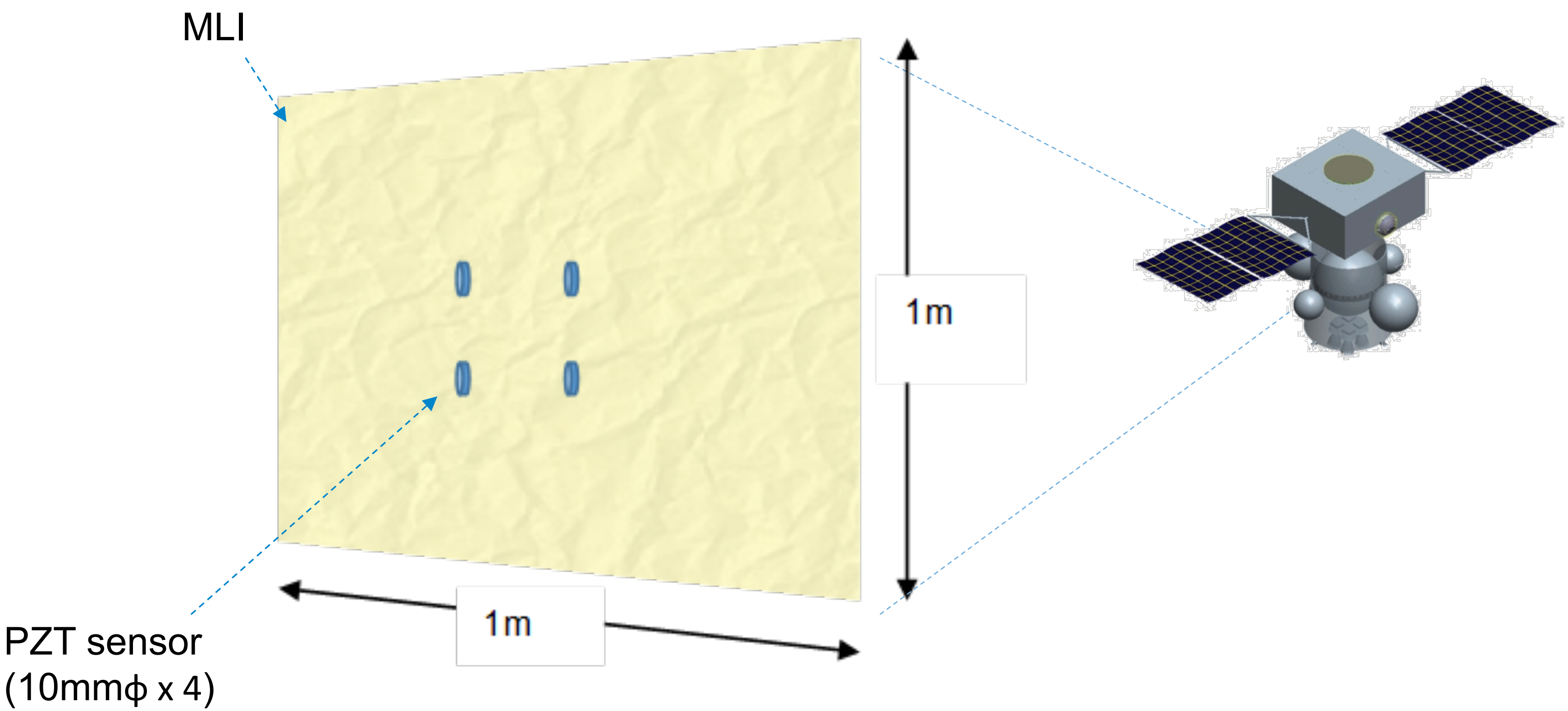
Experiments, so far

- Projectiles of 300µm – 3mm, at 4 – 5 km/s
- Stainless steel and Almina
- Signal from the sensors has tens of mV to hundreds of mV, without amplifier.

Future experiments

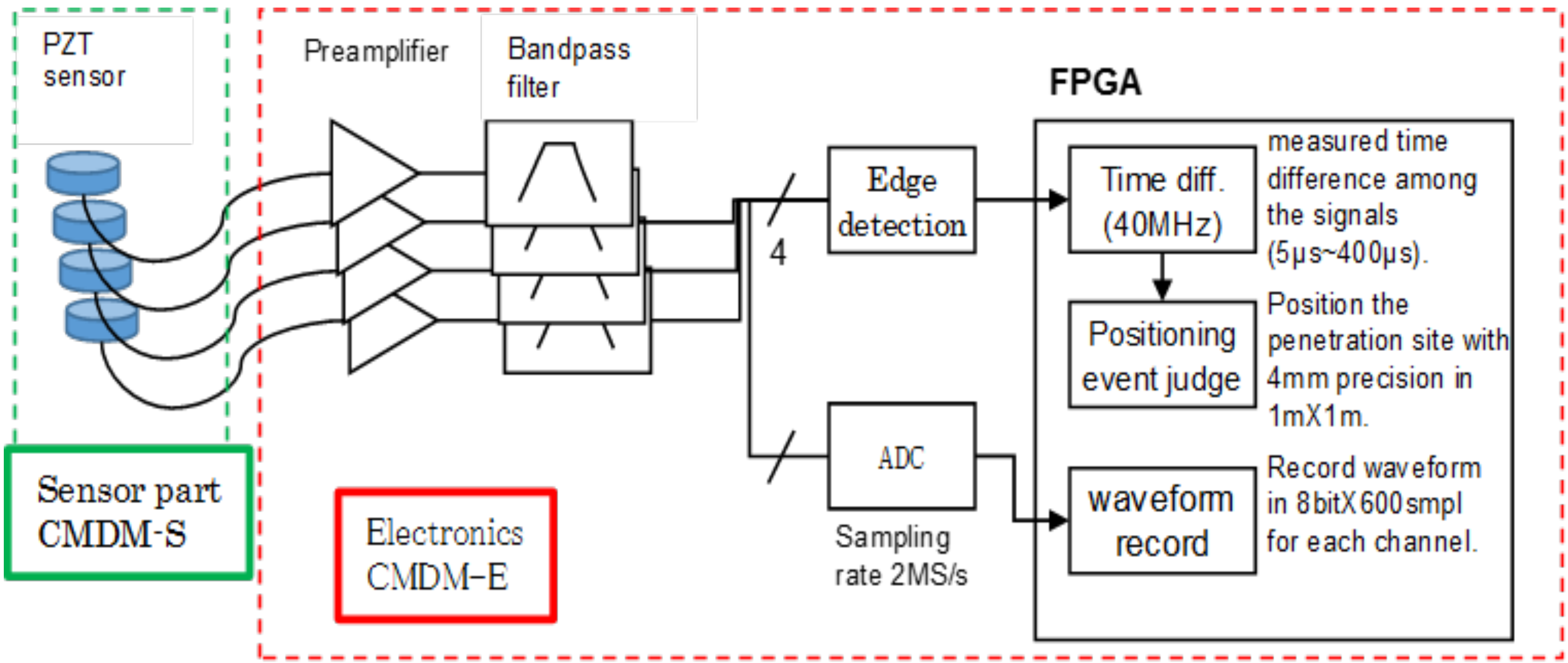
- Projectiles of 100 -200µm, at 4 – 5 km/s, Stainless steel by a light gas gun at JAXA in this month.
- Flyer acceleration technique using high-power lasers, up to 70km/s, at Osaka University, to investigate impact speed dependence in this year.

Concept image of dust sensor, Circum-Martian Dust Monitor (CMDM)



- 1m² detection area may have big impact on spacecraft system in terms of mass and thermal design. By exploiting MLI, the sensor dose not have an impact at least on thermal design.

Electronics



Electronics has no technological challenge

Technological feasibility in space

Parts and materials for the dust sensor should have sufficient tolerance to harsh space tolerance (which are placed on the outer layer)

- Thermal tolerance
  - PZT sensor has very wide range of operational temperature, -196 ^{o}C to +170 ^{o}C.
  - There are some space products of glue available in such wide temperature range. Those products will be evaluated in terms of sensor performance.
- Radiation tolerance
  - Piezoelectricity of the PZT sensor is not significantly deteriorated by radiation.
  - There are some space products of glue available in high radiation field. Those products will be evaluated in terms of sensor performance.

Maybe Glue for attachment of PZT sensor on MLI is key issue.

Resource requirements

Item		value
Mass	Sensor	0.05 kg
	Electronics	0.35 kg
	Harness	TBD
Power	Standby	< 2W
	Operation	< 3W
Size	Sensor (PZT)	10mmϕ×2mm×4pcs.
	Electronics	200mm×120mm×40mm
	Harness	TBD

Summary

- Dust sensor with a large detection area of $1m^2$ which has small resource requirement has been developed, targeting on > 10μm dusts.
- JAXA is planning to send MMX that will be launched in 2014. CMDM with the sensor will be on board MMX and may discover dust of Martian satellites.
- CMDM will observe > 10μm dusts of interplanetary dusts during cruising between the Earth and Mars orbits.