



OSIRIS REx

Science Processing & Operations Center (SPOC) and Science Engineering Peer Review

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OSIRIS-REX™
ASTEROID SAMPLE RETURN MISSION



24 – Deliverability Maps

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Agenda

- Overview
- Driving MRD requirements related to Deliverability Maps
- Requirements for map processing software
- Required inputs to map
- Nominal map development process
- Operational schedule
- Status of algorithm development
- Minimal mission scenario impact
- Work to go



Deliverability Overview

- The purpose of the Deliverability Map is to indicate the regions where the spacecraft can be successfully delivered to the surface with suitable targeting errors ($<25\text{m}$ and 2 cm/s) in a manner that can aid in site selection.
- Two deliverability maps are planned to support the site selection process:
 - A global map to provide early, coarse information describing which regions may be suitable for consideration as candidate TAG sites
 - Includes data on TAG performance at each site, and identifies sites that are unreachable using the baseline TAG design
 - Will be the first time TAG deliverability analysis is repeated with actual shape and mass of Bennu known
 - A number of high-resolution local maps for each of the candidate sites used to down-select to a single TAG site for sampling
 - TAG analysis performed with the latest models of Bennu shape and gravity for specific candidate TAG sites



Relevant MRD Requirements

- MRD-13 OSIRIS-REx shall contact the surface within 25m of the chosen sample site with $> 98.3\%$ confidence.
- MRD-31 OSIRIS-REx shall contact the surface of Bennu with a surface relative vertical speed of 10 ± 2 cm/s (3-sigma) and surface relative lateral speed of 0 ± 2 cm/s (3-sigma)...
- MRD-570 - OSIRIS-REx shall select a sample site that satisfies the following criteria: a. $>99\%$ probability of ensuring the safety of the flight system during sampling and b. $>80\%$ probability of acquiring > 60 g of bulk sample per sampling attempt.
- MRD-183 The Ground System shall produce the following data products on a global scale and for each candidate sample site in support of site selection during the encounter with Bennu: a. Safety Maps, b. Deliverability Maps, c. Sample-ability Maps, d. Science Value Maps
 - FDS-F-183 The FDS shall produce Deliverability Maps on a global scale for each candidate sample site in support of site selection during the encounter with Bennu.
 - FDS-OD-X-42 The FDS Orbit Determination Function shall deliver asteroid deliverability maps and associated data derived from Trajectory Analysis to the SPOC facility, in compliance with SPOC-FDS ICD (UA-ICD-9.0.0-100).



Map Requirements (Global and Site-Specific)

- Deliverability Map Requirements are summarized in more detail on the Science Team Wiki:
- https://sciwik.lpl.arizona.edu/wiki/pages/Y7p5U7F4p/Global_and_Sitespecific_Deliverability_Maps_MRD570b.html



Required Inputs

- **Global Deliverability Maps**
 - Bennu shape model (Global SPC Shape SPC_GS_075 & Global Terrain Model SPC_GTM075)
 - Bennu coordinate system and spin state
 - Bennu gravity model (constant density gravity model based on updated shape model)

- **Local Deliverability Maps**
 - Latitude/Longitude of each of the 12 potential TAG sites from the SPOC/ST
 - Updated shape model (SPC Global Regional Shape and Terrain Models SPC_GRS030 and SPC_GRTM030)
 - Updated Bennu pole, wobble and rotation period
 - Updated Gravity Field Model (post Orbit B radio science campaign)



Development Approach

- The general approach used to determine TAG delivery errors for a given TAG site is to use a Monte Carlo style analysis
 - Randomly samples the errors that affect the targeting
 - Propagates the spacecraft with these errors to determine the targeting error for that case
 - This is done for 500-1000 cases for each site to characterize the statistical TAG delivery errors for that site
- Deliverability maps are a product of the same tools used to design the TAG trajectory for TAG operations
 - The tool first develops a unique trajectory design and set of maneuvers for the specific TAG site
 - A MC style analysis is then conducted based on the nominal TAG design and error sources
 - Results of the MC analysis are post-processed to provide the data in the specified map formats.
- The level of effort for each candidate site is such that only a few dozen site studies can be conducted by one analyst per week
 - A coarse global map can be derived by the systematic analysis of 50-100 sites distributed across the asteroid surface
 - No more than 12 candidate TAG sites will be selected, and so the local maps can be completed within a few days of receiving all relevant inputs
- As we progress through proximity operations and we improve our knowledge of Bennu's properties and spacecraft performance, deliverability analysis may be updated



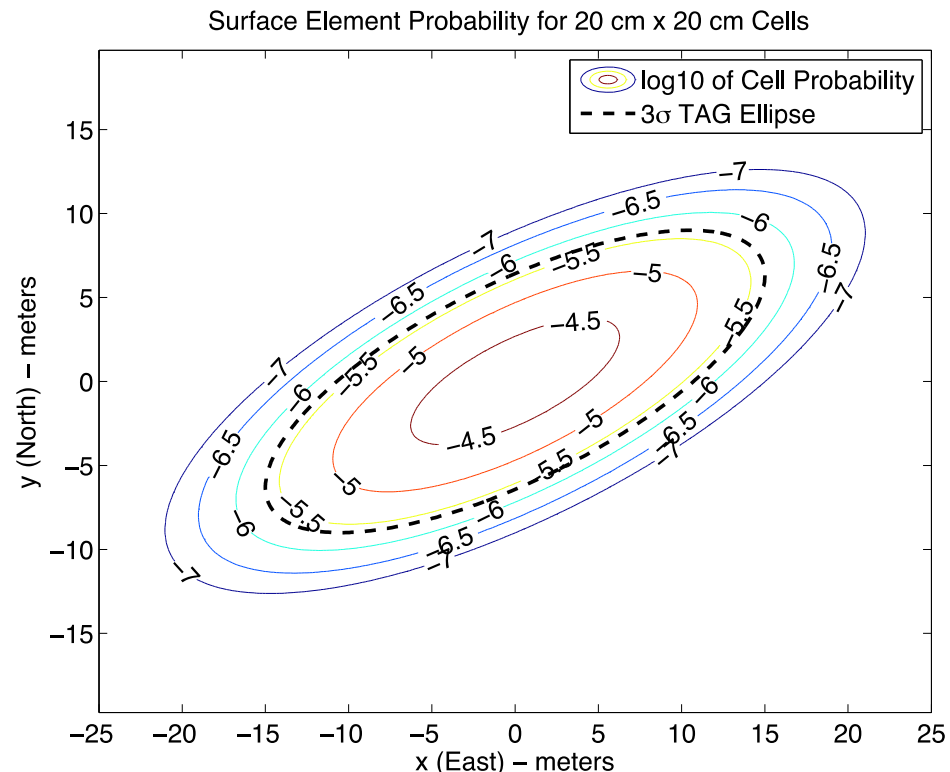
Global Deliverability Map

- Approach: distribute potential TAG sites in a grid across the body in a way that allows planners to understand which regions will not be reachable
- The global maps will support the 3D map format standard that allows ingest and display by the visualization tool under development by the SPOC.
 - Displayed ellipses will be supported in the map format “shape layer”
 - Other parameters describing TAG performance can be displayed as a layer through the ancillary data file described in the map format SIS (UA-SIS-9.4.4-324, Rev. 1.0).
- For each surface element the global map will provide:
 - The corners of the surface element (location)
 - The description of the TAG delivery ellipse for the center of the surface element
 - The $1-\sigma$ semimajor and semiminor axes of the ellipse in meters
 - The orientation of the semimajor axis, measured in degrees counterclockwise from East.
 - A quantitative measure of the deliverability (or TAG errors) at that location
 - The fraction of trajectories that meet the FDS TAG attitude requirements at touchdown
 - Statistics regarding the percentage of TAG attempts that would be unsuccessful to a given site (condition encountered resulting in abort)



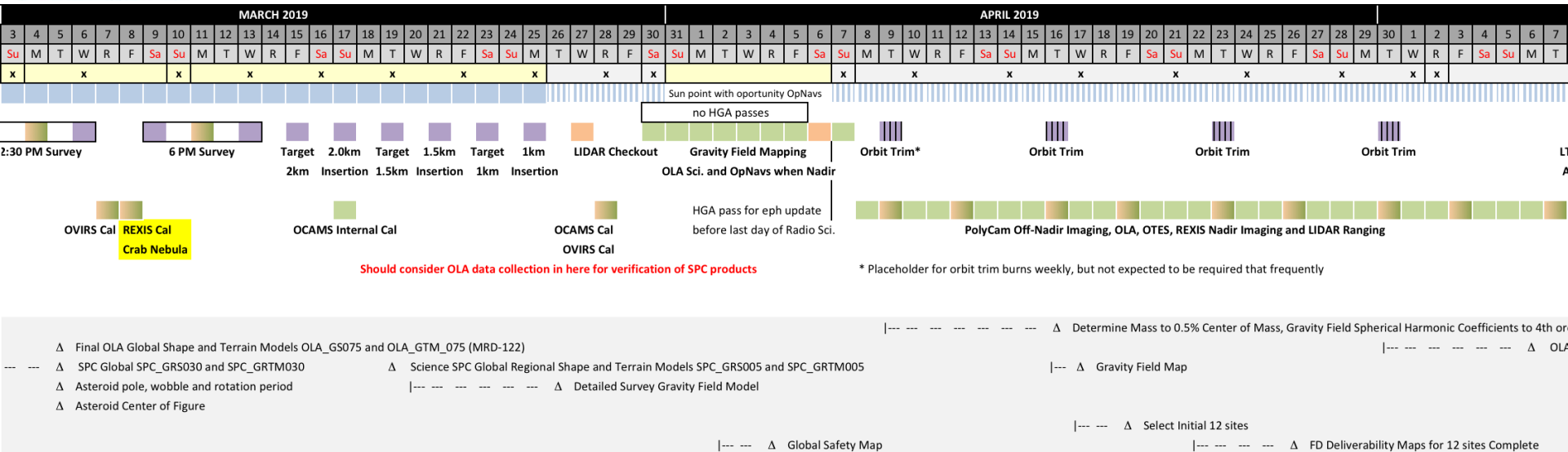
Local Deliverability Map

- Will support the 3D map format standard that allows ingest and display by the visualization tool under development by the SPOC.
 - Displayed ellipses will be supported in the map format “shape layer”
 - Other parameters describing TAG performance can be displayed as a layer through the ancillary data file described in the map format SIS (UA-SIS-9.4.4-324, Rev. 1.0).
- The mapped surface elements will now only cover the vicinity of the TAG site and the elements will be 20 cm × 20 cm on the surface.
- The only information per element is the probability that the center of the TAGSAM head will contact within that surface element.
- The map will include all cells with contact probability $>10^{-7}$.
- The figure provides a graphical depiction of the cell-by-cell contact probability.





Local Deliverability Schedule and Inputs



- Local deliverability maps will be produced for up to 12 candidate TAG sites
 - Will utilize updated shape and spin models delivered at the end of Detailed Survey
 - Requires updated gravity model resulting from radio science campaign early in Orbit B, which is available at about the same time as selection of 12 sites
- Deliverability maps for primary and backup TAG site may be updated prior to rehearsals if any significant model updates are made.
- Updated local deliverability maps may be delivered associated with preliminary and late update TAG designs



Status of Algorithm Development

- The formats for the exchange of deliverability maps between FDS and SPOC are documented in the following OIAs and software interface specifications:
 - OIA_ORX_040a – Site-specific Deliverability Maps
 - SIS ORX011 FDS to SPOC & MSA
 - OIA_ORX_040b – Global Deliverability Maps
 - SIS ORXTBD FDS to SPOC & MSA
- An initial version of the Flight Dynamics TAG and Deliverability Map Tools was delivered as part of GSFC Build 1 prior to CDR.
- The deliverability map SIS's are scheduled to be finalized in May 2015
 - Recommending unique SIS be developed for global deliverability map data – some details of this are still being finalized
- The final build of the tools is expected with GSFC Build 3 in June 2015, in support of GRT 2B.



Minimal Mission Scenario

- Global and Local deliverability maps are core products required to support site selection
- Shape/gravity inputs required to create the maps are also critical requirements for navigation
- No changes anticipated to plans for deliverability maps if minimal mission scenario is adopted



Work to go

- Finalize gravity modeling updates in TAG MC analysis tool (expected April 2015)
- Finalize SIS's for Global and Local Maps (expected by May 2015)
- ODTT3 – May 2015
- GRT 2B – August 2015



Next Topic (This slide will be done for you)

#	Start Time	Topic	Presenter
	7:45 AM	Coffee/Refreshments	
1	8:00 AM	Welcome	E. Beshore
2	8:10 AM	OSIRIS-REx Mission Overview and Priorities	D. Lauretta
3	9:10 AM	DRM Science Collection Overview	B. Boynton/J. Kidd
	9:55 AM	Break	
4	10:10 AM	Ground System Overview	J. Gal-Edd
5	11:10 AM	SPOC Overview	C. Shinohara
	11:55 AM	Lunch	
6	12:55 PM	Operations Overview	S. Barnes
7	1:40 PM	SPOC/Science Planning Process	B. Boynton/C. Hergenrother
	2:40 PM	Break	
8	2:55 PM	SPOC Implementation Process	S. Barnes
9	4:25 PM	SPOC Downlink Process	S. Balram
	4:55 PM	Board Caucus	Board



Backup