



PEANUTS - Probing Evolution of Asteroids aNd Uncovering Traces and Sources - A Proposal to ESA's Mini-F Call

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Introduction:

Asteroids are invaluable archives of Solar System history, preserving records of dynamical and compositional evolution across planetary epochs. They provide crucial insights into the processes that shaped planets and the distribution of material in the early Solar System. Despite significant advances from previous and ongoing international missions [1-6], much of this history remains unexplored. Substantial knowledge gaps persist, especially regarding asteroid spectral types that have not yet been explored by spacecraft, including many primitive and differentiated types critical for understanding the full spectrum of Solar System evolution. The PEANUTS mission aims to fill part of this gap by exploring an asteroid of a different spectral type (D-, E-, or Q-type) and smaller in size than those previously explored.

Target Types:

Our primary target is 2015 BM510, a D-type Near Earth asteroid. D-type asteroids exhibit almost featureless and highly red-sloped reflectance spectra, reminiscent of comet nuclei [7,8]. They are likely related to the parent body of comets, and are tied to migration of small bodies mobilized by the Grand Tack migration of Jupiter and Saturn [7]. No meteorites found on Earth have been conclusively linked to D-type asteroids [7]. This makes in situ exploration the only option for understanding their nature. Investigating their composition and dynamics will offer us a unique opportunity to illuminate these formative epochs.

In preparation, we have also selected a number of backup asteroid targets of previously underexplored types. These include one E-type asteroid (2001 QJ142), a type characterized by their high albedo and relationship to igneous minerals, possible relationship to LHB [12] indicating formation in mantel regions of differentiated proto-planets, as opposed to core material of M-types [9-10]. Our proposed backup target is determined to be of E- or M-type [10], an example of the ambiguity in certain ground observations, and highlighting the need to better understand any possible relationship between these two types.

The other backup targets for PEANUTS are of Q-types, which are spectrally related but bluer than the common S-type asteroids [13]. Debate persists on the process of transition from one type to another, through weathering or resurfacing [13-14]. An in-situ spacecraft mission to a Q-type

asteroid will help establish firm timelines in the processing of surface material on asteroids.

Other Criteria:

The majority of asteroids are smaller than sizes previously explored by spacecraft, and could exhibit different surface and dynamical properties than we would expect. In particular, asteroids under the ~200m diameter range are more likely to have rotational periods under 2 hours [15], creating environments where centripetal force can dominate gravity. This raises questions on whether these bodies are monolithic, or held together by yet-uncharacterized cohesive forces, and how these different bodies react to dynamical encounters. Finally, thermal modeling is not well constrained for these bodies, leading to large uncertainties in estimating their albedo [11,16].

Science Objective and Instruments:

Our science objectives are summarized as follows:

- Characterize the surface of a Near Earth Asteroid of a spectral type not yet well explored (baseline is D-type).
- Characterize the interior structure of a small Near Earth Asteroid.
- Model the thermal properties of a small asteroid.
- Constrain the dynamical history of the asteroid type we explore.

To accomplish this, we prepare to bring onboard a suite of instruments allowing remote sensing of surface composition on the asteroid. These include a VNIR spectrometer, a thermal infrared hyperspectral camera system, a visual wavelength camera system, and radio science instrument. The combination of VNIR and TIR detectors will enable comprehensive coverage of the spectral features for D-type asteroids and other backup targets, ensuring good characterization of the surface composition. The TIR also allows measurements that will enable thermal modeling of the asteroid surface. The camera system will allow analysis of surface morphology and regolith properties in order to fulfill the science goals. Radio science at the asteroid will provide the global density and probe the interior structures of the asteroid.

	SPKID	Name	Class [-]	Albedo*	H	D* [m]	Rotationa Max I PeriodCent/ [h]	Grav
Primary	3708945	2015 BM510	D	0.05	25.1	57.0	0.806	8.4
Backup		2001 QJ142	E/M	0.33**	23.43	34.0**	0.173	242
Backup	20350523	2000 EA14 Q		0.26	20.2	150	NA	NA
Backup	20612227	2001 QC34Q		0.26	20.02	260	NA	NA
Backup	3727176	2015 RF36 Q		0.26	23.4	54.0	0.025	8717

Table 1: Identified possible targets. *Albedo is assumed based on typical albedo of the given spectral types, and Diameter (D) is based on this albedo assumption, **except for 2001 QJ142 [11].

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