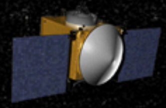
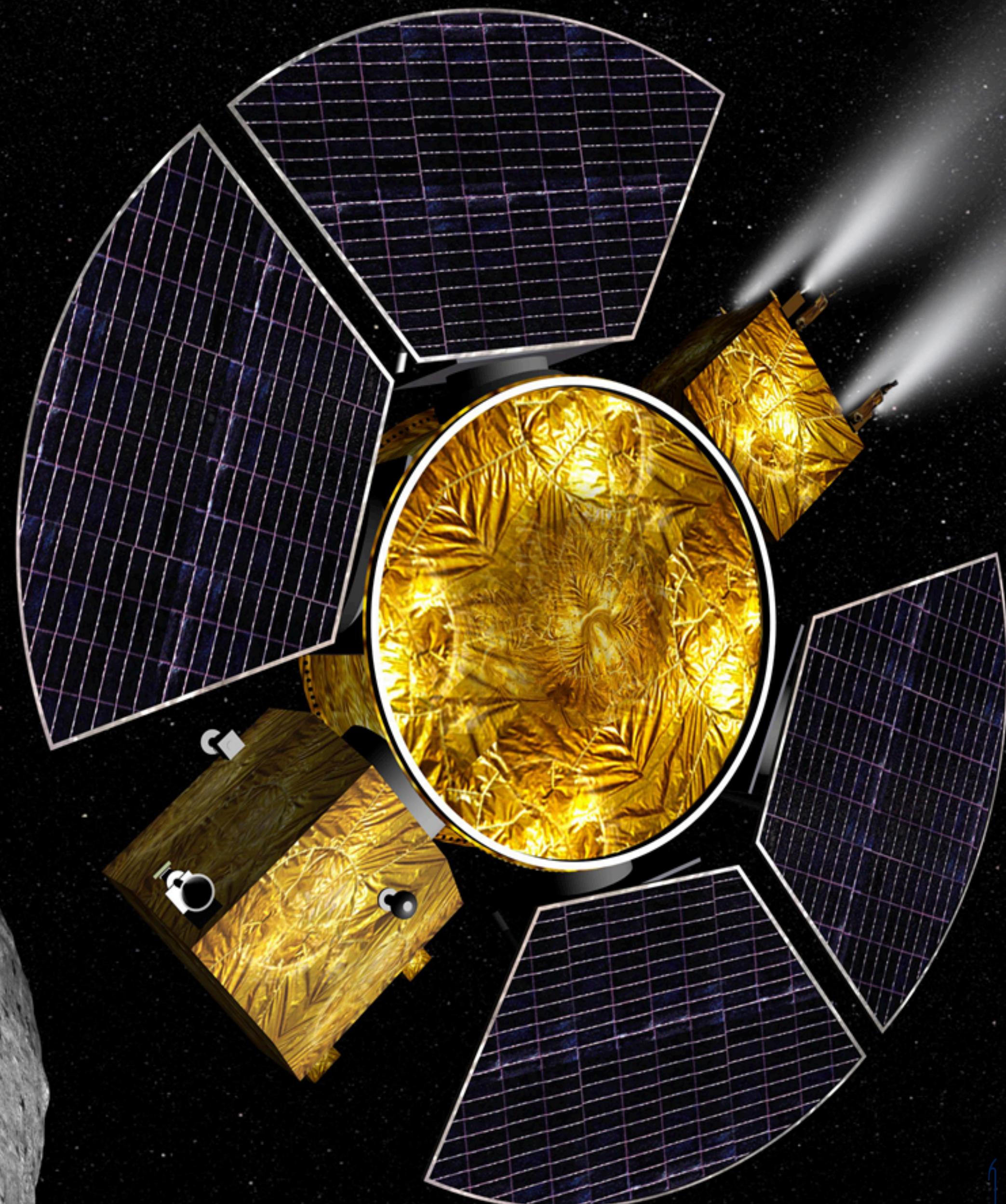


ISIS

Impactor for Surface and Interior Science



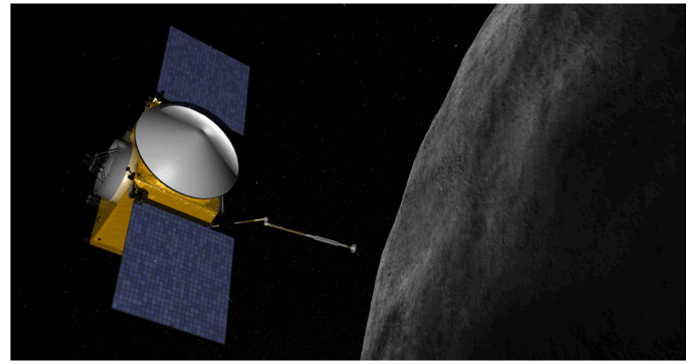
Steve Chesley & The ISIS Team

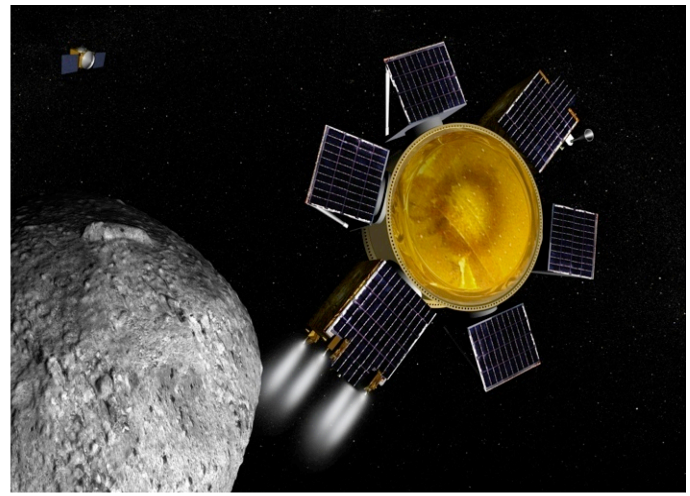
Small Bodies Assessment Group

July 11, 2013 Briefing

ISIS Mission Concept

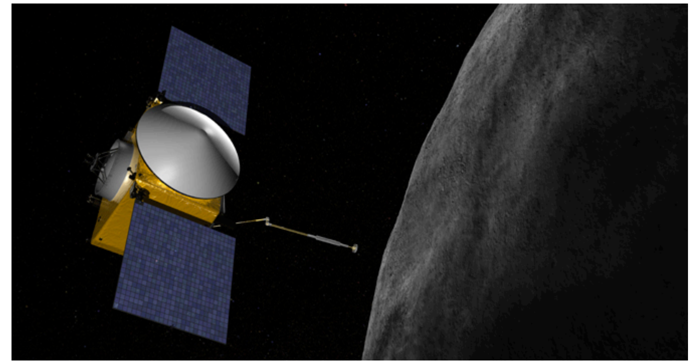
- ISIS launches as a secondary payload with the InSight mission
  - Flight system based on ESPA minimizes any impact on InSight
- Five years after launch, ISIS impacts the asteroid Bennu while OSIRIS-REx is in a position to observe
  - Arrival is timed after OSIRIS REx has finished primary mission, during 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

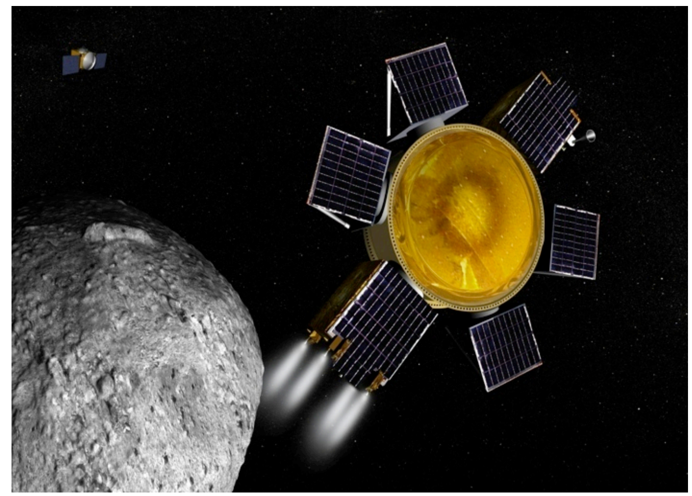




ISIS Mission Concept

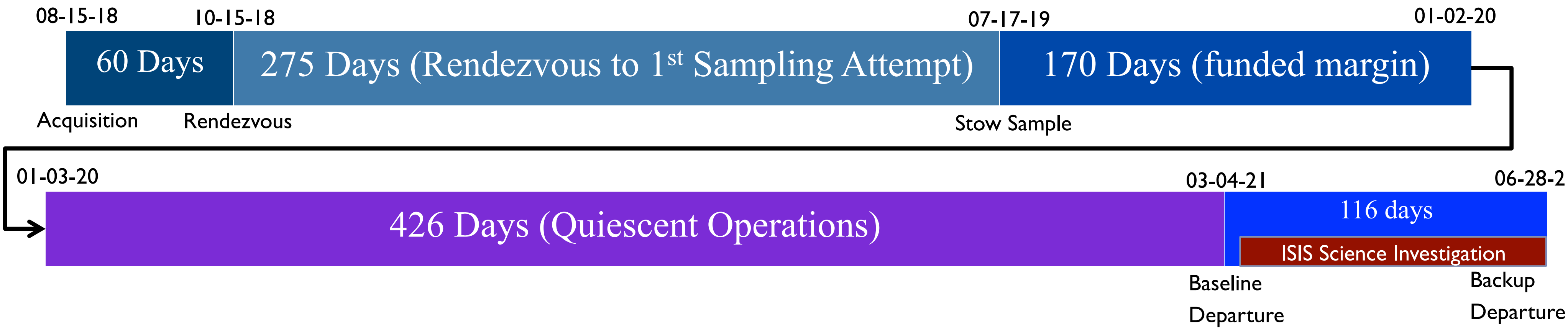
***ISIS** would leverage two significant NASA investments to deliver Discovery-level science while providing a first-time demonstration of asteroid deflection at a fraction of the cost of a stand-alone mission.*





ISIS/OSIRIS-REx Operations Concept

OSIRIS-REx Timeline

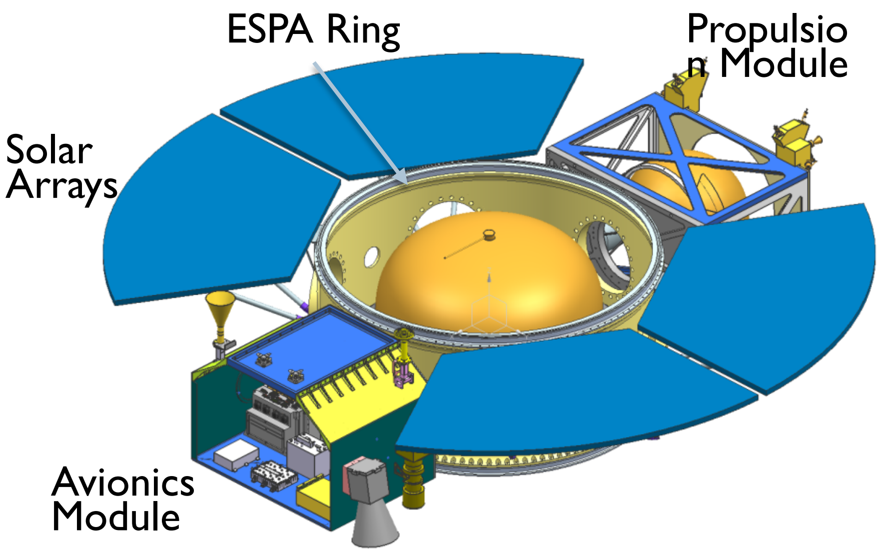


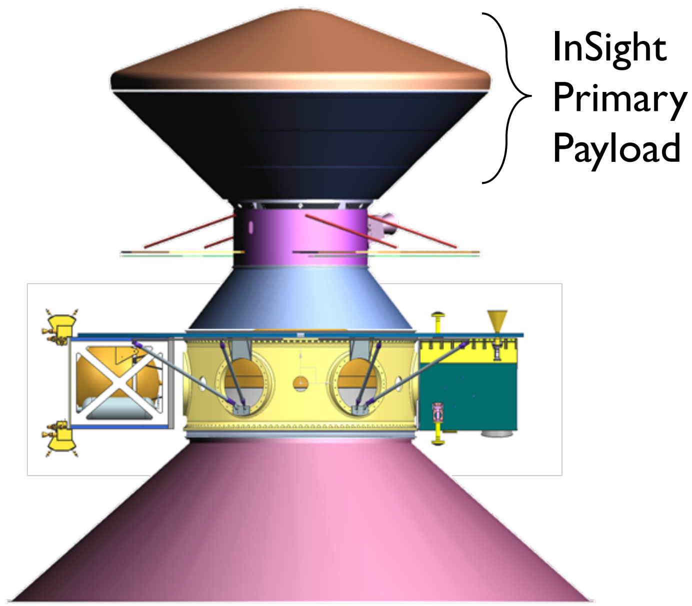
ISIS Baseline Mission	
Launch	04-Mar-2016
Mission ΔV	1.22 km/s
Arrival & Impact	10-Mar-2021
Arrival Phase Angle	10°
Impact Velocity	14.9 km/s
Impact Mass	530 kg
Impact Energy	59 GJ (~14t TNT)

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 Flight System Overview





- System designed around flight-qualified ESPA

  - Imposes <u>no impact</u> on host SC/LV interface
- Modular Flight System
- Spacecraft Architecture emphasizes simplicity and reliability
  - No Crosslink
  - No Pyrotechnics
  - No Deployments
  - No Mechanisms

NEO Grand Challenge

- 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"

ISIS Demonstrates Deflection Technology

- Demonstrate a capability to guide a spacecraft to a hypervelocity impact on a small asteroid
  - Relatively coarse terminal guidance (~1 km) demonstrated by Deep Impact. ISIS accuracy objective is 100 m with 99% confidence.
- Understand the deflection response of a small asteroid to a hypervelocity impact
  - Ability to even roughly predict response significantly eases deflection design
  - Demonstrate ability to "steer" an asteroid through an oblique impact
- The ability to launch a deflection mission on short notice (<29 months) is a key technological capability that will be proven by ISIS
  - Rapid development lessons learned white paper will be a mission deliverable

NRC 2010 Near-Earth Object Report

"Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies: Final Report"

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**, such as the Don Quijote mission that was previously considered, but not funded, by the European Space Agency. This mission would produce **the most significant advances in understanding** and provide an ideal chance for international collaboration in a realistic mitigation scenario."

- Following each PDC, an international consensus white paper is developed:
  - Granada, Spain (2009)
    - "Deflection-related testing should be included as part of science missions to asteroids and comets to increase information relevant to the mitigation process."
  - Bucharest, Romania (2011)
    - "Missions should be planned to demonstrate and validate the most promising deflection or disruption options."
  - Flagstaff, Arizona (2013)
    - Recommendations: "Verification of our ability to move an asteroid"

Small Body Exploration SKGs

2012 SBAG reports details Strategic Knowledge Gaps for Human Exploration

SKG Theme	SKG Category	SKG Example
II. Understand how to work on or interact with the SB surface	II-C. SB surface mechanical properties	II-C-1. Macro-porosity of SB interior
		II-C-2. (Critical) Geotechnical properties of SB surface materials
	II-D. Mobility around and interaction with surface in microgravity conditions	II-D-1. (Critical) Anchoring for tethered activities
III. Understand the SB environment and its potential risk/ benefit to crew, systems, and operational assets	III-A. The particulate environment in the proximity of Small Bodies	III-A-1. (Critical) Expected particulate environment due to impact ejecta
		III-A-2. Possible dust/gas emission via sublimation from volatile-rich objects
		III-A-4: (Critical) Possible particulate environment in the asteroid exosphere due to charged particle levitation following surface disturbances
	III-D. Local and global stability of small bodies	III-D-1: (Critical) Local structural stability based on remote
		III-D-2: (Critical) Global structural stability based on remote measurements
IV. Understand the SB resource potential.	IV-A. NEO Resources	IV-A-2. Knowledge of how to excavate/collect NEO material to be processed
		IV-A-3. Knowledge of extracting and collecting resources in micro-g.

SMD Solar System Exploration Roadmap

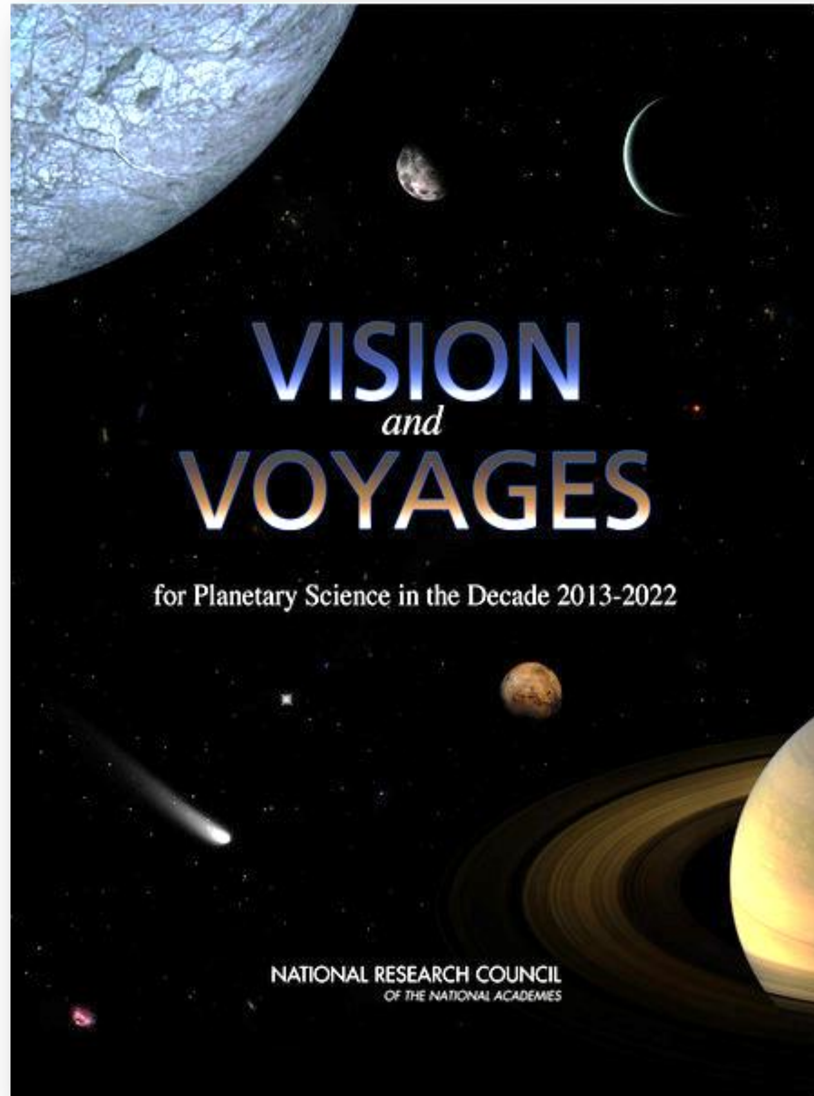
Theme	Question	Investigation
I. Origin	*How did primitive bodies originate?*	Study the processes that determine the original characteristics of bodies in the solar system
II. Evolution	*How did primitive bodies come to their present state?*	Determine how the processes that shape planetary bodies operate and interact
V. Exploration	*How can these bodies affect us, for good or ill?*	Determine the dynamics of bodies that may pose an impact hazard on Earth
		Understand the impact process in different planetary settings
		Characterize planetary resources that can sustain and protect human explorers

ISIS addresses Major SSE Questions

NRC 2011 Planetary Decadal Report

"Vision and Voyages for Planetary Science in the Decade 2013 – 2022"

- On prioritizing planetary missions: "The first and most important [criterion] was science return per dollar."
- Questions on "formation, accretion and evolution" of primitive bodies:
  - How do physical processes affect the evolution of small bodies?
  - What are the geophysical properties of primitive bodies?
  - What solar system bodies endanger Earth's biosphere?
  - How have the myriad chemical and physical processes that shaped the solar system operated, interacted, and evolved over time?

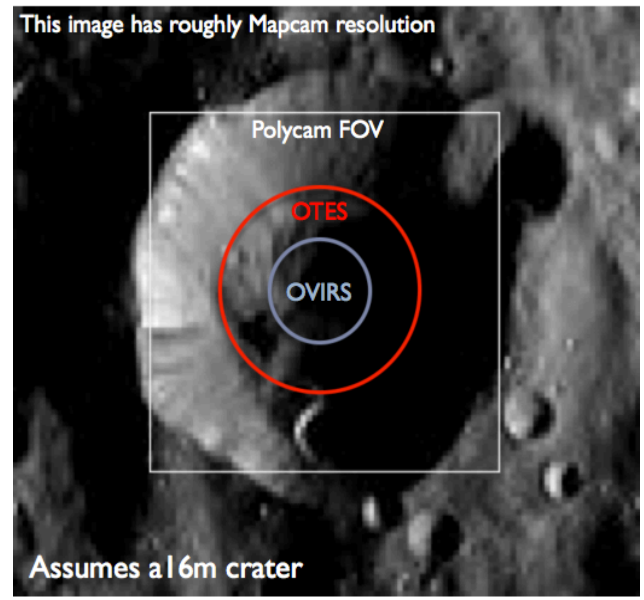


Planetary Defense, Exploration & Science Benefits

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

- 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 (ΔV, β)
  - Rotation change ($\Delta\omega$, I_{zz})
  - Change in shape
  - Seismic activity
    - Internal structure
    - Material mobility
    - Particulate environment
  - Debris Environment

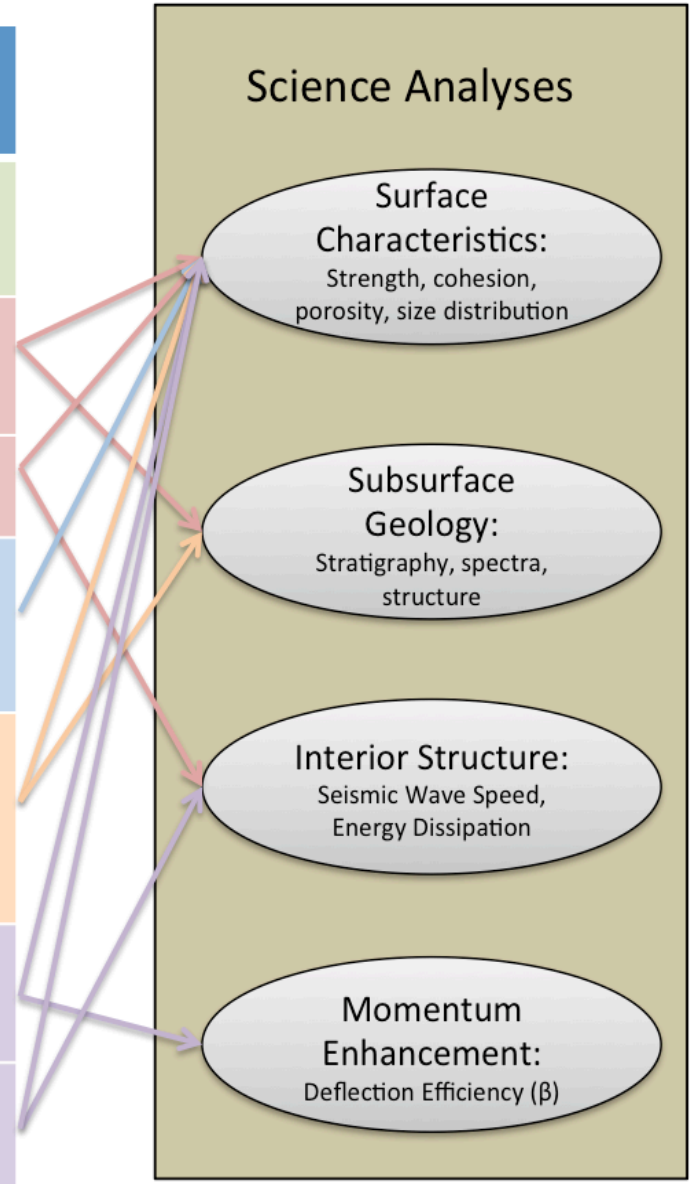
- What are the geotechnical properties of the near-surface material?
  - Strength
  - Cohesion
  - Porosity
  - Particle size distribution
- What is the geology of the sub-surface?
  - Stratigraphy
  - Structure
  - Composition
  - Mineralogy
  - Weathering



The Planetary Defense aspects of a deflection experiment will generate significant public interest.

ISIS/OSIRIS-REx Science Flow

Impact Mission Phase	Science Investigation	Obser-vation
Pre-Impact	**Preliminary Radio Science** Set asteroid ephemeris and rotational baseline prior to impact	Imaging, Radio
Impact	**Ejecta Field** Morphology, optical and spectral properties of ejecta plume	Imaging, Spectra
	Lofted Material Surface excitation from seismic wave	Imaging
Debris Clearing (~30 days)	**Ejecta Evolution** Population size distribution vs. time Dynamics of longer lived orbits Re-impacts and associated effects	Imaging
Low-phase Flyover (~10 days)	**Crater Reconnaissance** Crater size, morphology, stratigraphy, structure. Spectral changes, local topography, transported volume, thermal inertia	Imaging, Spectra, Altimetry
Terminator Orbit (~70 days)	**Radio Science** Orbital and rotational change with respect to pre-impact baseline	Imaging, Radio
	Surface Re-mapping Global surface variation: topography, geology, spectra, thermal inertia	Imaging, Spectra, Altimetry



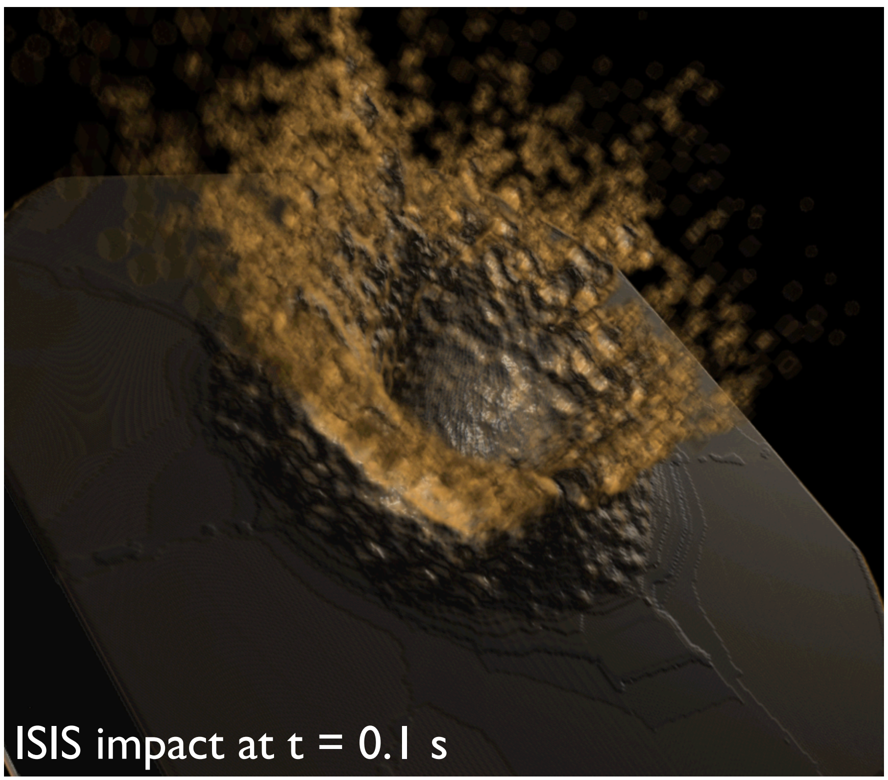
ISIS Impact Modeling

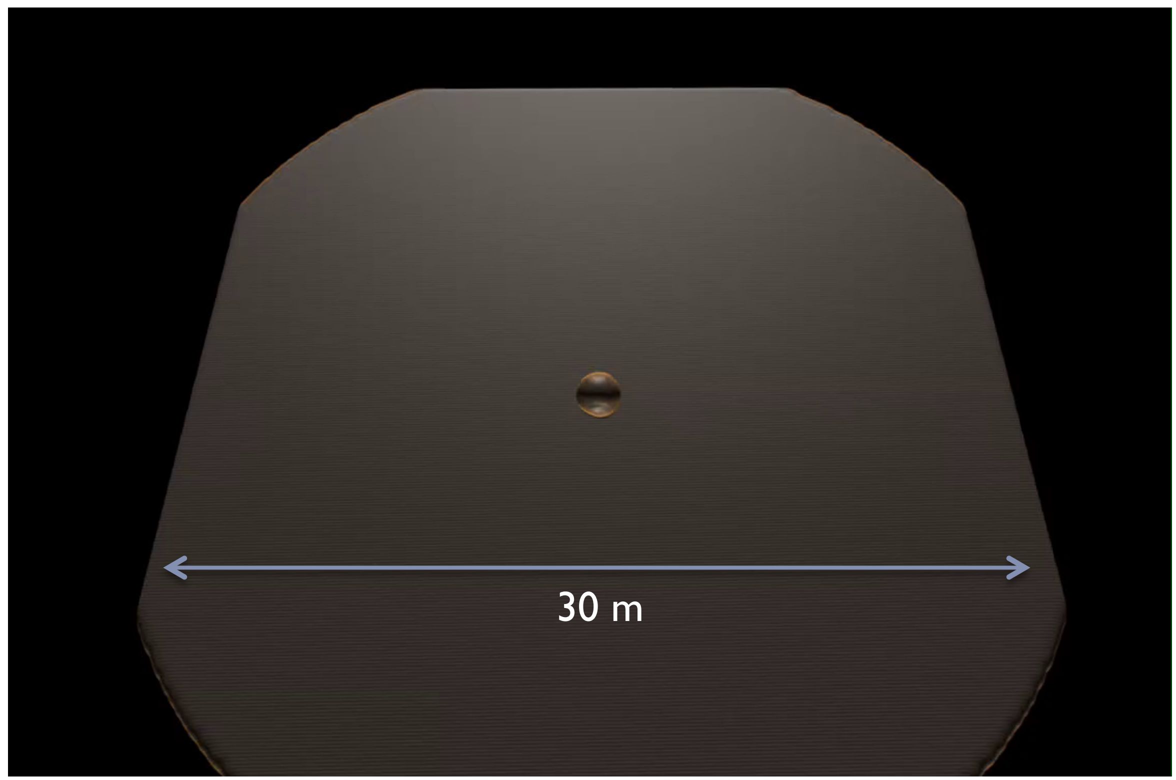
Preliminary SPH results (M. Jutzi & E. Asphaug):

- β=1.37 ± 0.06
- Crater diam. 15-20 m

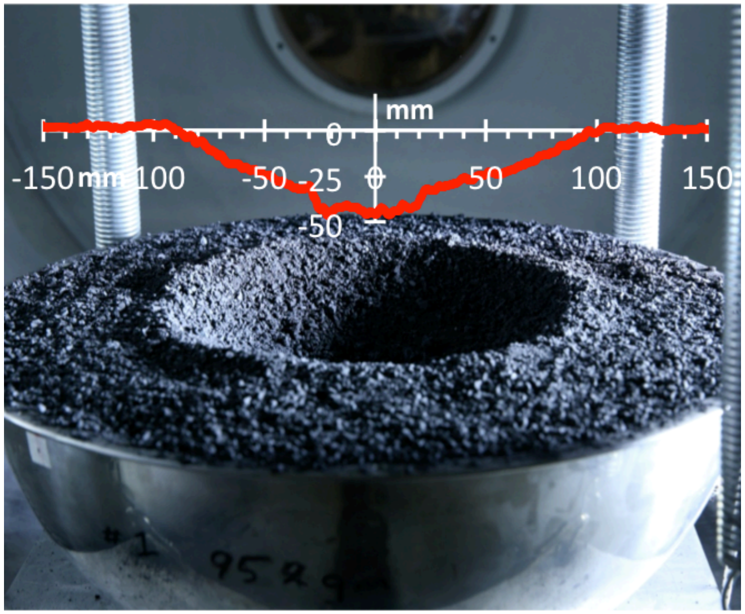
Scaling law predictions (K. Holsapple)

- β =1.2-1.5
- Crater diam.10-40
- Depth similar to diameter

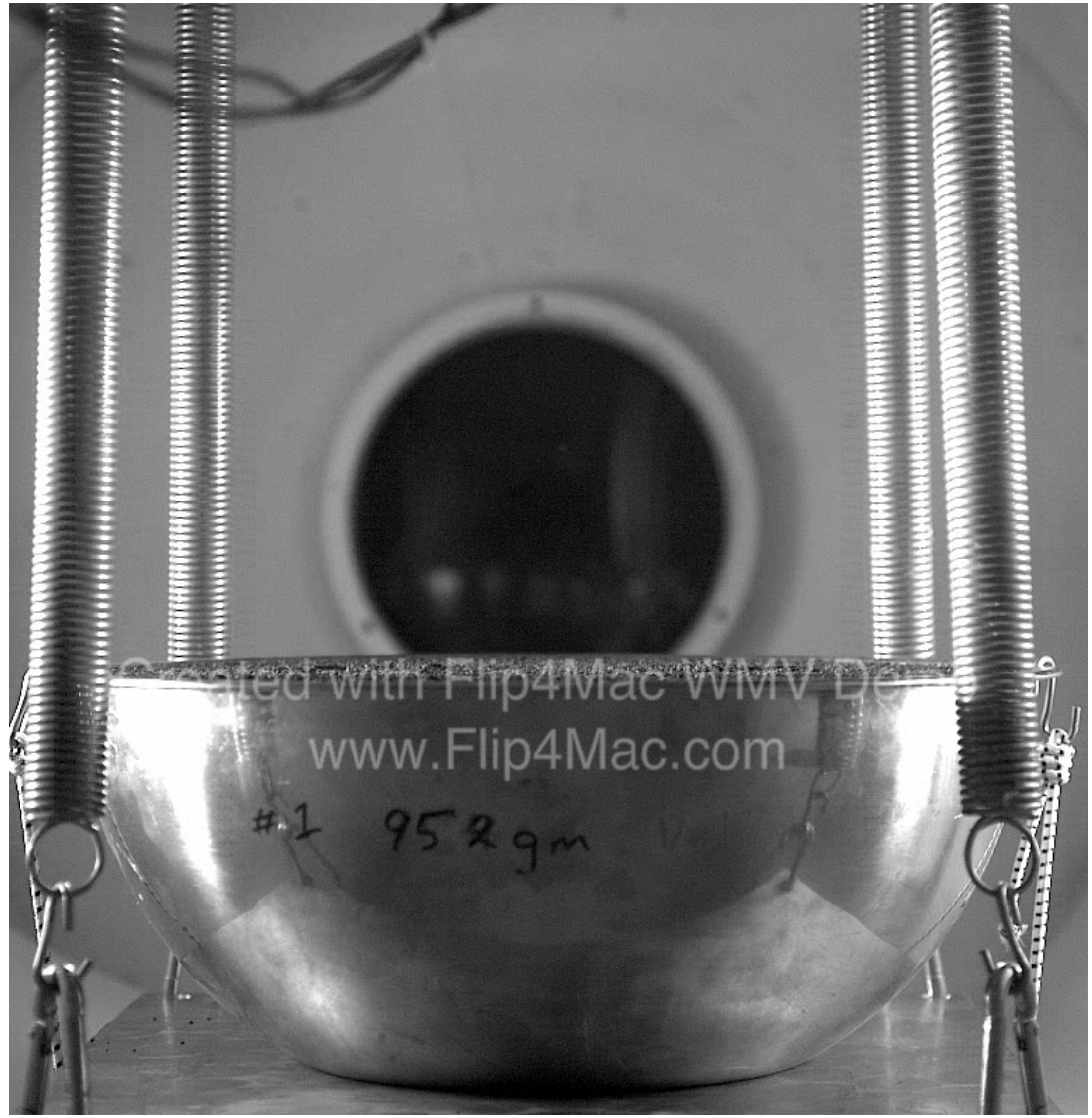




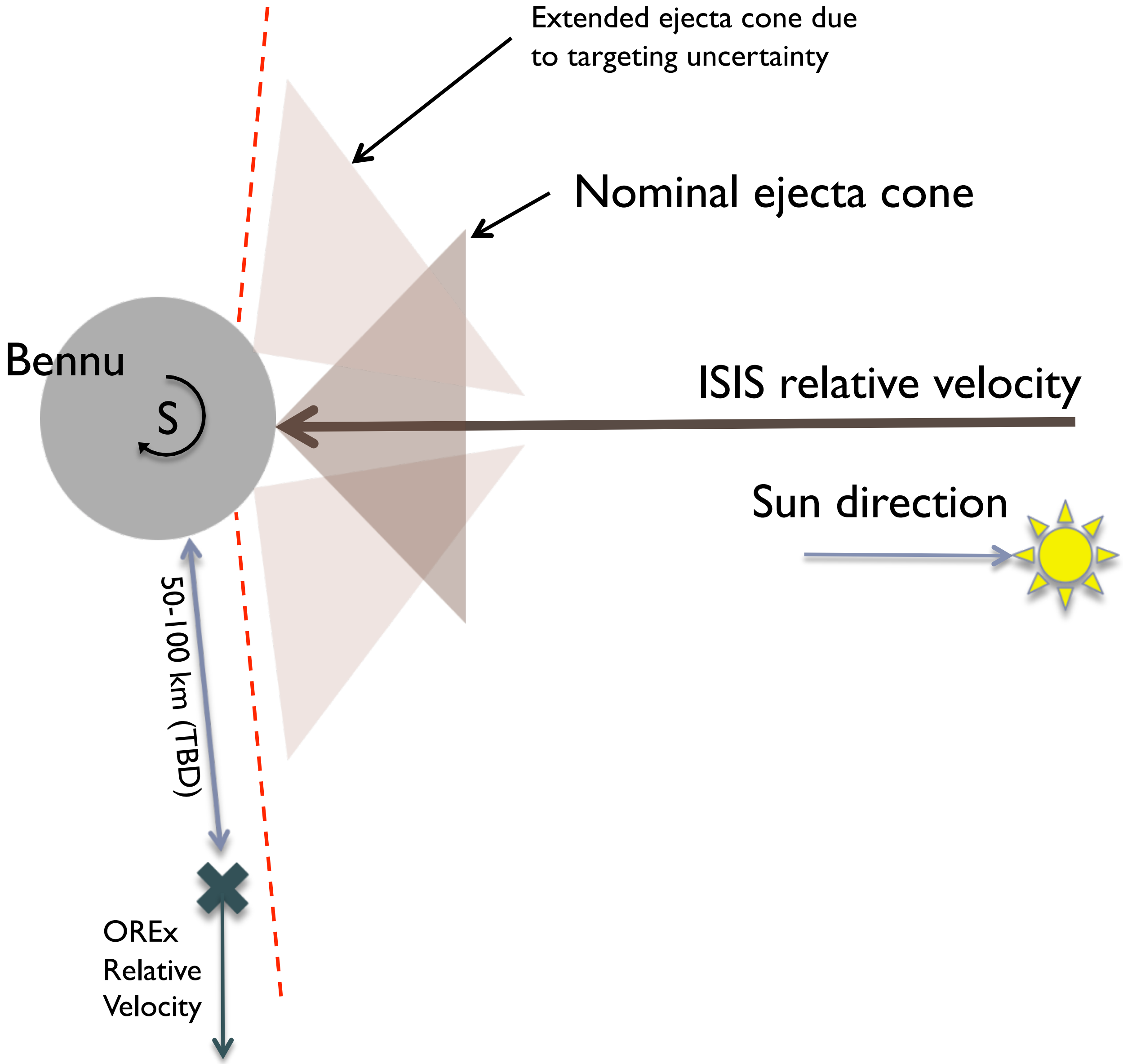
ISIS Impact Modeling



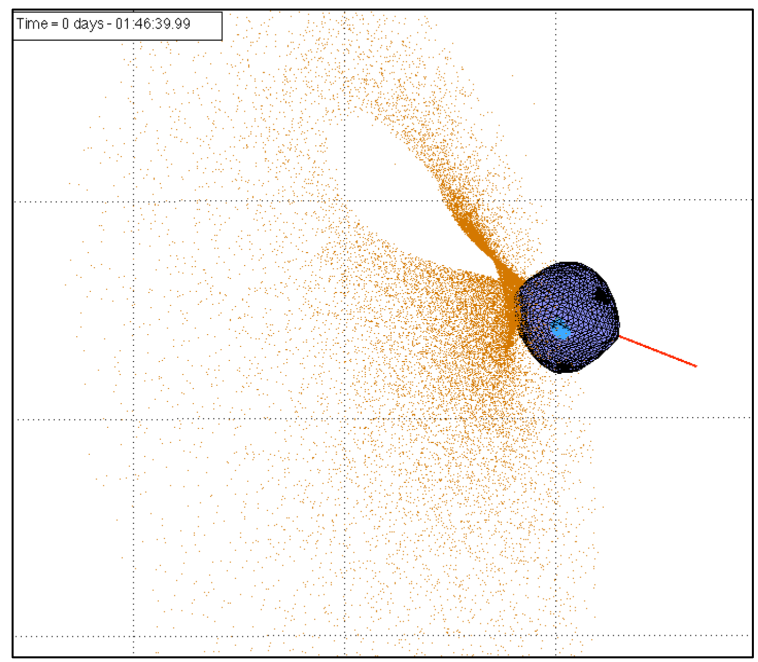
- K. Housen has conducted high-speed gun experiment into OSIRIS-REx regolith simulant provided
- Scaling to ISIS/Bennu leads to
  - β =1.2-1.3
  - Crater diameter ~40m
    - Upper bound 110m



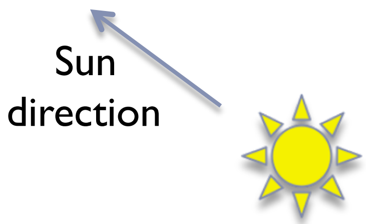
Impact Event

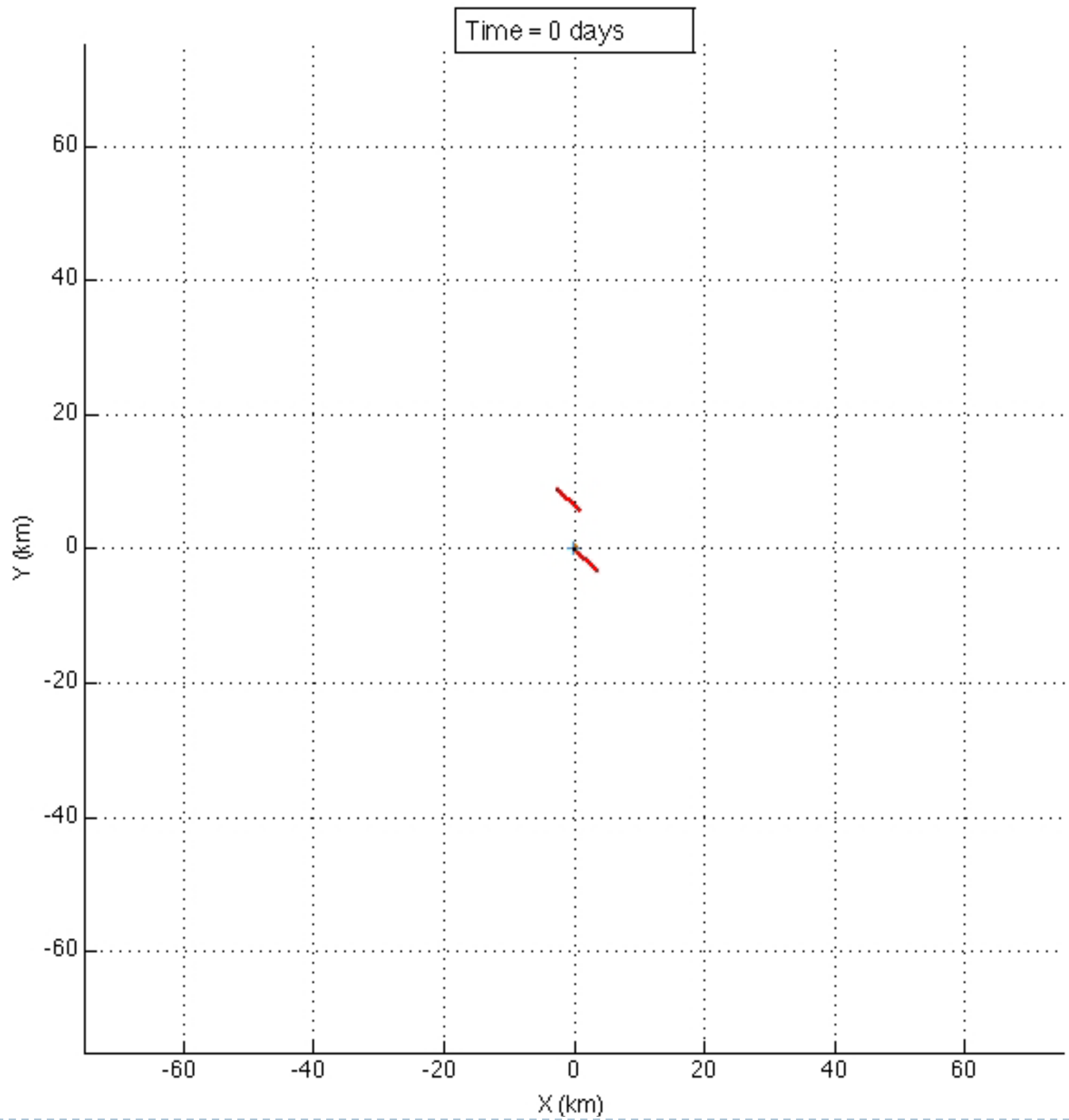


At impact OREx is well clear of possible ejecta zone and moving away. Asteroid rotation keeps crater visible for ~2.5 hours.



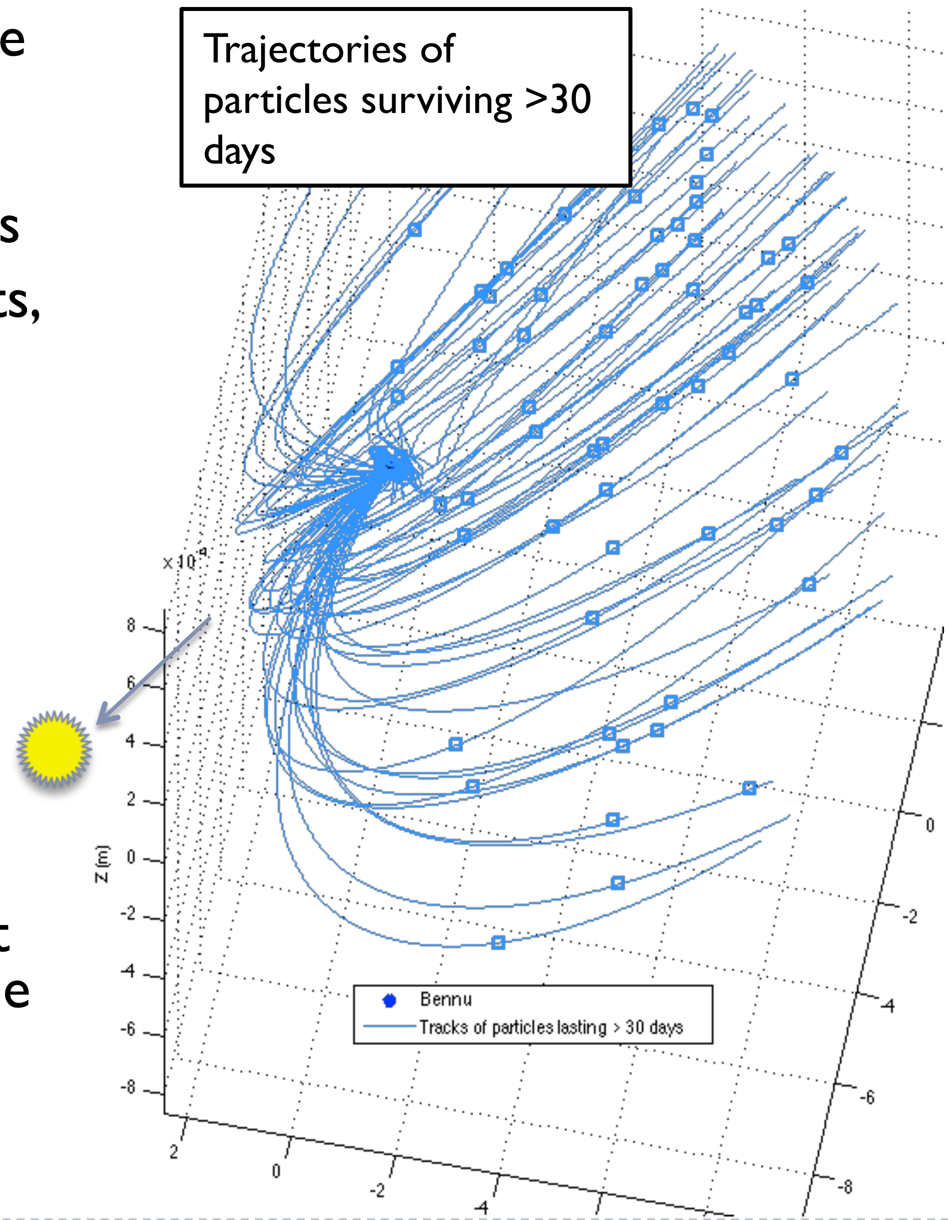
Particle Evolution



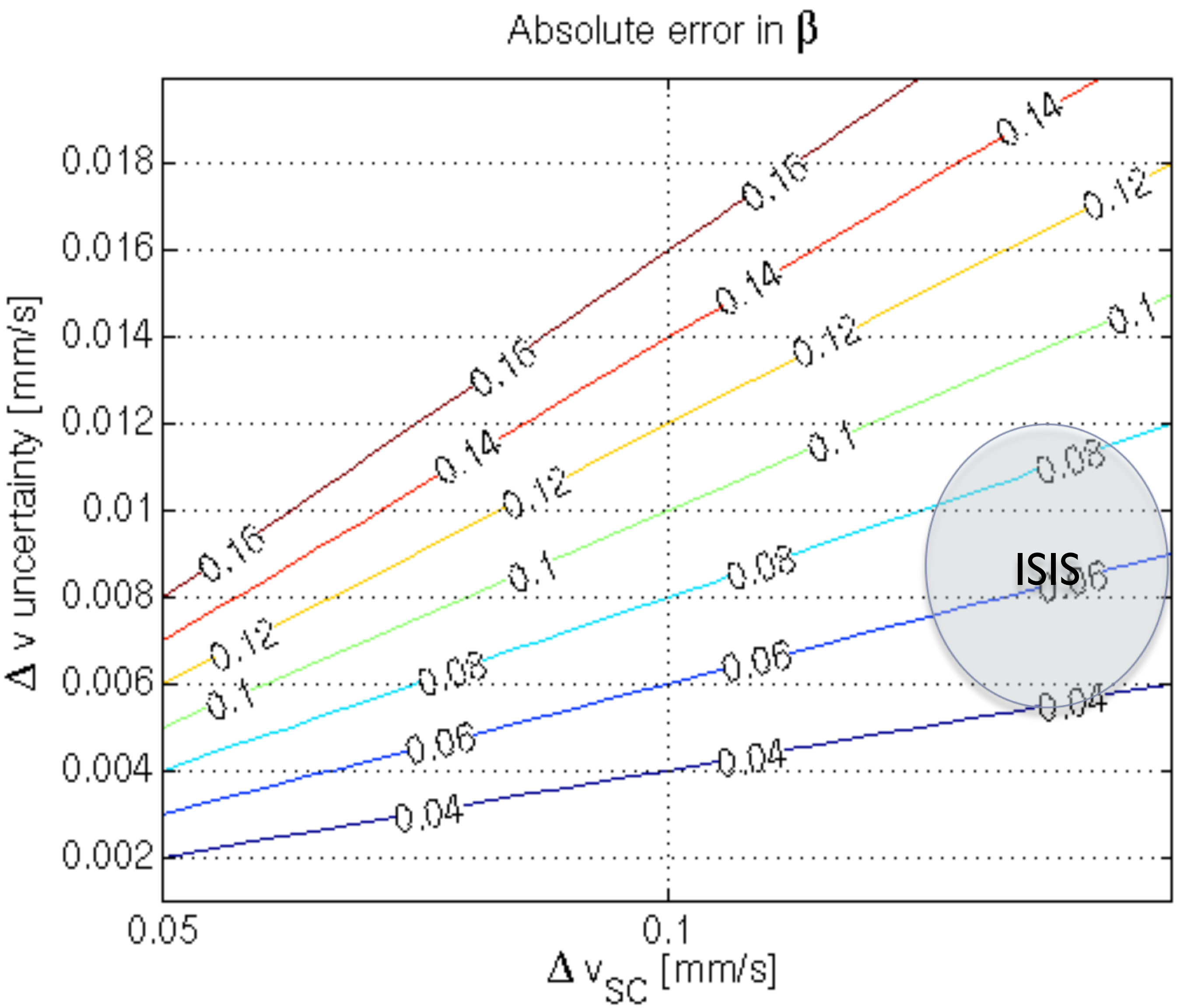


Debris Clearing

- Detailed study of debris clearing time not yet complete
- What we know is that the far field (outside ~5 km) is cleared by 30 days
- A few objects remain in tighter orbits, but estimating number density and associated hazard suffers from low number statistics
- Ongoing study seeks to quantify the hazard associated with terminator orbit
  - How many objects per cubic km
  - Associated collision hazard
  - Collision damage at ~20 cm/s
- In operations, OSIRIS-REx spacecraft would be able to stand off on sun line and track any remaining objects



Measuring Beta



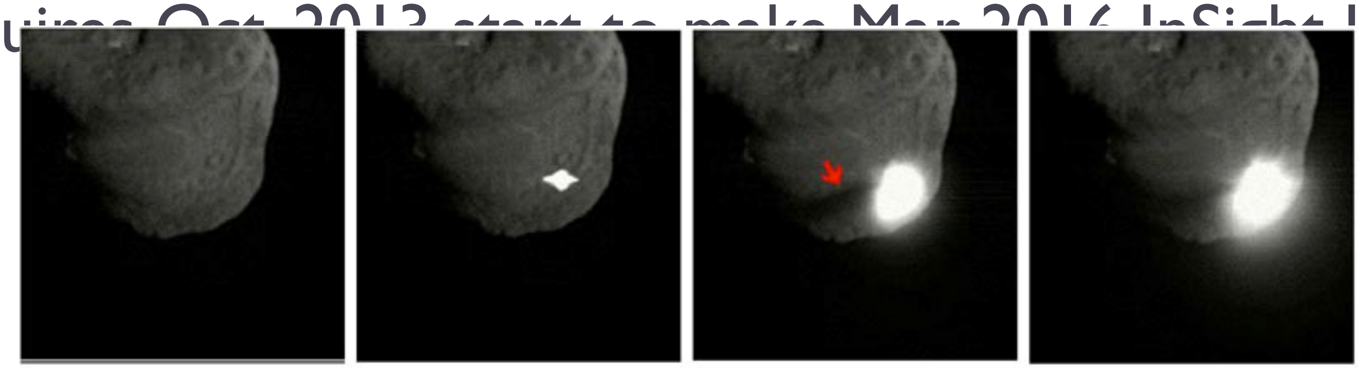
The momentum enhancement from ejecta is a central question. The ΔV from the ejecta can be estimated with uncertainty

$$\sigma_{\beta} = \sigma_{\Delta V} / \Delta V_{sc}$$

The ISIS mission will measure β with uncertainty <0.1

ISIS Schedule

- The InSight launch date provides a critical constraint on the ISIS schedule
- NASA-funded 3-month pre-phase A study now underway
  - Will achieve high concept maturity crucial to support short development schedule
  - Leading to a late FY2013 Decision Point
- ISIS development schedule assumes ~30 month Phase A-D
  - Requires Oct 2013 start to make Mar 2016 InSight launch



Conclusions

- ISIS is a low-cost mission that addresses NASA strategic goals and provides Discovery-class science returns across a wide range of small body science disciplines.
  - The mission leverages NASA's investment in the OSIRIS-REx mission and takes full advantage of the New Frontiers-class instrumentation on the observer spacecraft.
  - Co-manifesting with InSight further improves the cost-effectiveness.
- NEAR-Shoemaker is NASA's only NEA rendezvous mission so far. The second will be OSIRIS-REx, twenty years later.
  - The convergence of OSIRIS-REx schedule and Insight launch opportunity is an extraordinary alignment that will not be repeated again soon.
  - ISIS represents a once-in-a-generation opportunity to fly a low-cost asteroid cratering experiment.