Geant4 simulation for proton irradiation experiments of space-use imager

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Outline

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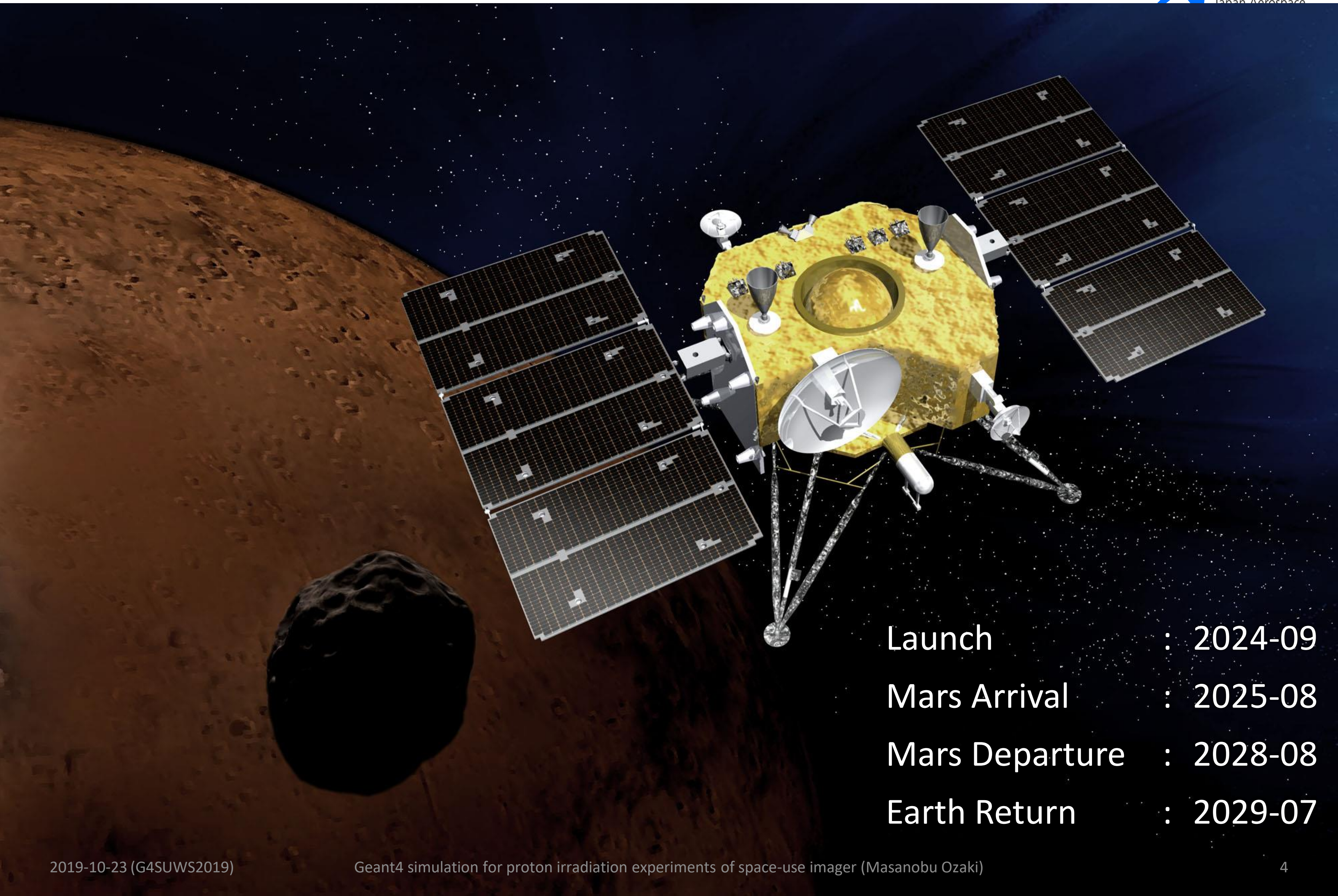
Notice

This is on-going activity, and Geant4 adaptation is at very beginning phase:

simulation setup or results not presented.

I apologize if you need such information.

Target Mission: MMX



Launch	:	2024-09
Mars Arrival	:	2025-08
Mars Departure	:	2028-08
Earth Return	:	2029-07

Target Device

Imaging sensor: CCD or MOS imager

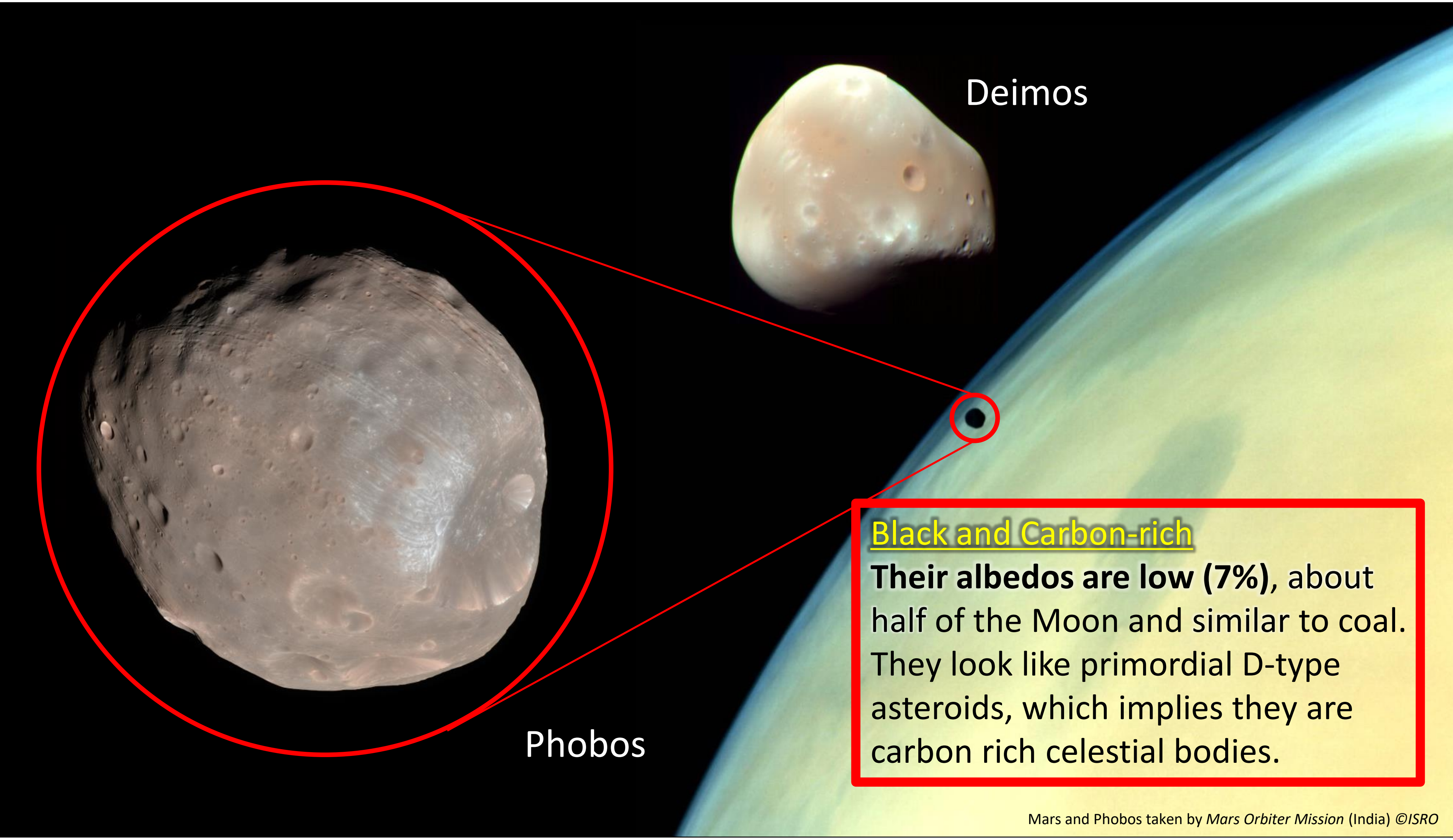
Known effects by radiation:

- Dark current increase – significant noise source
- CTE (Charge Transfer Efficiency) decrease, in case of CCD
  recover significantly when field is bright

Dark Current:

- Depend on temperature: double/half by 6–7 degC
  → Usually suppressed by cooling
- Hard to suppress on asteroid/moon day-side surface: high environment *T*, unless using big cooler

Requirement for Sensor: low noise



Target Radiation Environment

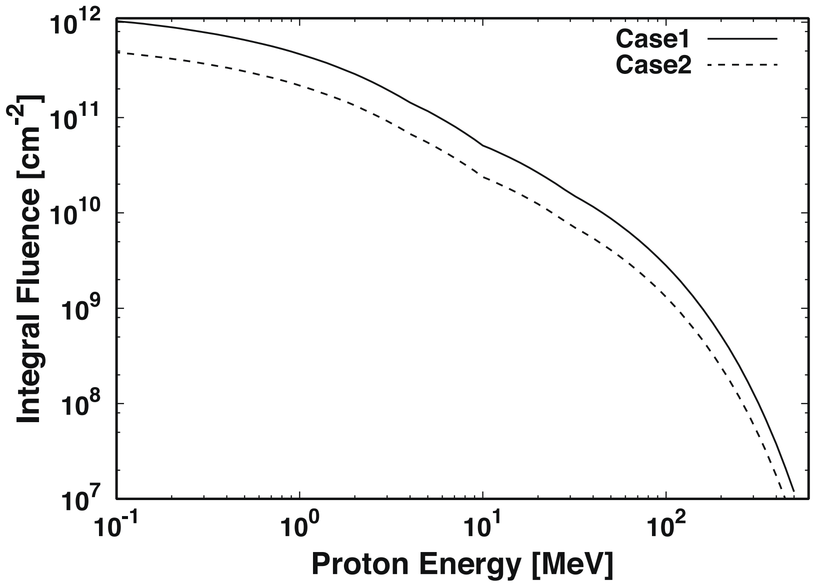
- Mars has almost no magnetic fields or magnetospheres
  - No trapped particles
  - No magnetic shields for Solar flares

↓ ↓

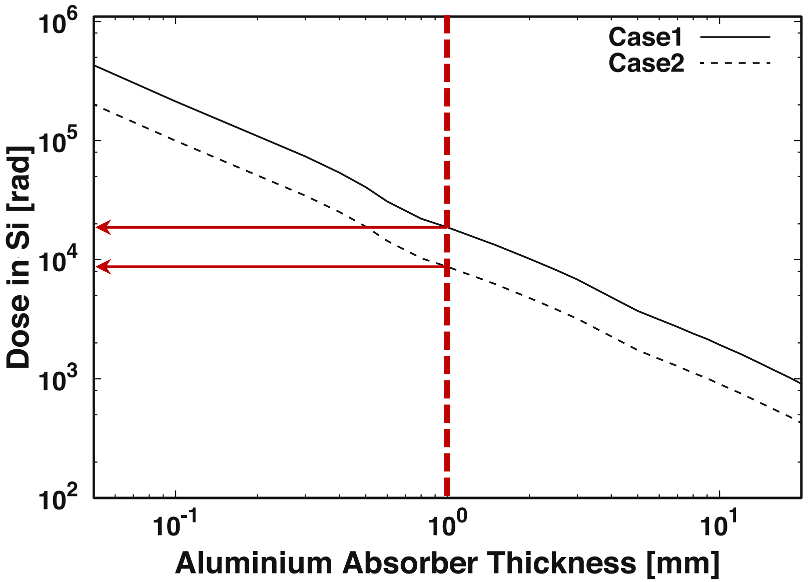
Main radiation source is Solar flares

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

Expected fluence spectrum through the mission



Expected total dose through the mission



Experiments

Target Device:

Commercial grade CCD

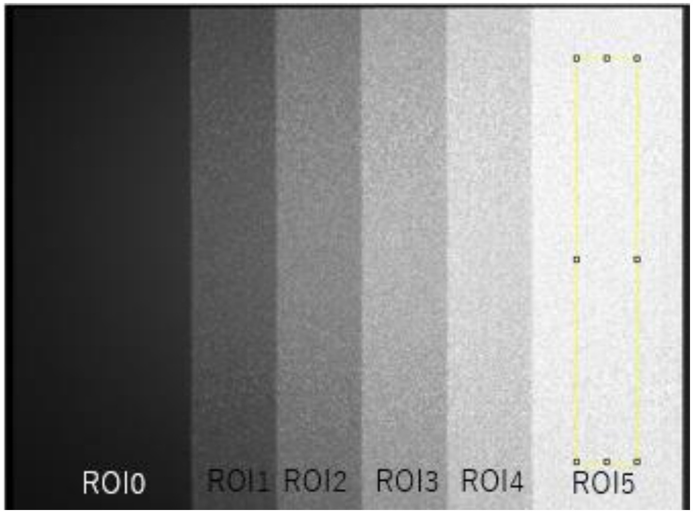
Proton irradiation:

- Main damage source in space mission, very wide energy range
- Significant NIEL
- Carried out with accelerator
  - 8 MeV, as low energy sample
  - 70 MeV, as high energy sample

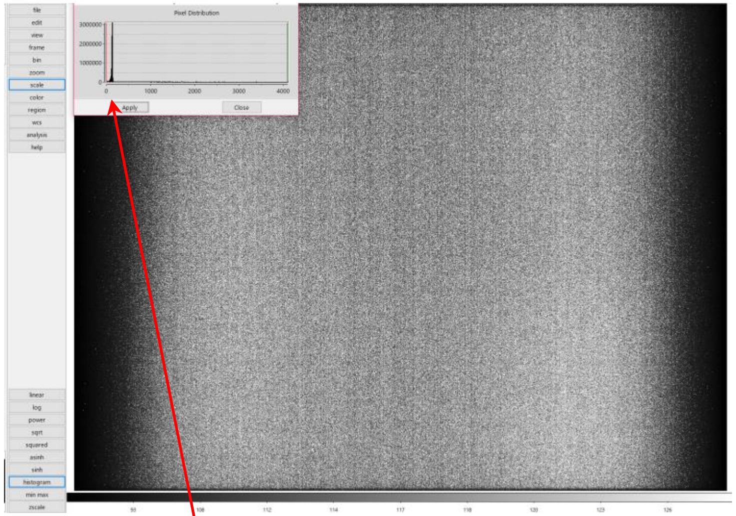
^{60}Co irradiation:

- Standard method for TID effect evaluation
- Carried out as a reference

Experiment Results



8MeV-p, TID 0.5 krad (ROI5)



^{60}Co, TID 12 krad

very low level

70MeV-p,
TID 0.9 krad

Experiment results and Geant4

Big difference between 8 MeV and 70 MeV proton cases

- Much larger than TID difference
- (NIEL-dose difference is similar to TID)

Why?

- Misconfiguration of experiments?
- Single NIEL-energy dependency of damage creation?
- …

Geant4 usage candidates:

- Experiment configuration verification
- Precise NIEL evaluation inside device

Summary

Beam test for space-mission candidate CCD carried out

- Significant damage difference by energy

Geant4 will be used for

- experiment setup verification
- NIEL precise estimation