Science Goals of the Mars-moon Exploration with GAmma rays and NEutrons (MEGANE) Investigation for the MMX Mission

*David J Lawrence[1], Tomohiro Usui[2], Patrick N Peplowski[1], Andrew W Beck[1], Morgan T Burks[3], Nancy L Chabot[1], Richard C Elphic[4], Carolyn M Ernst[1], John O Goldsten[1], Scott L Murchie[1]

1. Johns Hopkins University Applied Physics Laboratory, 2. Tokyo Institute of Technology, 3. Lawrence Livermore National Laboratory, 4. NASA Ames Research Center

A fundamental question regarding the Mars moons Phobos and Deimos concerns how they came to be in orbit about their host planet. Namely, are they captured asteroids, or were they formed via an impact of a larger body into Mars? One of the primary ways to answer this question is to measure the chemical composition of these moons. The Martian Moon eXploration (MMX) mission, which is being planned by the Japan Aerospace Exploration Agency (JAXA), will answer this and other key questions regarding Phobos and Deimos. MMX will accomplish its objectives by making comprehensive remote sensing measurements of Phobos and Deimos, and then returning to Earth regolith samples of Phobos.

The Mars-moon Exploration with GAmma rays and NEutrons (MEGANE) investigation was recently selected by NASA to fly onboard the MMX mission. MEGANE will acquire elemental composition data of Phobos using gamma-ray and neutron spectroscopy. MEGANE uses gamma-ray and neutron spectrometers that measure gamma rays and neutrons created when energetic galactic cosmic ray protons impact Phobos’ surface. Gamma-ray and neutron spectroscopy has become a standard technique for measuring planetary surface compositions, having successfully made composition measurements of the Moon, Mars, Mercury, and the asteroids Eros, Vesta, and Ceres. MEGANE is a high-heritage design based on the successful MESSENGER gamma-ray and neutron sensors and the Lunar Prospector neutron spectrometer.

MEGANE science goals mirror those of the MMX mission, and are designed to complement other MMX measurements, to assist the sample site selection, and provide compositional context for the returned samples. MEGANE’s first science goal will use global average elemental compositional data to determine if Phobos is a captured asteroid or was formed by an impact of a larger body onto Mars. The spectral resemblance between Phobos and Deimos and primitive outer solar system objects suggests that these moons may be captured objects from elsewhere in the solar system. If true, Phobos and Deimos are predicted to have elemental compositions similar to the carbonaceous chondrites. In contrast, the impact formation theory is motivated by the difficulty in capturing two objects into circular, equatorial orbits about Mars. In this scenario, Phobos and Deimos will have elemental compositions similar to Mars’ crust, or a mix of Mars’ crust plus the composition of the impactor, and be depleted in volatiles like Earth’s moon. MEGANE will make multiple, redundant elemental composition measurements (H, O, Na, Mg, Si, K, Cl, Ca, Fe, Th, U) as well as neutron-based (neutron absorption, atomic mass) composition measurements to determine if Phobos has a chondritic or achondritic (Mars-like) composition.

MEGANE’s second science goal will use compositional variations across Phobos’ surface to understand surface processes on airless bodies in Mars’ orbit. Phobos’ surface shows evidence for compositional diversity via two distinct spectral units. A “blue unit” is associated with the ejecta of the large Stickney crater, and the remainder of the surface forms a “red unit”, which also covers Deimos’ entire surface. Spatially resolved compositional data from gamma rays and neutrons will be used in concert with other MMX data to better understand the processes that are responsible for Phobos’ spectral diversity.

MEGANE’ s third science goal will be to support the primary MMX mission goal of Phobos sample return by providing input to the sample site selection process and supplying compositional context for the returned samples. MEGANE compositional maps can be used to resolve varied petrologic materials, and will be combined with higher spatial resolution spectral unit maps to develop inter-instrument criteria for sample site selection. The full MEGANE dataset will also be used to understand how well the MMX returned sample represents Phobos’ surface.

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