OSIRIS-REx: Engineering Challenges of Sampling an Asteroid

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• Launch highlights: https://www.youtube.com/watch?v=AG1pE90ue5w&feature=youtu.be
• Launch Video: https://youtu.be/ULfQdFY9PQM
Flight System Facts

- 2104 kg (4639 lbs), half is fuel!
- 2 meters (6.6 feet) per side
- 1200 W
- 8.5 m² (91 square feet) of solar panels
- Lithium ion batteries
- 5 Instruments:
  - Measurements in x-ray, visible and infrared
  - Laser measurements
- Touch-and-Go Sampler
- Sample Return Capsule

It’s based on other planetary missions (MAVEN, Juno, MRO)
EXPLORATION OF THE UNKNOWN

• OSIRIS-REx must retrieve sample from an asteroid that has never been seen up close
• Design Reference Mission provides the step-by-step plan to build our knowledge
  • Created and maintained by project systems engineering team
  • Touches all aspects of the mission design
  • Drives mission architecture and requirements
• Design Reference Asteroid documents what we do know about Bennu and how well we know it (uncertainties)
  • Created and maintained by the science team
  • Based on many observations (Arecibo, Herschel, HST, Magellan 6.5-m, SOAR 4-m, Spitzer, TNG 3.6-m, VATT 1.8-m, VLT 8.4-m, WHT 4.2-m and Kuiper 1.5-m) as well as analysis
  • Peer-reviewed information
  • Drives some aspects of environmental requirements document
<table>
<thead>
<tr>
<th>Event</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch</td>
<td>(9/8/16 - 10/11/16)</td>
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<tr>
<td>Outbound Cruise</td>
<td>(712 days)</td>
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<tr>
<td>Bennu Acquisition</td>
<td>(8/17/18)</td>
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<tr>
<td>Approach</td>
<td>(94 days)</td>
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<tr>
<td>Preliminary Survey</td>
<td>(20 days)</td>
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<tr>
<td>Orbit-A</td>
<td>(31 days + 45)</td>
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<tr>
<td>Detailed Survey</td>
<td>(63 days)</td>
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<tr>
<td>OKDP-1 Prime &amp; Backup Sites</td>
<td></td>
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<tr>
<td>Recon</td>
<td>(98 days)</td>
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<tr>
<td>OKDP-2 Go for Rehearse &amp; TAG</td>
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<tr>
<td>Rehearsal</td>
<td>(42 + 185)</td>
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<tr>
<td>Sample Collection</td>
<td>(23 days + 42)</td>
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<tr>
<td>Baseline Asteroid Operations</td>
<td>(431 days + 308)</td>
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<tr>
<td>OKDP-3 Stow Sample</td>
<td></td>
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<tr>
<td>Thermal Keep-out Zone</td>
<td></td>
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<tr>
<td>Operations Margin</td>
<td>(191 days)</td>
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<tr>
<td>Return Cruise</td>
<td>(934 days)</td>
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<tr>
<td>OKDP-4 Earth Return</td>
<td>(9/24/23)</td>
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- 80 days of margin mitigates pre-Recon risks
- 185 days of margin mitigates pre-TAG risks
- 42 days of margin mitigates an aborted TAG
TAG OPERATIONS CONCEPT

- Terminator Orbit Plane (Edge On)
- De-Orbit Burn
- Slew to Inertially Fixed Attitude
- Lidar Range Check
- Checkpoint Burn
- Matchpoint Burn
- TAG Operations Concept
- Rotation Direction
- Timeline
  - De-Orbit Burn
  - 3.6 hr
  - Lidar Range Threshold Crossing
  - 18 min
  - Lidar Range Check
  - 2 min
  - Matchpoint Burn
  - 10 min
  - TAG
  - 8 min

To Sun

To Earth
GUIDED TAG APPROACH

- Orbit knowledge error and orbit departure maneuver execution error lead to large dispersion at Checkpoint
- Range threshold and pre-Checkpoint LIDAR measurements allow closed loop corrections to Checkpoint maneuver to achieve original Matchpoint location
- Matchpoint corrected to original TAG approach trajectory
**Design Reference Asteroid**

- **Orbital Properties**
  - Known extremely well, through ground-based astrometry and radar observations in 1999, 2005, and 2011
  - Approach imagery will be easy

- **Bulk Properties**
  - Size and shape known to within about 10 m
  - Mass and density uncertainty is reasonable for navigation analysis

- **Rotational Properties**
  - Spin rate known to 0.05%
  - Pole known to within 2 degrees

- **Radar Properties**
  - Does not drive mission design

- **Photometric Properties**
  - Drives camera design
• Spectroscopic Properties
  • Drives spectrometers

• Thermal Properties
  • Thermal model used for spacecraft thermal analysis
  • Thermal modeling done with engineering feedback to ensure results were useful
    • Engineering tools assume spherical object

• Surface Analog Properties
  • Used for TAG simulations

• Environmental Properties
  • Satellites (stability, size limit, etc.)
  • Dust
SRC FROM STOWCAM, ILLUMINATED BY STRAY LIGHT
• Stardust successfully returned a sample from a comet’s tail, but one of the parachute deployment pyros did not fire (the other one did)

• OSIRIS-REx performed some testing which discovered an unexpected shock environment, likely explaining the issue

• Other testing uncovered issues with the parachute cord

• Just because something works once doesn’t mean it will work reliably a second time.

• Reliability of spacecraft is outside the experience of every-day life.
MASS GROWTH

Flight System Mass

- NTE Dry Mass, kg
- MEV, kg
- CBE Mass, kg

Key Milestones:
- PDR
- CDR
- ATLO Start
- Launch
- First lift in ATLO after Harness wrap
- Spin Balance
- Final Ballast
This Job is Difficult!

- Space missions are really hard because:
  - It requires a tremendous amount of energy to get into space—essentially a controlled explosion
  - Once on its way, it would take another launch to get to the spacecraft and fix any hardware problems
  - The level of reliability is beyond everyday experience
  - A single failure can end a mission

- We do these things in space, “not because they are easy, but because they are hard.” --JFK

- My job is fun because it is hard.

- A successful mission is the product of many people and many perspectives