OSIRIS-REx™
ASTEROID SAMPLE RETURN MISSION

Global and Site-Specific Topographic Maps, and Coordinate Systems

April, 2015

Altimetry Working Group
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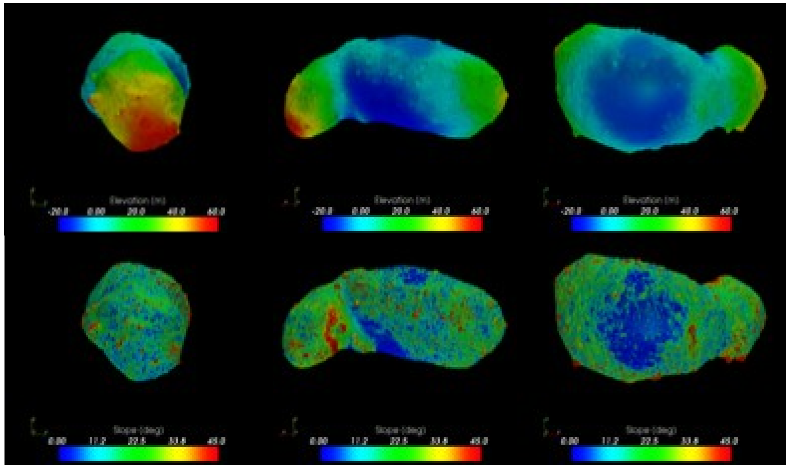
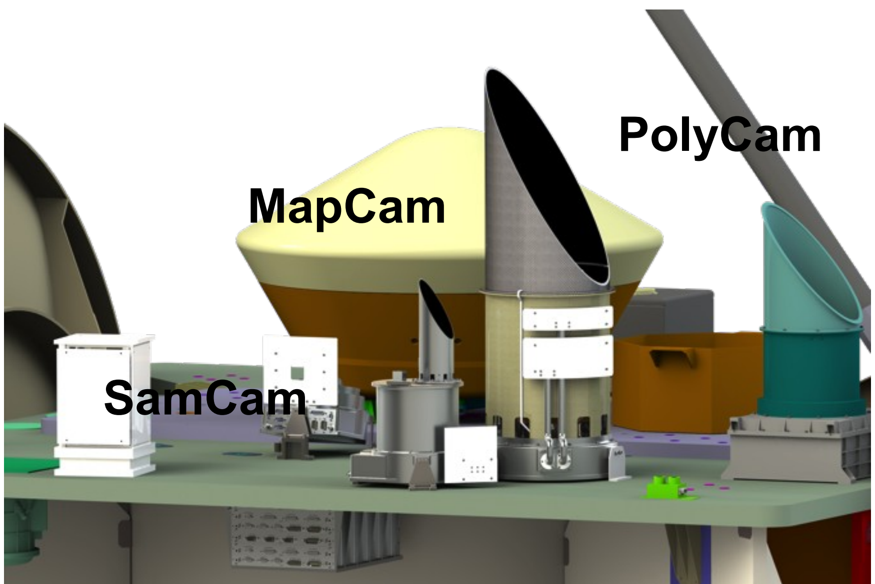
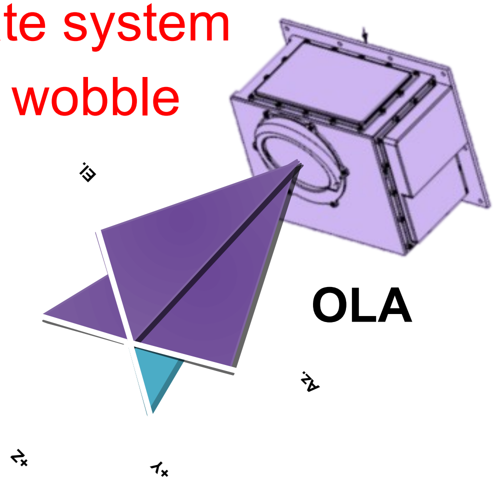
Altimetry Working Group



SPC Itokawa shape model



- Objective
  - To generate all the global and local topographic products using the OCAMS camera suite and Osiris-REx Laser Altimeter to safely sample to surface of Bennu
- Data products include:
  - Local and global topography
  - Local and global shape models
  - Asteroid coordinate system
  - Pole location and wobble
  - Rotation period
  - Asteroid volume
  - COM-COF offset



Key Altimetry Products

Science Product	Flt. Dynamics	NFT	Deliverability	Safety	Sampleability
Coordinate System (MRD-125)	●	●	●	●	●
Spin State (MRD-127; 128; 129)	●	●			
Science Shape Model <1m (MRD-122)					
Science 12-Site Specific Topographic Maps <5 cm GSD (MRD-115)				□	●
Science 12-Site Specific Tilt Maps (MRD-608)			●	●	●
Asteroid volume (MRD-132)					
Center of figure (MRD-124)					
FD Global Terrain Maps <0.75m GSD (MRD-NEW 1-4)	●				
FD/NFT Global Terrain Maps <0.35m GSD (MRD-NEW 6-8)	●				
NFT Global Terrain Maps <0.10m GSD (MRD-NEW 9-13)		●			
NFT 2-Site Specific Topographic Maps <5cm GSD (MRD-NEW 14-18)		●			

● Primary product – required for development
□ Secondary product – supports creation of primary product

Science Requirements for Topographic Products

- Science
  - Requirements remain unchanged since CSR
  - Requirements defined by map resolution with accuracies and precision on the order of, or better than the ground sample distance (resolution) and timing to support creation of site selection products

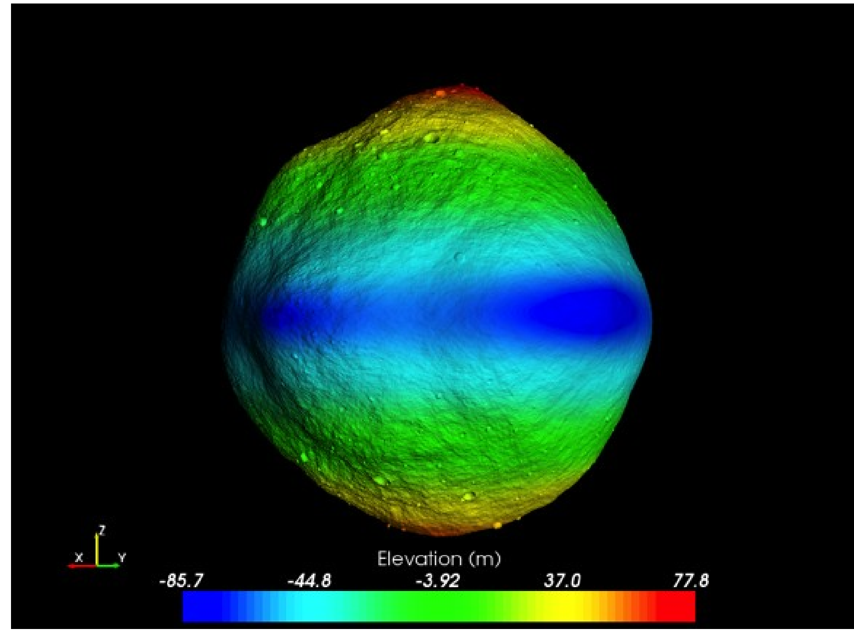
	Ground Sample Distance	Vertical Accuracy	Vertical Precision	Horizonal Precision	Product source and timing
Sci 100cm	<100cm	<100cm	<100cm	<100cm	SPC – PreSurvey/Orb A OLA –Detailed survey
Sci 5 cm	<5cm	<100cm	<5cm	<5cm	SPC-Detailed Survey OLA-Orb B/Recon
Sci tilt 32 cm	<32cm	<100cm	<4cm	<32cm	Detailed Survey OLA-Orb B

Science Global Shape Model (MRD-123)

A global map of the surface of Bennu.

Spatial resolution (ground sample distance, accuracy and precision) of <1 m

These data are needed for sample site selection, general science and long-term science. Key input for asteroid volume (MRD-132), COM-COF (MRD-124)



Enhanced global shape model of Bennu

Timing of Data Product Generation

SPC – End of Preliminary Survey/Early Orbital A
OLA – End of Detailed Survey
OLA/SPC – Detailed Survey

Approach

SPC processing: MAPLETS collected to generate a shape model
OLA processing: Global altimetry or local maps (mapolas) are generated using SOEST GMT and collected to make a global shape model

Data Description

ASCII file of vertices (“v x y z”) followed by facets (“f 1 3 7”)
SPICE DSK shape model file
Associated data with each facet including slope, gravity, elevation, geoid (assuming uniform density), tilt, and associated errors shape.

Science Global Topographic Map (MRD-122)

A global map of the surface of Bennu that accompanies the Global Shape Model.

Spatial resolution (ground sample distance, accuracy and precision) of <1 m

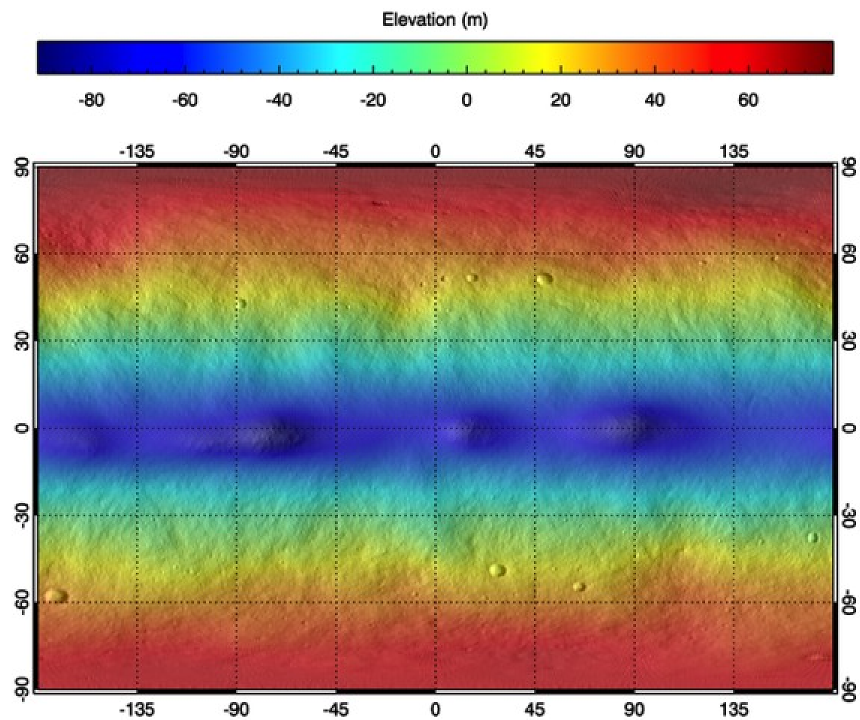
These data provide the global topography to quickly identify suitable candidate sample sites.

Timing of Data Product Generation

SPC – End of Preliminary Survey/Early Orbital A
OLA – End of Detailed Survey
OLA/SPC – Detailed Survey

Approach

SPC processing: Collect MAPLETS and use bigmap to generate global data.
OLA processing: Global altimetry or local maps are collected to make a global map using SOEST GMT.



Global Map of elevation relative to a reference geiod for Bennu at 8 pixel/deg

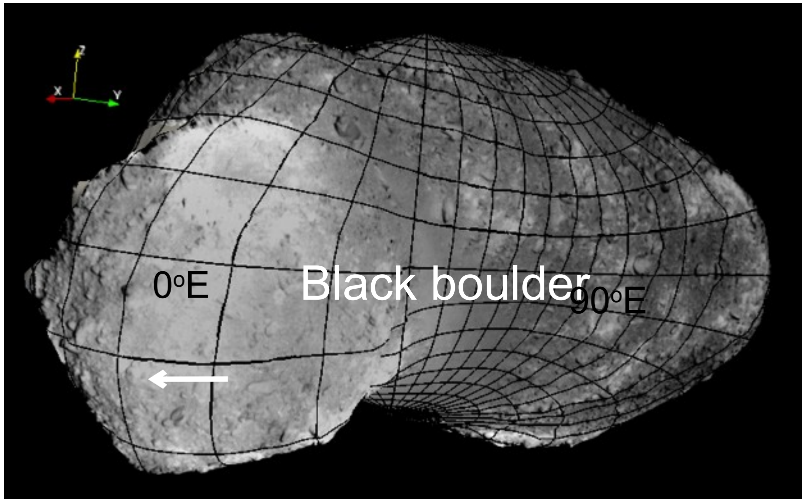
Data Description

Double precision grid of Radius, Elevation, Slope, Gravity, Tilt, estimate of errors associated with each pixel, at 8 pixel per degree (~60cm per pixel at equator)
Simple cylindrical projection
Min Longitude= 0. Min Latitude =-90. Max Longitude = 360. Max Latitude = 90.

Asteroid Coordinate System (MRD-125)

The rotation angle of the prime meridian for Bennu relative to Bennu's principal moments of inertia.

- ALTWG will identify a geological feature associated with the prime meridian (pm)
  - Will maintain pm at same location during encounter on the feature chosen as imaging resolution/topography improves.
  - This rotation angle will be applied to the shape model and topographic maps produced by the ALTWG.
  - Applied to other products through use of a NAIF SPICE PCK File generated by ALTWG.
  - Ultimate pm used for products delivered to PDS and submitted to the IAU for approval will be proposed by the ALTWG, vetted and approved by the science executive committee and the mission PI, and then submitted to the IAU.



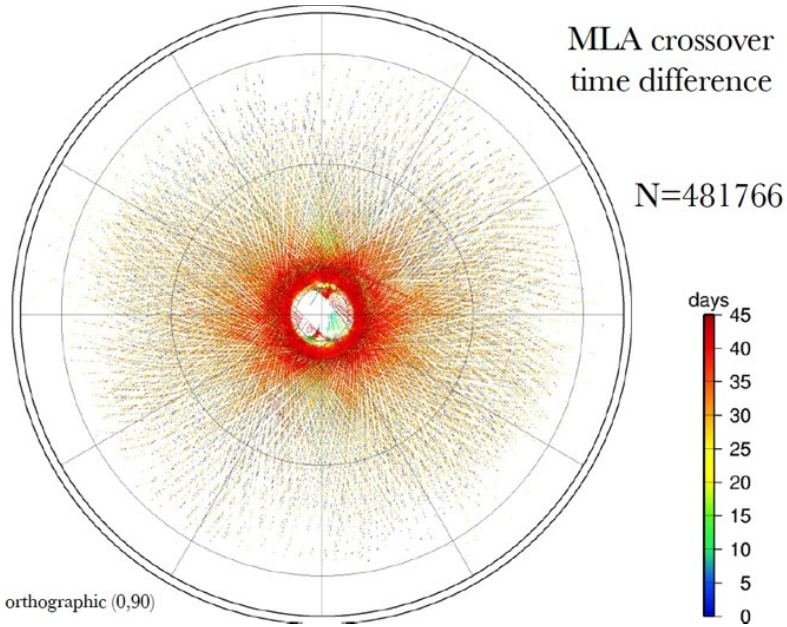
Coordinate system for Itokawa defined by longitude of "black boulder"

Coordinate center will be set to COM by Orbital A. COF will be used prior to estimate of GM.

Pole location (MRD-127), wobble (MRD-128) and rotation period (MRD-129)

Pole orientation, Rotation rate and Pole Nutation

These data are needed to safely sample Bennu and to produce an accurate shape model/topography



Approach used to refine Mercury's libration

Data Product Generation

SPC – Approach Phase and Preliminary obs used to develop rotation state (additional observations in Orbital A if needed)
NAV develops independent rotation state from Mirage using Science determination for guidance and verification.
OLA/GEODYN – Detailed Survey: Further refinement.

SPC processing: Tracking landmarks across the asteroid as it rotates to determine pole and model wobble
FD processing: Estimate wobble of landmarks while producing ODs.
OLA/GEODYN processing: Minimizing offsets between altimetric data sets obtained at differing times by modeling the orientation of the asteroid's pole, wobble and rotation rate.

Data Description

SPICE PCK text or binary file (e.g., Moon) providing pole RA and DEC, rotation rate, and RA and DEC nutation. For complex wobble case, generate a Bennu attitude SPICE CK file output from a dynamical wobble model for period of mission encounter.

Evolving Requirements for Topographic Products

- Navigation
  - Recently determined that existing science requirements were insufficient to support navigation activities
  - New set of requirements delivered to ALTWG ~ March 18, 2015.
    - Flight Dynamics (Navigation Team) - 2 new sets
      - Driven by precision and accuracy to support landmark navigation
      - Driven by timing to support Detailed Survey and Orbital B operations
    - Natural Feature Tracking (LM GN&C team) – 2 new sets
      - Driven by precision and accuracy of topography to support on-board feature matching algorithms
      - Driven by timing to support rehearsals for prime and (if required) backup site

	Ground Sample Distance	Vertical Accuracy	Vertical Precision	Horizonal Precision	Source Data
FDS Global 75	75cm	100cm		38cm	PreSurv Orb A
FDS Global 35	35cm	75cm		18cm	Detailed Survey
NFT Global 10	10cm	63cm	17cm	3.2cm	Detailed Survey
NFT TAG	5cm	14cm	1.8cm	1.7cm	Orbit B

ALTWG's response to these new requirements

- ALTWG leadership is engaged with FD and NFT
  - Weekly meetings with FD and NFT teams to understand requirements of both teams
  - Follow FD discussion relevant to ALTWG for development of shape, rotation state products
    - e.g., Thermal influence on pointing performance of the S/C both relevant to OLA and NavCam
- Discussions within ALTWG (SPC and OLA teams) to determine most efficient way to meet requirements, including
  - Re-evaluating observing plan
    - Does the DRM provide observations needed to meet FD/NFT requirements?
  - How SPC performs alone, how OLA observations can supplement or speed processing, where OLA is superior to SPC
  - Make use of additional data types such as S/C velocity from Doppler to assess size of the asteroid accurately
- Reassessments of staffing and budget
  - Support for testing plans
  - Support for operations

FD Global Digital Terrain Model (MRD-New1 to 3)

A global digital terrain model (DTM) of the surface of Bennu.

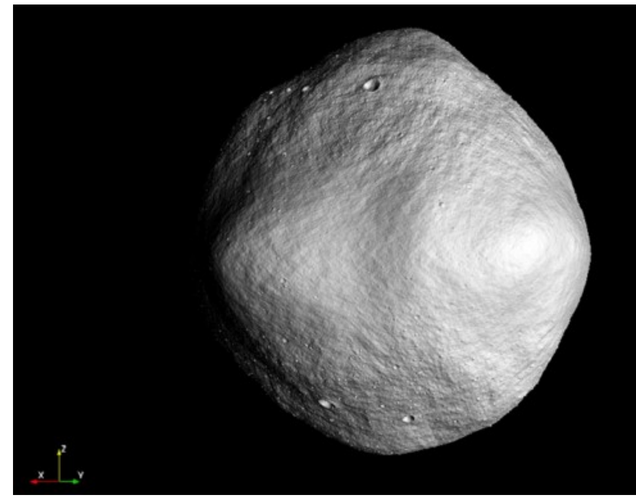
Spatial ground sample distance of <0.75 m
Relative lateral accuracy <0.38m (1 sigma)
Vertical accuracy <1m (1 sigma)
Delivered in Orbital A, after orbit insertion.

Timing of Data Product Generation
SPC – Approach to Preliminary Survey/Early Orbital A
OLA – OLA Preliminary Survey Data

Approach
SPC processing: MAPLETS collected to generate a shape model
OLA processing: OLA data to verify SPC precision and accuracy and minimize errors in navigation

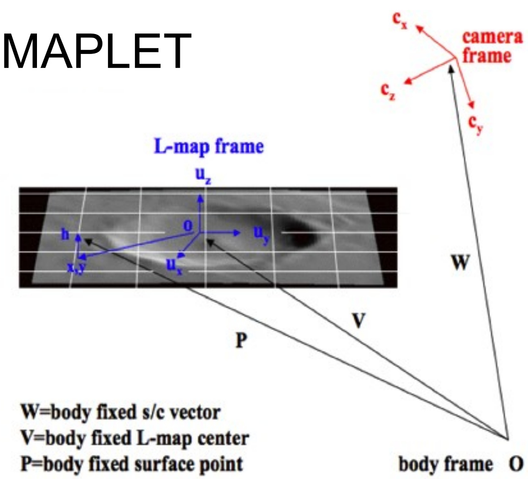
Data Description
SPC Native formats (eg., MAPLETS)
Science Team formats:
ASCII file of vertices ("v x y z") followed by facets ("f 1 3 7").
Uncertainties errors associated with maplets and shape

SPICE DSK shape model file.



Enhanced global shape model of Bennu

MAPLET



FD/NFT Global 0.35 m DTM (MRD-New 4-8)

A global map of the surface of Bennu.

Spatial ground sample distance of <0.35 m
Relative Accuracy <0.18m
Global accuracy <0.75m

These are required by FD and NFT for Navigation

Timing of Data Product Generation

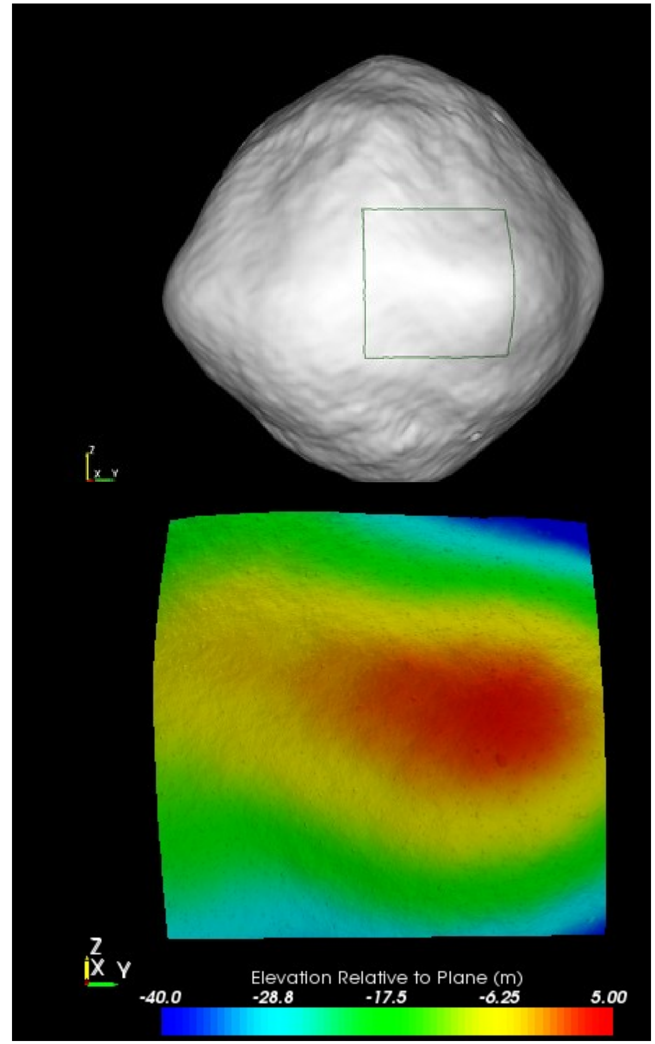
SPC – Before insertion in Orb B
OLA – OLA data from detailed survey used to verify accuracy (but not precision)

Approach

SPC processing: Collect MAPLETS and usse bigmap to generate global data. SPC mock testing verifies precision.
OLA processing: OLA point clouds and maps made using GMT are used to verify accuracy of SPC data collected; and Orb B data provides subsequent checks

Data Description

Set of double precision grids with 0.3m GSD (in in x, y ,z, lat, long, radius, albedo and model error) covering entire asteroid
Set of triangular plates (OBJ)



Regional Digital Terrain Model of enhanced Bennu.

NFT Global 0.1 m DTM (MRD-New 9-13)

A global map of the surface of Bennu.

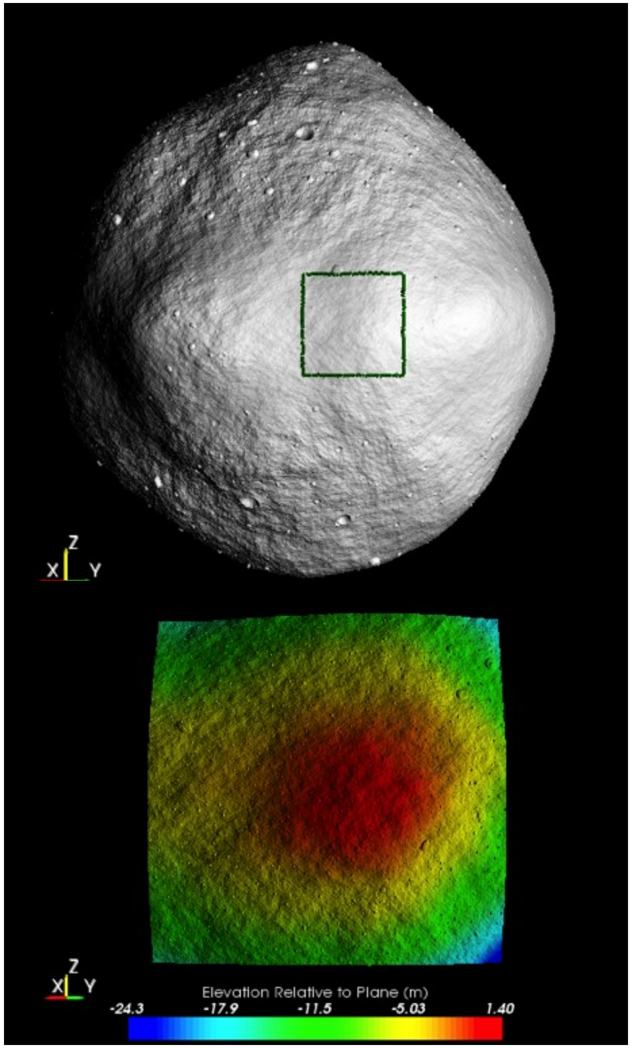
Spatial ground sample distance of <0.1 m
Relative accuracy <0.032m
Vertical precision <0.17m
Global accuracy <0.632m

These are required by FD and NFT for Navigation

Timing of Data Product Generation
SPC – Generated >6 weeks before start of TAG rehearsal using detailed survey and orbital B data
OLA – Verified with OLA data in Orb B and Recon

Approach
SPC processing: Collect MAPLETS and use bigmap to generate global data.
OLA processing: GMT and OLA Orb B point clouds are compared directly to verify SPC precision and accuracy.

Data Description
Set of double precision grids with 0.1 GSD (in x, y ,z, lat, long, radius, albedo and model error) covering entire asteroid with radius
Set of triangular plates (OBJ)



Regional Digital Terrain Model of enhanced Bennu.

NFT Site Specific Digital Terrain Map (MRD-New 14-18)

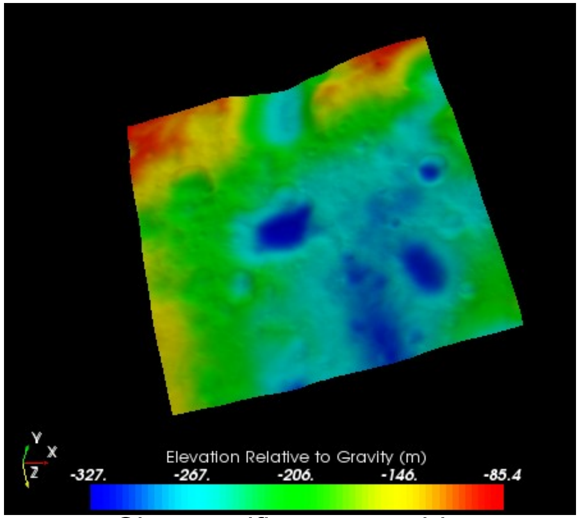
Prime and backup site map of the surface of Bennu for NFT

Spatial ground sample distance of <0.05 m
Relative accuracy (Lateral) <0.017m
Vertical precision <0.018m
Global accuracy <0.14m

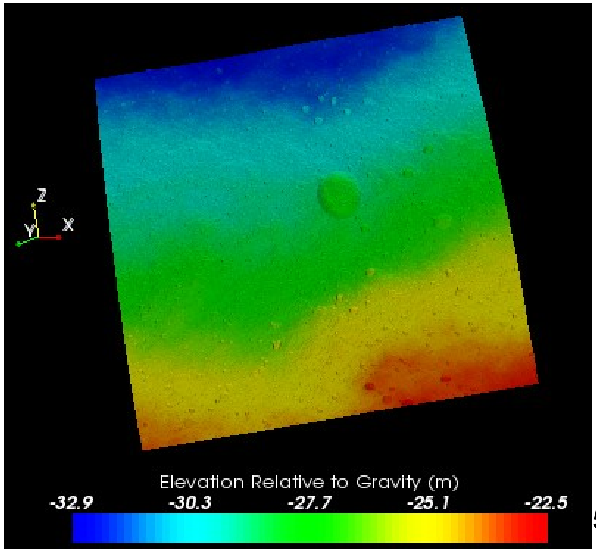
Data Product Generation
SPC – Orbital phase B
OLA – Reconnaissance Phase
OLA/SPC – Orbital phase B

SPC processing: Uses very small MAPLETS to generate these data. SPC mapmaker or bigmap are used to generate the final product.
OLA processing: These maps are generated using SOEST GMT from individual OLA data collected during recon.

Data Description
Set of double precision grids with 0.05 GSD (in x, y ,z, lat, long, radius, albedo and model error) covering entire asteroid with radius
Set of triangular plates (OBJ)



Site specific topographic map on Eros and Bennu

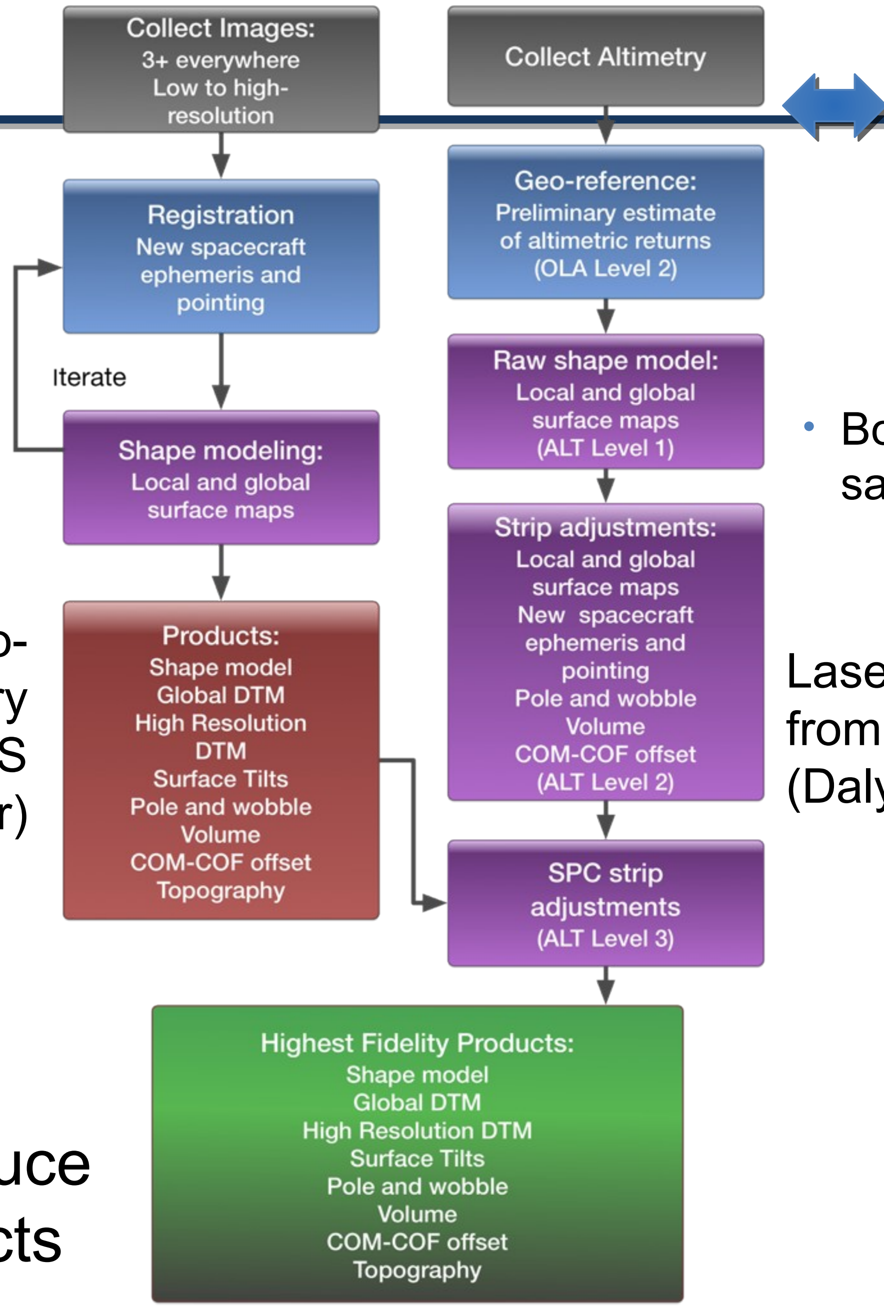


Altimetry Structure

FD and GEODYN

- Lead by Dr. Barnouin
  - Two parallel but independent approaches

Stereo-photoclinometry (SPC) from OCAMS (Gaskell/Palmer)



- Both generate the same products

Laser Altimetry from OLA (Daly/Johnson)

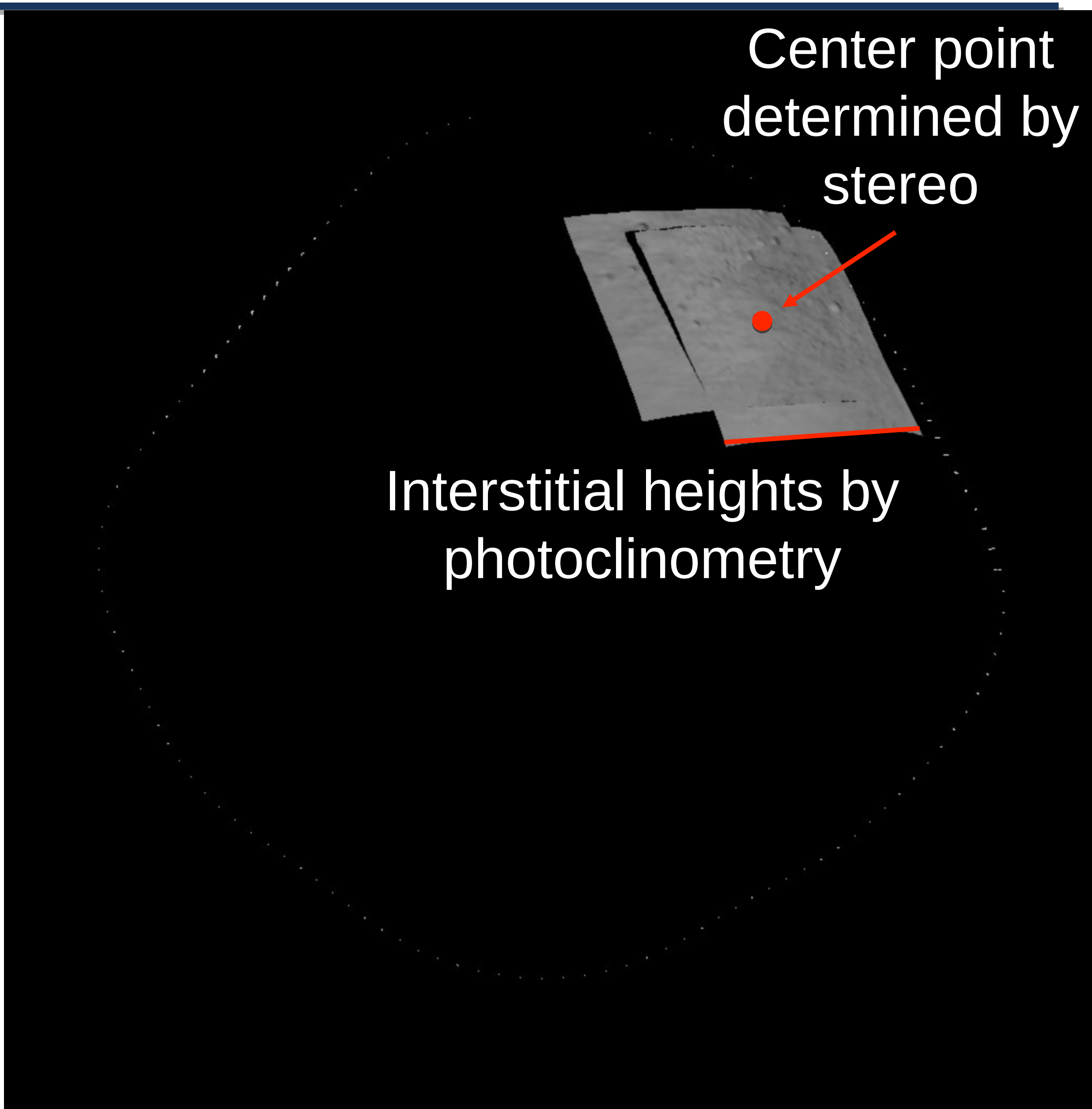
- Combined to produce high fidelity products

ALTWG Stereo-Photoclinometry (SPC)

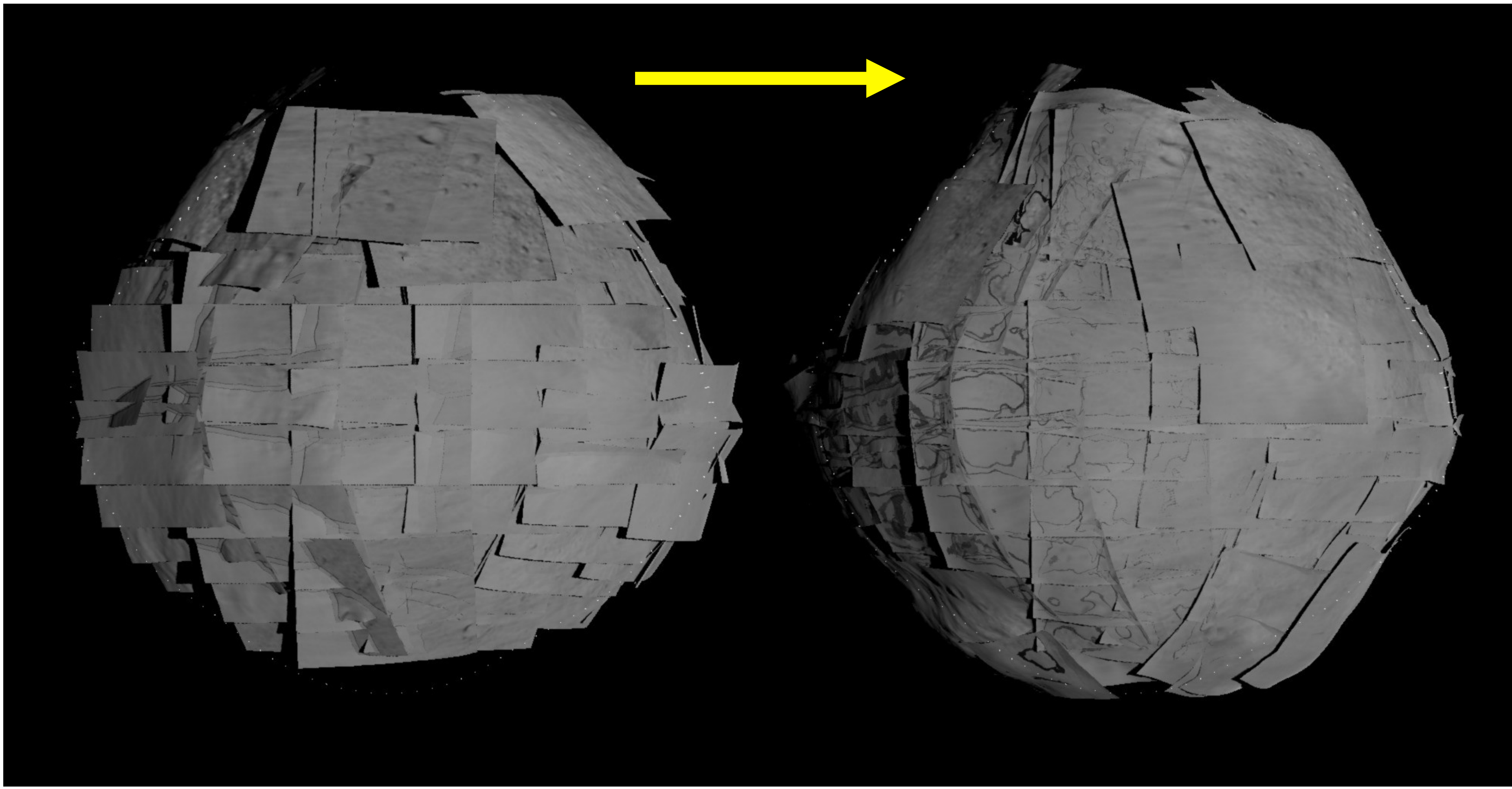
ORIGINS: For topography and navigation purposes, design an object (template) that can be identified and located in an image under any observation conditions.

CONCEPT: Construct topo/albedo maps of surface patches with control point at center.

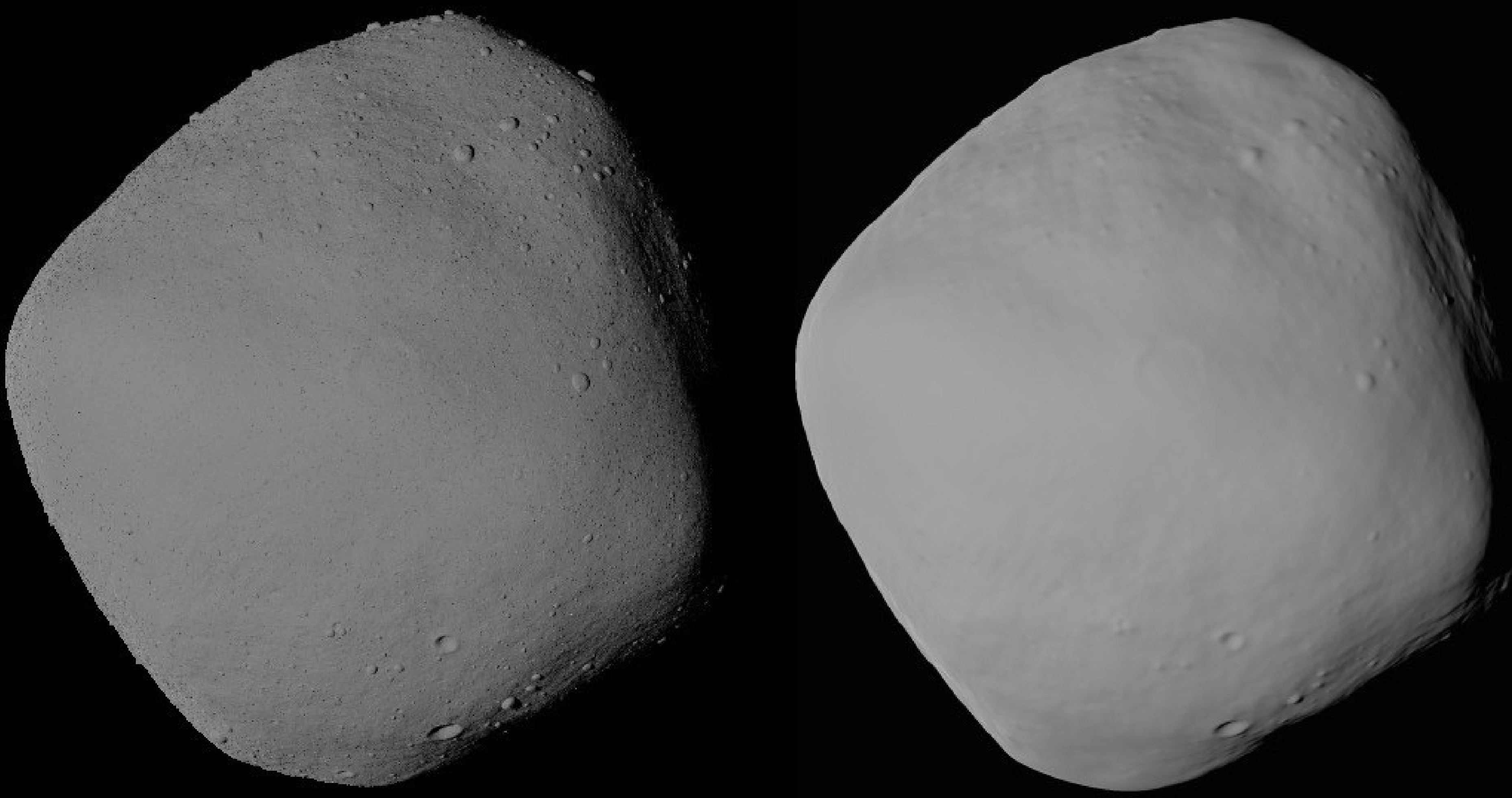
RESULT: Stereo on steroids. Precise control point location from huge stereo separation over multiple trajectories and even multiple spacecraft.



A Few Iterations



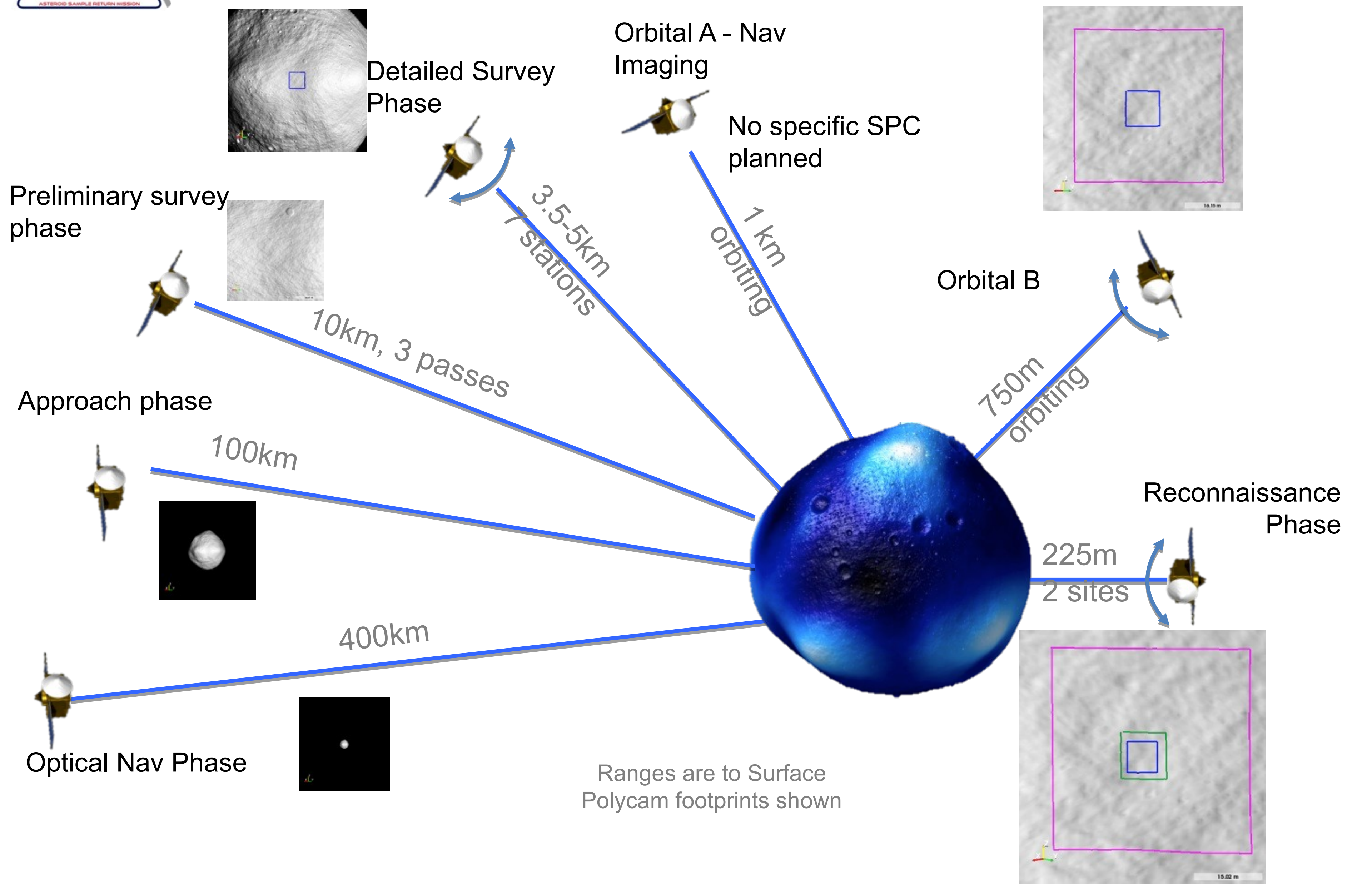
Comparison - Final



Software Status

- Code was modified to NASA standards
  - Major functions were consolidated into a “Common” library
- Documentation was added to SPC code (100,000+ lines of code)
- SubComponent test was completed last year
  - A test for each subcomponent (executable) was created and run
  - 84% of all Level 5 were bought off
- Component test (end-to-end) was completed in March 2015
  - 86% of Level 5 complete.
    - Remainder will be done via FDS Component test (in progress) and during a specific pole wobble test.
  - 78% of Level 4 complete
    - Remainder will be done via FDS Component test (in progress) and during a specific pole wobble test.

OCAMS/SPC Operations Overview



Data Used for Delivered Shape Models

- Approach - 2 shape models (far and initial)
    - Best level effort in terms of resolution
- Preliminary Survey
    - Generates FDS Global 75cm
- Orbit A
    - Off nominal - Refined FDS Global 75cm
- Detailed Survey
    - FDS Global 35cm
    - NFT Global 10cm
- Orbit B
    - TAG Site 5cm
- Recon, TAG Rehearsal, TAG
    - None

Early Shape Models

- Early-Approach - initial shape model with low resolution
  - Best effort
  - Allows FDS to get center of figure
  - PolyCam images — full rotation
    - 5m/pixel

- Post-Approach
  - Allows FDS to test their system
  - FDS can review the agreement between star and landmark nav
  - PolyCam images — several rotations
    - 110cm/pixel to 60cm/pixel

FDS 75cm DTM

	Ground Sample Distance	Vertical Accuracy	Vertical Precision	Horizonal Precision	Source Data
FDS Global 75cm	75cm	100cm		38cm	Approach Preliminary Survey

- Delivered during Orbit A
- Required by FDS for landmark navigation
    - Provides initial landmarks with sufficient accuracy to calculate the actual position of the spacecraft when each NavCam image was taken
    - These positions are fed into their “MIRAGE” program to determine the orbit
- FDS will evaluate the consistency of the shape model with the alignment of the landmarks from images. This will provide an external validation of the quality of the shape model.
- Data sources
    - PolyCam images
        - 60cm/pixel during Approach
        - 11cm/pix during Preliminary Survey
    - MapCam images at closest approach
        - 50cm/pix during Preliminary Survey

FDS 75cm DTM - Continued

- Output
  - 1.58 million vector model in ICQ format
  - 3 million plates model in OBJ format
- Work flow
  - Generate 150cm maplets over the NOLAN model
  - Register Approach images to the maplets
  - Register Preliminary Survey images to the maplets
  - Generate 75cm maplets over the surface
  - Evaluate for errors and correct
  - Build shape model
- Single combined product. Work will be 24/7 in shifts.

FDS 35cm DTM

	Ground Sample Distance	Vertical Accuracy	Vertical Precision	Horizonal Precision	Source Data
FDS Global 35cm	35cm	75cm		18cm	Detailed Survey

- Delivered before Orbit B
- Required for Reconnaissance and TAG navigation
  - Provides higher accuracy landmarks to FDS
- Data sources
  - Detailed Survey images - 7 stations with different phase angles
  - PolyCam images - 7 cm/pixel
  - MapCam images - 30 cm/pixel
- Output
  - DTM as a series of files
  - 35cm resolution at 1000x1000 pixels (350m x 350m)
- Work flow
  - Register Orbit A images to the maplets
  - Register Detailed Survey images to the maplets
  - Generate 30cm maplets over the surface
  - Evaluate for errors and correct
  - Build shape model
- Can work in parallel as long as spatially deconflicted

NFT 10cm DTM

	Ground Sample Distance	Vertical Accuracy	Vertical Precision	Horizonal Precision	Source Data
NFT Global 10cm	10cm	63cm	17cm	3.2cm	Detailed Survey

- Delivered during Orbit B
- Required for TAG
    - Provides NFT context for their approach into the TAG site
- Data sources
    - Detailed Survey images
    - Data is the same as previous requirement, but it will require significantly more processing
- Output
    - DTM as a series of files
    - 10cm resolution at 1000x1000 pixels (100m x 100m)
- Work flow
    - Generate 12cm maplets over the surface
    - Evaluate for errors and correct
    - Build shape model
- Can work in parallel as long as spatially deconflicted

NFT TAG Site 5cm

	Ground Sample Distance	Vertical Accuracy	Vertical Precision	Horizonal Precision	Source Data
NFT TAG 5cm	5cm	14cm	1.8cm	1.7cm	Orbit B

- Delivered after Orbit B
- Required by NFT for TAG
    - Provides topography for rendering comparison
- Data sources
    - Orbit B images
    - PolyCam images - 1 cm/pixel
- Output
    - Primary and Backup TAG Site
    - 25x25 meter DTM
        - 5,000x5,000 pixels with 5cm ground sample distance
- Work flow
    - Register Orbit B images to the maplets
    - Generate 5cm maplets over the TAG sites
    - Evaluate for errors and correct
    - Build DTM
- Each TAG site is independent, but only one person can work on it at a time

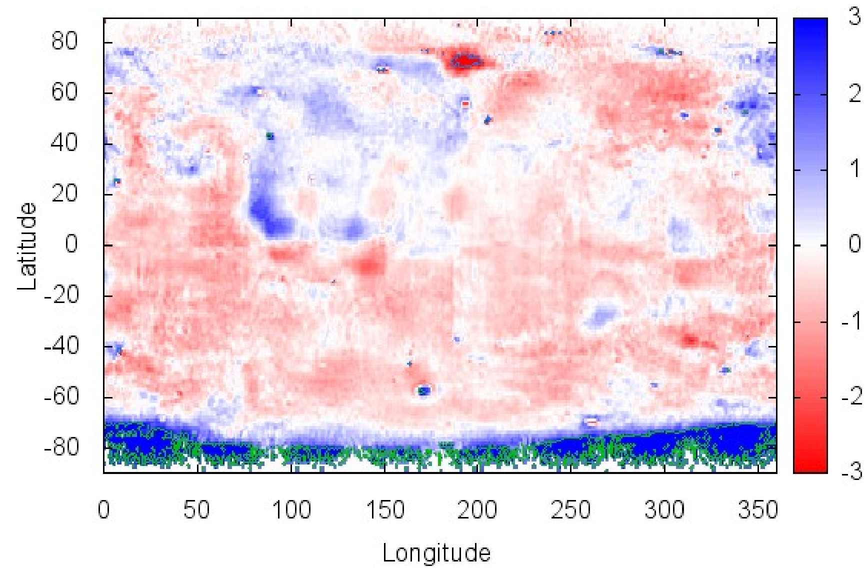
Off Nominal

- FDS Global Shape Model 75cm
  - Requires 75cm accuracy
  - Risk-reduction imaging during Orbit A would provide additional high-resolution data to improve the shape model
  - Refined shape model would be delivered as part of transition to landmark navigation
  - Sensitivity testing (later this year) will demonstrate if this data is needed to meet accuracy requirements

- NFT TAG Site 5cm
  - Requires 14cm accuracy
  - Additional limb imaging may be needed to ensure higher accuracy requirements are fulfilled. Desire getting 14cm/pixel images containing limbs
  - Sensitivity testing (later this year) will demonstrate if this data is needed to meet accuracy requirements

Status of SPC testing, verification and validation

- See SPC testing talk
- Currently very confident SPC will achieve all the FD requirements
- Planning and testing for verification and validation of 0.35m FD requirement, and all NFT requirements are a work in progress
  - Requirements were just recently received
  - Main task going forward

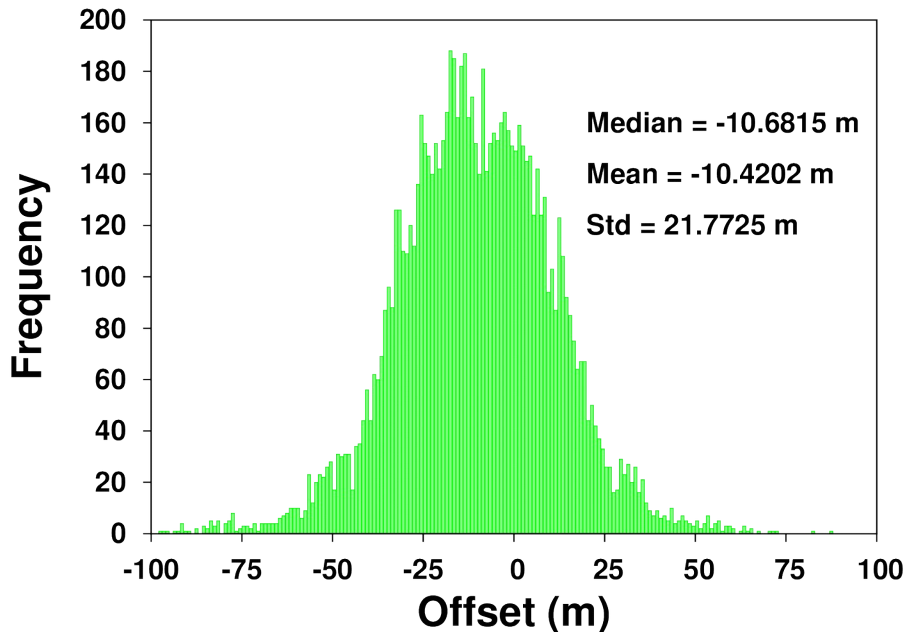


RMS deviation=0.87m (1 sigma)

Max=9.28m (pole)
Mean=0.62

Risk Reduction - Making use of OLA

- Investigating use of OLA data to calibrate SPC products with while generating the FDS/NFT Global Shape Model and the NFT local products
  - Sensitivity and verification testing (later this year) will confirm if speeds process of meeting precision and accuracy requirements
- No new observations required
  - SPC can be correlated to OLA observations
  - Might reveal that acquiring OLA observations sooner than currently planned will help (e.g., collect OLA recon data immediately after OCAMS images obtained for SPC/stereo).



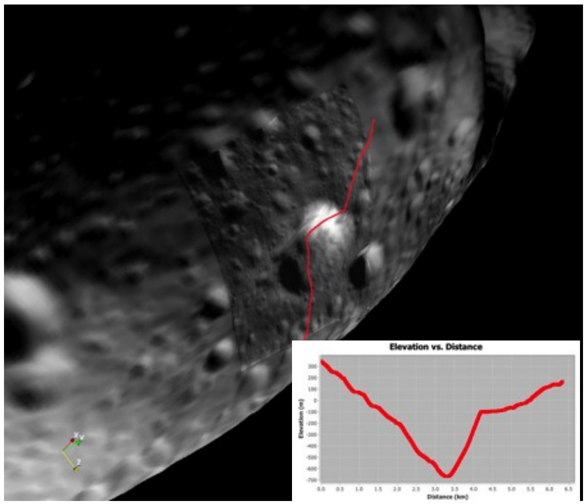
Comparison of NLR range to SPC range to the same spot on the surface of Eros using NEAR data

Work to Go

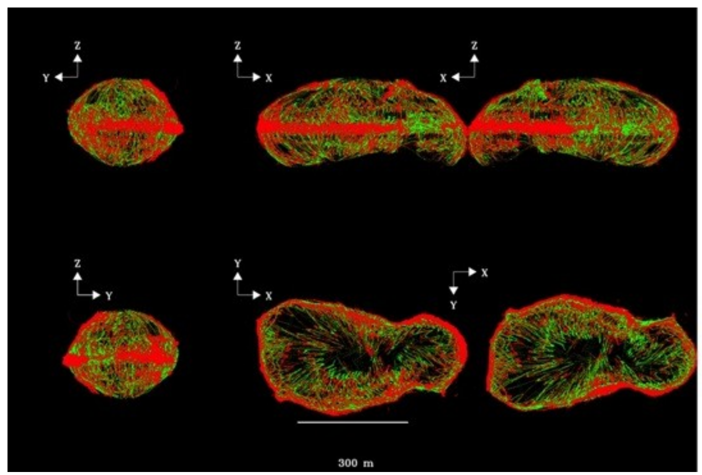
- Generate, review and implement detailed new test plan for FD and NFT requirements
  - Explore approach to scale sensitivity tests for FD to NFT requirements so that global simulated modeling at very high resolution are not needed (expensive in cost and man power)
  - Include use of OLA data in some phases of mission to speed up achievement of requirements
- Finalize and test new components of SPC Pole Wobble code for initial wobble solution
  - Work with OLA team, FD and GEODYN folks to finalize best way to verify implementation approach and results, and transfer of subsequent results back to a PCK or asteroid attitude kernel.
- Finalize and test new components of SPC Distance code that adjusts the inflation factor of the asteroid due to down track error

ALTWG OLA processing - Heritage

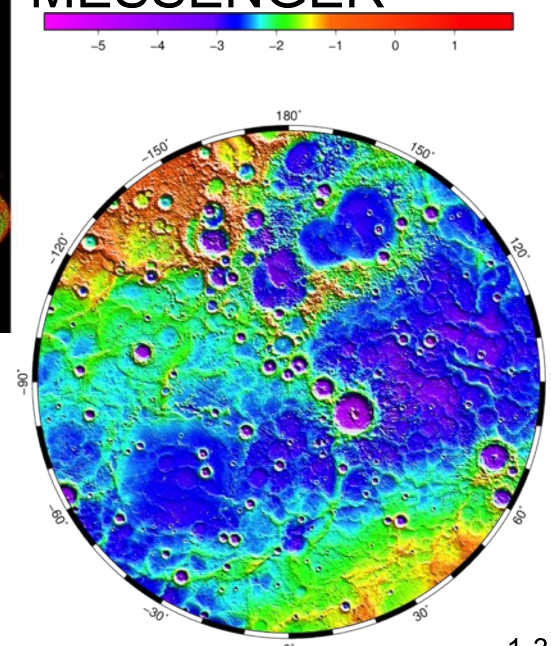
NEAR-Shoemaker



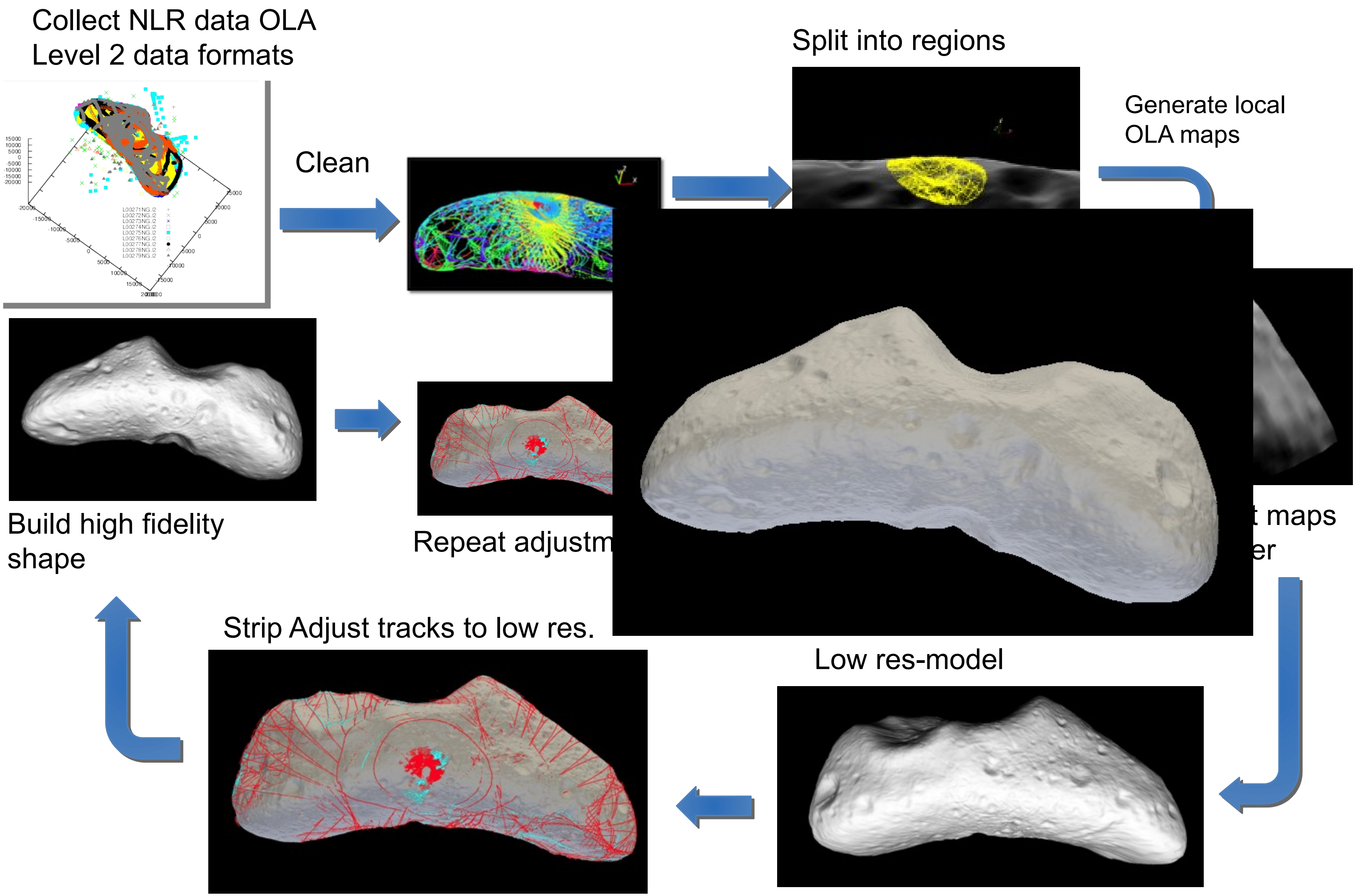
HAYABUSA



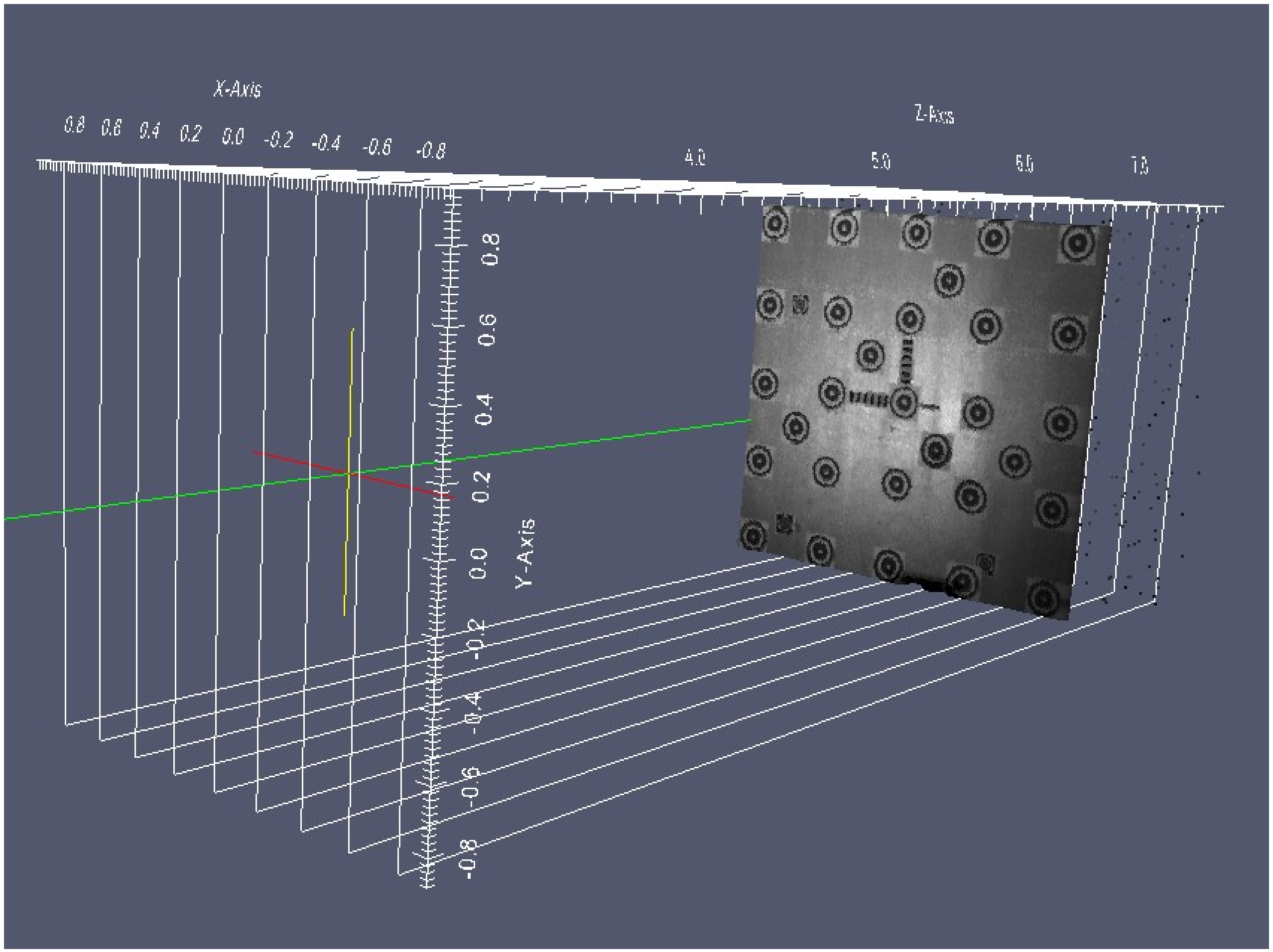
MESSENGER



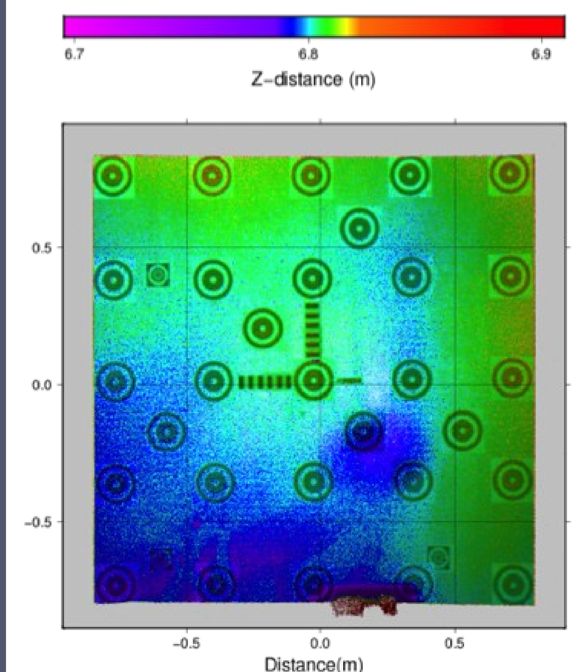
OLA - Altimetry Software – Path 1 – Eros tests



Different type of instrument: OLA capabilities

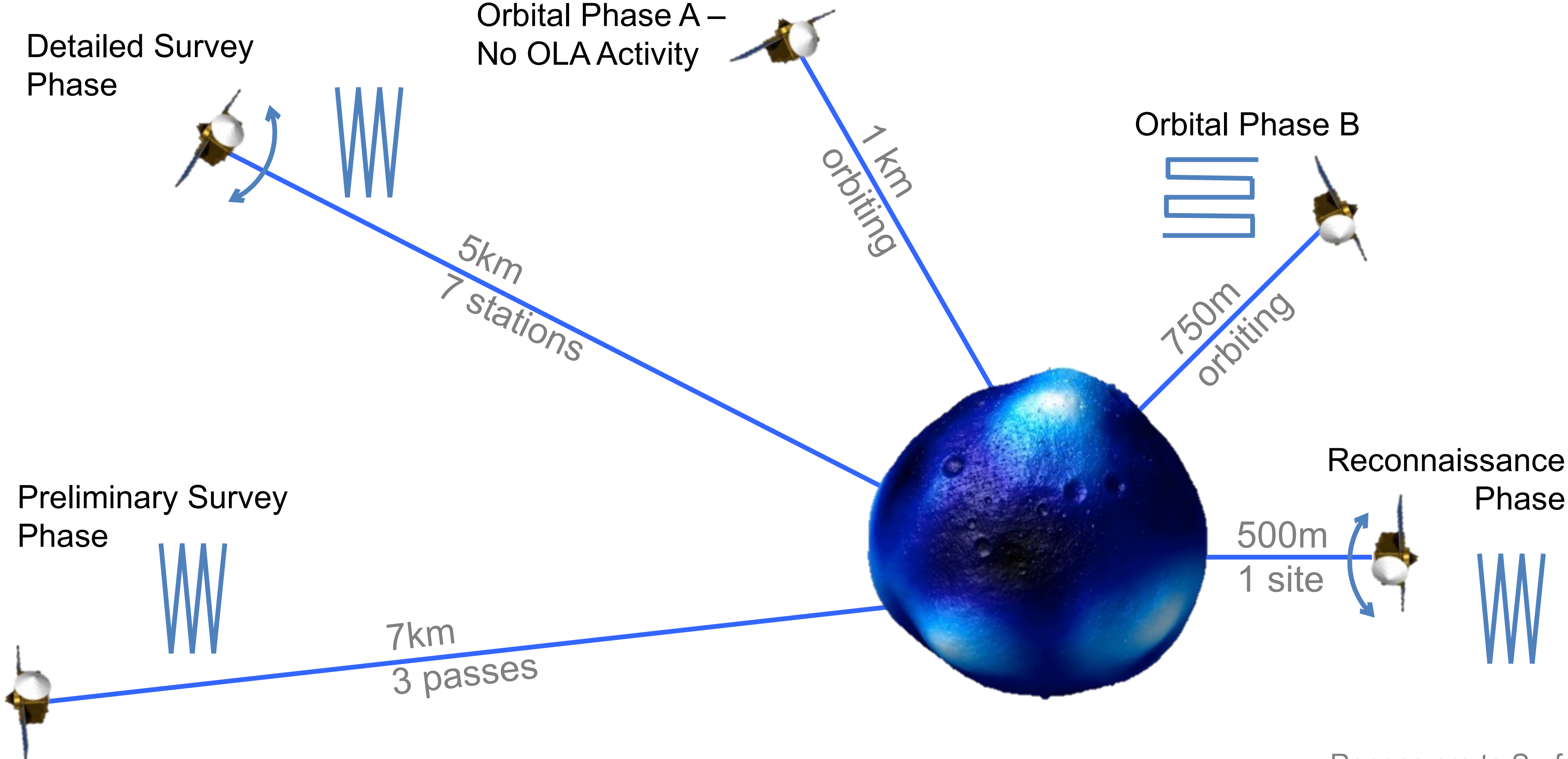


Point cloud of a 7 m wall at MDA from OLA EM



ALTWG DTM of wall from point cloud data

OLA Operations Overview

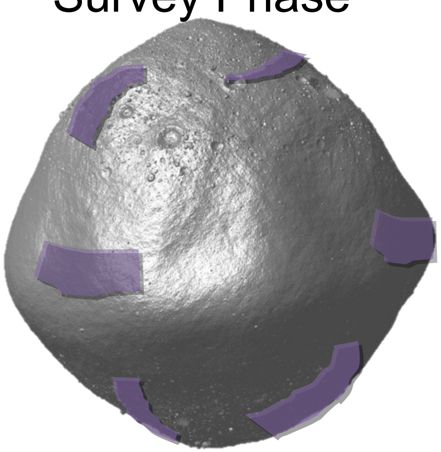


Ranges are to Surface

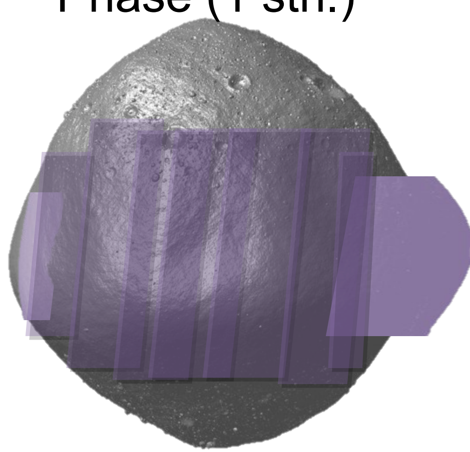
Baseline OLA Data Products by Phase

Mission Phase	Coverage
Prelim. SP	Partial, < 2%
Detailed SP	Global, 93%
Orbital A	No OLA Activity
Orbital B	Global, 100%
Recon.	Partial, Sample Sites

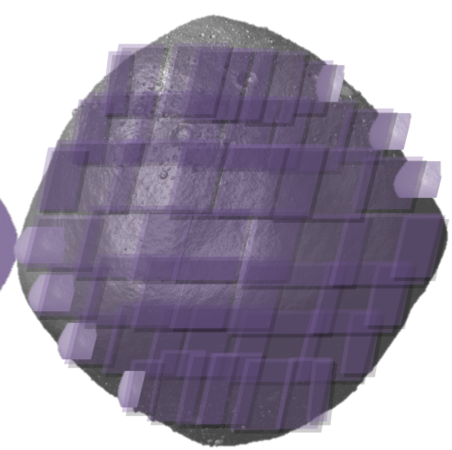
Preliminary Survey Phase



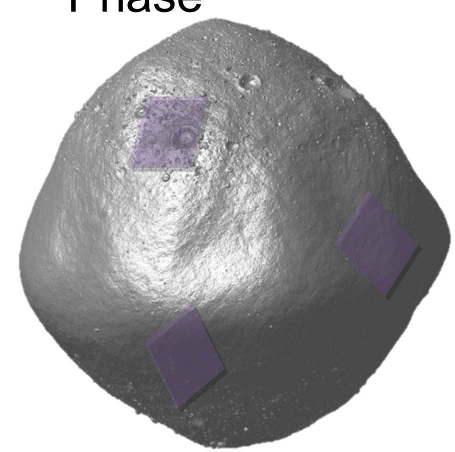
Detailed Survey Phase (1 stn.)



Orbital Phase B

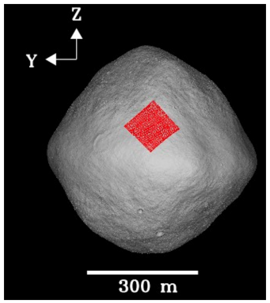


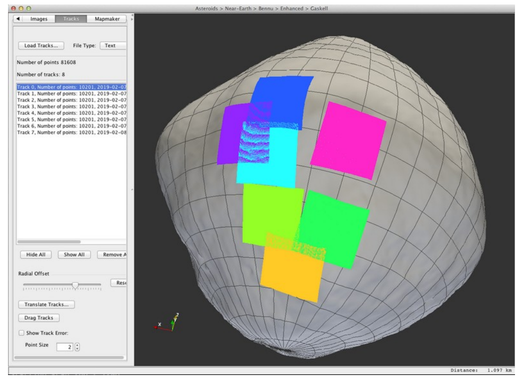
Reconnaissance Phase



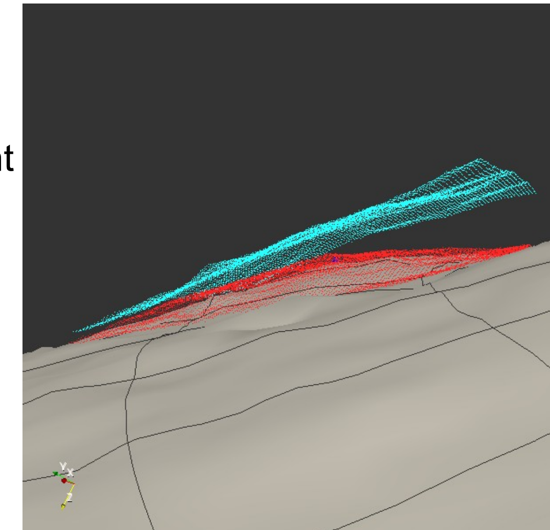
OLA - Altimetry Software – Path 2: Simulated Bennu tests

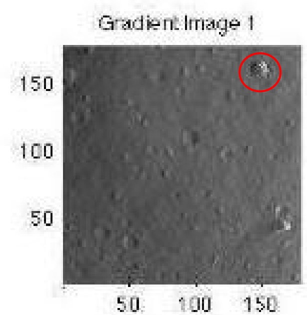
Collect OLA Level 2 data

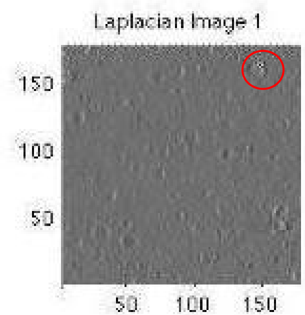


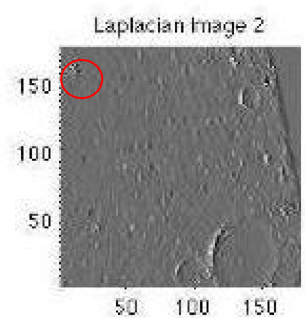


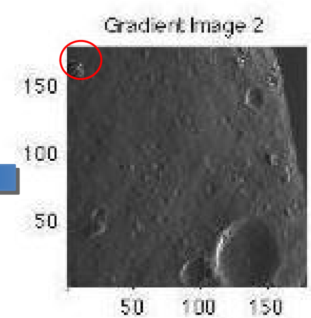
Initial adjustment

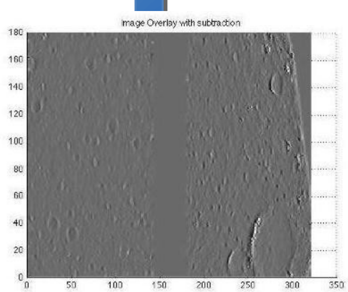


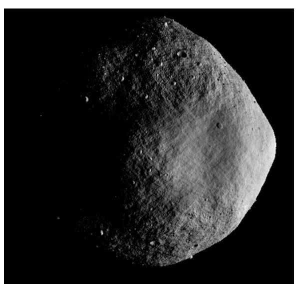












Build high fidelity shape

*Matching Features

Status of OLA - ALTWG testing

- Initial set of software algorithm completed and tested
  - Build 2 Delivery of ALTWG OLA tools on April 15, 2015
    - Capable of generating a full suite of PDS-compliant data products from OLA and SPC data
      - Including global and local shape models
      - Tilts maps
      - Other important geo-technical data such as local gravity and surface slope (using uniform density assumption)
    - Initial performance testing done using Detailed Survey-like data (using OLA-NLR simulated data).
      - Requirement verification and validation still needed
      - Limited by lack of realistic orbits and shape model now/soon to be available across project
  - Developed working algorithm for strip adjusting using overlapping individual data clouds
    - Remains to be implemented into overall ALTWG tool kit
  - Optimization and sensitivity assessments of both approaches, and decisions on when to employ one approach over another remains in their infancy

Status of OLA-SPC combinations

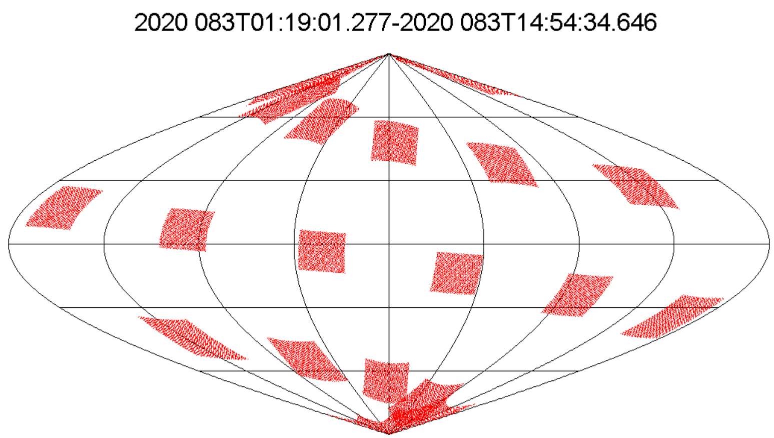
- Testing three approaches to combine OLA and SPC products through the use of MAPOLAs (local DTMs in same format as SPC MAPLETs):
  - Global Shape Modeling via Densify
    - Make MAPOLAs part of MAPLET database accessed by Densify
  - Regional mapping
    - Make MAPOLA part of the MAPLET database employed by Bigmap
  - Individual SPC maplets
    - Provide MAPOLA as height conditions in generation of individual maplets in Lithos
- Outside of SPC toolkit
  - Make use directly of OLA ranges to calibrate camera focal length
  - Provide precise S/C position relative to surface when in combination with an OCAM image.

OLA - ALTWG work forward

- Work forward (Now to Dec 2015)
  - Generation and implementation of detailed test plan to verify and validate OLA products using simulated data
    - Planned meeting at York University, May 18-20, 2015.
  - Evaluation of best strip adjustment approach for the differing phases of the mission.
  - Optimism strip-adjustment variables and initial shape models resolutions for best results via sensitivity tests with NLR data and simulated OLA data from Bennu (for nominal and off-nominal cases)
  - Make use of additional constraints
    - Allowable spacecraft and pointing displacements
    - Orbital dynamics
  - Wobble modeling using OLA strip adjustment data in Orb B (and possibly Orb A)
  - Complete evaluations of SPC/OLA combinations via SPC toolkit, as well as independently

Off-nominal observations

- OLA data collection is somewhat flexible – some opportunities for risk reduction and recovery
  - For example, use of Orb A to collect data of the asteroid
    - Mimic planned Orb B observations lead to quicker generation of maps with improved vertical and spatial resolution relative to those collected collected later in detailed survey
      - Quicker accurate wobble assessment
    - Implication – some loss of some detailed equatorial survey stations (due to laser lifetime issues)
      - Minor impact - Very redundant dataset for OLA
  - Loss of Orb B observation would be painful, but are partially recoverable
    - Partial recoverable - Nadir orbits expected in recon before and between rehearsals when OLA could be used to acquire datasets
    - If thermal conditions are not as bad as expected
      - Global coverage achievable in 5 days (rather than 21 days) with 10-20min pauses in laser firing
    - If performance is better than anticipated and some data can be collect at Orb A
    - Use of Orb A data to get at wobble



Example of Orb B observations

Relevant Schedule and Inputs

- Flight Dynamics and NFT product requirements exceed science DTM requirements. Once the delivery dates of products with more stringent requirements are determined, science product deliveries will naturally fall out.
- Following pages shows delivery dates of science ALTWG based on MRD Rev G requirements

Science 75 cm Resolution Shape Model (SPC)
(MRD Rev G)

- Observations for product begin:
  - 11/9/18
- All observations for product in to SPOC:
  - 11/18/18
- Processing begins:
  - Before 11/19/18 (Update: Before 11/26/18)
- Product available:
  - 11/23/18 (Update: 12/7/18)
- Data product lead(s): Eric Palmer, Bob Gaskell

Rotation State
(MRD Rev G)

- Observations for product begin:
  - 11/9/18
- All observations for product in to SPOC:
  - 11/29/18
- Processing begins:
  - Before 12/10/18 (associated with 30 cm shape modeling effort)
- Product available:
  - 12/17/18
- Data product lead(s): Eric Palmer, Bob Gaskell

Coordinate System
(MRD Rev G)

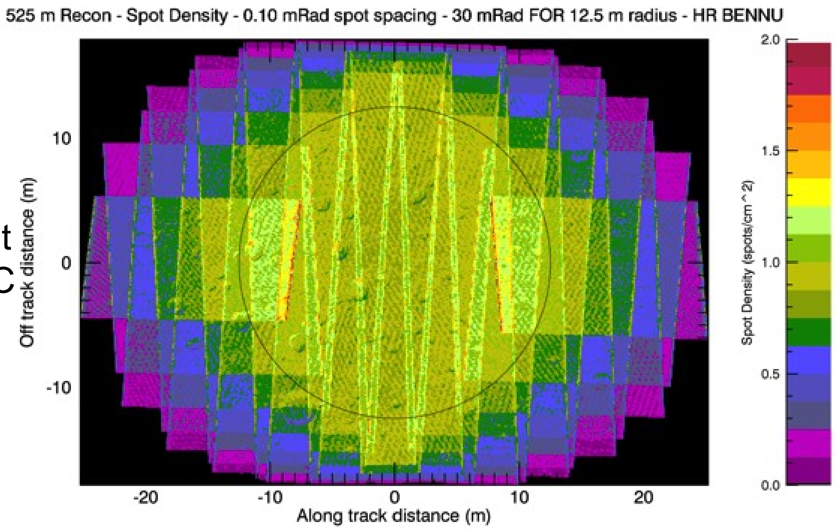
- Observations for product begin:
  - 11/9/18
- All observations for product in to SPOC:
  - 11/29/18
- Product available:
  - Initial ~11/9/18 (Update: NLT 12/18/18)
- Data product lead(s): Olivier Barnouin
- Note: Will be seeking coordinate system release and update schedule that minimizes data reprocessing requirements. Schedule is work to go.

Science Site-Specific DTMs and Tilt
(MRD Rev G)

- Observations for first site begins:
  - 4/19/19
- All observations for all sites in to SPOC:
  - 4/27/19
- Processing begins:
  - 4/12/19 (first site)
- Product available:
  - 5/1/18 (final site)
- Data product lead(s): Eric Palmer, Bob Gaskell (DTMs), Olivier Barnouin (tilt)
- Note: Tilt is a straightforward derivative of DTM, and lags DTM production by ~1 day. Last tilt maps released 5/2/18. All dates presume even distribution of observations across Orbital B.

Minimum Mission Scenario

- Minimal consequences for OCAMs observations for SPC
  - Minimum mission ensures required products will be available, although impacts on production schedule are still being evaluated
  - Judicious use of OLA to speed up processing will be explored
    - Use of OLA to ensuring SPC products achieve requirements more quickly
    - Use of OLA in Orb A to speed up wobble assessment and generate lower fidelity that can still evaluate SPC products
    - Injection of OLA observations from 225 m soon after necessary data from OCAMs is acquired
      - OLA will be able to sweep the entire landing region with the resolution required in just one simple observation which should significantly speed up preparations to sample
- Heavily influences OLA observations
  - Loss of significant portions of Orb B would reduce OLA's ability to alone contribute to key global scientific products



Summary slide

- ALTWG SPC and OLA efforts
  - Significant progress in the last year
    - Able to generate shape models and topographic products needed to
      - Sample surface of asteroid,
      - Generate general products for general scientific use
    - Capable of making products separately for cross-verification
  - Developed close effective working relationships with all the partners who benefit from ALTWG products
    - NFT, FD (Kinetx and GSFC) and SPOC
- New FD and NFT requirements provide some new challenges
  - Higher accuracy and precision of maps calls for extensive verification and validation plans
  - Use of more OLA-SPC cross pollination
- Tackling challenges head on
  - Extensive plans to verify and validate SPC and OLA products
  - Detailed sensitivity studies to evaluate factors influencing SPC and OLA process
  - Development and testing of approaches to best combine SPC and OLA data sets