ISIS
Impactor for Surface and Interior Science

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ISIS Mission Concept

- **ISIS launches as a secondary payload**
  - Multiple host launch options available
  - Flight system based on ESPA minimizes impact on primary payload

- **After 2-4 year cruise, ISIS impacts the asteroid Bennu while OSIRIS-REx is in a position to observe**
  - Arrival is timed after OSIRIS REx has collected its sample, during period of “quiescent” operations

- **ISIS creates crater tens of meters in diameter**
  - OSIRIS-REx images the impact from a safe vantage point

- **After debris clears, image crater and collect spectra of pristine material exposed by impact**
- **Measure asteroid delta-V due to impactor**
ISIS would leverage significant NASA investments to deliver potential Discovery-level science while providing a first-time demonstration of asteroid deflection at a fraction of the cost of a stand-alone mission.
June 18 NASA Asteroid Initiative included the Grand Challenge to “find all asteroid threats to human populations and know what to do about them.”

- An intersection of Technology, Exploration and Science goals

- Specific program goals include: “Accelerating efforts to improve detection, characterization, and mitigation of potentially hazardous asteroids to help plan for the defense of our planet against the threat of catastrophic collisions”
**Recommendation**: “If Congress chooses to fund mitigation research at an appropriately high level, the first priority for a space mission in the mitigation area is an experimental test of a kinetic impactor along with a characterization, monitoring, and verification system… This mission would produce the most significant advances in understanding… in a realistic mitigation scenario.”
ISIS Addresses
Small Body Exploration SKGs

2012 SBAG reports details Strategic Knowledge Gaps for Human Exploration goals.

<table>
<thead>
<tr>
<th>SKG Theme</th>
<th>SKG Category</th>
<th>SKG Example</th>
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<tbody>
<tr>
<td>II. Understand how to work on or interact with the SB surface</td>
<td>II-C. SB surface mechanical properties</td>
<td>II-C-1. Macro-porosity of SB interior</td>
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<td></td>
<td>II-C-2. (Critical) Geotechnical properties of SB surface materials</td>
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<td></td>
<td>II-D. Mobility around and interaction with surface in microgravity conditions</td>
<td>II-D-1. (Critical) Anchoring for tethered activities</td>
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<td>III. Understand the SB environment and its potential risk/benefit to crew, systems, and operational assets</td>
<td>III-A. The particulate environment in the proximity of Small Bodies</td>
<td>III-A-1. (Critical) Expected particulate environment due to impact ejecta</td>
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<td></td>
<td>III-A-2. Possible dust/gas emission via sublimation from volatile-rich objects</td>
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<td>III-A-4. (Critical) Possible particulate environment in the asteroid exosphere due to charged particle levitation following surface disturbances</td>
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<td>III-D. Local and global stability of small bodies</td>
<td>III-D-1: (Critical) Local structural stability based on remote measurements</td>
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<tr>
<td></td>
<td>III-D-2: (Critical) Global structural stability based on remote measurements</td>
<td></td>
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<tr>
<td>IV. Understand the SB resource potential.</td>
<td>IV-A. NEO Resources</td>
<td>IV-A-2. Knowledge of how to excavate/collect NEO material to be processed</td>
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</table>
ISIS Addresses Major Science Questions

- What is the local response?
  - Ejecta field properties
    - Creation of meteorite precursors
    - Ejecta blanket
    - Re-impacts
  - Crater morphology
  - Possible volatile release

- What is the global response?
  - Trajectory change ($\Delta V, \beta$)
  - Rotation change ($\Delta \omega, I_{zz}$)
  - Change in shape
  - Seismic activity
    - Internal structure
    - Material mobility
    - Particulate environment
  - Debris Environment

- What are the geotechnical properties of the near-surface material?
  - Strength
  - Cohesion
  - Porosity
  - Particle size distribution

- What is the geology of the sub-surface?
  - Stratigraphy
  - Structure
  - Composition
  - Mineralogy
  - Weathering

ISIS delivers potential Discovery-level Science, closes Exploration SKGs and demonstrates NEO Deflection Technology, all for a fraction of the cost of a Discovery mission.
ISIS Flight System Overview

- System designed around flight-qualified ESPA
  - Imposes no impact on host SC/LV interface
- Modular Flight System
- Spacecraft Architecture emphasizes simplicity and reliability
  - No Crosslink
  - No Pyrotechnics
  - No Deployments
  - No Mechanisms
  - No Science Instruments

Pre-Decisional Information. For Planning and Discussion Purposes Only.
ISIS Targeting Scenario

Initiation of terminal guidance with AutoNav at ~E-2 hours

1st targeting maneuver at ~E-1 hr

Images taken at 2 min intervals. 1st OD solution after ~30 min

2nd targeting maneuver at ~E-30 min

3rd targeting maneuver at ~E-2-4 min

Images taken at 30 sec intervals.

Terminal guidance provided through JPL AutoNav technology. Demonstrated on Deep Impact mission.

Abort Scenario
Spacecraft would be on a miss trajectory until first terminal maneuver at 60 min before impact. Targeting would not occur unless pre-defined, NASA-approved criteria are met. Abort commands could be issued as late as 30 minutes before impact.
**Notional ISIS Baseline Mission**

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch</td>
<td>Late 2017</td>
</tr>
<tr>
<td>Arrival &amp; Impact</td>
<td>March 2021</td>
</tr>
<tr>
<td>Impact Velocity</td>
<td>14 km/s</td>
</tr>
<tr>
<td>Impact Mass</td>
<td>600 kg</td>
</tr>
<tr>
<td>Impact Energy</td>
<td>78 GJ (~19t TNT)</td>
</tr>
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</table>

**OSIRIS-REx Activities**

1. Pre-impact characterization of asteroid ephemeris
2. Image impact from a safe location
3. Monitor ejecta as it dissipates
4. Crater reconnaissance
5. Radio science and global remapping
## ISIS Potential Launch Opportunities

<table>
<thead>
<tr>
<th>Launch Opportunity</th>
<th>Launch Date</th>
<th>Maneuver ∆V (m/s)</th>
<th>Impact Velocity (km/s)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>InSight Primary</td>
<td>Mar-2016</td>
<td>1220</td>
<td>14.9</td>
<td>Originally the primary option. No longer available due to schedule and fiscal issues.</td>
</tr>
<tr>
<td>OSIRIS-REx</td>
<td>Sep-2016</td>
<td>360</td>
<td>11.0</td>
<td>Ideal launch opportunity, but not an option due to schedule and fiscal issues.</td>
</tr>
<tr>
<td>InSight Backup</td>
<td>Nov-2017</td>
<td>600</td>
<td>13.8</td>
<td>Good option, but unlikely to materialize</td>
</tr>
<tr>
<td>b612 Sentinel</td>
<td>Aug-2017</td>
<td>1200</td>
<td>8.0</td>
<td>Privately funded NEO survey mission is awaiting donor commitments to move into Phase A. 2018 and later launches not suitable.</td>
</tr>
<tr>
<td>Generic Mars 2018</td>
<td>May-2018</td>
<td>600</td>
<td>13.8</td>
<td>Good, but no obvious EELV launches on schedule</td>
</tr>
<tr>
<td>GTO – Target Bennu</td>
<td>Mid-2017 to late 2018</td>
<td>700 – 1100</td>
<td>10 – 15</td>
<td>Assumes extra help from LV in some cases. Feasible, but many options to be considered. Need to know specifics of candidate GTO launch.</td>
</tr>
<tr>
<td>GTO – Target 1999 JU3 (Hayabusa 2)</td>
<td>Early 2017 to mid-2018</td>
<td>900-1100</td>
<td>8.0 – 9.5</td>
<td>Similar to or better than GTO. But not ESPA compatible</td>
</tr>
<tr>
<td>SLS Test Launch</td>
<td>2017-18</td>
<td></td>
<td></td>
<td>Similar to or better than GTO. But not ESPA compatible</td>
</tr>
<tr>
<td>Dedicated launch</td>
<td>2018-19</td>
<td>0 – 500</td>
<td>10 – 15</td>
<td>Any of the GTO escape cases can be used. Many of the solutions are ballistic.</td>
</tr>
</tbody>
</table>
Current ISIS Planning Activities

- Direct engagement with OSIRIS-REx project
  - Objectives include development of
    1. Science Management plan
    2. Operational implementation plan
    3. ISIS-related requirements
    4. ROM cost to OSIRIS-REx project for ISIS investigation
  - Face-to-face OREx/ISIS meeting planned for late January to conclude interaction

- Working to develop new baseline mission plan
  - Consulting with satellite and launch providers to identify suitable GTO launch in late 2017 or early 2018
  - Phase A start early to mid-FY15

- Continuing with higher fidelity debris clearing simulations
- Objective is to be ready for a quick start in the event that budget situation improves