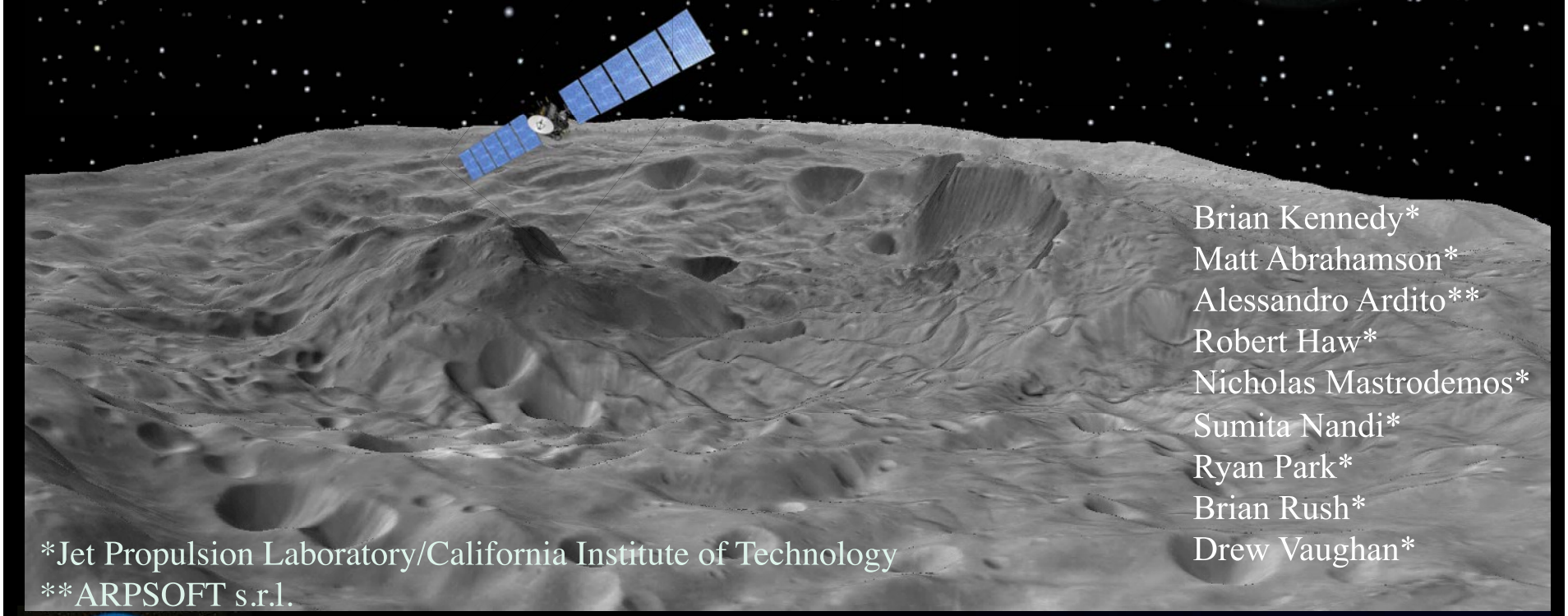
23rd AAS/AIAA Spaceflight Mechanics Meeting

Dawn Orbit Determination Team: Modeling and Fitting of Optical Data at Vesta.



Brian Kennedy*
Matt Abrahamson*
Alessandro Ardito**
Robert Haw*
Nicholas Mastrodemos*
Sumita Nandi*
Ryan Park*
Brian Rush*
Drew Vaughan*

*Jet Propulsion Laboratory/California Institute of Technology
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Agenda

- Overview
- Approach to Vesta
- Initial processing of orbit imagery
- Study of Low-altitude imagery
- Current study of High-altitude imagery
- Concluding remarks and the Ceres mission

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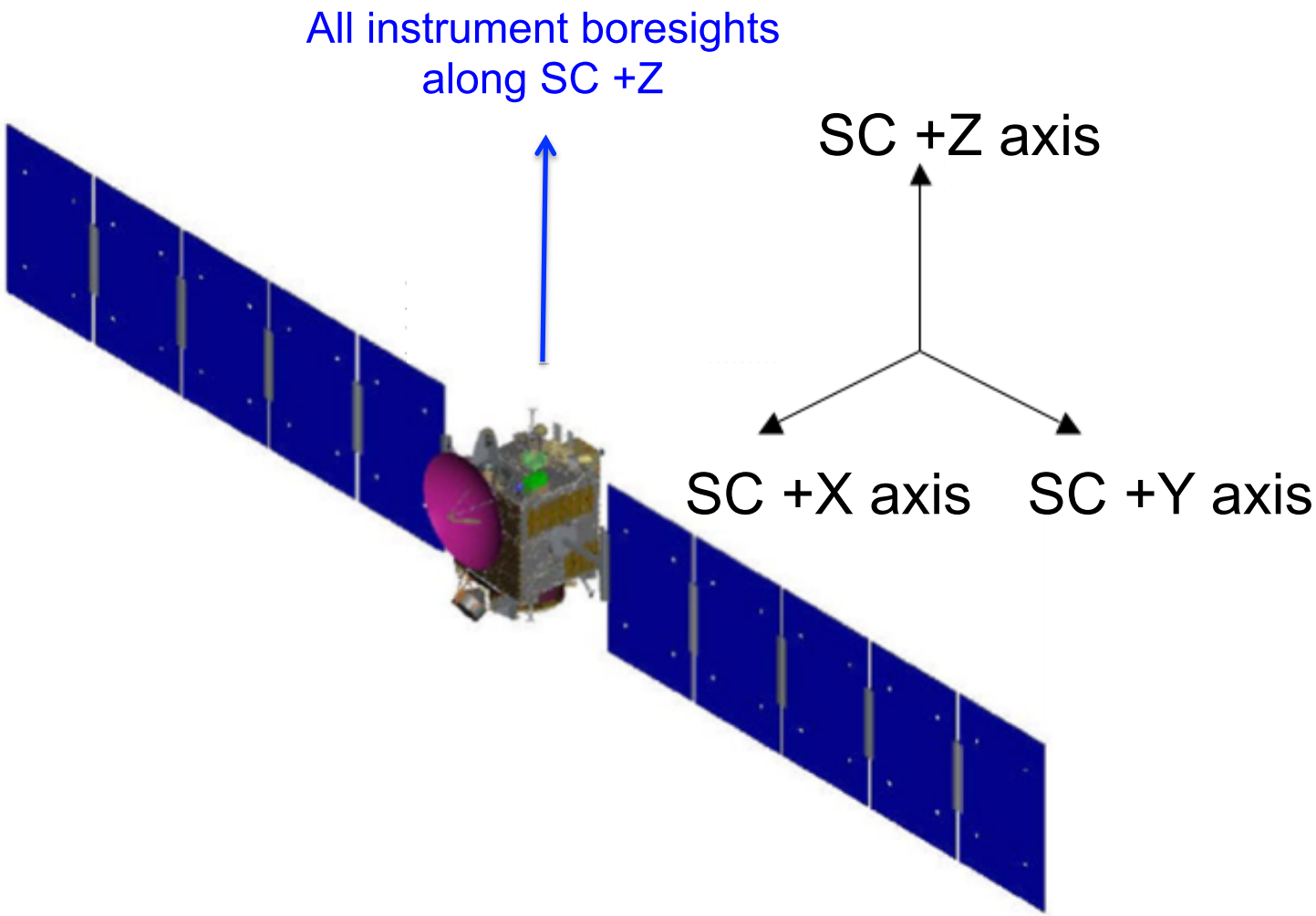
Spacecraft



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Dawn's first target: Vesta

- The asteroid Vesta is a massive, asymmetrical, highly oblate asteroid, located in the main asteroid belt.
  - Orbital period: 3.63 years
  - Rotational rate: 5.342 hours
  - GM: 17.28838 +/- 0.00015 km^3/sec^2

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Mission Trajectory

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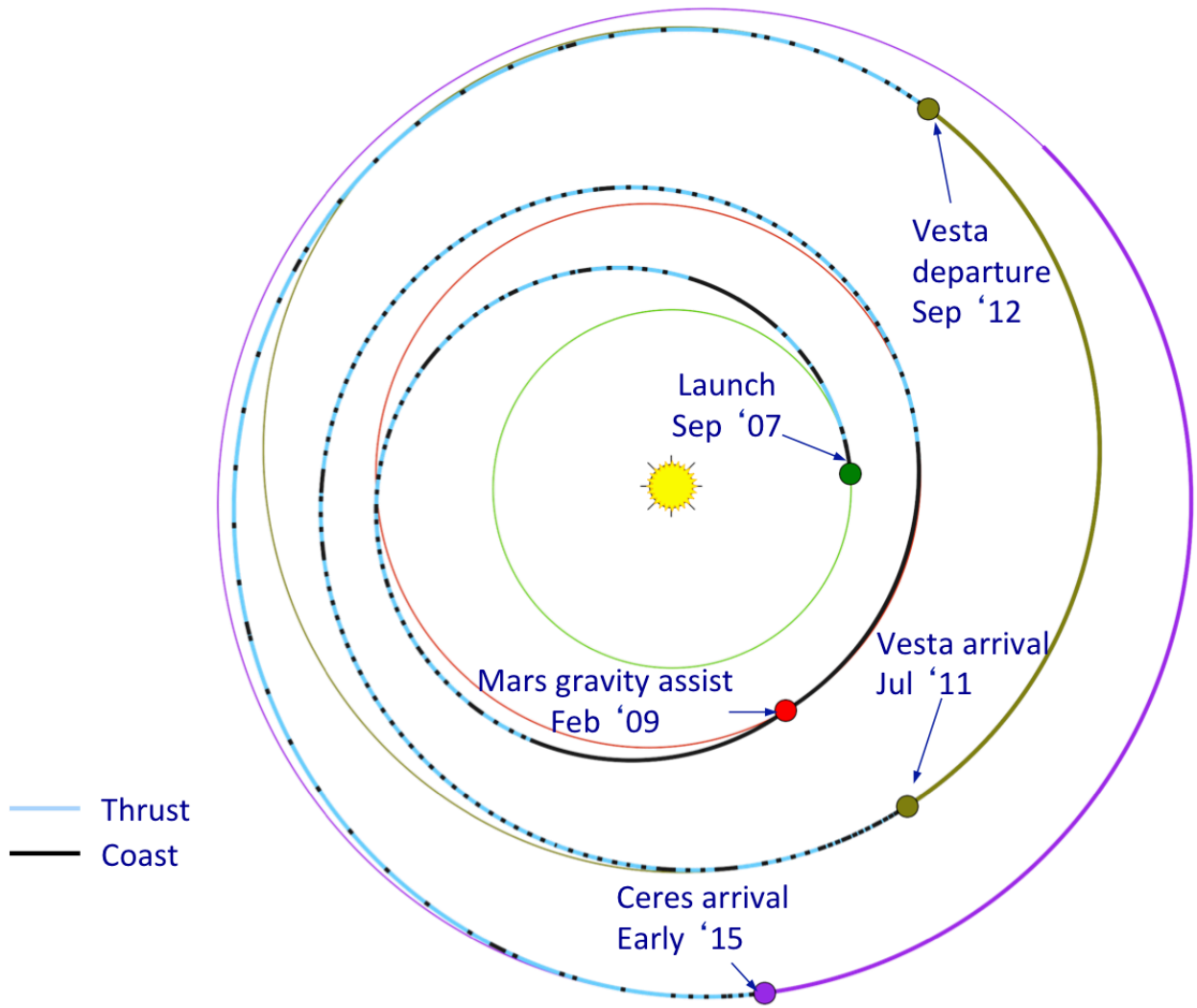

Science phases

Phase	Distance from Vesta	Orbit period	Dates of phase
Approach	1,800,000 km – 3000 km	N/A	April, 2011 – August 2nd, 2011
Rotational Characterizations (RC1-3)	6000 km down to 4000 km	N/A	Late July, 2011
Survey	3000 km	2.5 days	August, 2011
High Altitude Mapping Orbit (HAMO)	950 km	12 hours	October, 2011
Low Altitude Mapping Orbit (LAMO)	47 5km	4 hours	December 2011 –May, 2012
High Altitude Mapping Orbit-2 (HAMO-2)	950 km	12 hours	June, 2012 – July, 2012

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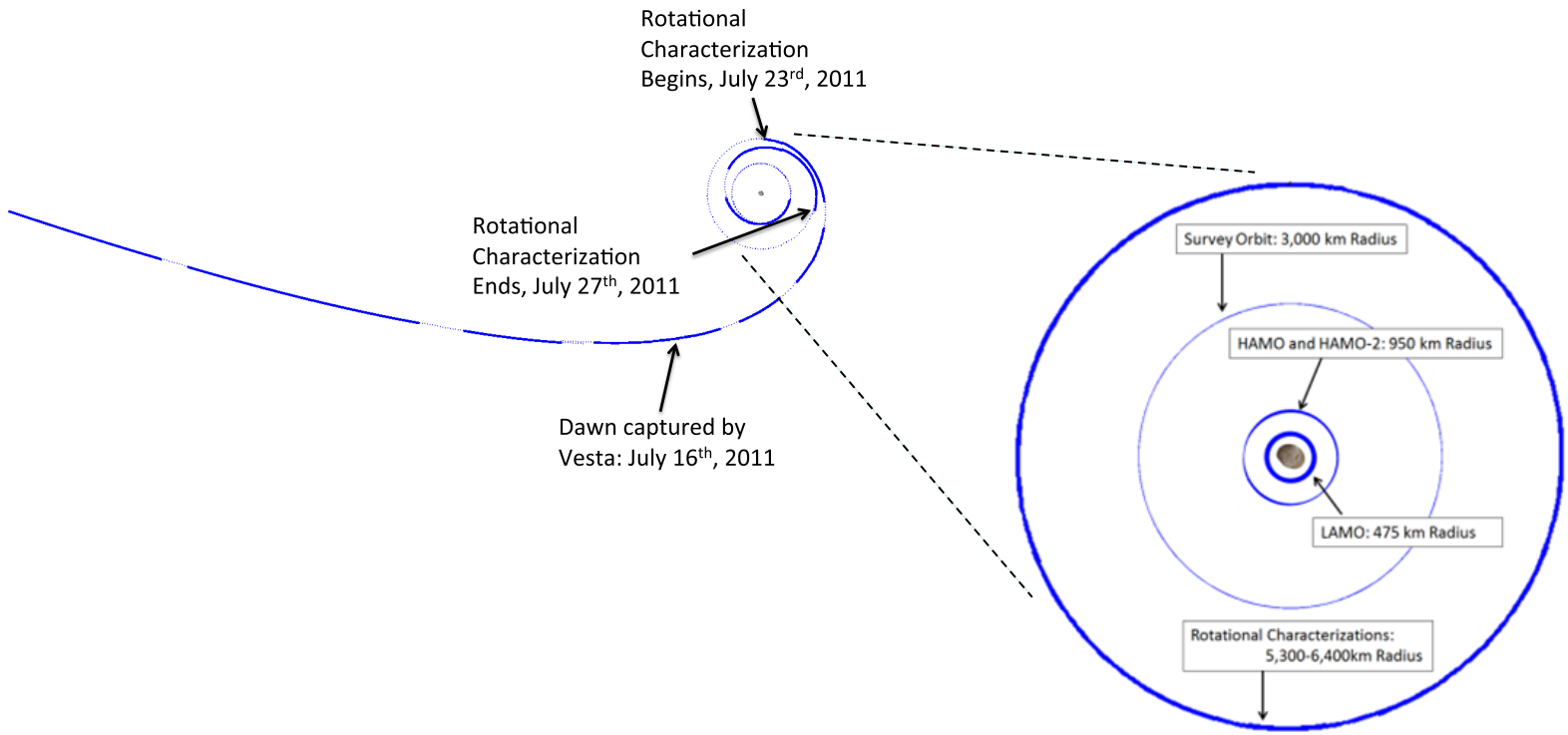
Approach to Science polar orbits



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Optical Navigation Data Overview

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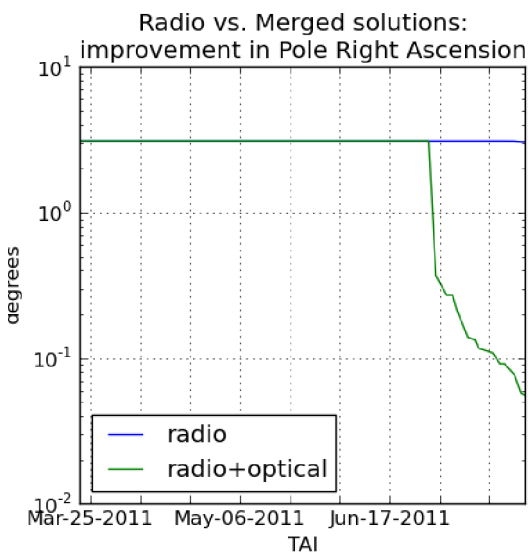
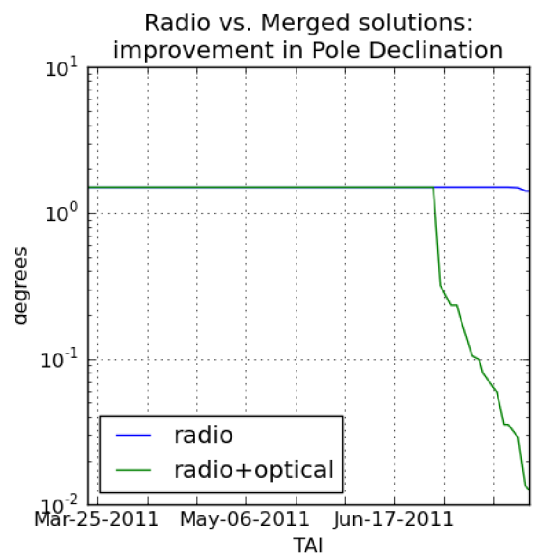
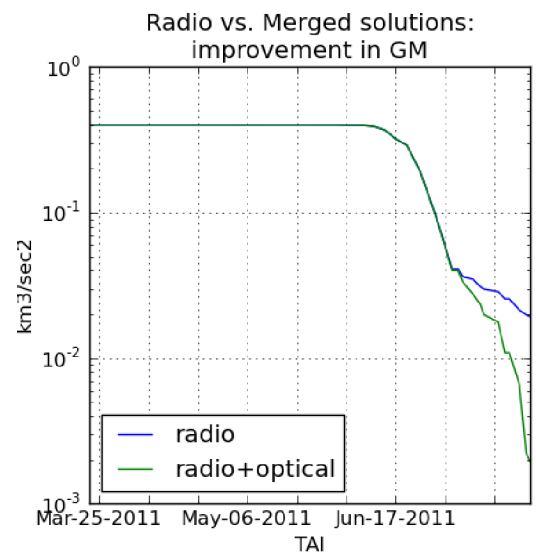
- The Image data from the Framing Cameras is processed by the Optical Navigation (Opnav) team.
- Opnav provides the Orbit Determination (OD) team with these two inputs:
  - The landmarks database, which is a text file of Vesta body fixed Cartesian vectors for each assigned and modeled landmark. Landmarks models are created from image data.
    - Each landmark is assigned to a latitude/longitude grid to uniformly cover the Vesta surface.
  - A Picture Sequence File (PSF) containing the following for each FC image:
    - timestamp
    - attitude fix
    - pixel line coordinates of each landmark and/or Vesta Center observations within the picture.

Optical strength

- The OD team normally fits just radiometric data to estimate the trajectory and Vesta parameters.
- Covariance studies of optical data claim that they can be used to estimate the orientation of the Vesta pole and the GM of Vesta with higher confidence than only radio data.
- These plots show the improvement in Pole and GM knowledge when the landmarks from Approach observations are in the filter.







FC Imagery

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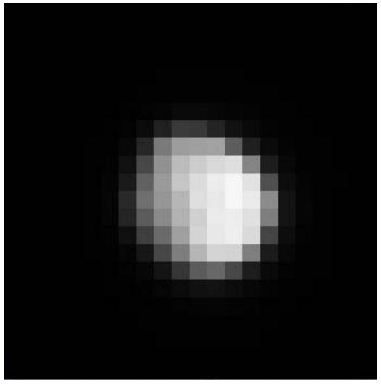
Images from the FC are taken from May 3rd, 2011 through the next year, resolving Vesta from different altitudes.

Optical Navigation Session #4
5/22/2011
Range = ~700000 km
1 pixel = ~70 km
FOV = ~70000 km

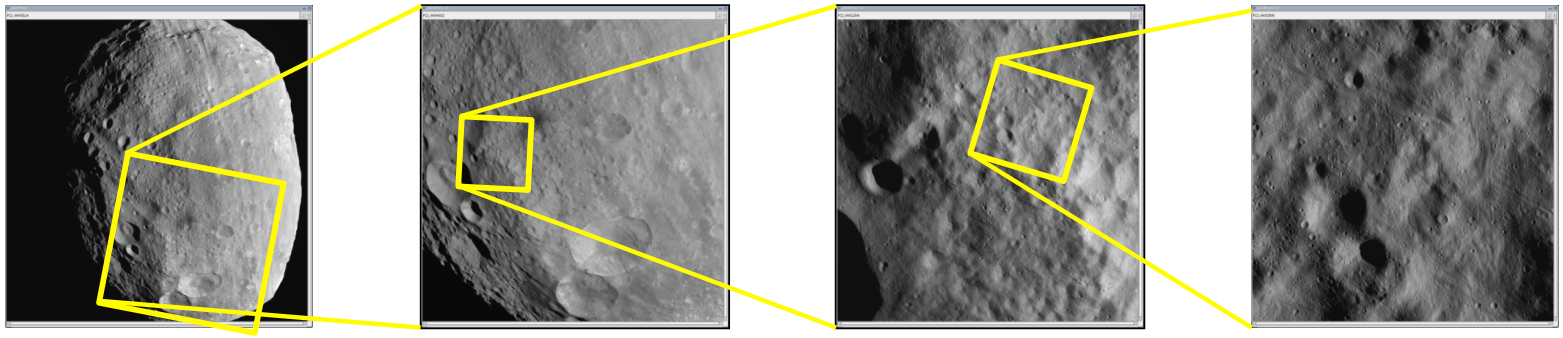


RC3
7/24/2011
Range = ~5500 km
1 Pixel = ~490 m
FOV = ~500 km

Survey
8/12/2011
Range = ~3000 km
1 Pixel = ~260 m
FOV = ~260 km

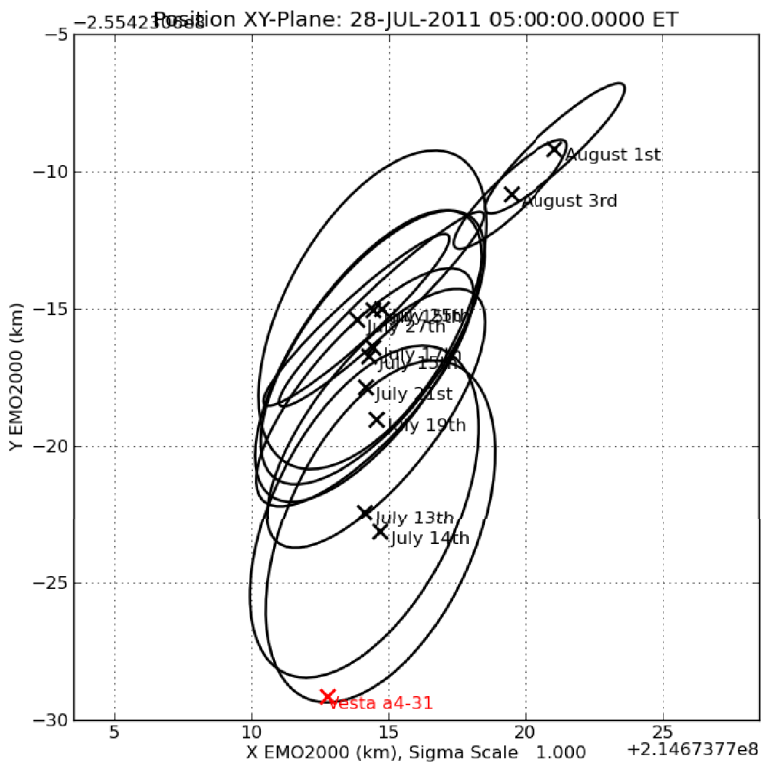
HAMO
10/25/2011
Range = ~950 km
1 Pixel = ~65 m
FOV = ~66 km

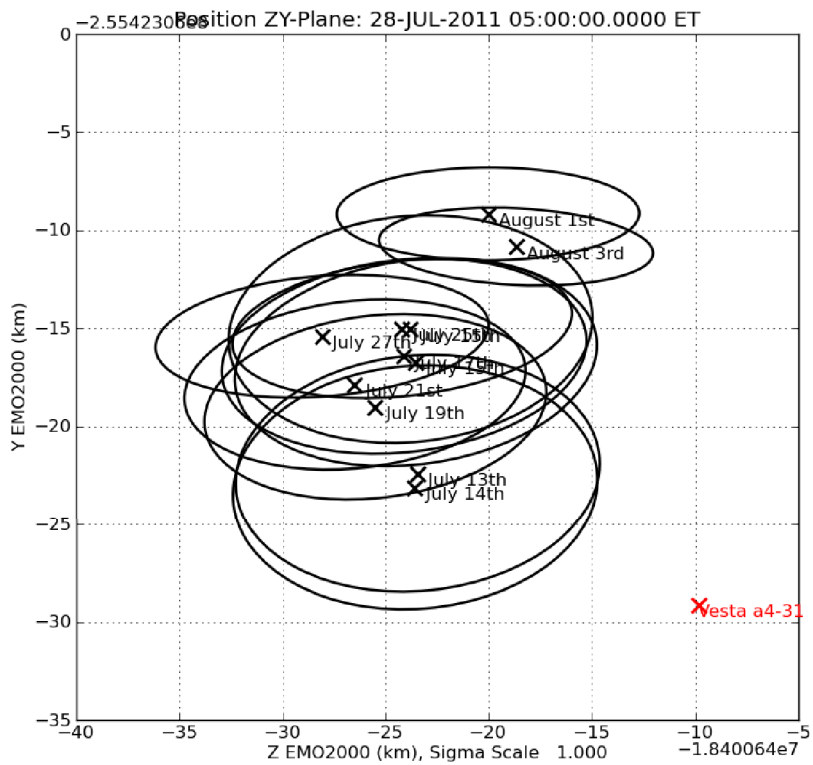
LAMO
3/17/2012
Range = ~475 km
1 Pixel = ~21 m
FOV = ~21 km



Vesta Ephemeris

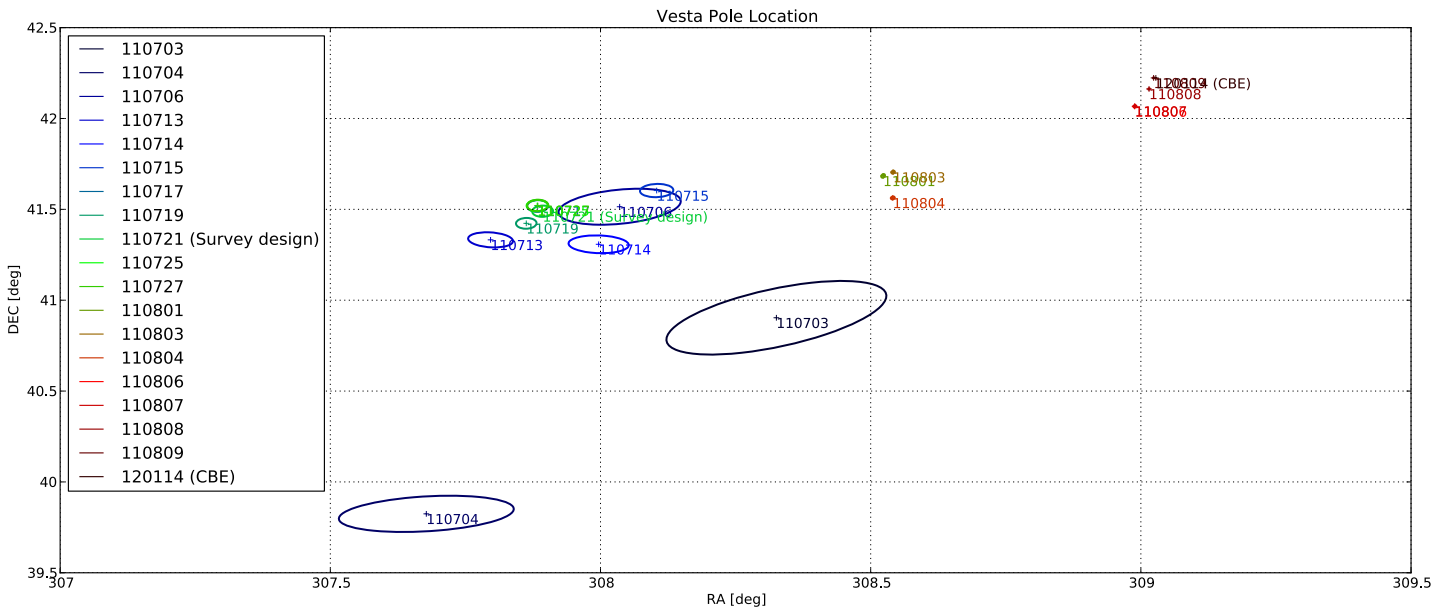
- During the Approach to Vesta, slight corrections to the Vesta ephemeris were observed. As Dawn entered into the Survey, the final correction to the ground-based ephemeris were at the level of 20 km.





Pole estimations during Approach

- During the Approach, the pole solutions moved around in a significant fashion. This is largely due to optimistic error modeling combined with poor lighting conditions.
- Reprocessing of these data sets to find more accurate error models is work in progress.



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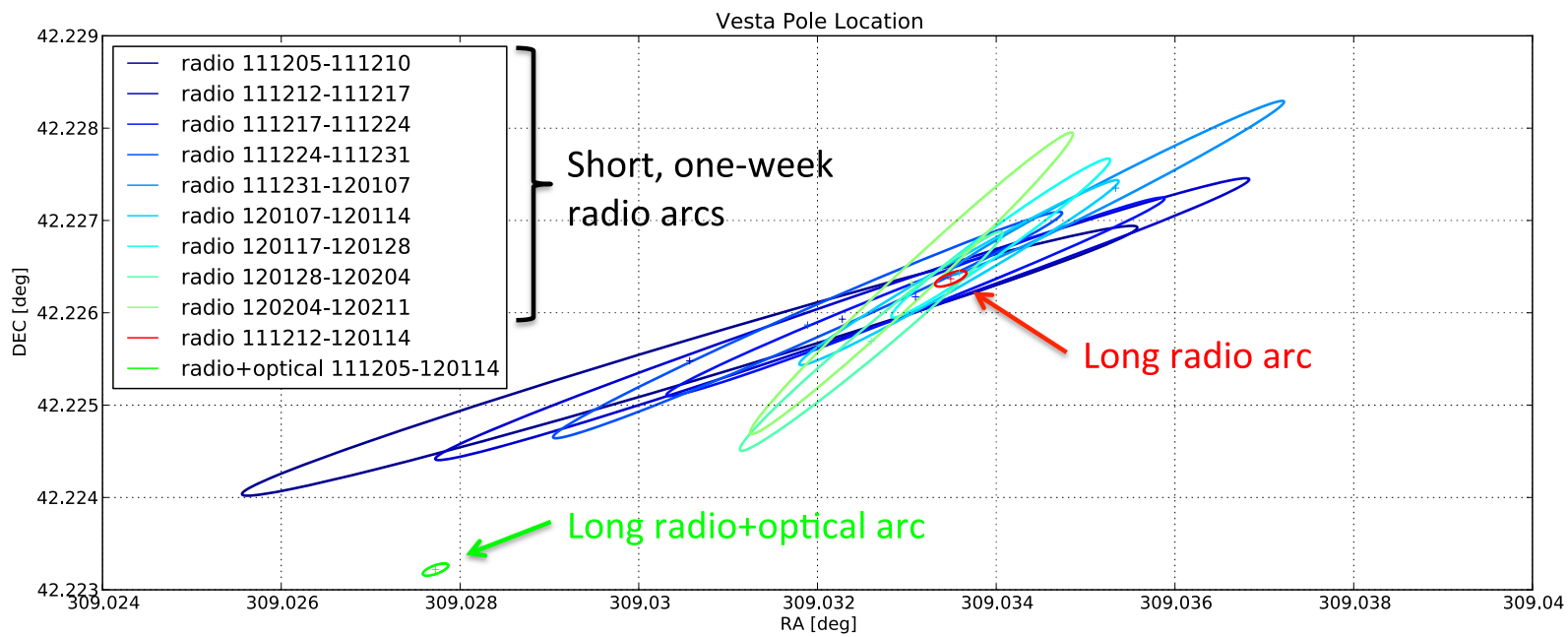
Parameter estimation from Survey/ HAMO/LAMO data

- Routine processing of the data as merged and radio-only solutions was performed to find the pole and the GM.
  - Survey showed 1-sigma agreement
  - HAMO showed 2-sigma agreement
  - LAMO showed **multi-sigma disagreement**
- Body rate were estimated in HAMO, and found to agree at 1-2 sigma
- A center-of-figure and center-of-mass (CFCM) offset of 750 meters was also seen in HAMO.

Solution	Pole R.A. (°)	Pole Dec. (°)	GM (km^3/s^2)
Ground-based	301.0 +/- 3.1	41.0 +/- 1.5	17.8 +/- 0.4
Survey Optical/Radio	309.03616 +/- 0.00024	42.24816 +/- 0.00027	17.289225 +/- 0.000022
Survey Radio	309.003 +/- 0.059	42.229 +/- 0.016	17.28864 +/- 0.00068
HAMO Optical/Radio	309.03418 +/- 0.00022	42.226924 +/- 0.000080	17.288582 +/- 0.000013
HAMO Radio	309.0348 +/- 0.0026	42.22659 +/- 0.00017	17.28879 +/- 0.00013
LAMO Optical/Radio	309.02773 +/- 0.00014	42.223219 +/- 0.000066	17.286586 +/- 0.000073
LAMO Radio	309.03349 +/- 0.00018	42.226367 +/- 0.000085	17.288380 +/- 0.000095

LAMO processing

- Based on study of solutions using shorts independent, short data arcs, the radio solutions are behaving the most consistently.
- Optical solutions in LAMO are significantly out of family.



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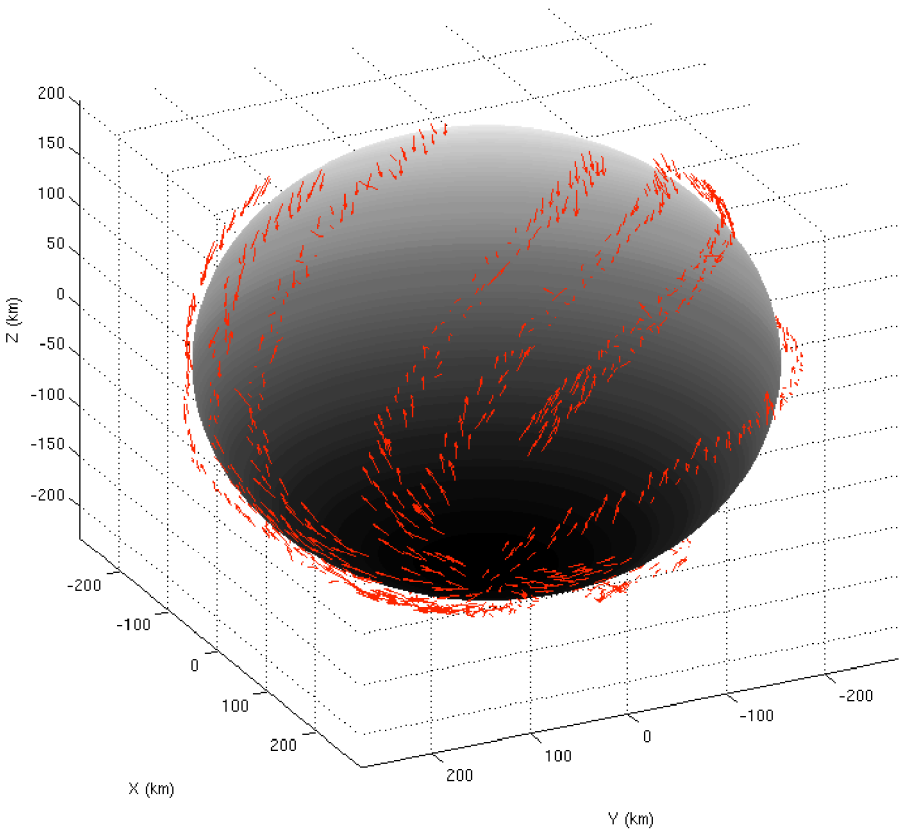
Landmark estimation

- Landmark location estimation was done using a short trajectory arc that observes 990 landmarks over eleven orbits.
- The signatures seen in the vector shifts did not indicate a lingering rate or CFCM error.



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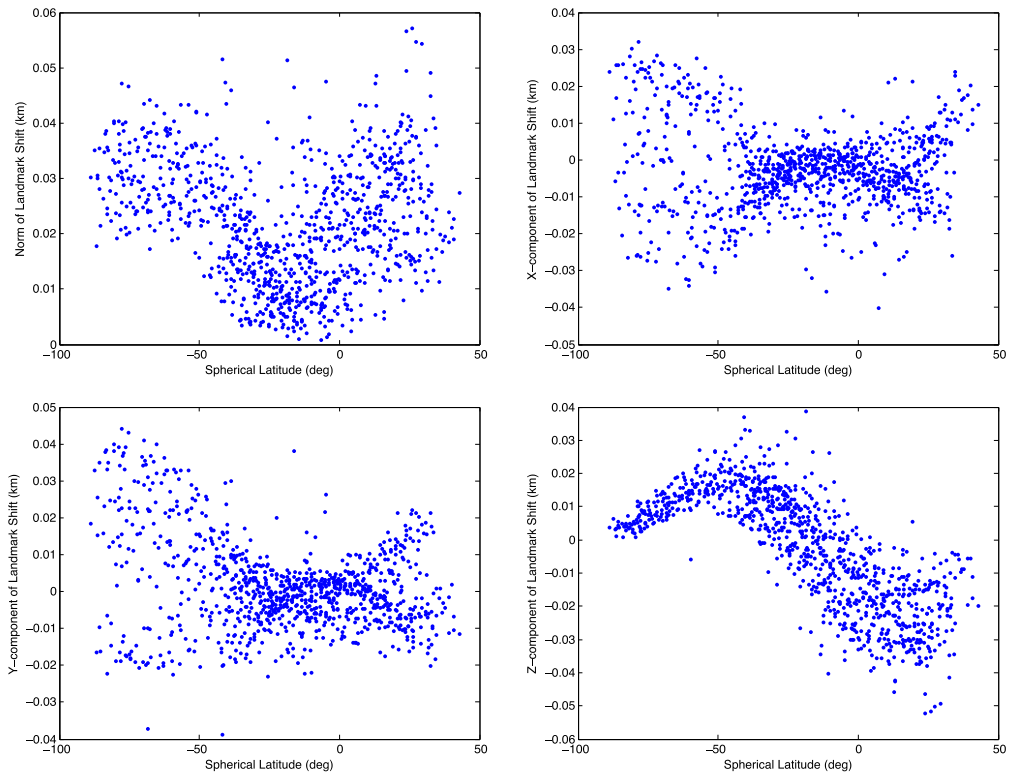
LAMO landmark shift signatures

- The landmark estimates do show shifts from less than 20 meters to almost 60 meters (~3 pixels).
- Z shift shows a (still unexplained) signature
- Smallest shifts occur between latitude 0º and -40º.



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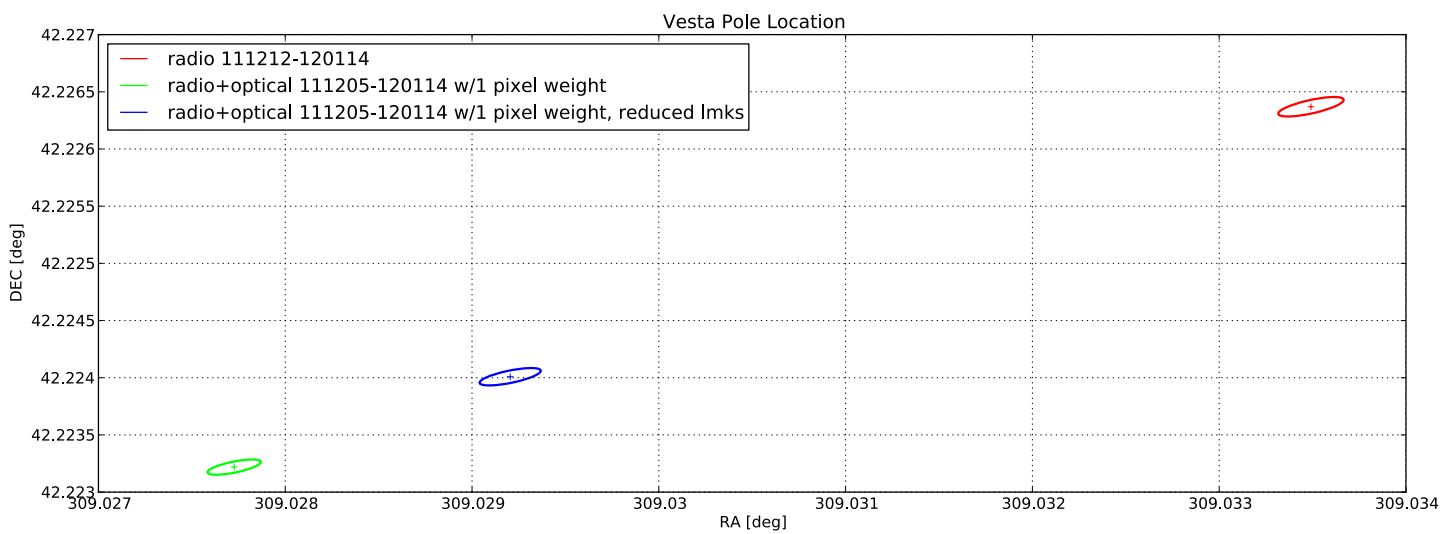
Reprocessing with "well-behaved" landmarks

- Assuming that modeling of landmarks outside of the range of 0º to -40º was in error, only the 0º to -40º subset of landmarks was fit.
  - The change to the pole solution is in the right direction, but not in a significant way.
  - This area is study is still a work in progress.



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A new approach

- A more methodical approach to landmark fitting is being performed using HAMO-2 data.
- HAMO-2 is a ten-orbit, five-day repeat cycle and the longitude crossings are consistent. This allows OD to fit multiple observations of given landmarks into one solution.
- Ten sets of independent data can be created.

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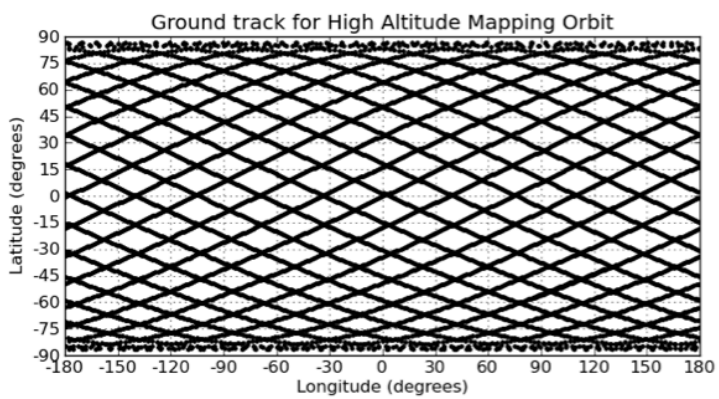
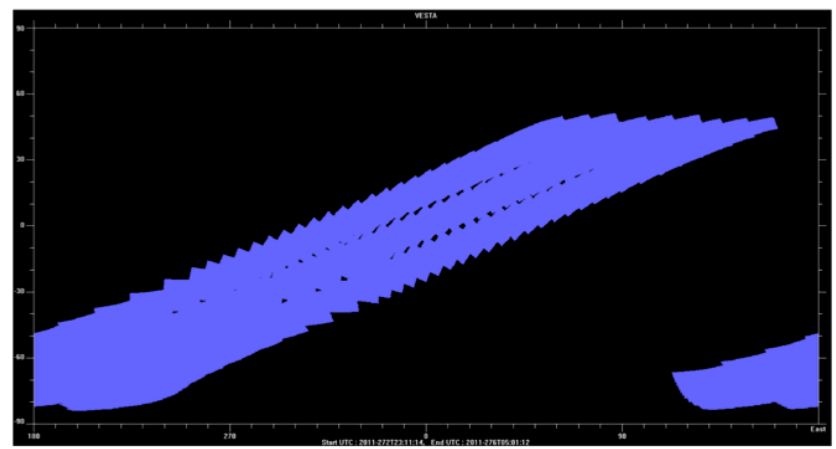
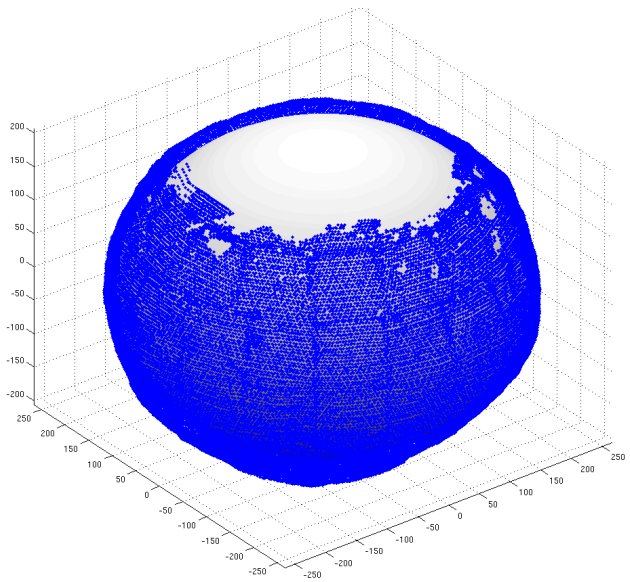
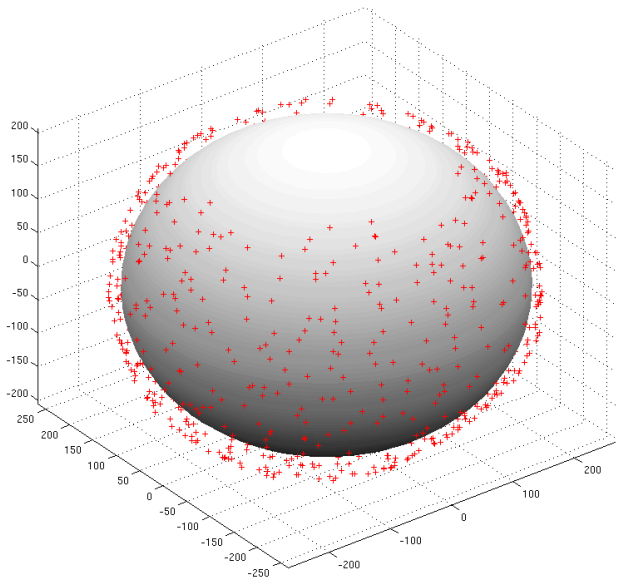




Landmark down selection

- The HAMO-2 landmark database was randomly down selected from 69,157 landmarks down to 866.
- The ten independent sets of image data can be filtered independently and the results combined to get a final, single solution.
- Work is still in progress. Studies include, but are not limited to, optical-only cases, weight schemes, location estimation and location error consider.





Concluding remarks

- Performing OD at Vesta using optical data has been very challenging.
- Work towards understanding data modeling and error modeling is in progress.
- Applying any findings towards the Ceres Approach phase is the main driver of further studies.

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