Binary Asteroid in-situ Explorer Mission (*BASiX*): A Mission Concept to Explore a Binary Near Earth Asteroid System, Robert. C. Anderson[a], Daniel Scheeres[b], Steven Chesley[a], and the BASiX Science Team, [a]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [b]University of Colorado Boulder, CO 80203, Department of, USA, Robert.c.anderson@jpl.nasa.gov

Motivation: The Binary Asteroid in-situ Explorer (*BASiX*) Mission will actively probe the geophysics of a near-Earth Asteroid (NEA) in a controlled and repeatable manner. *BASiX* will make the first quantitative measurements of an asteroid's strength and seismic properties, and be the first to explore a binary asteroid system's mass morphology.

Introduction: In the decade since the *NEAR* mission explored Asteroid 433 Eros, ground-based and spacecraft observations of Near-Earth and small main belt asteroids (NEAs and MBAs) have caused a profound shift in our understanding of these bodies: 1) NEAs are "rubble-piles," aggregates of components forming a size distribution ranging from micron-sized particles to decameter-sized boulders, 2) NEA surfaces are driven by seismic phenomena and change by regolith migration, segregation, and space weathering processes, 3) NEAs commonly split apart to form new asteroids that either escape from each other or form stable binary systems, and 4) the geophysics of rubble pile bodies are expected to be fundamentally different than planetary bodies [1].

Despite the clear evidence that small asteroids undergo drastic physical evolution, the geophysics and mechanics of these processes remain a mystery due to a lack of scientific data on the mechanical properties of small asteroids in the unique micro-gravity regime they inhabit, on their mass distribution and morphology, and on their sub-surface and global geophysics. Previous explorations of NEAs stopped at remote observation or sample capture, and did not take the next step: direct interaction to measure how an asteroid responds to its environment. This has led to a profound gap in our knowledge of asteroid geophysics that *BASiX* will address.

The implications of the BASiX investigations go beyond understanding rubble pile asteroids. The interaction of aggregates in micro-gravity settings has occured throughout the solar system, both spatially and temporally. They were present in the early solar system when proto-planetary materials were interacting with each other forming the initial planetesimals [2] and continue to be present today in planetary rings [3] and on the surfaces and interiors of asteroids and comets [4]. In these micro-gravity environments, physical phenomena other than gravity, such as van der Waals and electrostatic forces, may play a crucial or even dominant role for the mechanics of solar system aggregates [5]. The direct study of micro-gravity physics on an asteroid surface – the best attainable physical analogue of early planetesimals – would revolutionize our understanding of aggregate mechanics in all of the realms they inhabit across the solar system.

This lack of knowledge about the strength, cohesion, and seismic properties of asteroids also limits our ability to plan and prepare for future exploration missions. Such information has been idenfitied by NASA as key Strategic Knowledge Gaps crucial for the exploration of these bodies. This information is also fundamental for the development of mitigation technologies to divert hazardous asteroids.

Until we can address this gap in our science, our understanding of asteroids as physical bodies will remain at a crossroads with fundamental questions concerning them remaining open.

What is a Rubble Pile Asteroid? A rubble pile asteroid is an object that is not made up of a single piece of rock, but consists of numerous smaller particles (a size distribution of boulders and grains that extends from microns to decameters). These are rock fragments that have coalesced following catastrophic collisions between larger asteroids. Rubble pile asteroids were first identified because they have low density (high porosity), presumably due to a high number of voids. Many of the calculated densities for this family of asteroids were significantly less than those identified for meteorites, which in some cases where determined to be pieces of specific asteroids by their chemical and spectral analysis. Such high porosities may be sustained by weak molecular cohesive forces between components of the size distribution, which can become dominant in this microgravity environment.

***BASiX* Objectives:** *BASiX* addresses fundamental questions concerning asteroids and aggregates in micro-gravity environments by focusing on two main scientific goals: 1) Understanding the unique geomorphology, dynamics, and evolution of a binary Near-Earth asteroid, and 2) Determine the strength, seismic, and space weathering properties of the surface and sub-surface of a Near-Earth asteroid.

Science Implementation Goals: To carry out these objectives *BASiX* will focus on carrying out clear and simple experiments in this novel environment:

- Explain and explore the unique global morphology of binary asteroids by carrying out detailed imaging and tracking campaigns in the binary system
- Quantify the strength and cohesion of an asteroid surface by detonating calibrated blasts on the surface and characterizing the surface and subsurface response
- Constrain and measure the seismic properties of a small solar system body by sensing calibrated experiments with surface packages
- Explore the fundamental geophysics of a rubble pile body by characterizing the rate at which tides dissipate energy
- Explore space weathering and compositional heterogeneity on the surface and interior of a rubble pile asteroid by mapping colors and spectra across its surface and subsurface

Target Selection: 1996 FG_3 is a primitive Near-Earth minor planet in the Apollo Group. 1996 FG_3 is an accessible binary asteroid that was previously the target for both the JPL/APL Galahad and Marco-Polo-R sample return missions. It is well characterized in terms of size, spin and orbit and has also been mapped spectrally and found to be heterogeneous with significant spectral variations [6].

The *BASiX* Team: *BASiX* is a joint proposal between the University of Colorado, JPL and Ball Aerospace, and has significant contributions from CNES. The PI is Dan Scheeres (CU), the Deputy-PI is Steve Chesley (JPL), and the Project Scientist is Bob Anderson (JPL). The Science Team has eminent scientists from across the globe, who are well prepared to implement and execute the fundamental investigations that are envisioned.

SUMMARY: The *BASiX* mission will perform the first geophysics science exploration of a primitive asteroid system. It will open a new understanding on the evolution aggregates in the solar system, enable future exploration of asteroids, and provide key information necessary for the mitigation of hazardous asteroids.

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