

Intrepid:

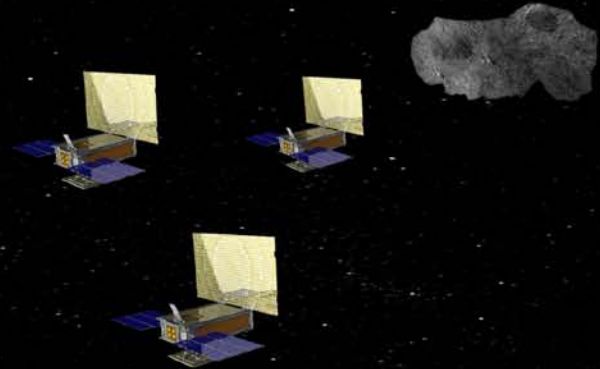
A Dual-use Spacecraft Concept

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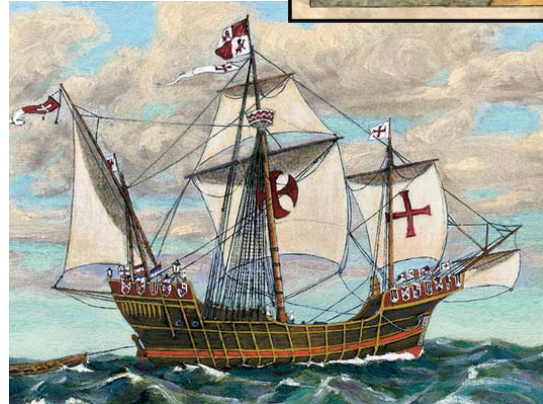


Jet Propulsion Laboratory
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Intrepid: A dual-use spacecraft concept

A Fleet of Highly Autonomous SmallSat Explorers

- Send 50-100 spacecraft to rendezvous with dozens of NEO targets
- Exploration objectives
 - Science characterization
 - Resource identification
 - Deflection preparedness
- Key feature: Low cost to
 - Build – streamlined production
 - Launch – secondary payload up to 10 s/c per ESPA
 - Operate – high levels of autonomy
- Submitted to NASA's recent "Planetary Science Deep Space SmallSat Studies" ROSES call
 - Not selected for further study (at this time...)



Intrepid: A dual-use spacecraft concept

Rapid-response NEO Characterization and Observation

- Characterize potentially threatening asteroid as quickly as possible
 - Avoid lengthy spacecraft development process (Minimum ~2-3 years to launch)
 - Use fleet-proven, off-the-shelf spacecraft
 - Flyby or rendezvous, depending on objectives, schedule and trajectory constraints
- Serve as observer spacecraft to confirm deflection
 - For demonstration or real-world deflection



Intrepid Overview

The Intrepid Fleet Exploration Concept

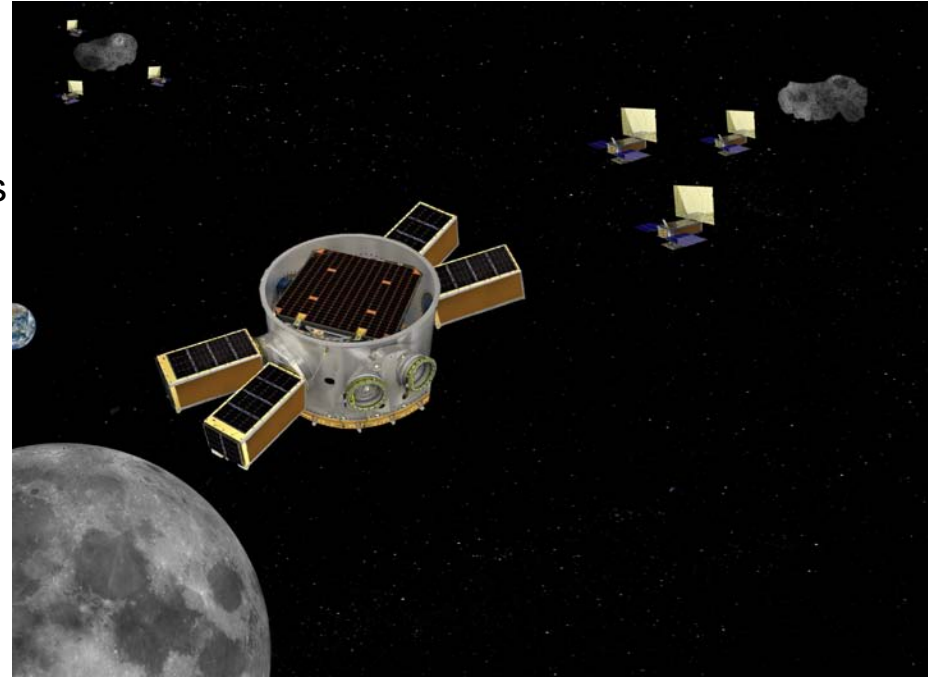
- Employ commercial fabrication approaches to reduce spacecraft cost
 - Leverage UAV development efforts
- Include 2-3 modular instruments per spacecraft
- Deploy 2-3 spacecraft per target asteroid
- “Launch-and-forget” SEP spacecraft self-navigate to target without ground support
 - Autonomous rendezvous
 - Autonomous execution of global mapping (for generic targets)
 - Only occasional contacts for status checks



Intrepid Development & Deployment

The Intrepid Fleet Exploration Concept

- Deploy from ESPA/SHERPA-style upper stage to reach $C3 \lesssim 0$ at separation
 - Post-deployment, use SEP system increase energy through lunar encounters
 - Allows 10 spacecraft per ESPA
- Mass production requires deliberate prototyping and testing
 - Ground-testing of integrated s/c
 - Flight testing of 2-3 s/c to single target
 - Flight testing of 10 s/c to ~5 targets
 - Full deployment of 10-20 s/c per year
- Size of Ops team roughly constant as autonomy matures and number of deployed spacecraft grows



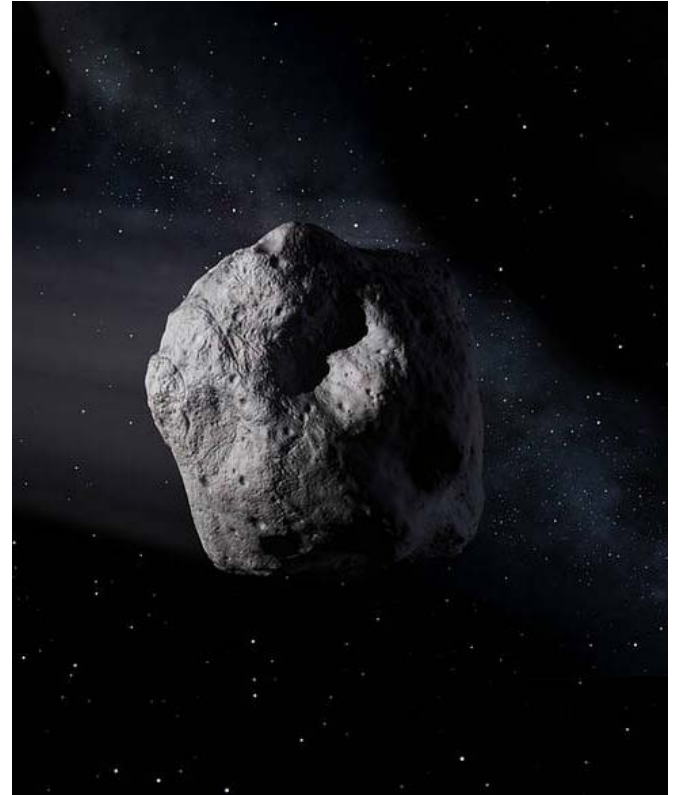
Intrepid Science

The Intrepid Fleet Exploration Concept

Small Body Science: Intersection with resources and planetary defense

First Order Questions:

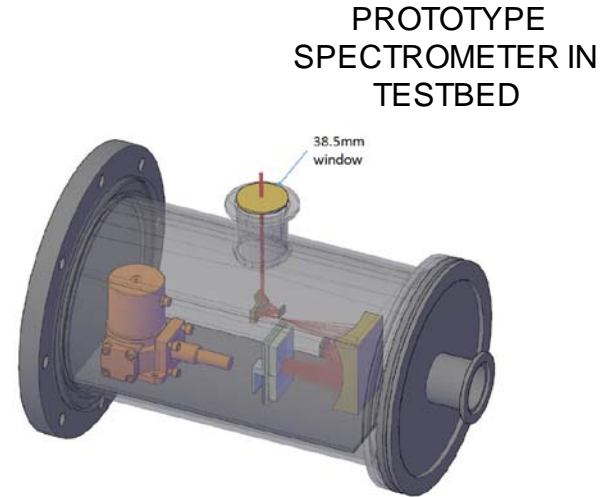
- What is the total quantity of water (includes both ice & hydrated silicates) contained in each object?
 - How is the water distributed (ice, silicates)?
 - Are organics present? What types?
- What is the physical structure of the objects?
 - What is the macroporosity?
 - Layering, water ice lenses?
 - How would object respond to impact/deflection?



Intrepid Science

The Intrepid Fleet Exploration Concept

- Multiple (modular) instrument concepts
 - Imaging camera
 - IR/thermal spectrometer
 - Thermal imager
 - Neutron spectrometer
 - Radar sounder
 - Seismic charge & probe
 - Altimeter
- Numerous instrument options available for SmallSat missions at varying levels of readiness
- Concept study needed to develop and refine instrument concept

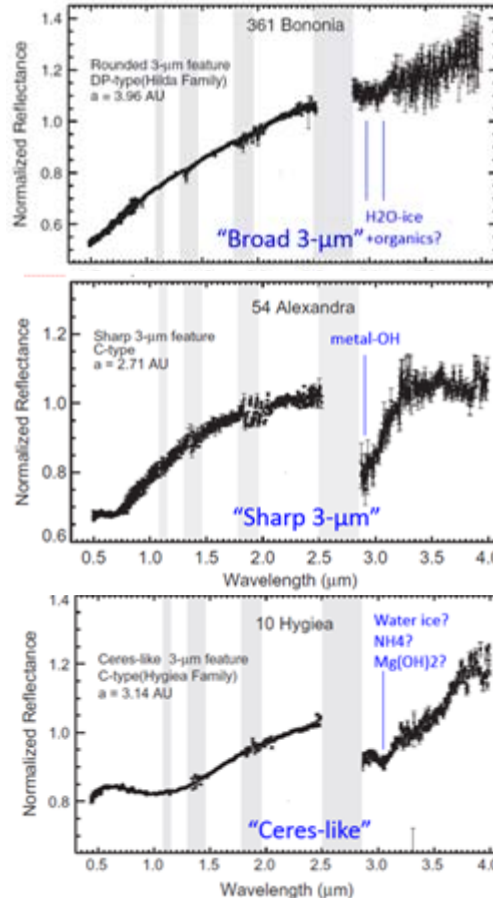


Intrepid Science

Payload element: IR point spectrometer

- We are developing a 2U form factor point spectrometer for surface volatile assessment (quantity, nature of the host material)
- Instrument performance set by the ability to distinguish 3 classes of meteorites and observed telescopic variability
- SWIR (2.5 – 3.5 μm) and Thermal IR (5.5 – 12 μm) in a single instrument

Both SWIR + Thermal IR data are needed

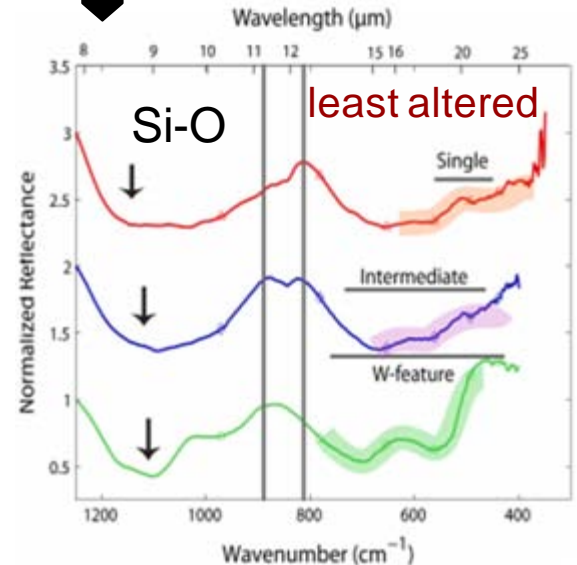


Volatiles in Asteroids

Takir & Emery, 2012

Silicates in Primitive Meteorites

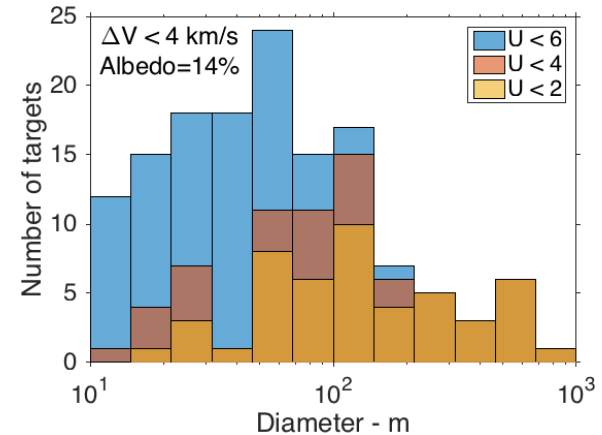
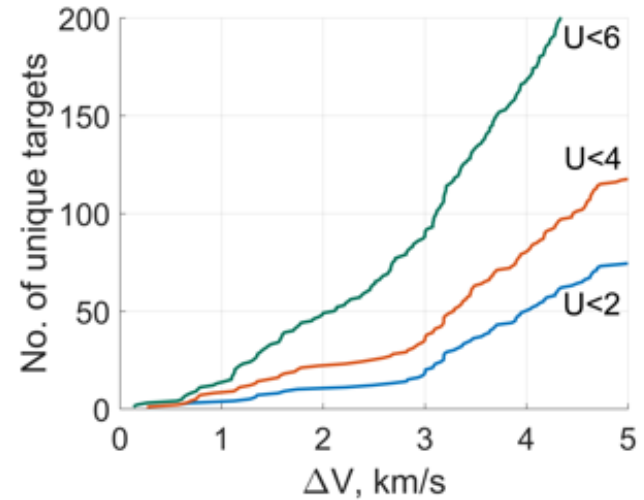
McAdam et al., 2015



Intrepid Targets

The Intrepid Fleet Exploration Concept

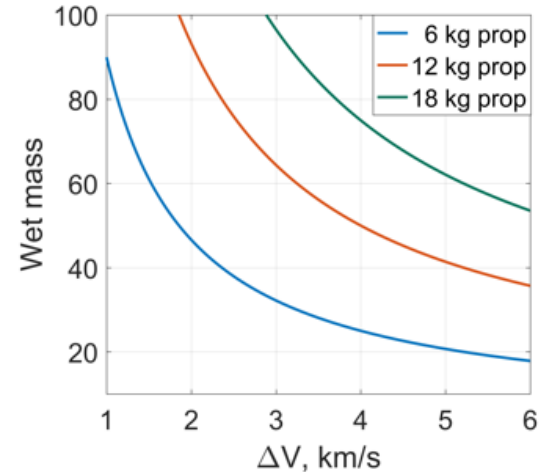
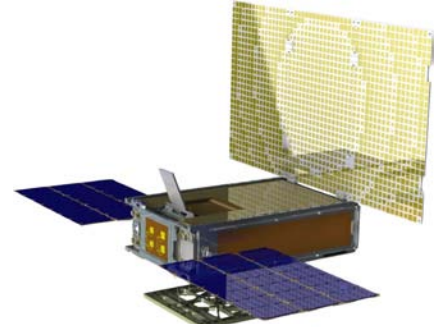
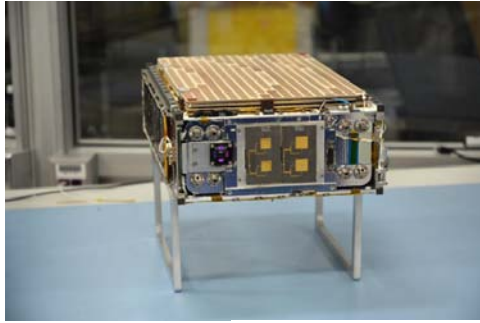
- Earth-similar orbits required for SmallSat rendezvous from $C3 < 0$
- There are ~80 accessible candidate targets in the *current* NEA catalog
 - For ΔV capability ~4 km/s
 - Orbital uncertainty $U < 4$
- Diameters: 10s to 100s of meters



Intrepid Spacecraft

The Intrepid Fleet Exploration Concept

- Relies on significant recent advances on SmallSat development
 - Marco is a good point of departure
- ~50-100 kg mass at launch
 - 2-4 Hall thrusters at 6 kg xenon each
 - Shielded EP thrusters (in development) may increase propellant throughput, reducing the number of thrusters needed to obtain a given ΔV



Intrepid Autonomy

The Intrepid Fleet Exploration Concept

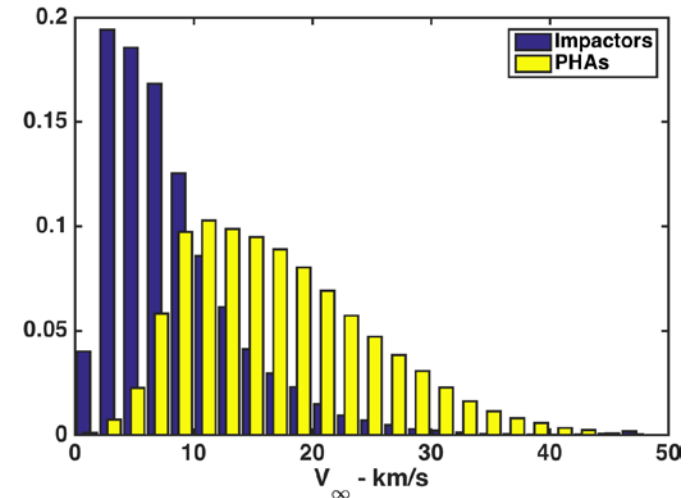
- Autonomous cruise navigation and guidance
 - Derived from JPL autonav system
 - Optical navigation based on “beacon” positions
 - Earth or Moon prior to departure
 - Main-belt asteroids in cruise
 - Target asteroid for rendezvous
 - Beacon nav demonstrated with main-belt asteroids by the DS1 mission
- Post-rendezvous exploration strategy based on execution of template trajectories and instrument sequences
 - Agile Science capability allows for automated measurements of unexpected events
- Downlink of science archive at intervals or at conclusion of target exploration

Intrepid as a First Responder

The Intrepid Rapid-Response Characterization Concept

- The Intrepid spacecraft concept is well-suited to provide a rapid-response characterization capability
 - Mass, shape, multiplicity, even surface response
- Characterization spacecraft could also serve as deflection observer for confirmation
 - Or Intrepid observer could be launched later on different trajectory
- The Intrepid exploration program could preserve a few spacecraft in FIFO storage for use in urgent situations
 - Whenever shelf life is approaching, launch as an exploration mission
- Since the program does not get to choose its target, extra boost capability may be needed
 - Larger launch vehicle
 - Larger (SHERPA) boost stage
 - Only 1-3 spacecraft on one boost stage
 - Can readily reach high C3, and even use boost stage for DSMs

For a random PHA or potential impactor, the Intrepid spacecraft may not be able to effect a rendezvous from $C3 \sim 0$, but extra boost capability can be provided as needed.

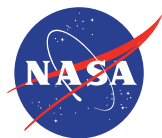


Conclusions

Intrepid as a Swiss Army Knife?

- Intrepid functions
 - Fleet of explorers
 - Rapid responder
 - Impact observer
- Must be
 - Small
 - Simple
 - Versatile





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