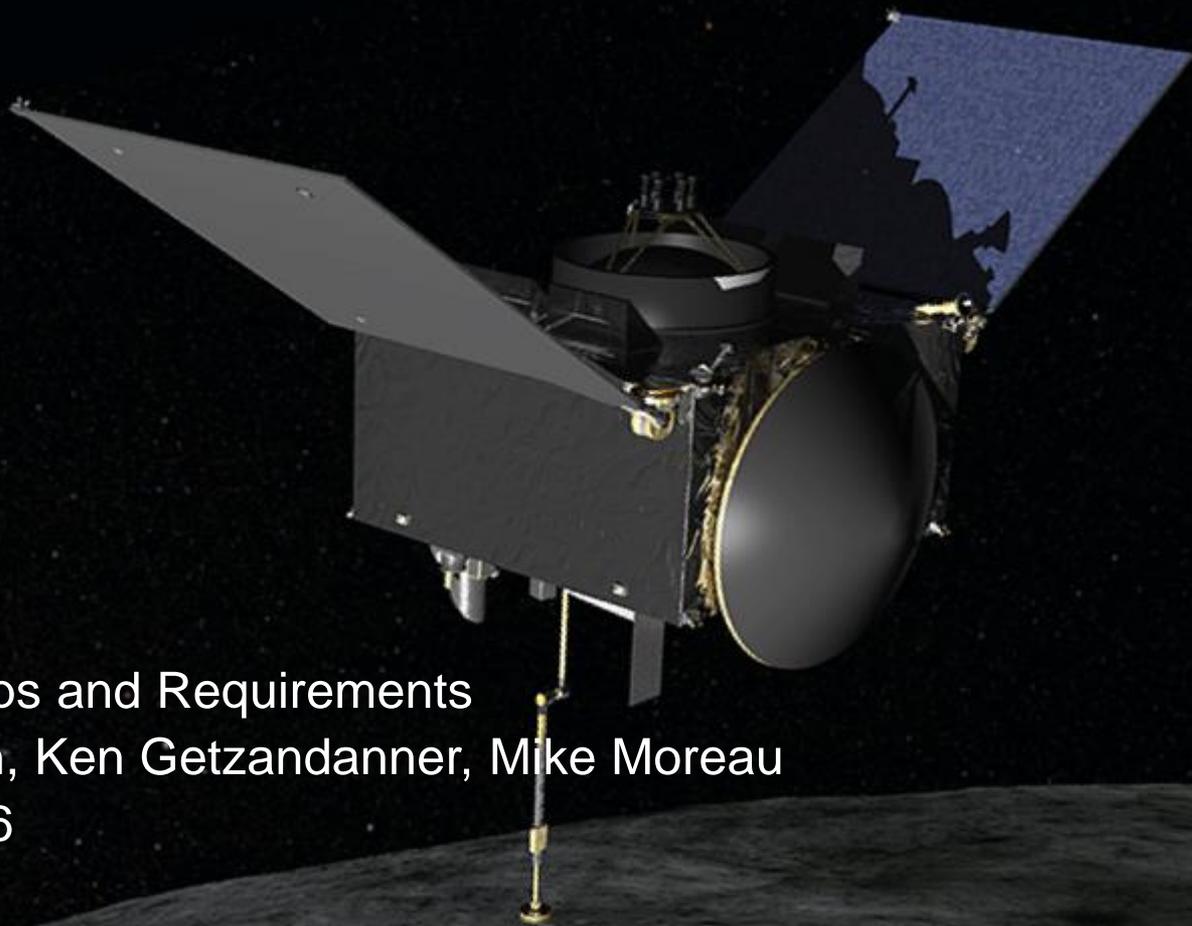




OSIRIS-REx™

ASTEROID SAMPLE RETURN MISSION



FDS DTM Conops and Requirements
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Topics

- Landmark Tracking Conops
- Conops for coordinate frame updates
- FDS DTM Requirements, and Status
- Forward work, issues



Landmark Tracking ConOps

- Late Approach-Preliminary Survey
 - ALTWG delivers preliminary 75 cm DTM set
 - Can be evaluated against requirements but does not need to meet them
 - FDS receives preliminary 75 cm DTMs
 - Begins navigation landmark evaluation and selection process
 - Parallel processing of NavCam images with KXIMP and SPC
 - As time/staffing allows, preliminary OD comparisons between star-based and landmark data
- Orbital A
 - ALTWG delivers official 75 cm DTM set to FDS (not entire project, yet)
 - Evaluation of DTMs w.r.t. requirements. Recommendation for best 80% of landmarks
 - FDS ingests official 75 cm DTMs
 - Landmark selection
 - Re-evaluation of navigation landmark statistics
 - May begin with full (80%) landmark set and pare down outliers based on post-fit OD residuals
 - Parallel processing of NavCam images with KXIMP and SPC
 - OD comparisons between star-based and landmark data
 - Filter Tuning
 - Iteration for resolving CM vs COF offset (next slide)
 - ALTWG delivers final 75 cm DTM to Project
- Late Detailed Survey - Orbital B
 - ALTWG delivers official 35 cm DTM set to FDS (not entire project, yet)
 - FDS ingests 35 cm DTMs
 - Landmark selection
 - OD comparisons between 75 cm and 35 cm landmark sets; Filter Tuning
 - Iteration for resolving CM vs COF offset (next slide)
 - ALTWG delivers final 35 cm DTM to Project



ConOps For Coordinate Frame Update

1. FDS receives shape model and spin state (PCK) and (when appropriate) uniform density gravity field from ALTWG before formal project delivery
2. FDS solves for 1st degree and order gravity harmonics and spin state
 1. MIRAGE using landmarks
 2. GEODYN independently solves for offsets and compares
3. Give ALTWG offsets and spin state
4. ALTWG updates spin state and re-adjusts landmarks
 1. ALTWG provides recommended set of SPC commands (SHIFT, NEW_POLE) to account for offsets in FDS landmarks
5. FDS verify new landmarks
 1. FDS processes new landmarks, verify MIRAGE solution for 1st degree terms and spin state differences are “small enough”
 2. If not, iterate (back to 3.0)
6. ALTWG formally delivers shape model
7. FDS produces a SPK consistent with CM and spin state (no offsets, zeroed 1st degree and order terms)



Process for Dealing with Offsets In Between ALTWG and FDS Modeling Between Deliveries

1. Start with shape model that's already been rectified to have zero offsets
2. Begin acquiring new tracking data (radio, landmarks) and performing OD (no offsets, zeroed 1st degree and order terms)
 1. In parallel, run MIRAGE so that we estimate the 1st degree terms and spin pole and rate
 2. When estimates exceed a threshold, then we take action:
 1. FDS pass estimates of offsets to ALTWG
 2. ALTWG provides recommended set of SPC commands (SHIFT, NEW_POLE) to account for offsets in FDS landmarks
 3. FDS adjusts the navigation landmarks to account for the offsets
3. Continue performing OD with new adjustments that should result in no offsets, zeroed 1st degree and order terms
 1. These SPKs are delivered to the project
4. When it's time for a new delivery from ALTWG, follow ConOps on previous page.



FDS 75 cm DTM Requirements

- MRD-676: FDS - Global 75cm DTM Product Requirements
 - Note: These requirements assume use of Approach and Preliminary Survey products, and some Orbital A data.
 - Note: These requirements are intended to support FDS operations from the end of Orbital A through Orbital B insertion.
- MRD-677/678: Global 75cm DTM Ground Sample Distance
 - **The Ground System shall, for > 80% of the asteroid surface, produce a set of DTMs at < 0.75 m in ground sample distance (sample resolution).**
 - Note: Ground sample distance is defined as the sample spacing of the surface in m/pix.
 - Rationale: Ground sample distance of DTMs should be comparable to navigation imager(s) ground sample distance (m/px) for relevant mission phases.
- MRD-679/680: Global 75cm DTM Relative Accuracy (Precision)
 - **The Ground System shall, for > 80% of the asteroid surface, produce a set of DTMs with post-fit residual RMS < 0.38 m (1-sigma) for each maplet.**
 - Note: Post-fit residual of a maplet is defined as the (pixel, line) difference between predicted model and observed images of the maplet.
 - Rationale: The RMS post-fit residual from the DTM geometry solution should be less than 0.5 DTM pixels (1-sigma). Landmarks consist of an image spanning multiple pixels. Errors in the correlation of an OpNav image to a landmark will be introduced if there are distortions in the features of the landmark, or relative shifts in the positions of adjacent landmarks. This requirement bounds the allowable distortion of features across the landmark, or variations in the relative position shifts of nearby landmarks, which factors into the FDS landmark centerfinding error budget through errors in the correlation of OpNav images with a landmark.
 - Note: Verifying this requirement in flight assumes use of images for shape modeling that have a better ground sample distance than the maplets (i.e., Mapcam or Polycam imaging), as well as use of OLA data.
- MRD-681/682: Global 75cm DTM Accuracy
 - **The Ground System shall, for > 80% of the asteroid surface, produce a set of DTMs with a 3D RMS accuracy < 1m (1-sigma).**
 - Rationale: Global accuracy of the delivered landmark centers factors into the FDS landmark-tracking error budget.
 - Note: Accuracy will be verified in flight through analysis and/or with OLA data.



FDS 35 cm DTM Requirements

- MRD-685: FDS – Global 35cm DTM Product Requirements
 - Note: These requirements assume use of imaging data up through Detailed Survey.
 - Note: This requirement is intended to support FDS operations from Orbital B through TAG.
- MRD-686/687: Global 35cm DTM Ground Sample Distance
 - **The Ground System shall, for > 80% of the asteroid surface, produce a set of DTMs at < 0.35 m in ground sample distance (sample resolution).**
 - Note: Ground sample distance is defined as the sample spacing of the surface in m/pix.
 - Rationale: Ground sample distance of DTMs should be comparable to navigation imager(s) ground sample distance (m/px) for relevant mission phases.
- MRD-688/689: Global 35cm DTM Relative Accuracy (Precision)
 - **The Ground System shall, for > 80% of the asteroid surface, produce a set of DTMs with post-fit residual RMS < 0.18 m (1-sigma) for each maplet.**
 - Note: Post-fit residual of a maplet is defined as the (pixel, line) difference between predicted model and observed images of the maplet.
 - Rationale: The RMS post-fit residual from the DTM geometry solution should be less than 0.5 DTM pixels (1-sigma). Landmarks consist of an image spanning multiple pixels. Errors in the correlation of an OpNav image to a landmark will be introduced if there are distortions in the features of the landmark, or relative shifts in the positions of adjacent landmarks. This requirement bounds the allowable distortion of features across the landmark, or variations in the relative position shifts of nearby landmarks, which factors into the FDS landmark centerfinding error budget through errors in the correlation of OpNav images with a landmark.
 - Note: Verifying this requirement in flight assumes use of images for shape modeling that have a better ground sample distance than the maplets (i.e., Mapcam or Polycam imaging), as well as use of OLA data.
- MRD-690/691: Global 35cm DTM Accuracy
 - **The Ground System shall, for > 80% of the asteroid surface, produce a set of DTMs with a 3D RMS accuracy < 0.75m (1-sigma).**
 - Rationale: Global accuracy of the delivered landmark centers factors into the FDS landmark-tracking error budget.
 - Note: Accuracy will be verified in flight through analysis and/or with OLA data.



FDS DTM Delivery Timing Requirements

- **MRD-683/684: Global 75cm DTM Delivery**
 - The Ground System shall provide the global 75cm DTM product to FDS within 14 days of downlink of all Preliminary Survey OCAMS and OLA data.
 - 14 days ensures the global 75cm product is available for the transition to landmark-based optical navigation and verification of Detailed Survey-level performance prior to the end of Orbital A.
- **MRD-692/693: Global 35cm DTM Delivery**
 - The Ground System shall provide the global 35cm DTM product to FDS within 14 days of downlink of all Detailed Survey "Baseball Diamond" OCAMS and OLA data.
 - Rationale: 14 days ensures the global 35cm product is available early in Orbital B to demonstrate the predictive accuracy needed for Recon and TAG.



Requirements Status and Forward Work

- From Eric Palmer:
 - Navigation Error sensitivity test, his results are showing for 75cm DTM:
 - 1.06298m RMS accuracy over 100% of body compared with truth using CompareOBJ
 - 0.7143m RMS accuracy over best 80% of body
 - ALTWG working on adding functionality into CompareOBJ to calculate accuracy over 80% of surface
 - For calculations of the post-fit residuals, as stated by FDS in the L2 requirements, we need to get clarification if that means we look at the average RMS of all the maplets with: images, images + overlaps, images + limbs, or images + limbs + overlaps.
 - Bob's RESIDUALS.TXT reports both images + limbs and images + overlaps + limbs.
 - We are gathering info to provide to FDS/Coralie that shows the difference between each option so FDS can officially define which residual metric they want (the expectation is images + limbs).
- FDS comments:
 - The requirement states: The Ground System shall, for > 80% of the asteroid surface, produce a set of DTMs with post-fit residual RMS < 0.38 m (1-sigma) for each maplet.
 - We interpret this as: for a set of DTMs that together cover >80% of the surface, **each** DTM must have a post-fit residual RMS < 0.38m (1-sigma)
 - Post-fit residual of a maplet is defined as the (pixel, line) difference between predicted model and observed images of the maplet.
 - Have not seen how current results evaluate against RMS requirements.
 - **We are not yet concerned about ALTWG meeting these requirements, and do not think there's cause to modify any requirements currently.**
 - Once tools are developed to evaluate all requirements, we will assess.



75 cm DTM Verification Matrix — DRM Rev C

| Requirement | SPC | SPC+OLA | OLA |
|--|-----|---------|-----|
| For > 80% of the asteroid surface, produce a set of DTMs at < 0.75 m in ground sample distance (sample resolution). | X | X | X |
| For > 80% of the asteroid surface, produce a set of DTMs with post-fit residual RMS < 0.38 m (1-sigma) for each maplet | | X | X |
| For > 80% of the asteroid surface, produce a set of DTMs with a 3D RMS accuracy < 1m (1-sigma). | | X | X |
| Provide the global 75cm DTM product to FDS within 14 days of downlink of all Preliminary Survey OCAMS and OLA data. | X | X | |



35 cm DTM Verification Matrix — DRM Rev C

| Requirement | SPC | SPC+OLA | OLA |
|---|-----|---------|-----|
| For > 80% of the asteroid surface, produce a set of DTMs at < 0.35 m in ground sample distance (sample resolution). | X | | X |
| For > 80% of the asteroid surface, produce a set of DTMs with post-fit residual RMS < 0.18 m (1-sigma) for each maplet | | | |
| For > 80% of the asteroid surface, produce a set of DTMs with a 3D RMS accuracy < 0.75 m (1-sigma). | | | |
| Provide the global 35cm DTM product to FDS within 14 days of downlink of all Detailed Survey "Baseball Diamond" OCAMS and OLA data. | | | |



Missing FDS DTM Requirements?

- **Does trajectory reconstruction drive more stringent DTM requirements than FDS baseline?**
 - FDS needs to evaluate OpNav imaging schedule for Recon, TAG rehearsals, and TAG.
 - There may be regions where $<35\text{cm}$ DTMs would be more appropriate given image resolution and NFT or Science DTMs would be requested.
 - Currently do not anticipate levying any additional requirements on these products, but FDS may need to be added as recipients of the data



Undocumented Interfaces?

- From E. Palmer:
 - SPC has no requirement, OIA or SIS to deliver anything to FDS once we finish the DS shape model. It makes a lot of sense for there to be more back-and-forth between FDS and SPC throughout the mission. However, there is nothing on the books. I think it is worth considering a significantly expanded interface between FDS and SPC, especially in regard to updated reconstructed kernels — i.e. I give you a draft shape model, you fit an arc to it and update the kernels, I use those updated kernels to get a better shape model, etc. From my testing of F1 and F3, I have identified that the shape model with 1-sigma nav errors decreases the accuracy of the shape model by a factor of two.
- Question:
 - Besides the iterative process already described, do we want to consider a requirement to perform SPC processing of NavCam/OCAMS images from Approach and PS to create an improved, reconstructed ephemeris for performing an update to the shape model?