Meteoroid Impact Detection for Exploration of Asteroids (MIDEA): A concept for asteroid prospecting

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Meteoroids are dispersed throughout the solar system and provide a constant source of impacts on larger bodies, resulting in erosion of the material on their surfaces. The Meteoroid Impact Detection for Exploration of Asteroids (MIDEA) concept, shown in Figure 1, leverages this natural phenomenon to determine the composition of asteroid surfaces through distributed plasma sensors on nanosatellites.

The material excavated from an asteroid surface by a meteoroid impact includes solid and molten ejecta, but some of this material is vaporized and ionized, forming a plasma that expands into the environment around the asteroid. The plasma can be detected by a low-power electrostatic probe at a range of up to several hundred meters, characterized through time-of-flight mass spectrometry, and traced back to the point of impact to construct a composition map of the asteroid surface.

This paper focuses on the characterization of impact rate on asteroids using models of meteoroid flux. Itokawa is one of over 7000 known near-Earth asteroids ranging from 100 to 1000 m in size, and was chosen as a representative case. Figure 2 shows the impact rate of nanogram and larger meteoroids from the sun direction over Itokawa's orbit. Impact plasma formed on the sun-facing size will expand from a positively biased surface due to photoemission, allowing electrons to be re-absorbed into the surface and leaving the positive ions free to reach the orbiting sensors. The impact rate was computed using NASA's Meteoroid Engineering Model with Itokawa's orbital position and velocity from JPL's HORIZONS system, and extrapolated from microgram to nanogram meteoroids using the Grün interplanetary flux model. An impact velocity threshold of 20 km/s was applied to consider only those impacts fast enough to produce a discernable charge from an overhead spacecraft.

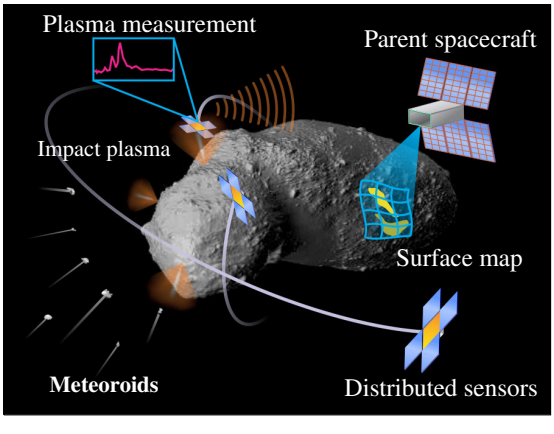

Figure 1: Overview of the MIDEA system concept. A parent spacecraft synthesizes impact plasma measurements collected by distributed sensors on smaller spacecraft to construct a map of potential resources on the asteroid surface.

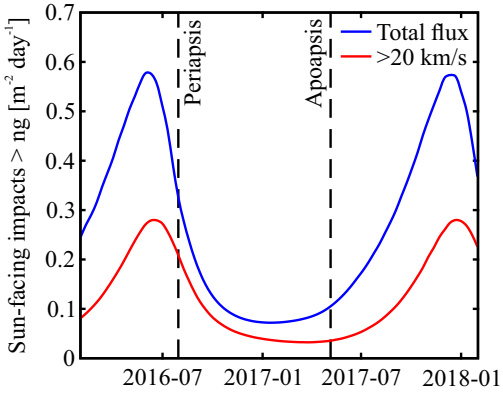

Figure 2: Impact rate of nanogram and larger meteoroids from the sun direction over Itokawa's orbit.

The impact rate was found to vary from 0.037 to 0.27 $\mathrm{m}^{-2} \cdot \mathrm{day}^{-1}$ with the maximum coinciding with the time period prior to periapsis, when Itokawa's sunward velocity component is greatest. These rates correspond to approximately 3–25 impacts per minute over the total sun-facing area of the asteroid, allowing for rapid characterization of the surface composition.

This material is based upon work supported by NASA under award No. NNX15AD70G