Smead Scholar Alumni Update: Working Mission Operations for OSIRIS-REx

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About me:

• **Past:**
  • Undergraduate Degree: Purdue University, Aerospace Engineering, May 2012
  • Masters/PhD: University of Colorado, Aerospace Engineering Sciences, December 2017
    • NSTRF and NSF award recipient
    • Thesis: “Natural and Artificial Satellite Dynamics and Evolution Around Near-Earth Asteroids with Solar Radiation Pressure”
    • Advisor: Dan Scheeres

• **Currently:**
  • Aerospace Engineer at NASA Goddard Space Flight Center (Greenbelt, MD)
  • Based in Denver, CO
  • Maneuver Design Analyst for OSIRIS-Rex

• **Spare Time:**
  • Climbing, Skiing, Traveling, Reading
OSIRIS-REx Overview

- **Origins**
  - Return and analyze a sample of pristine carbonaceous asteroid regolith
- **Spectral Interpretation**
  - Provide ground truth for telescopic data of the entire asteroid population
- **Resource Identification**
  - Map the chemistry and mineralogy of a primitive carbonaceous asteroid
- **Security**
  - Measure the Yarkovsky effect on a potentially hazardous asteroid
- **Regolith Explorer**
  - Document the regolith at the sampling site at scales down to the sub-cm

**OSIRIS-REx MISSION OPERATIONS TIMELINE**

<table>
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<tr>
<th>Launch</th>
<th>Earth Gravity Assist</th>
<th>Approach Maneuver</th>
<th>Nominal Sample Collection</th>
<th>Departure Maneuver</th>
<th>Return Cruise</th>
<th>Sample Return</th>
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How Tall is Asteroid Bennu?

- Bennu: ~510 m
- Empire State Building: 443 m
- Eiffel Tower: 324 m
Flight Dynamics Operations Concept

• Navigation team performs three primary functions:
  • Trajectory Analysis – Includes re-planning of mission trajectories once physical characteristics of Bennu are confirmed
  • Orbit Determination – Includes Optical Navigation function
  • Maneuver Design

• All navigation activities ground-based with the exception of onboard guidance performed during the TAG trajectory

• Maneuver Design Process
  • Preliminary planning process performed bi-weekly: Assumes ~10 days after data cutoff to plan, implement, test and execute maneuvers
  • Late Update: At least 24 hours of OD data collection followed by 24 hours for tweak, minimal retest and execution of maneuver

• “Sporty” cadence throughout proximity operations
  • Preliminary survey: maneuver every other day for two weeks
  • Detailed survey: 2 maneuvers/week for 14 weeks
  • Performed 24 maneuvers since December
Bennu First Light (August 17th, 2018)
Full rotation PolyCam mosaic from Approach
SamCam Images TAGSAM in Flight Nov 14, 2018

These images show the OSIRIS-REx Touch-and-Go Sample Acquisition Mechanism (TAGSAM) sampling head extended from the spacecraft at the end of the TAGSAM arm. The spacecraft’s SamCam camera captured the images on Nov. 14, 2018 as part of a visual checkout of the TAGSAM system,
- **Navigation Campaign**
- **Site Selection Campaign**
- **Sample Acquisition Campaign**

**Timeline Events:**
- **2018**
  - Preliminary Survey
  - Detailed Survey: Equatorial Stations
- **2019**
  - Approach Arrival
  - Orbital A
- **2020**
  - Orbital B
  - Rehearsal
  - Sample Collection Tag
NavCam Image of Earth, the Moon, and Bennu
First Scientific Discovery: Evidence of Hydrated Minerals
Orbit A Insertion

2 x 1.5 km “Frozen” Orbit
Orbit A– As Flown

- Plots below show evolution of OREx Orbital A phase as flown (over a span of 8 weeks)
- Frozen orbit with a radius between 2.1 km and 1.6 km
- A true frozen orbit exists only in theory. In reality, other effects will reduce its ‘frozenness’. Desats (OREx had 2/week) and any attitude change will alter SRP force on S/C and thus orbit design.
- Navigation Campaign:
  - Estimate GM, Bennu’s spin pole, rotation rate
  - Optical navigation transitional to landmarks
This three-dimensional view of asteroid Bennu was created by the OSIRIS-REx Laser Altimeter (OLA), contributed by the Canadian Space Agency, on NASA’s OSIRIS-REx spacecraft. From Feb. 12 through 17, OLA made more than 11 million measurements of the distance between OSIRIS-REx and Bennu’s surface as the spacecraft flew less than 1.2 miles (2 km) above the surface – the closest orbit ever achieved by spacecraft. OLA obtained these measurements by firing laser pulses at Bennu and measuring the amount of time it takes for the light to bounce off the asteroid’s surface and return to the instrument. That time measurement is then translated into altitude data. Using this data, the OLA team created the 3-D model of Bennu’s surface. The colors represent the distance from the center of Bennu: dark blue areas lie approximately 197 feet (60 meters) lower than peaks indicated in red. Some parts of the asteroid have not yet been measured, which creates gaps in the image. OLA will take nearly a billion more measurements throughout 2019 to complete the first-ever high-resolution 3D lidar map of a near-Earth asteroid.
This view of asteroid Bennu ejecting particles from its surface on January 19 was created by combining two images taken by the NavCam 1 imager onboard NASA's OSIRIS-REx spacecraft: a short exposure image (1.4 ms), which shows the asteroid clearly, and a long exposure image (5 sec), which shows the particles clearly. Other image processing techniques were also applied, such as cropping and adjusting the brightness and contrast of each layer.
Bennu’s Big Surprise...

• Bennu is an “Active Asteroid”
  • Major scientific implications

• Particulates detected in NavCam imagery after Orbit A insertion

• At least 5 major events detected

• Project determined it was safe to continue with Orbit A and proceed to Detailed Survey

• Ongoing analysis to detect and characterize particles (including quasi-stable orbiters)
Thank you! Any Questions?