Explosive Surface Pods

Surface Pods for Low-Cost Geophysical Measurements

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BACKGROUND

Development of Explosive Pods Motivated by the Binary Asteroid in-situ Explorer (BASiX) Mission Concept

BASiX PI is Dan Scheeres, University of Colorado
- Ball Aerospace, JPL
- NASA Discovery Mission Concept
- Goal 1: Understand the unique geomorphology, dynamics, and evolution of a binary Near-Earth Asteroid (NEA) - Remote observations
- Goal 2: Determine the strength, seismic, and space weathering properties of the surface and subsurface of a NEA - Remote observations and in-situ cratering experiments using calibrated blasts

BASiX investigates the physics of solar system aggregates in microgravity to understand the planetary accretion processes
- Small NEAs are aggregates composed of large boulders to tiny particles
- Structures are continuously evolving and splitting
- Regolith migrates and segregates
- But, the geophysics and mechanics of NEA formation and evolution are unknown

BASiX will provide critical information for planning and preparing for human exploration of an asteroid and mitigation of threats

SCIENCE MEASUREMENTS

Science Measurements Address NASA Themes of Formation, Evolution, and Exploration of Solar System

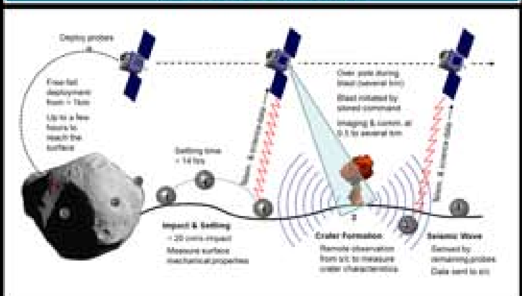
Primary Science

- Determine the physics of solar system aggregates in micro-gravity by exploring the structure and dynamics of "rubble pile" NEAs
- Quantify the *strength and cohesion* of an asteroid surface
  - Crater size (and formation time from ejecta)
    - Sensitive measure of surface strength
    - Scaling laws relate crater to abundant field data
  - Characteristics of the ejecta plume
    - Observe late-stage ejecta further from the blast
  - Morphology of the ejecta blanket
    - Determine if crater forms in strength or gravity regime
- Validate the hypothesis of *space weathering* on an asteroid surface
  - Spectral slopes and colors before and after blast

Enhanced Science

- Constrain the *seismic properties* of a small solar system body
  - Changes in surface from blast indicate efficiency of seismic shaking
  - Seismic waves characterize regolith porosity, depth, and interfaces
    - Travel time, amplitude, and width of first peak are good indicators of regolith characteristics
    - Seismic noise cross-correlation could detect regolith layering

MISSION CONCEPT



Simple, robust, and scalable mission design enables geophysics measurements of a near-Earth asteroid

DESIGN CONCEPT

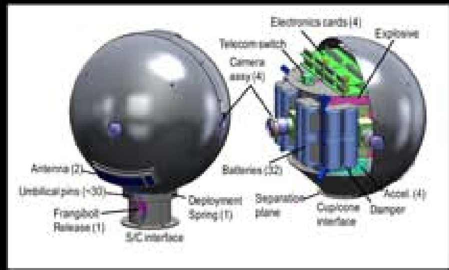
Simple, orientation-independent design

Scalable for the size of explosion and mission life required

27 cm diameter

16.25 kg mass - with 5.0 kg of explosive

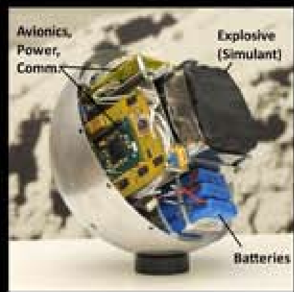
7 day nominal life



PROTOTYPE DEVELOPMENT

Ball Aerospace & Technologies Corp. is increasing the TRL of critical components for low-cost surface probes through a series of independent research and development projects.

Pod structure showing dual-band UHF antennas

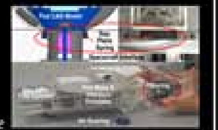


Pod structure showing internal electronics and explosive charge

SUBSYSTEMS

Spherical aluminum structure is independent of orientation
- *Internal housing for explosive simplifies integration and thermal management*

Release mechanism demonstrated proof of concept
- *Detailed error budget shows >29% margin on release velocity error requirement*
- *Error sources include deflection, spring relaxation (load, temp), spring constant, spring hysteresis, separation connector springs*
- *Excellent repeatability of separation velocity and angle*

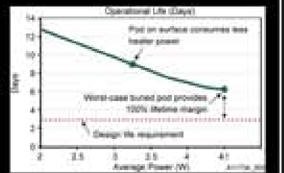


Metal foam damping system minimizes settling time
- *Passive approach with minimal weight and volume reduces probe velocity by ~50% on impact*

Key electronics developed under IRAD
- *Avionics board developed to TRL 4*
- *Compact, low power, highly functional and versatile*

Explosive system meets safety requirements with minimum size, weight, and cost
- *Hexanitrostilbene-II (HNS-II) was used for similar experiments during Apollo program*
- *Safe and arm system has 10 inhibits distributed throughout system*

Thermal and power designs and analysis shows good margin
- *Worst-case is buried pod at 1.5 AU – cold*



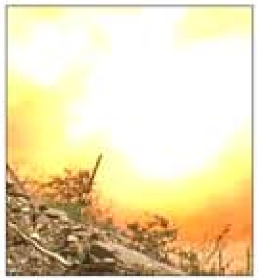
Accelerometers
- *Measure surface strength on impact*
- *Determine when probe is settled*

Geophone
- *Constrain the seismic properties of an asteroid*

Numerous commercial communications system options
- *Demonstrated at LEO*
- *Close ranges and low data rates relaxes requirements*

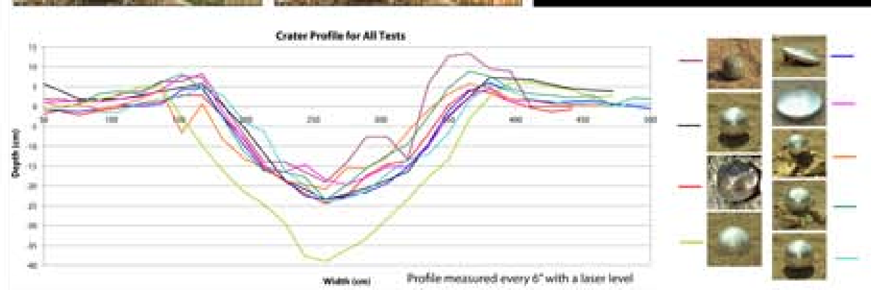
Ball Aerospace-built dual-band Tx/Rx UHF patch antennas
- *2 antennas oriented to minimize interference pattern*
- *95% coverage of hemisphere ~ -17 dBi*

FULL-SCALE BLAST TESTING

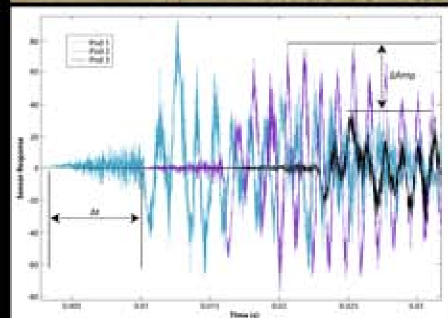


Test Objective:
Determine the effect of the pod structure, shape, orientation, and surface coupling on the size of the blast crater and signal received by distant sensor pods.

Conclusions:
1. Crater size is not dependent on pod structure, shape, or orientation on the surface.
2. Crater size is dependent on the extent of burial of the pod.
3. Seismic wave velocities and amplitudes can be measured from distant sensor.



Profile measured every 6" with a laser level



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