Collectible Projectosats

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Outline

• Introduction: Femtosatellites
• Goal: Asteroid Sample Return
• Motivations for Goal
• Concept Description: Collectible Projectosats
• Focus on Magnetic Recollection
• Variations in Design and Use
• Conclusions
Introduction: Femtosatellites

• Femtosatellites = 0.1 kg or less
• Easy to mass produce and to transport
• What can’t be miniaturized?
  – Communications, Delta-V, propellant
• Ideal for:
  – remote inspection
  – distributed measurement
  – disposable sensors
Potential Application:
Asteroid Sample Return

Comets too!
KBOs?
Past, Present, and Future Missions

• Various teams and countries
  – Hayabusa/Muses-C, Hera, RISR
• Advocacy Groups
  – www.permanent.com
• Extensive analysis of many aspects
  – Several NIAC Projects
• Therefore: Focus on Collectible Projectosat concept feasibility

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What are asteroids made of?

*Castalia: 50% Porosity*

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Scientific Motivation

- Primordial Leftovers: Asteroids, Comets, and Kuiper Belt Objects
  - Provides data on solar system formation
- Structure and History
- Sample Return: exact chemical analysis, isotopic ratios, biogenic tests, meteor comparisons, minerological structure…
- Avoiding NEA Impact

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Commercial Motivation (?)

- Asteroid Mining
  - “Fort Knox in the sky”
- Source of volatiles for other space missions
- Other In-Situ Resources
- Natural space stations
- Earth to Mars via asteroids
- Etc.

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Engineering Difficulties

- Most asteroids are rapidly rotating (movie)
  - Some even rotate irregularly
  - Spinning up to asteroid rotation is costly
- Microgravity environment is challenging
Concept Description: Collectible Projectosats

Release dozens of simple femtosatellites near an asteroid, thus tracking the gravity field. When they land, they passively (or actively) capture surface regolith. Some of the collectible “projectosats” (coined by DR) are returned to the mother satellite using a powerful electromagnet. This process can then be repeated for non-metallic asteroids. In such a manner, samples from dozens of locations on several asteroids can be carefully collected, processed, analyzed, and/or returned to Earth for further study.
Asteroid Superstructure

- Internal structure currently unknown: rubble piles?
- Mass concentrations?

- Use radar tracking of projectosats to map gravity field (maybe magnetic field?)
  - Known masses and orbits give lots of data
  - Higher harmonics reveal density concentrations

- Difficulty: when the asteroid obscures

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Analysis: Magnetic Recollection

• Using modest parameters, magnetic force is about 1mN / d^4 (m^4)
  ➔ From a 1 km asteroid, d = ~12 m
    Magnetic force scales as r_{ps}^3
    Asteroid surface gravity scales as R, g ~ R_{ast}
  ➔ Maximal distance (for small asteroids): d = 30 m

• Difficulties:
  – High velocities near the electromagnet
  – “Stickiness” of surface
  – No iron meteorites

\[ F = \frac{3\mu_0 \mu_A \mu_B}{2\pi d^4} \]
Getting the mothersat close

• Retrograde quasi-periodic orbits are stable even near the surface for stably-rotating asteroids (Scheeres, 1996)
• Easier than current “touch-and-go” sampling
• Thrust necessary for non-stable orbits <μN
  – Not hard: Micro-thrusters or Ion Engines
• Surface feature avoidance
  – Mostly no “boulders” → surfaces roughly level
  – Respond in minutes → possible in microgravity
→ Probably not effective for entire surface
Variations on the Release

- Use electromagnet “cannon” to shoot projectosats at high velocities
  - Study cratering pattern
  - Collect subsurface samples!
  - Important for determining presence of volatiles = water
    → assay for future mining
- Gather ejecta as samples!
  - a la RISR

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Focus on Magnetic Recollection

- (Remember: projectosats are disposable)
- Time-consuming to cover entire surface
  → Use for small numbers of projectosats
  → Use for cratering and then subsurface sampling and then recollection
  → Extra advantage: great for imaging and other sensors
Variations on Projectosats

• Different shapes and sizes
• More powerful magnets (NIB) increase collection range
  – Equip with mini-electromagnets?
• Jump (using a spring) up to the mothersat
• Release chemicals or irradiation on a small surface to aid analysis
• Use “in-situ” projectosats: local pebbles?
• Active thrust, sensors, communications
  – Perhaps even rover(s) could be deployed and collected
• MEMS technology
MEMS Technology

- Gathering materials
- Moving
- Burrowing
- Imaging
- Seismology
- Power collection

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Other Projectosats!

• Launch/shoot probes
  – like mass drivers, but not for cargo and not necessarily launched from a surface
  – can impart huge $\Delta V \approx 10 \text{km/s}$
  – into usually unattainable orbits
  – large distances in short times
  – remember: no atmospheric drag

• Difficulty: extremely high accelerations
Conclusions

• To zeroth order, concept is feasible and scaleable!
• Many possible variations; some useful
  – Distributed network to map gravity field
  – Magnetic recollection at ~10 meters for single objects
  – Impart large $\Delta V$
• Future Work: I’m not done yet!
  – Simulation of many projectosats falling onto an irregular body
  – Comparison to current asteroid sample return missions
  – Potential high-energy atypical orbit study
  – Refining electromagnet properties and use
  – Publishing?

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