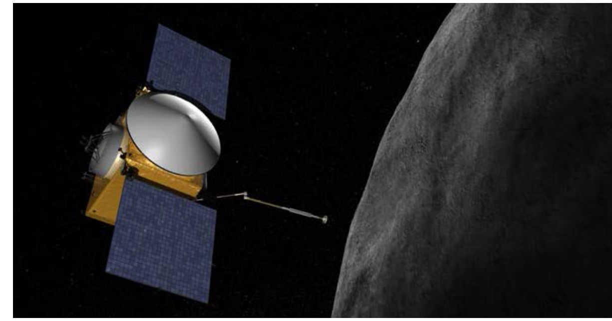
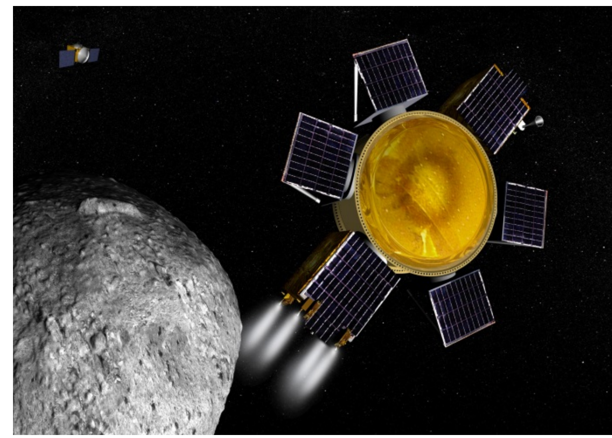

ISIS
Impactor for Surface and Interior Science
John O. Elliott
and the ISIS Team
Low Cost Planetary Missions Conference
June 19, 2013
Jet Propulsion Laboratory, California Institute of Technology
Copyright 2013 California Institute of Technology. Government sponsorship acknowledged

ISIS Mission Concept

- Send an independent, autonomous impactor spacecraft to Bennu, the target of the OSIRIS-REx mission
  - Co-manifest impactor with InSight launch
  - Arrive after OSIRIS-REx has completed its science objectives (i.e., sample collection)
- ISIS creates crater tens of meters in diameter
  - OSIRIS-REx images the impact from a safe vantage point (~1-meter resolution)
- Seismic reverberations throughout the asteroid cause global modifications
  - After debris clears, approach asteroid for imagery of crater and previously mapped terrain (~2 cm resolution). Also collect spectra of pristine material exposed by impact
- Deflection experiment
  - Measure asteroid delta-V due to impactor





ISIS/ORIRIS-REx Operations Concept

1. Pre-impact characterization of asteroid ephemeris
2. Image impact from a safe location
   - 50 km range: 0.7 m/pixel
3. Monitor ejecta as it dissipates
   - 2-3 weeks
4. Perform slow flyby(s) for crater imaging/spectra
   - 1 km range: 1.3 cm resolution
5. Enter radio science mode until OSIRIS-REx departure
   - 1.5 km terminator orbit

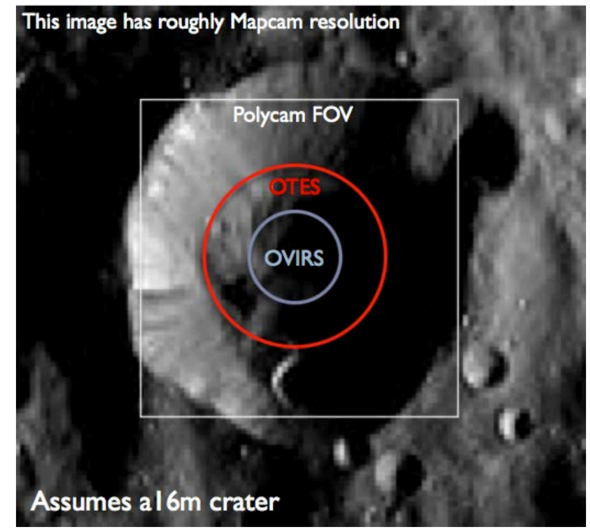
ISIS baseline includes >110 days of science operations from impact to departure, including margin.

Cross-cutting Exploration & Science Benefits

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

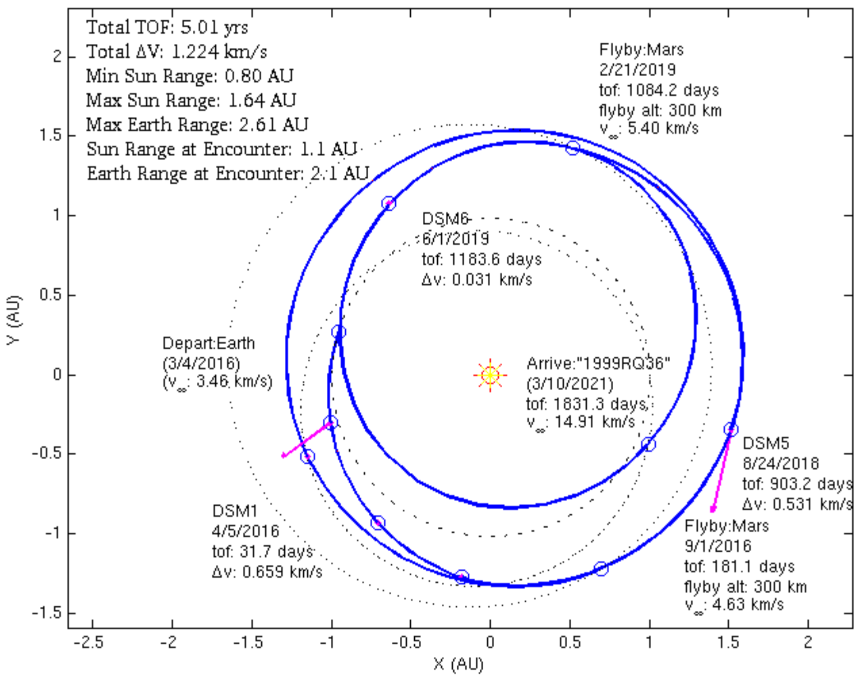
- What is the local response?
  - Ejecta field properties
    - Creation of meteorite precursors
    - Ejecta blanket
    - Re-impacts
  - Crater morphology
  - Possible volatile release
- What is the global response?
  - Trajectory change (ΔV, β)
  - Rotation change ($\Delta\omega$, I_{zz})
  - Change 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 Schedule Compatible with OSIRIS-REX



ISIS Baseline Mission	
Launch	4-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)

08-15-18 | 10-15-18 | 07-17-19 | 01-02-20

60 Days | 275 Days (Rendezvous to 1st Sampling Attempt) | 170 Days (funded margin)

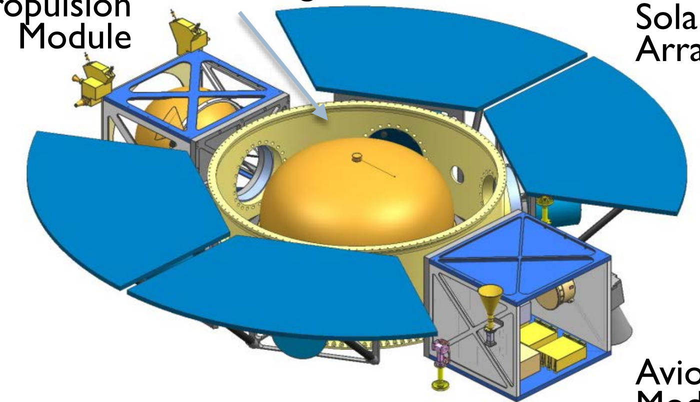
Acquisition | Rendezvous | Stow Sample

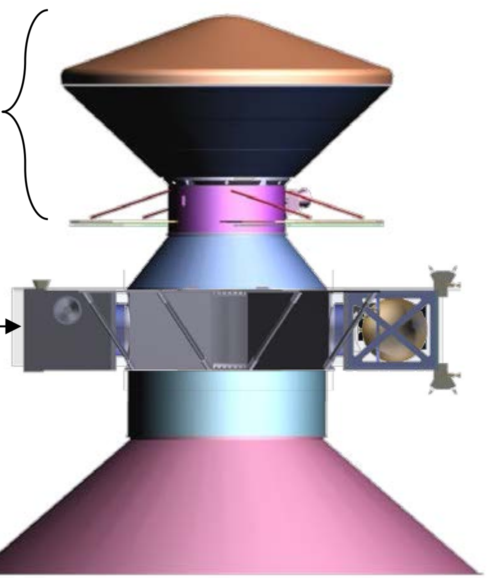
01-03-20 | 03-04-21 | 06-28-21

426 Days (Quiescent Operations) | 116 days — ISIS Science Activity

Baseline Departure | Backup Departure

ISIS Flight System Overview

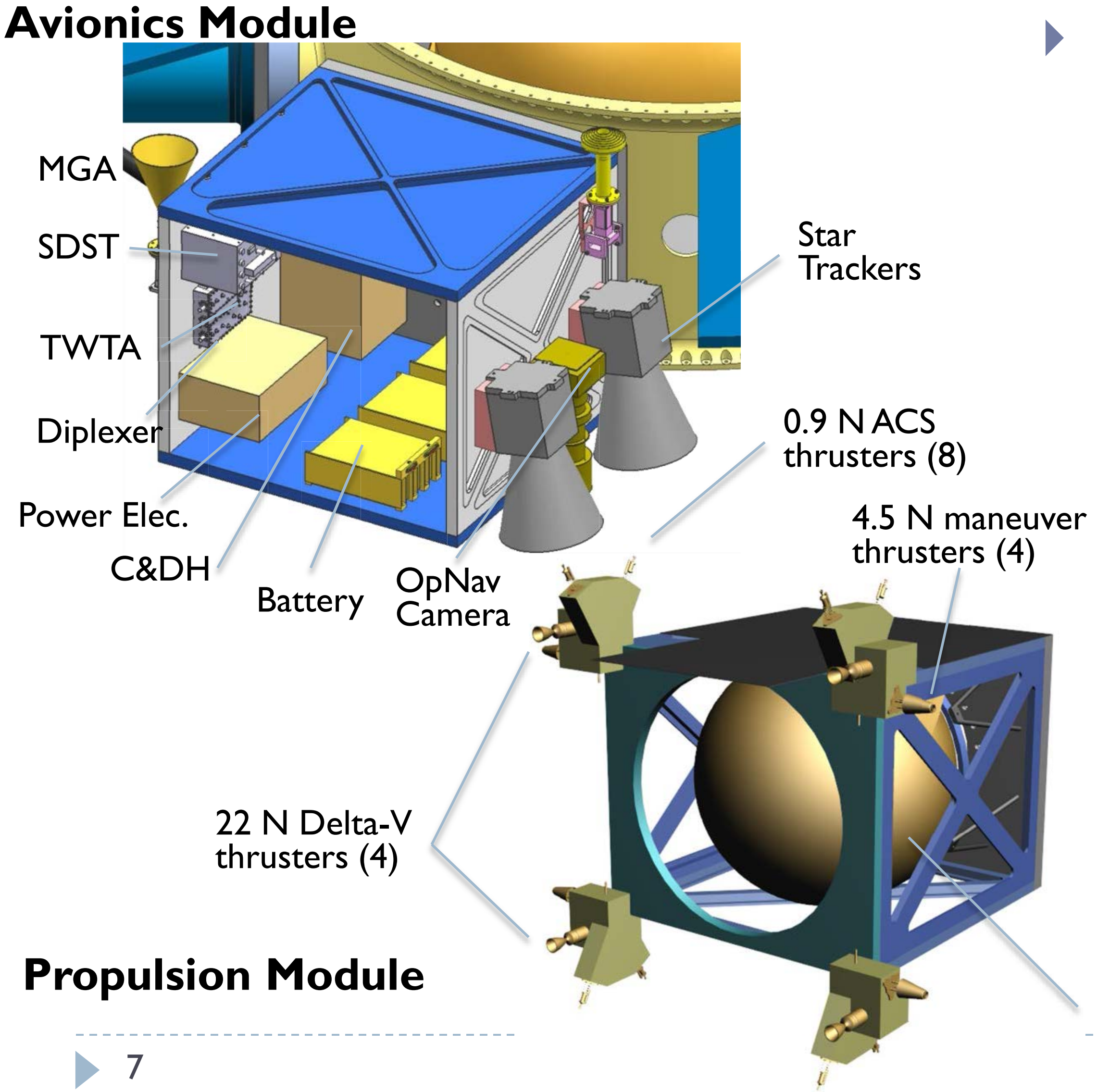




- System designed around flight-qualified ESPA
  - Imposes <u>no impact</u> on host SC/LV interface

- Modular Flight System
  - Avionics Module
    - All subsystems but propulsion
  - Propulsion Module
    - Holds thrusters, lines, plenum tank
    - 450 kg capacity fuel tank in ESPA
    - This design provides up to ~1400 m/s Delta V
  - Solar arrays on unused ports
    - 3.8 m^2 active cell area, >1380 W at 1 AU
- Spacecraft Architecture emphasizes simplicity and reliability
  - No Comm. Crosslink (to observer s/c)
  - No Pyrotechnics
  - No Deployments
  - No Mechanisms

Spacecraft Modules



- Common Module structure simplifies design, build and testing, conforms to ESPA envelope requirements
  - Avionics Module contains all non-propulsion subsystems
  - Propulsion Module incorporates all components of propulsion subsystem except main fuel tank

Mass and Power Margins

ISIS Flight System

	CBE Mass (kg)	Contingency (%)	Total Mass (kg)	Heritage/Comments
C&DH	9.3	13%	10.5	JPL Ref. Bus
Power	34.7	11%	38.5	Solar Arrays + battery/Ref. Bus
Telecom	11.8	11%	13.0	25W RF TWTA, SDST
Structures	256.6	19%	306.0	Includes ESPA ring, tank support
Thermal	14.7	30%	19.1	Heaters, MLI, thermostats
Propulsion	65.8	11%	73.2	Catalog tanks, thrusters, components
GN&C	10.5	10%	11.6	MIMU, AA-STR, OpNav camera
Spacecraft Total	**403.3**	**17%**	**471.9**	
System Margin			51.1	
Dry Mass Total		**43%**	**523.0**	43% on all but ESPA (8%)
Propellant			436.5	
Wet Mass Total			**959.6**	
LV Mass Allocation			1142.0	F9 cap. to C3=19.41 - 673 kg Insight
Launch Mass Margin			182.4	

- Individual modules exhibit robust margins with respect to ESPA secondary payload allowable of 180 kg

Module	CBE Mass (kg)	Contingency (%)	Total Mass (kg)	Allocation (kg)	Margin* (kg)
Avionics	82.8	43%	118.4	180	61.6
Propulsion (dry)	56.2	43%	80.4	180	99.6
Propulsion (wet)	56.7	43%	81.1	180	98.9

**Mass margin against ESPA payload allowance*

- Current wet mass estimate for baseline mission leaves significant mass margin on smallest LV (Falcon 9 v1.1)
  - Atlas V 401 would increase margin by 95 kg

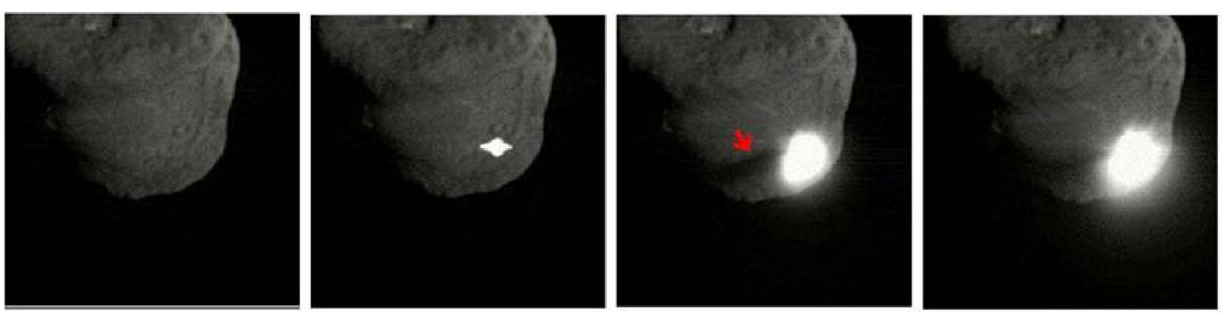
ISIS Power Summary

SA Power Output (EOM, 1.26 AU)	790 W
Battery Capacity	30 A-hr
S/C Cruise Average Power	320 W
S/C Peak Power (man. + telecom)	630 W
Peak Battery DoD (launch mode)	59%

- Solar arrays power all cruise operations, augmented by battery where needed

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
  - ~Sep. 2013 Phase A 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.