Geant4 usage at JAXA 2019

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Brief Summary

- Not used frequently for spacecraft or manned-structure designing by engineers

  Most of the radiation tolerances are ensured by rad-hard parts and thick radiation shields

- Used for detector design/calibration and astrophysical simulations by scientists
  - Payload design/calibration
  - Detector development
  - Astrophysical simulations
- The activity to popularize Geant4 is constantly carried out

  at Japanese tutorials by Geant4 developers

Activities

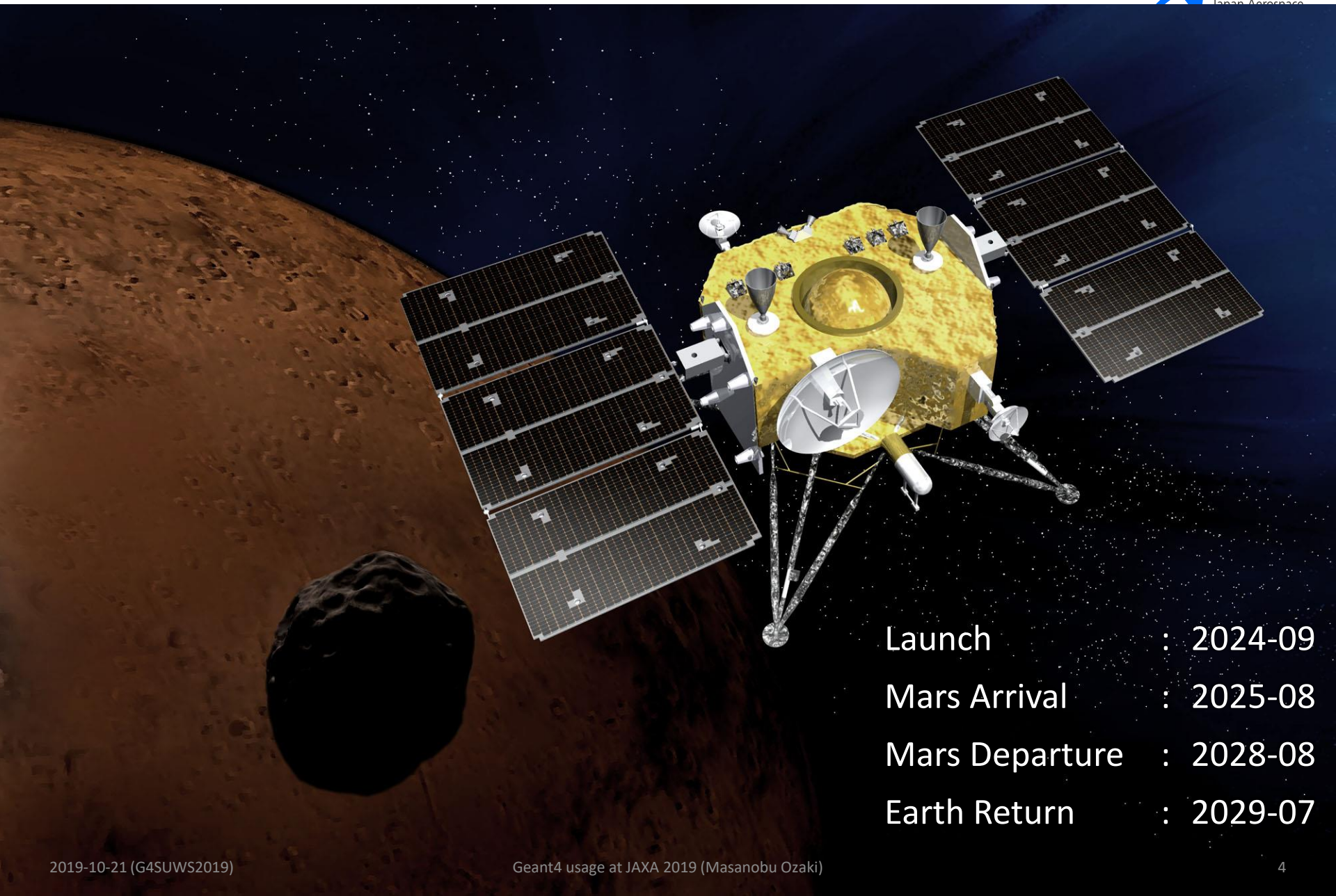
Popularization:

- Geant4 Japanese tutorial course by Geant4 developers
  - Once/year, 2 or 3 days, hosted by universities, with prepared virtual machine
  - From introduction to sensitive detectors
  - Not specialized for space mission, but universal for physics experiments

Space-science missions: candidates of Geant4 users

- SLIM: pinpoint landing on Moon (FY2021, dual launch with XRISM)
- MMX: Martian moons exploration (2024)

MMX: Martian Moons eXploration



Launch : 2024-09

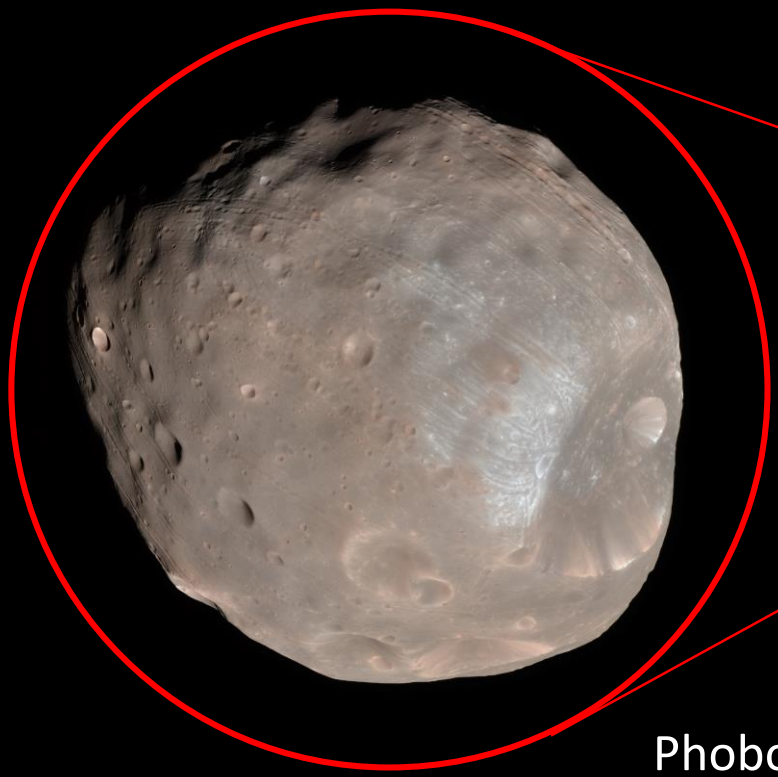
Mars Arrival : 2025-08

Mars Departure : 2028-08

Earth Return : 2029-07

Martian Moons: Phobos and Deimos

Japan Aerospace Exploration Agency



Phobos

Deimos

Black and Carbon-rich

Their albedos are low (7%), about half of the Moon and similar to coal. They look like primordial D-type asteroids, which implies they are carbon rich celestial bodies.

Low and Circular Equatorial Orbit

Phobos orbits only 6,000 km above the Mars surface, while the Mars radius is about 3,400 km: this is the lowest altitude among the solar system's satellites. Phobos and Deimos orbits are almost circular, and their orbital planes are almost same to the Mars' equatorial plane.

Curiously Small and Light

Their sizes are about 23 km (Phobos) and 12 km (Deimos). Unless orbiting around Mars, they had been considered as mere asteroids. Their densities are estimated as 1,870 kg/m^3 (Phobos) and 1,480 kg/m^3 (Deimos), which are quite lower than Moon (3,340) or Earth (5,510) and as low as coal.

Mars and Phobos taken by *Mars Orbiter Mission* (India) *©ISRO*

Martian Moons: Time Capsule of the Solar System

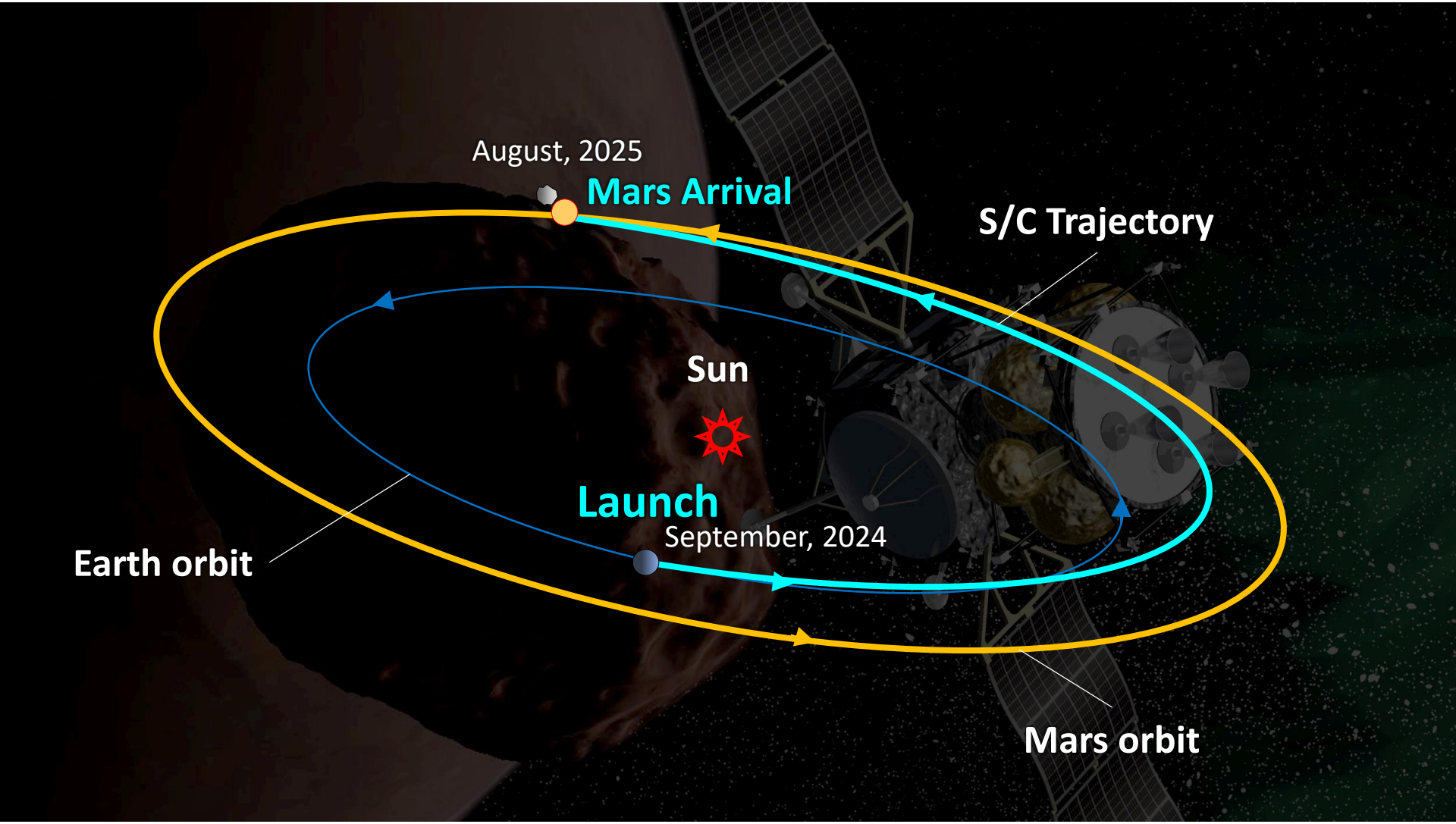
Japan Aerospace Exploration Agency

- Mars orbit is the frontline, where all the asteroids from beyond the snow line pass through.
  - Many asteroids should have collided onto the moons and made traces on them.
  - The moons themselves might be samples of the water carriers, if they are asteroids origin.
- The traces are expected to be preserved, while ones on Mars surface should have been completely wiped out by atmosphere and water.

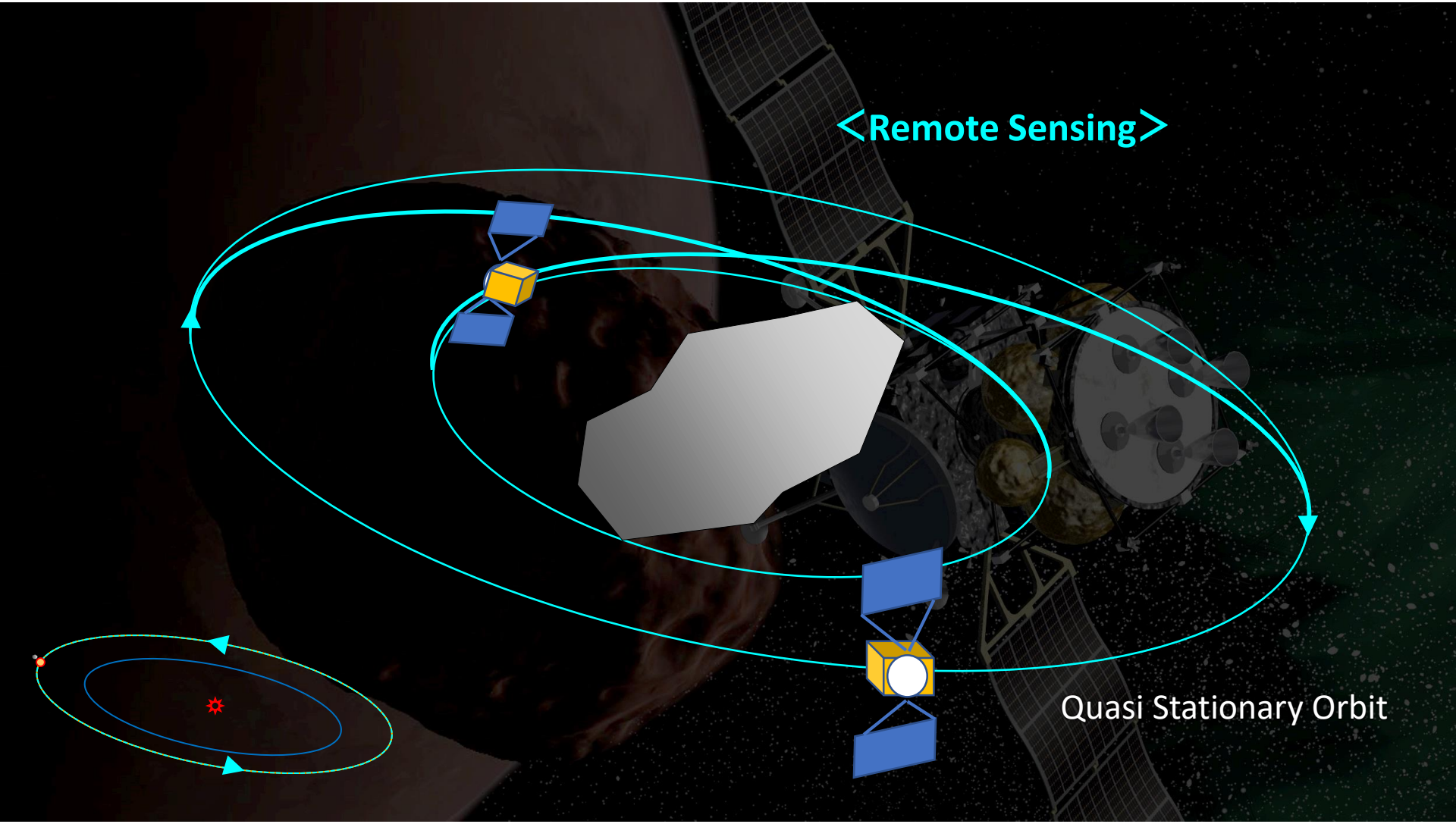
… So,

Analyzing the return samples from the moons must give us the information of the material movement in the Solar System evolution.

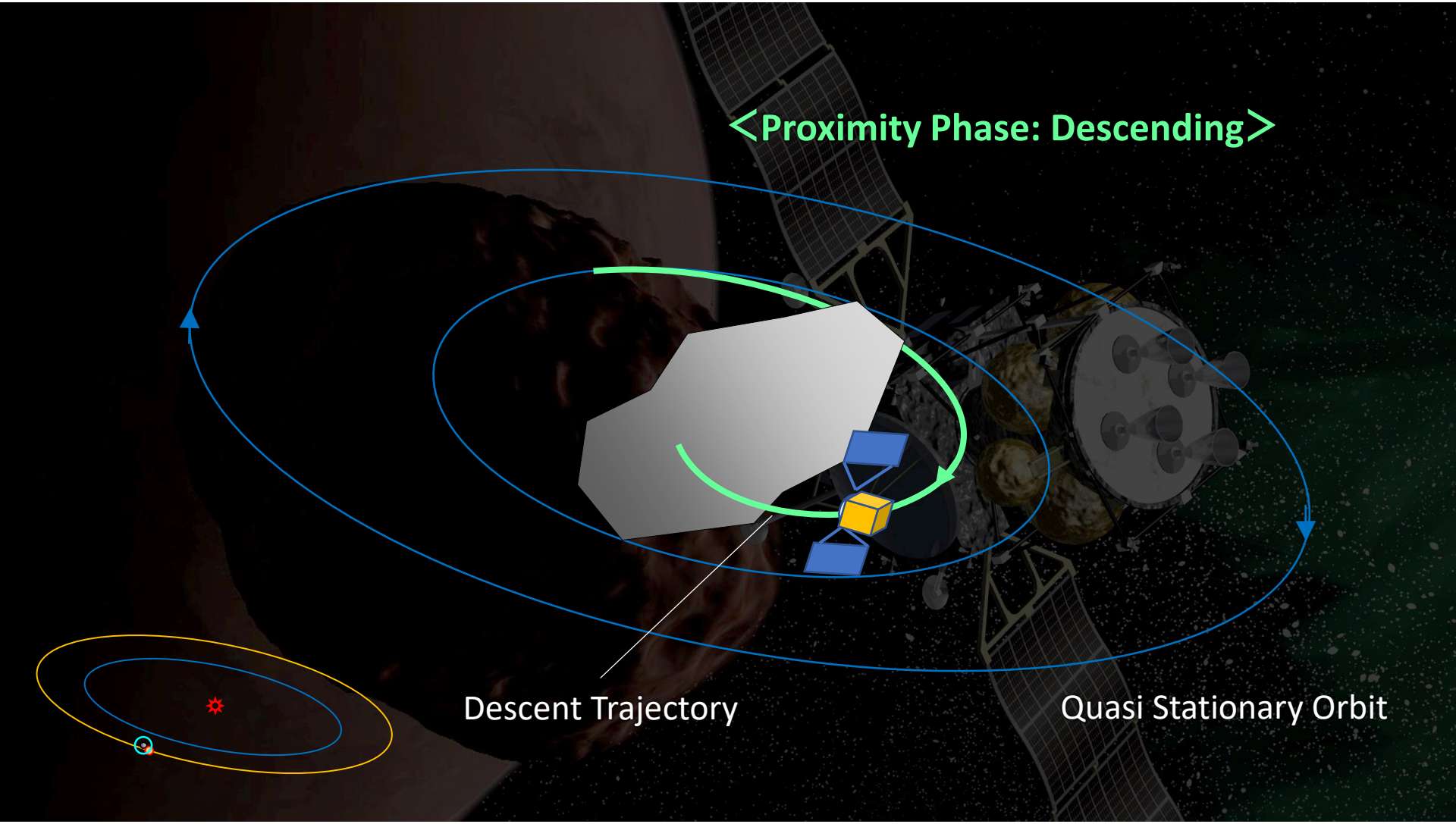
MMX: Mission Profile



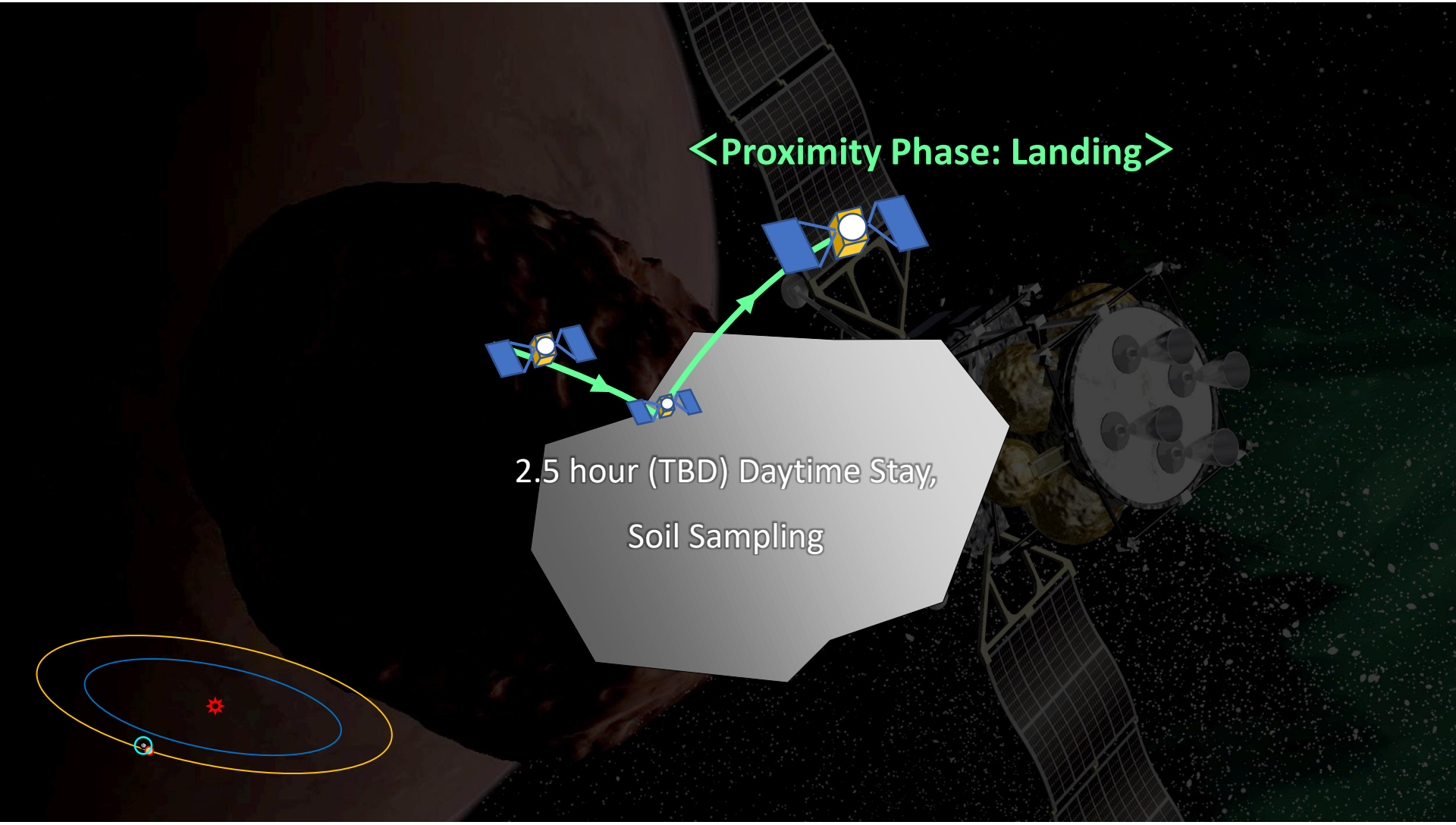
MMX: Mission Profile



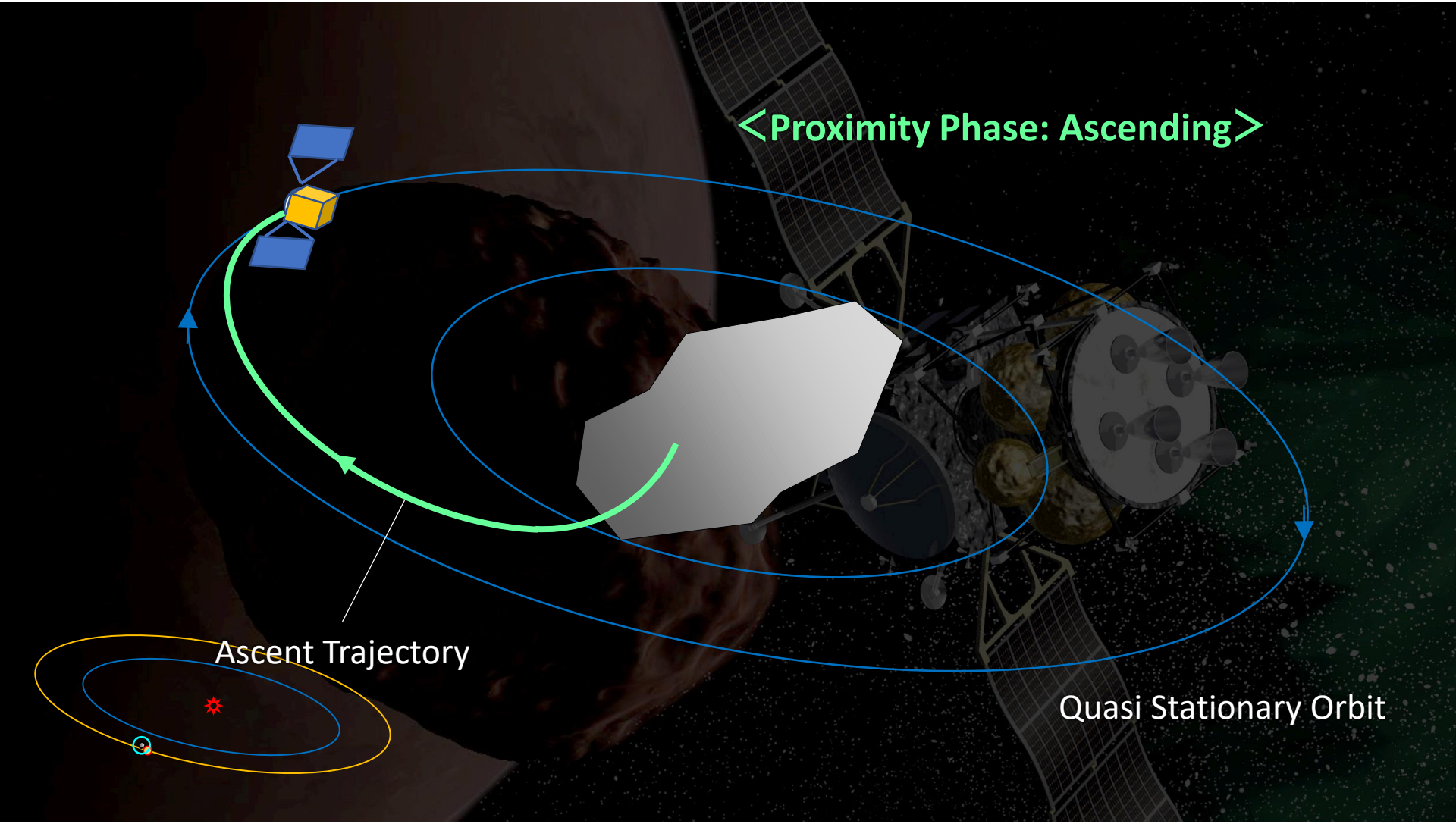
MMX: Mission Profile



MMX: Mission Profile



MMX: Mission Profile



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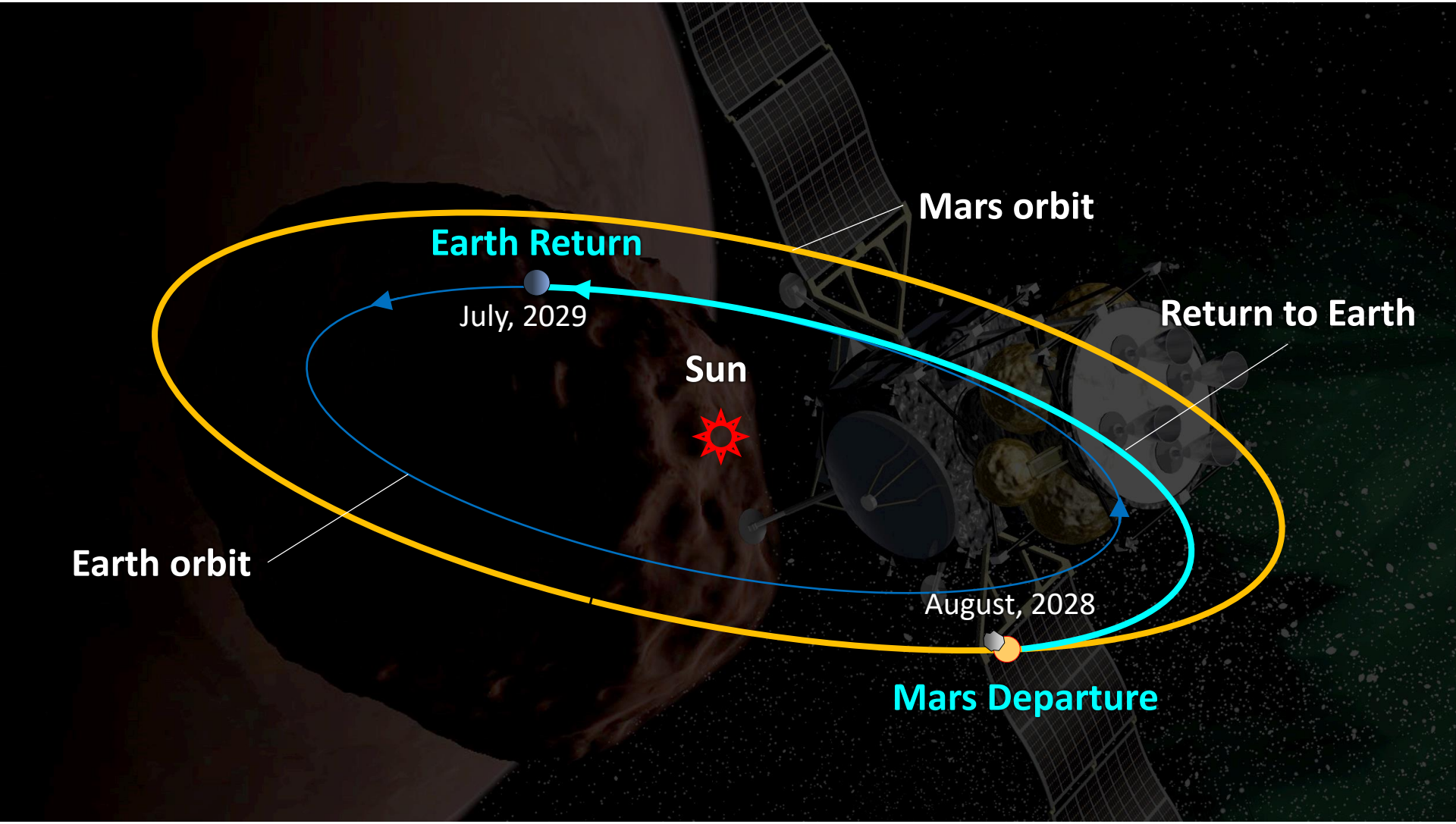
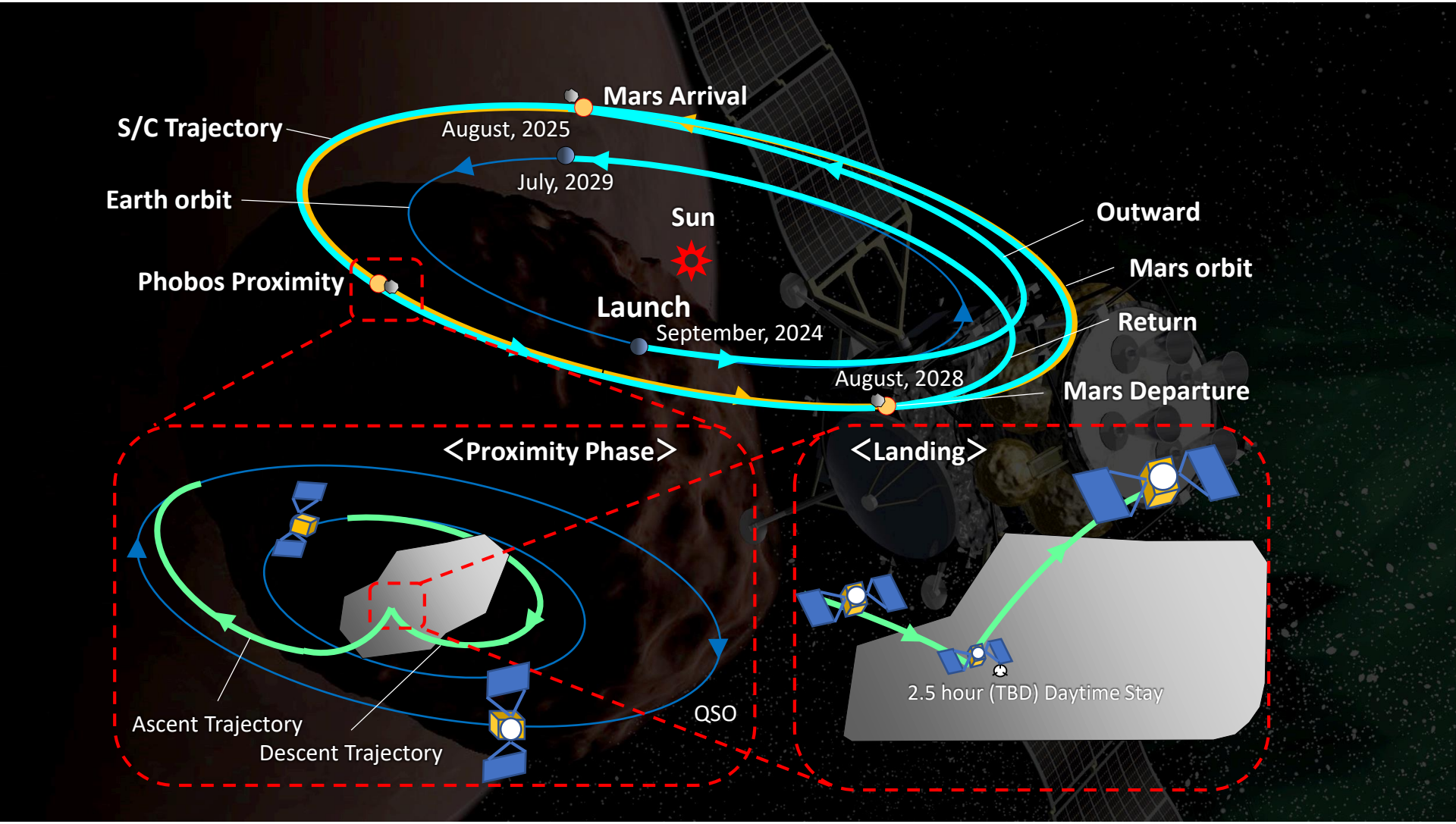


MMX: Mission Profile



MMX: Radiation Environment

- Mars has almost no magnetic fields or magnetospheres
  - No trapped particles
  - No magnetic shields for Solar flares

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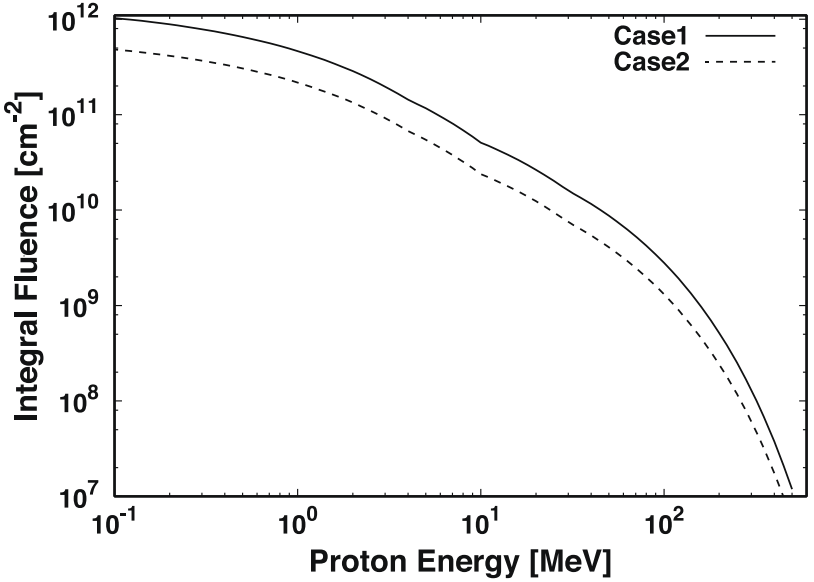
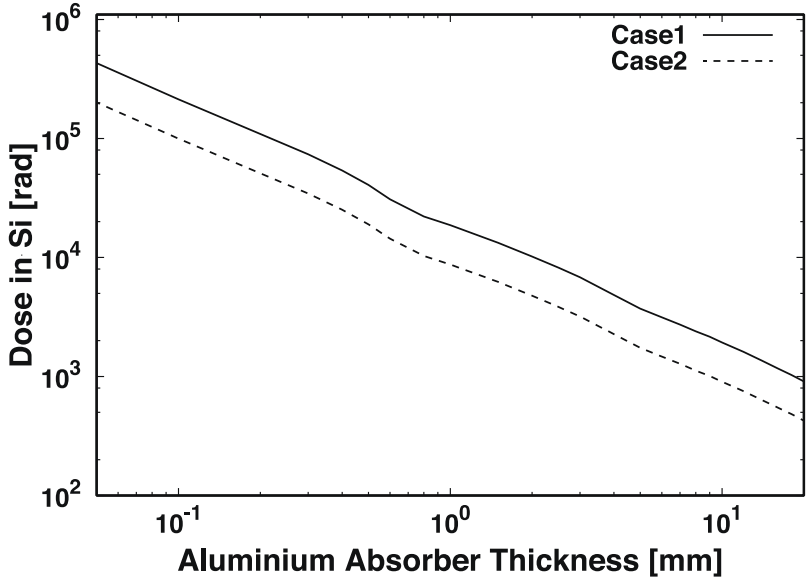
Main radiation source is Solar flares

- Radiation environment is predictable and tolerable by usual Al shields and usual rad-hard devices.

Expected fluence spectrum through the mission



Expected total dose through the mission



Geant4 use case for MMX

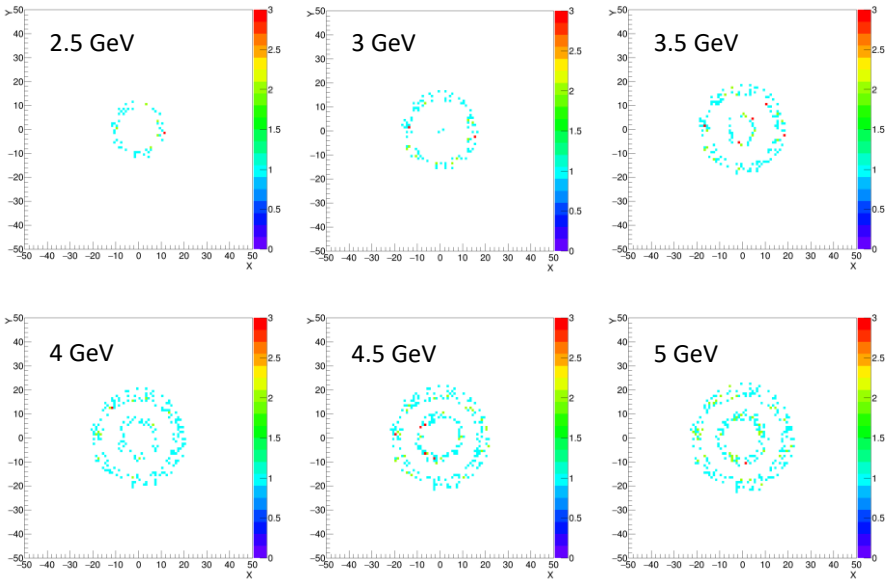
Japan Aerospace Exploration Agency

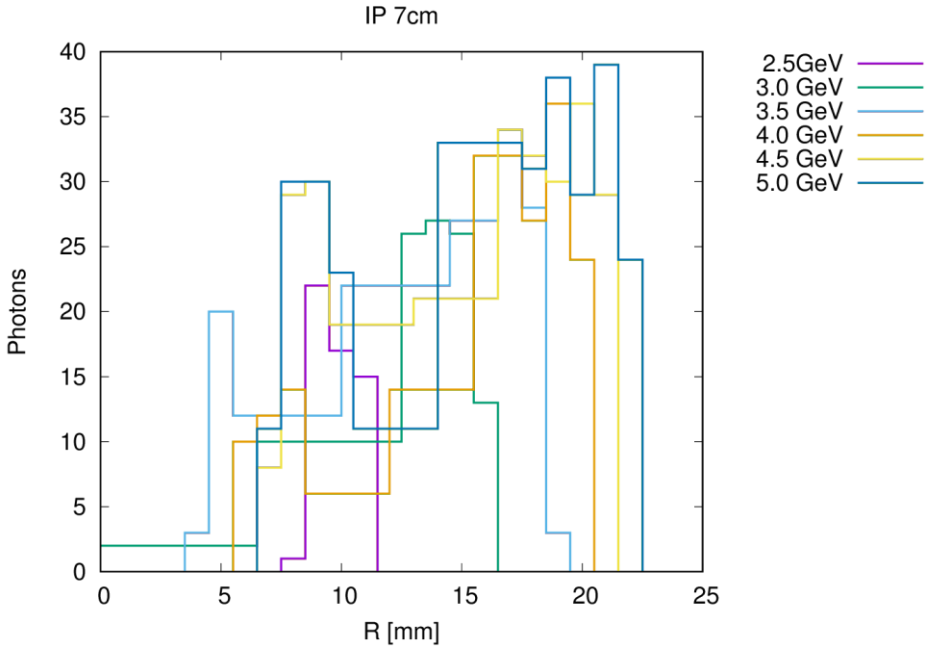
- Radiation Monte Carlo is required for precise detector response study or dose-sensitive device shielding
  - Detector response for Galactic cosmic rays: radiation environment monitor
  - Radiation shielding: CCD cameras with long exposure
  - …

Geant4 in radiation monitor study

- MMX will carry a radiation environment monitor *IREM* for future manned missions around Mars.
- In the conceptual study phase, a detector using Cherenkov radiation was proposed: Geant4 was chosen for the radiation simulation, while other parts were carried out by PHITS, and showed the idea's viability.

  (The design was, however, abandoned based on trade-off studies.)





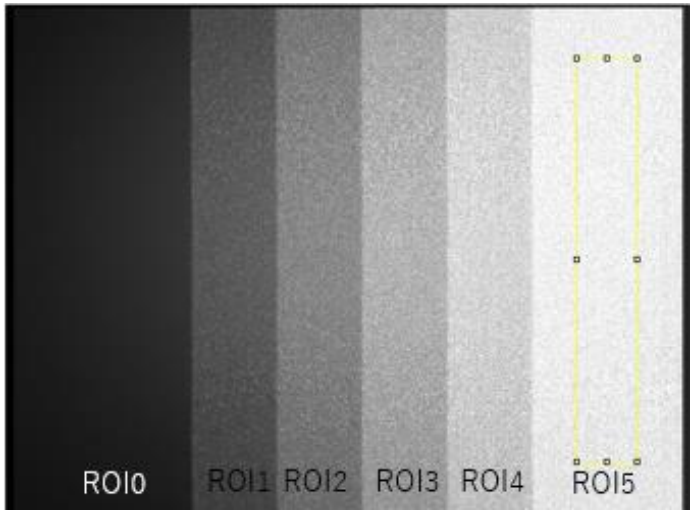
(Courtesy of Haruka Ueno at JAXA)

Radiation shield for CCDs

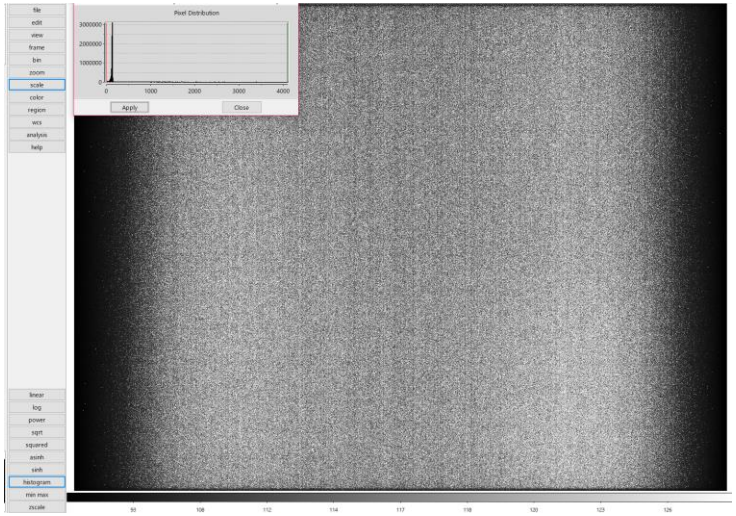
- MMX will carry several CCD cameras for high-S/N spectroscopy and high resolution imaging.
- Dark current is a key for high quality data, and sensitive to total dose especially in room temperature environment.
- Dark current and hot pixels depend on both dose and radiation quality: careful shielding design is required for light-weight instruments.

(see next page…)

CCD radiation damage examples



8MeV-p, 0.5 krad (ROI5)



^{60}Co, 12 krad

70MeV-p,
0.9 krad

Summary

- Geant4 not used frequently for spacecraft or manned-structure designing by engineers
  - Maybe some use PHITS
- Used for detector design and shielding simulations for science mission by scientists
  - Calibration, detector development and astrophysical simulations are also expected to be active (see SUWS2018 report)

- Continuous effort to expand Geant4 in space experiments and academic fields have been done by Japanese Geant4 developers.