



# Assessing OLA shape model

Nominal pointing, spacecraft  
trajectory and OLA data



# Purpose of discussion

- Evaluate OLA Digital Terrain Maps
  - Terrain Maps
    - Global and local shape
  - Quality of products at various phases of the mission
- Talk outline
  - ALTWG Requirements
  - Schedule of OLA products are generated (in contrast to SPC ones)
  - Review of OLA performance at the instrument level
    - CBE
    - Show some actual results
  - Statistical assessment of overall DTM character
    - Folding current error estimates for pointing knowledge (and a guess at nav performance), and best guess at surface roughness.
- Results of OLA products nominal processing with no errors.
  - Global and local models
- Work forward
  - Need to fully characterize instrument properties
  - Need to assess ALTWG processes with errors
    - Have shown we can reproduce model that match uncertainties expected by Nav at Eros
    - Need to confirm that we can do the same at Bennu



# ALTWG product requirements

- Science, Sampleability, Safety

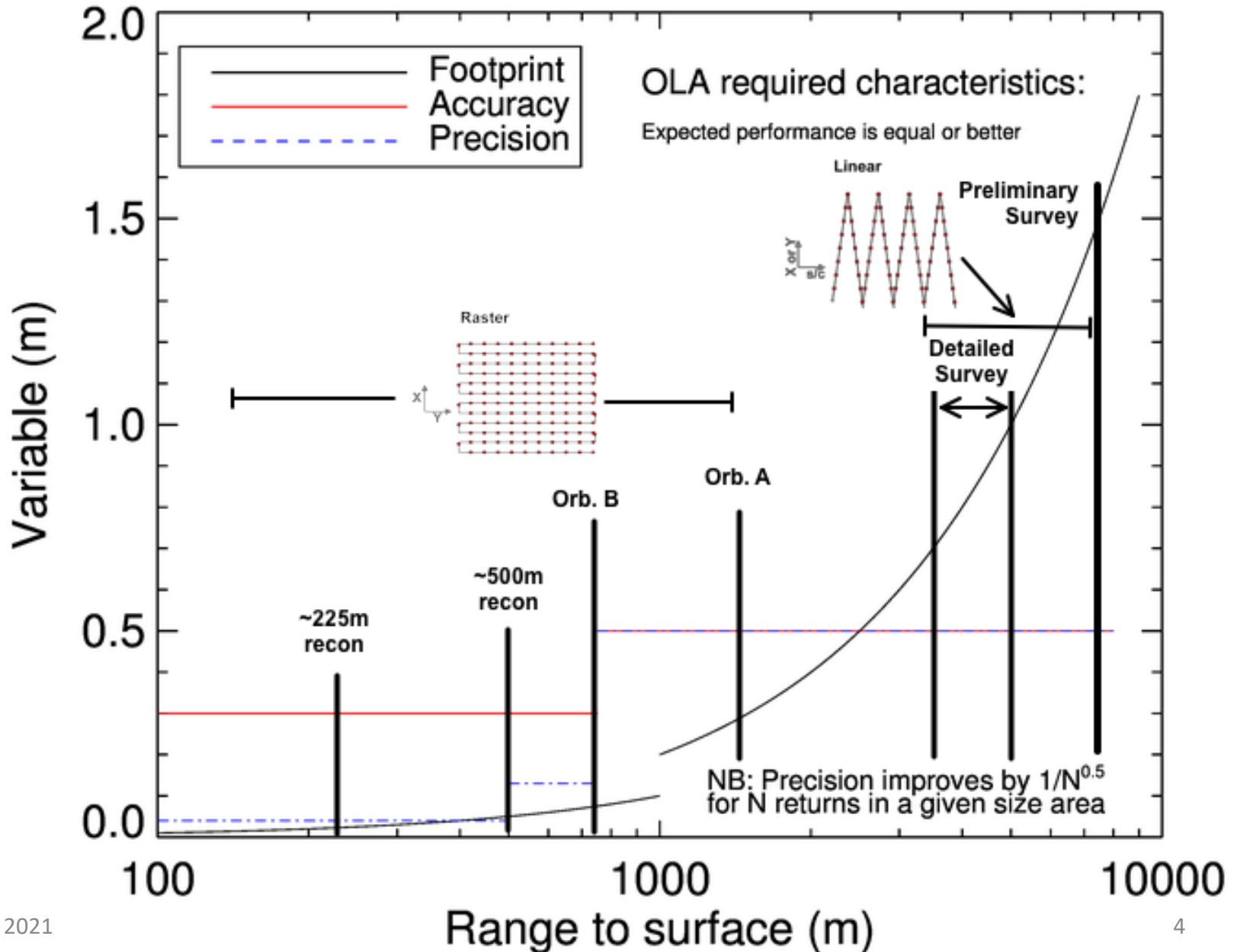
	Ground Sample Distance	Accuracy	Vertical Precision	Horizontal Relative Accuracy	Product source and timing
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Sci tilt 32 cm	<32cm	<100cm	<4cm	<32cm	Detailed Survey OLA-Orb B

- Navigation and NFT

	Ground Sample Distance	Accuracy	Vertical Precision	Post Residual Fit	Product source and timing SPC only
FDS Global 75	75cm	100cm		38cm	PreSurv Orb A
FDS Global 35	35cm	75cm		18cm	Detailed Survey
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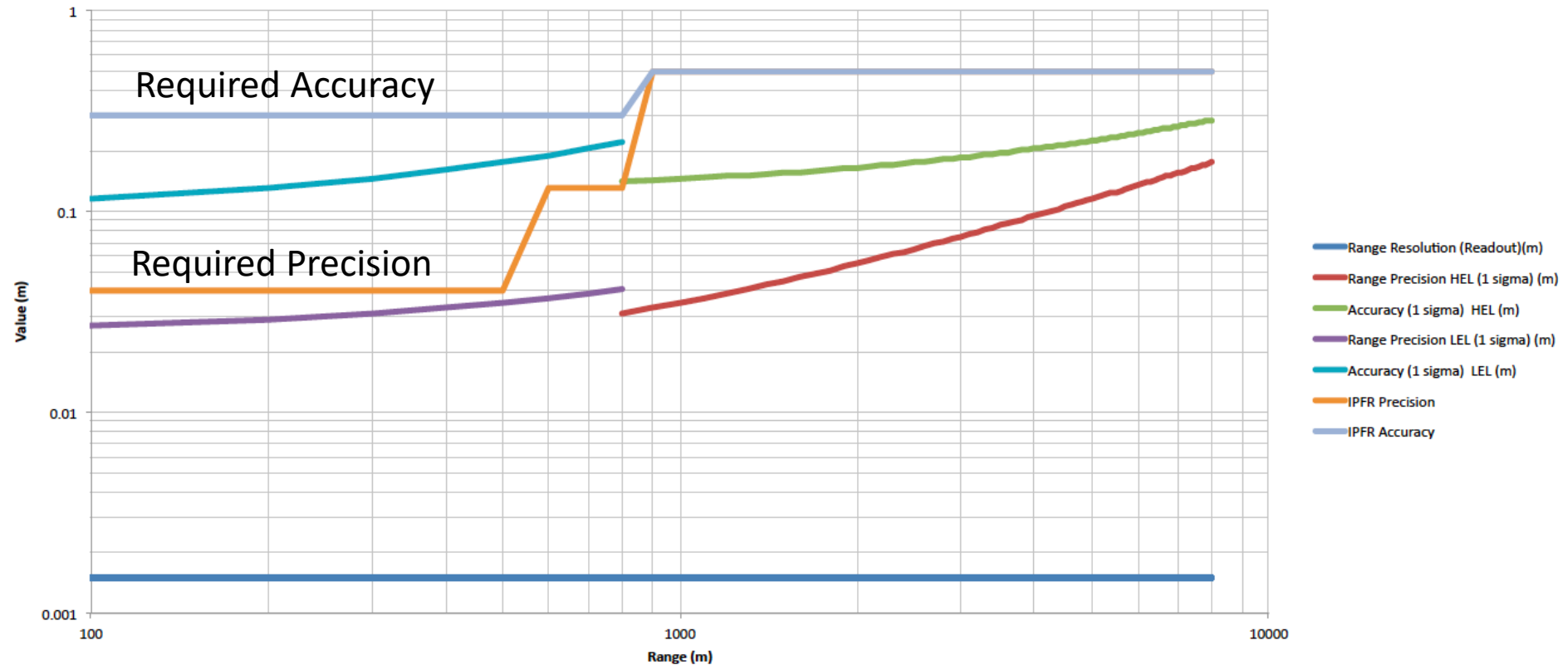


# Why later in mission?





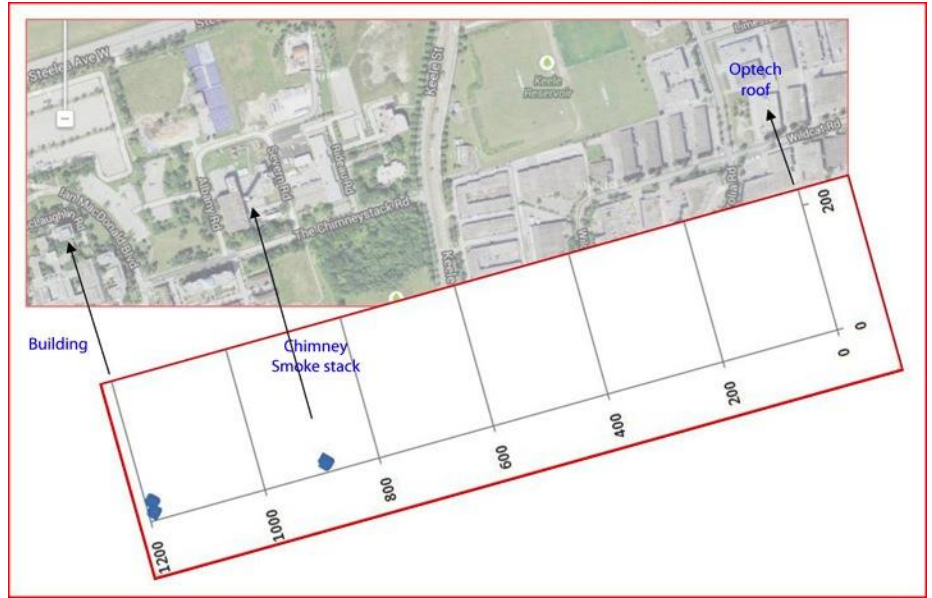
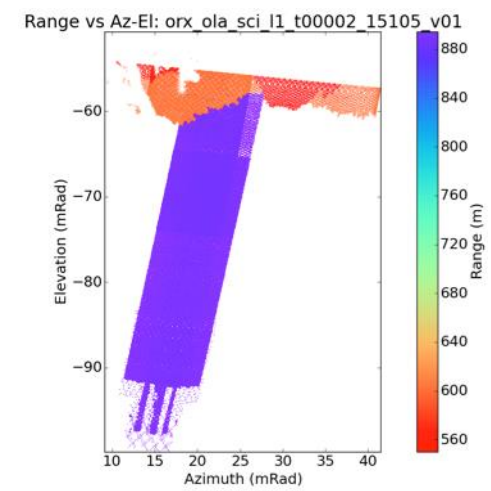
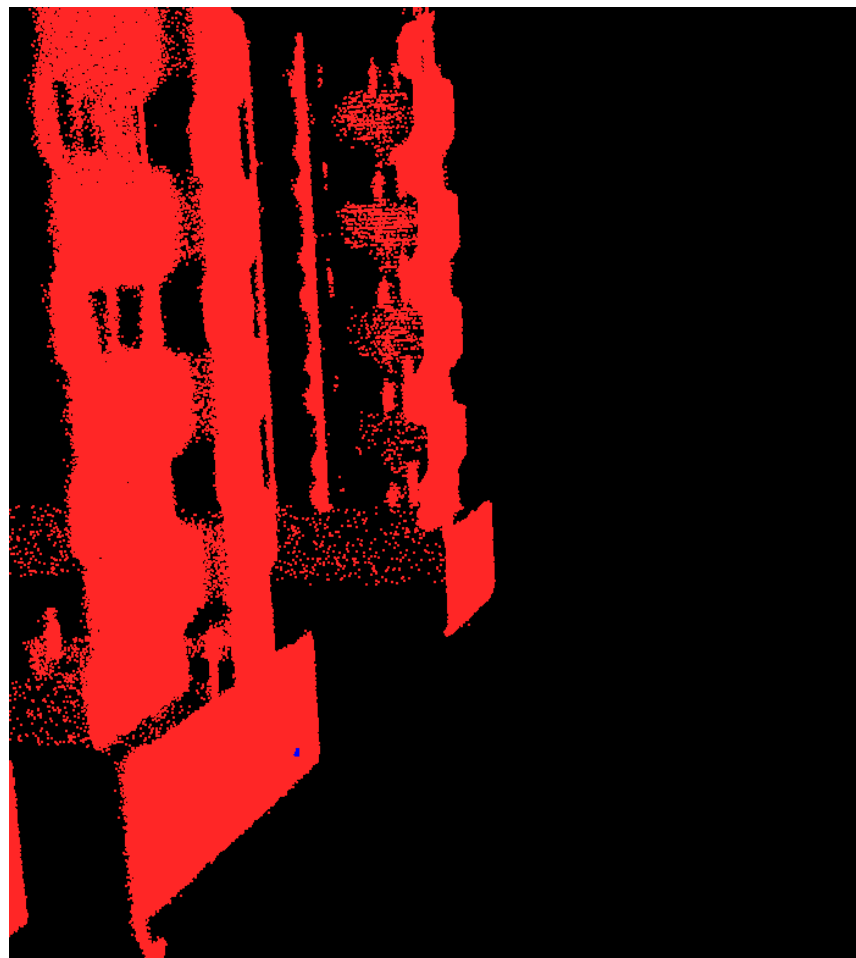
# OLA Instrument Expected Nominal\* Performance



\*Ignores possible noise issue that was associated with one test set up (applies only to LEL)  
This performance does not include s/c pointing errors and nav errors. Just instrument level.



# Some measured performance – will have more in the next weeks



In SBMT – Building at 1.2 km from instrument

March 17, 2021



# Statistical assessment folding in other errors

Error source at distance (km) of	7	1	0.75	0.5	0.225 km	Notes
Constant Fraction Discriminator Error/precision	0.1600	0.0330	0.038	0.0330	0.0300 m	1 sigma
Clock frequency error (1 part per million)/Accuracy	0.1800	0.1230	0.18	0.1800	0.1300 m	1 sigma
Measurement quantization	0.0020	0.0020	0.002	0.0020	0.0020 m	Performance
OLA Pointing stability	0.1	0.1	0.1	0.1	0.1 mrad	mrad over 2.5 min
Pointing control OLA	1.98	1.98	1.98	1.98	1.98 mrad	Systematic – correctable
Spacecraft pointing knowledge	0.67	0.67	0.67	0.67	0.67 mrad	3 sigma
Spacecraft stability	0.017	0.017	0.017	0.017	0.017 mrad	3 sigma over 1 s
Spacecraft pointing control or accuracy	1.5	1.5	1.5	1.5	1.5 mrad	Systematic – correctable
Pointing knowledge uncertainty (OLA+S/C)	0.142	0.142	0.142	0.142	0.142 mrad	1 sigma
Resulting lateral error in pointing, y (m)	0.987	0.705	0.141	0.0705	0.031 m	1 sigma
Resulting error from roughness within spot	0.23	0.047	0.037	0.027	0.014 m	Based on Eros
Resulting error from surface roughness (lateral uncertainty)	0.31	0.061	0.048	0.035	0.018 m	Based on Eros
Resulting error from roughness within spot	0.4	0.3	0.3	0.3	0.2 m	Based on Itokawa
Resulting error from surface roughness (lateral uncertainty)	0.5	0.5	0.3	0.3	0.2 m	Based on itokawa
Spacecraft orbit knowledge	10	1	0.35	0.35	0.35 m	At start of process
Total (root sum squared) Itokawa	10.03135	1.2025897	0.652953	0.652681	0.5102 m	Folding everything Itokawa
Total (root sum squared) Eros	10.01034	1.0110153	0.400026	0.397425	0.375265 m	Folding everything Eros
Spacecraft orbit knowledge – strip adjustment correction	0.36	0.246	0.36	0.36	0.26 m	
Total (root sum squared) Itokawa	0.870405	0.7118553	0.658368	0.658098	0.453215 m	Folding everything Itokawa
Total (root sum squared) Eros	0.580176	0.2875204	0.408804	0.40626	0.293128 m	Folding everything Eros

← OLA performance

← Pointing uncertainties

← Asteroid cooperation

← Navigation errors

Only navigation errors are the ones we can do something about via strip adjustments.  
 Expect to drop down to 2x OLA accuracy – assessment through testing only just begun.



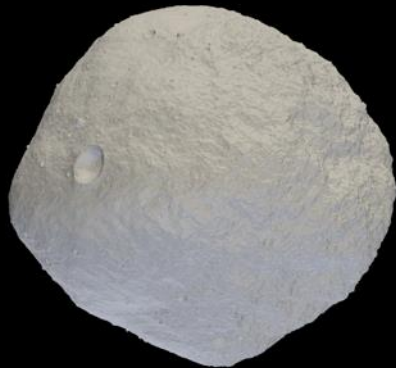
# Nominal testing

- Just begun effort.
- Assessed OLA products relative to truth model 3.
  - Investigated global model (produced in detail survey)
  - Regional models (produced from Orb B obs)
  - Tag model from (produced from Orb B obs)
- Remain to undertake recon case
  - Little clarity on what is ultimately planned
    - We will begin some of our own efforts to develop a reasonable plan (including development of CKs using the nominal SPKs)
- Used nominal data:
  - No errors in measured range (accuracy or precision)
  - No pointing errors
  - No nav errors



# Global models

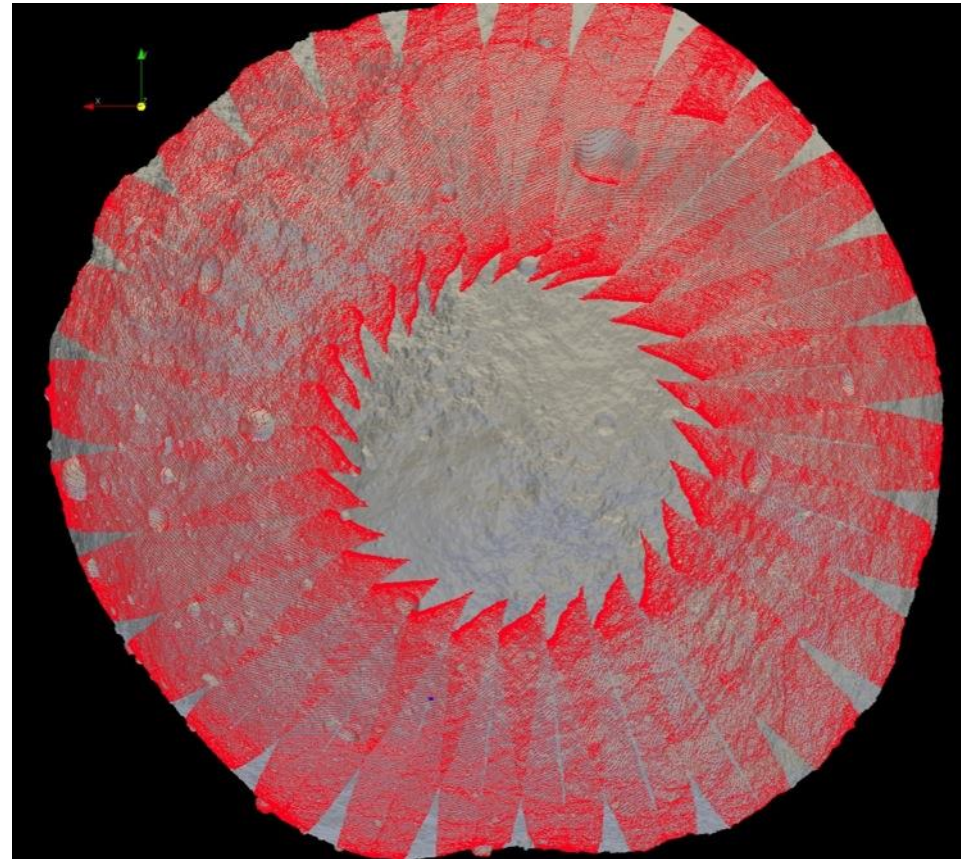
Reference model – Truth model at 0.87m





# Preliminary survey data

- Collected from baseball and equatorial stations
  - Spot size 0.75 -1 m
  - Sampling uneven (attempt to keep as even as possible)



OLA data near S pole from baseball station



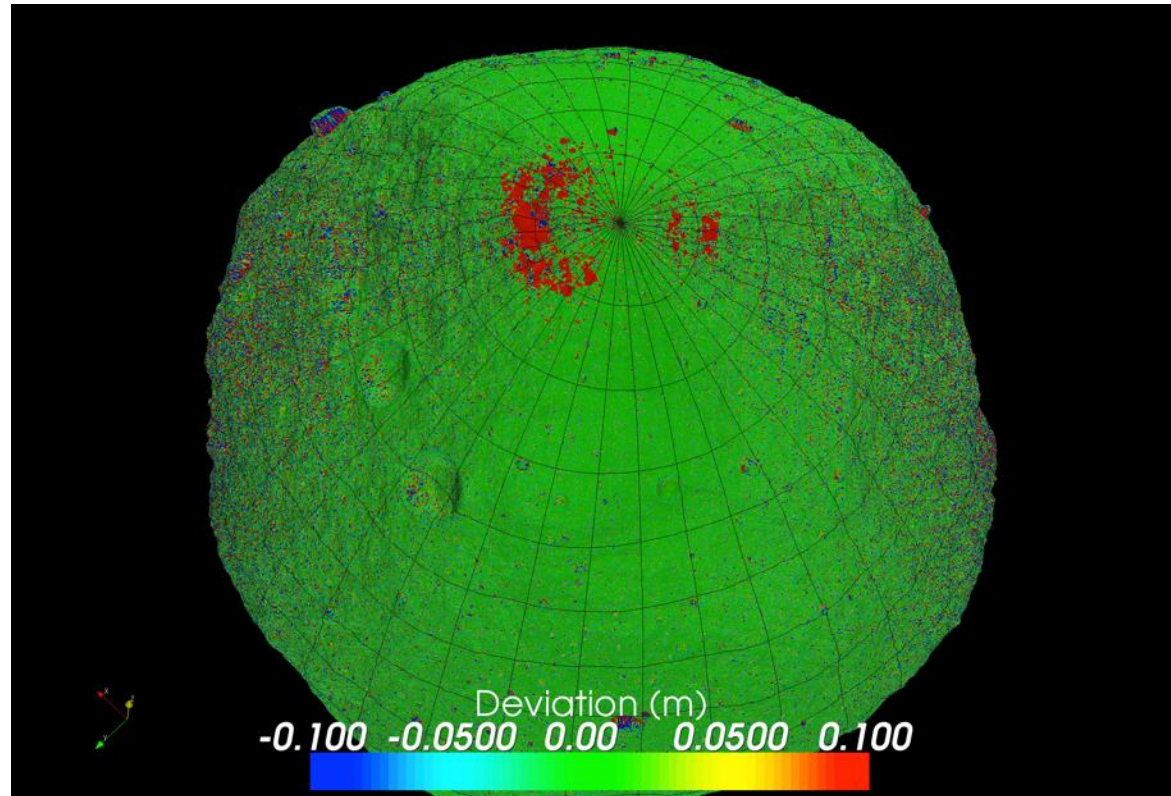
# Detailed Survey Model





# Global Deviations – detailed survey

- Detailed survey data and truth
- Deviations are greatest at
  - Poles
  - Some blocks
  - Due to poor emission angle
- Range spans
  - Min < -10 m
  - Max = 0.62m
- RMS accuracy
  - 0.11 m
- No need for translation



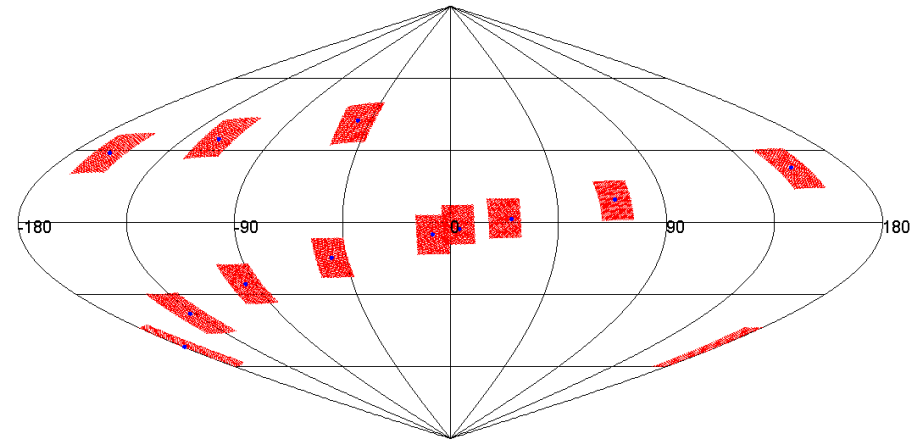
**Minor issues at poles**



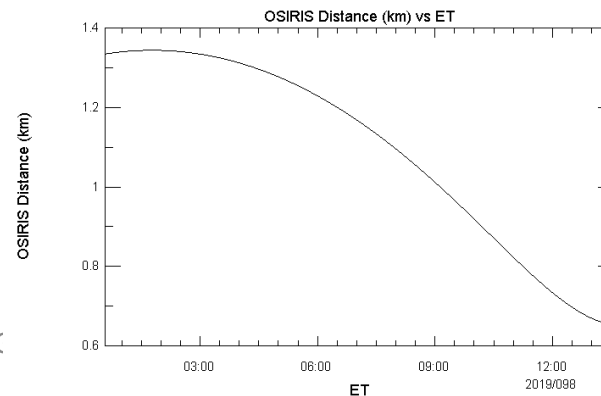
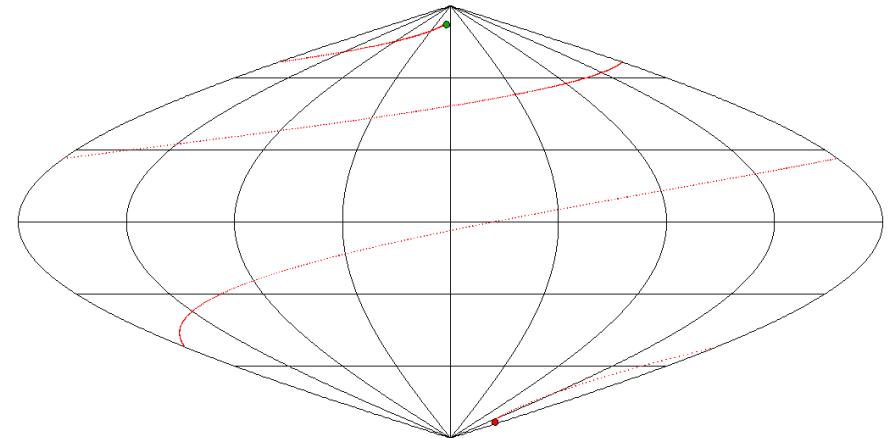
# OLA Orb B data collect

- Essential Nadir observation
  - Spacecraft looks slight sunwards for imaging
  - Compensate by pointing OLA Mirror boresight back to true nadir
- Every 30 minutes or so
  - A 2.5 min scan
    - About 90x90m scan
  - Each return at 0.1 mrad separation (also footprint size)
  - 6 and 9 cm spacing

2019 098T00:33:20.619-2019 098T13:32:33.195 (13.0 hrs)



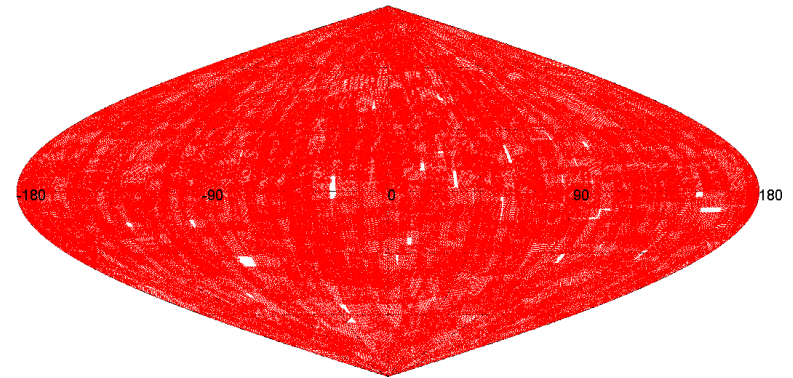
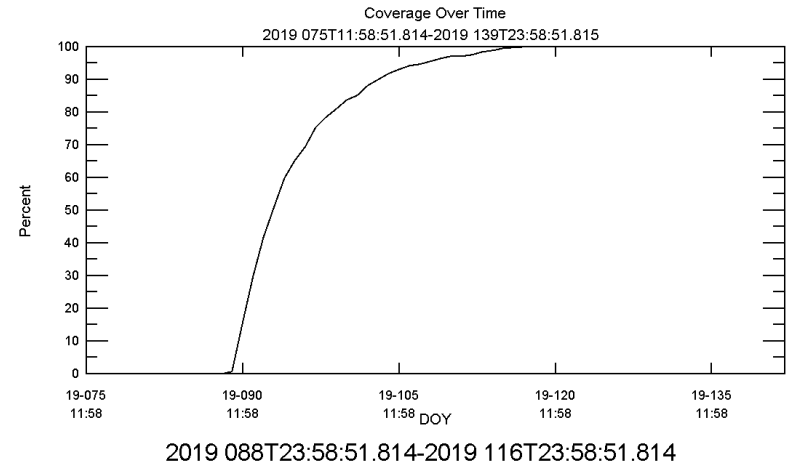
2019 098T00:33:20.619-2019 098T13:32:33.195



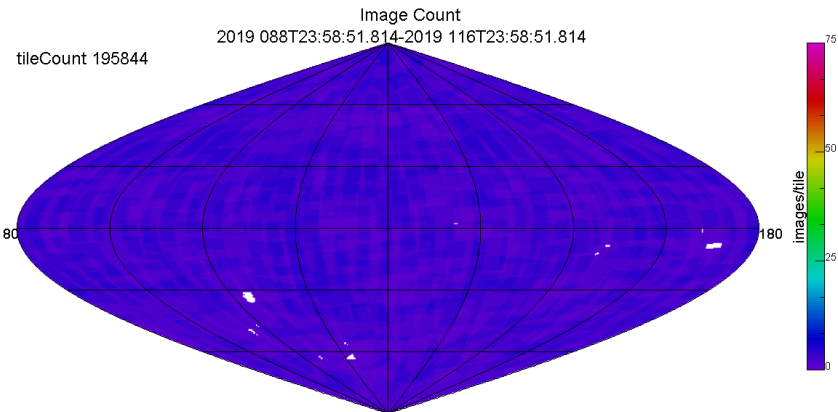
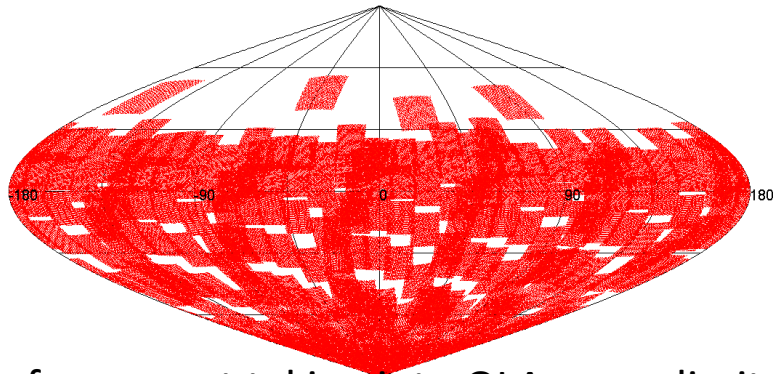


# Orb B Global Coverage

- After 30 days or so (if orbits stay below 850m range)
  - Nearly complete coverage achieved
- If we maintain current orbit geometry
  - OLA will only cover half the planet
  - Working to a solution with Nav to precess the orbit



2019 088T23:58:51.814-2019 116T23:58:51.814



Data for current taking into OLA range limitation

March 17, 2021



# Orb B Model – assuming OLA can range to surface



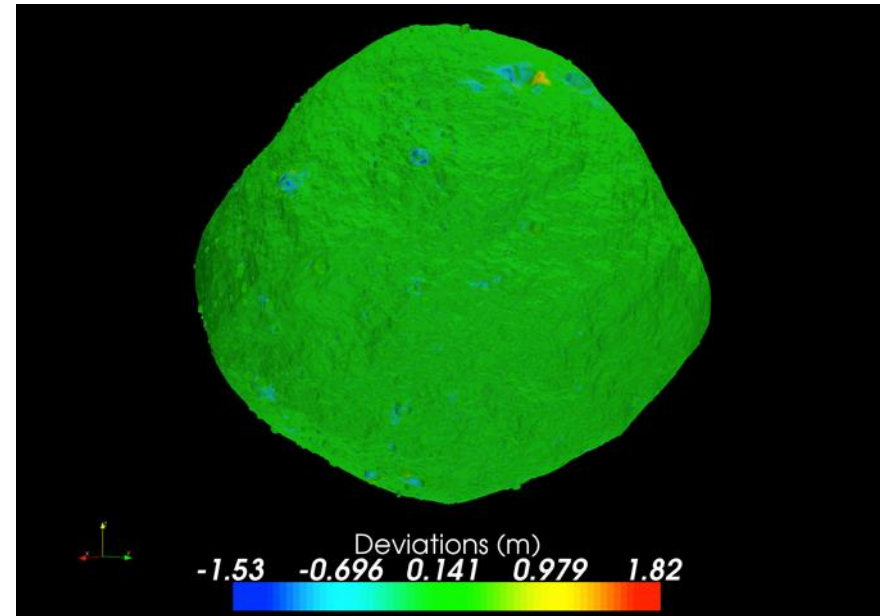
- Derived directly from global data. No use of intermediate mapolas.
- Little crisper than truth at craters
  - OLA data sample higher resolution 5 cm GSD truth data



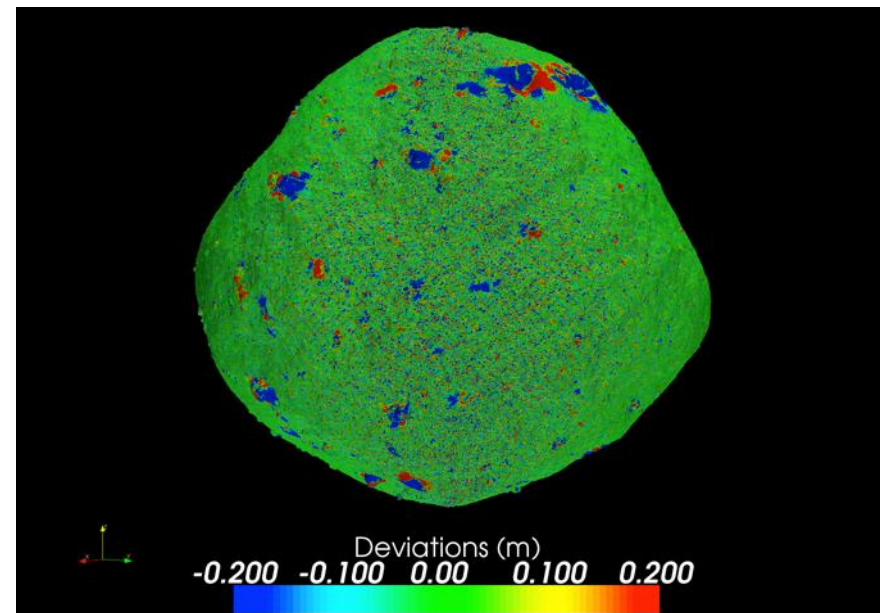
# Global Deviations – Orb B

- Orb B and truth
- Most deviations at edges of craters and blocks
  - Min = -1.53m
  - Max = 1.82m
  - Looks like Orb B model is better than truth
- RMS accuracy
  - 0.115 m
- No need for translation

Full range



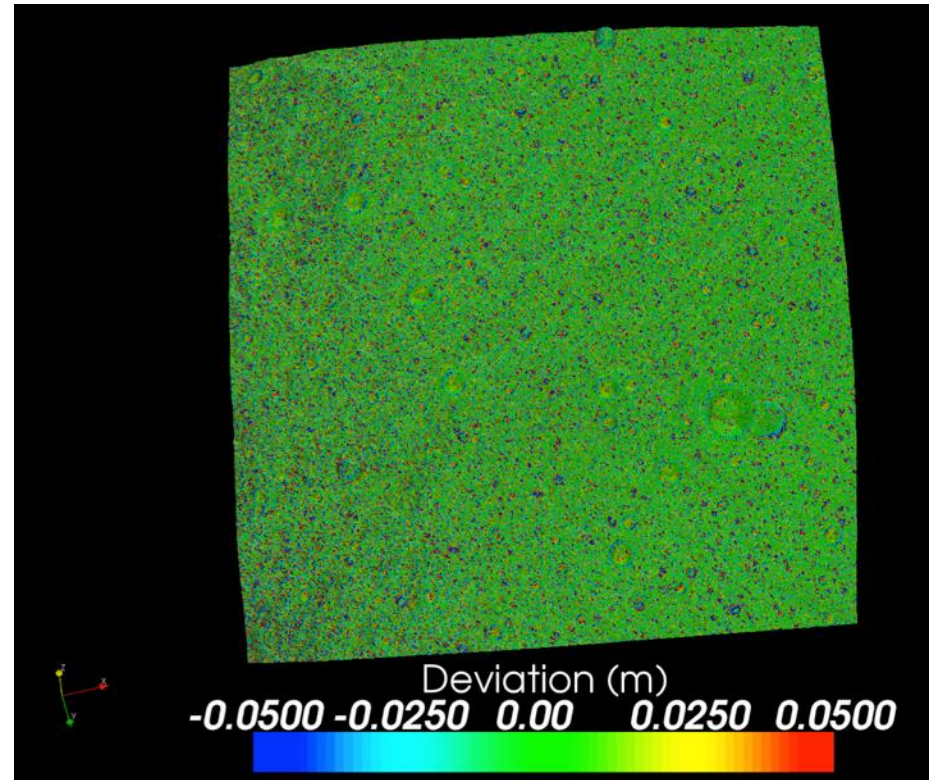
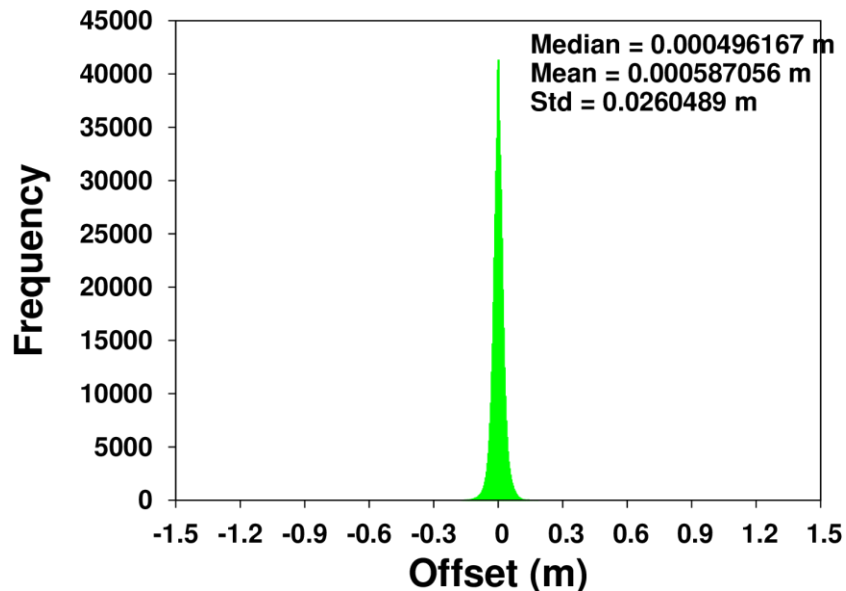
Narrow range





# Regional assessment

- Comparing
  - OLA mapola 30 cm gsd from ORB B data
  - Truth model 5 cm gsd
- RMS error = 2.26 cm
- Vertical error=3.34 cm
- Small horizontal error < 1cm

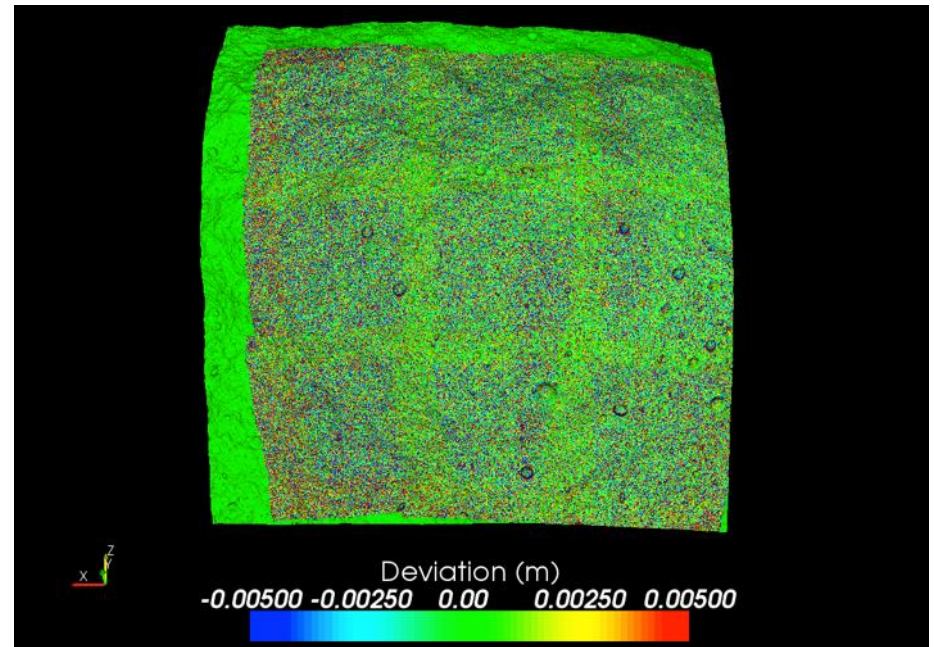
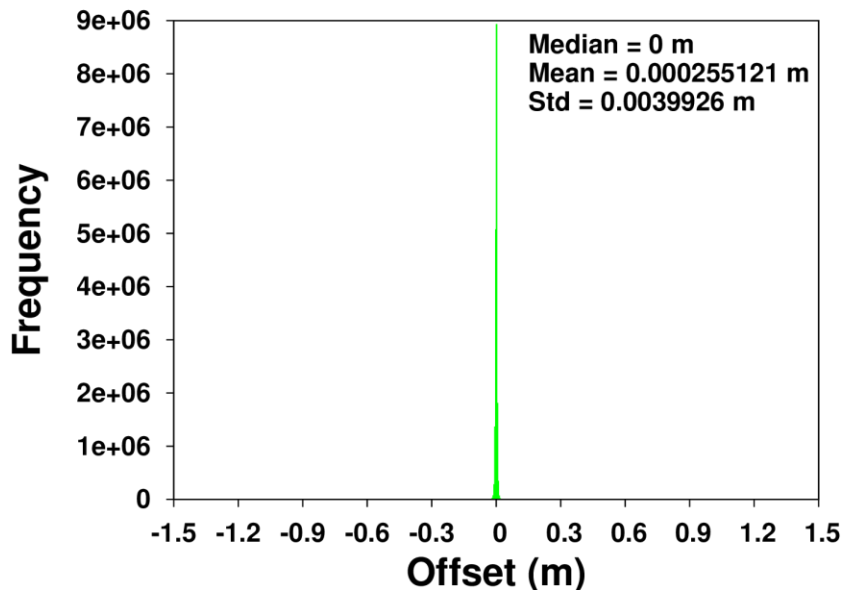


- True noise character



# Tag assessment

- OLA mapola 5 cm gsd from ORB B data
- Truth model 5 cm gsd
- RMS error = 0.44 cm
- Vertical error=0.86 cm



- True noise character
  - Means great alignment laterally



# Some additional statistics about the OLA TAG map

- Makes use of 12540893 OLA returns
- 7568133 pixels of the total of 9million pixels are filled with
- Rest are interpolated with splines (see GMT SOEST for how)



# Nominally satisfies all current req.

- Science, Sampleability, Safety

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# Conclusion

- Find OLA can satisfy many of the needs of the mission for nominal mission
  - Possible much better than SPC
  - Caveat
    - OLA data needs to have more realistic performance
      - But significant overlap data should make precision error small
    - Navigation and pointing errors need to be included



## Baseline OLA for NFT

Initially assessment of impact on  
schedule and observation plan



# Current Plan - Global Models

- In support of FDS
  - GSD of 0.75 m or better
    - SPC – Preliminary survey
      - OLA only provides regional verification
    - OLA – Detailed survey
      - Sufficient for global coverage
        - » 2019 034T10:42:18 (Feb 3, 2019)



# Current Plan - Global Models

- In support of FDS
  - GSD of 0.35 m or better
    - SPC – Detailed survey
    - OLA: End of Orb: GSD of 8cm for 100% of surface; up to 5cm for 40% where there is more than one return
      - But as we saw above – OLA DS data may be good enough.
  - GSD of 5cm or better
    - SPC - Obtained from imaging acquired during Orb B
    - OLA – Requires >500 m flyby
      - But Orb B data may be good enough



# Baseline OLA for NFT – requires proposed recon phase changes

- For GSD below  $<3\text{cm}$  and low noise  $\approx 1\text{cm}$  or less
  - Use OLA during 225m flyovers early in recon phase or during Orb B.
    - Current plan has OLA observation in July of 2019; Plan for much sooner - May 2019
  - Closer flyby minimizes chances for OLA noise issue
    - Ensures sufficiently high intensity returns
- Make OLA primary for early tag site flybys
  - Separate OCAM from OLA obs
    - OCAMS rides along – mosaicking minimized to ensure best quality OLA data
  - Later OCAMs can drive and OLA can provide ranges for focusing



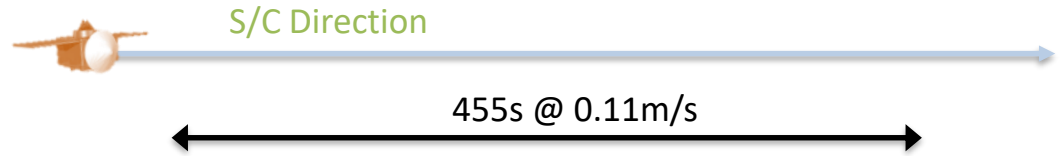
## One of two possible recon scenarios

- Will require analysis to determine which is best:
  - Continue with current baseline if current best estimate of spacecraft stability performance remains true while S/C slews
    - Spacecraft nods in direction of scan
    - OLA Scans across track
  - Otherwise - Make individual OLA 47 by 47 m raster scans or images as spacecraft looks nadir and flies over sample site

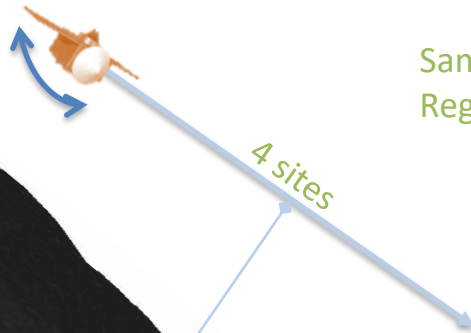


# Reconnaissance Phase (225m)

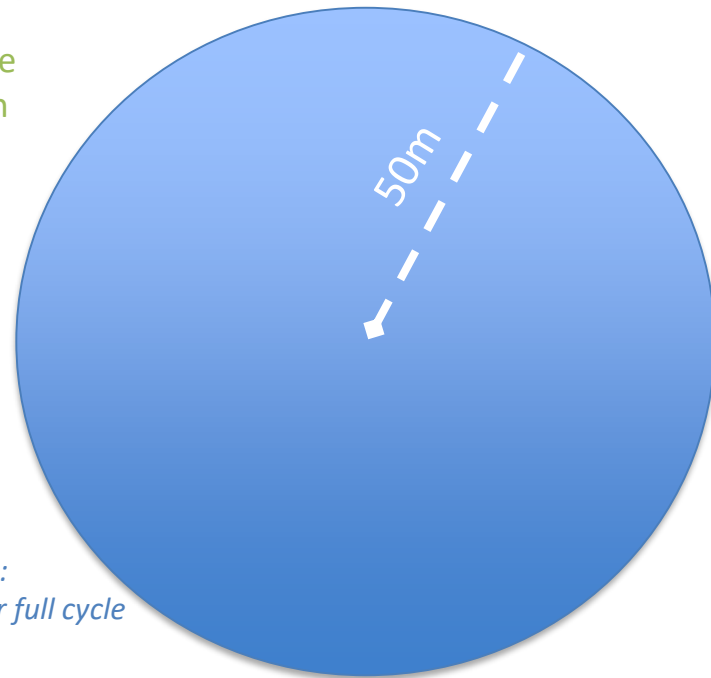
Nodding Slew:  
5.6° ,120s for full cycle  
75s



Sample Region



225 m



Nodding Slew:  
5.6° ,150s for full cycle  
75s



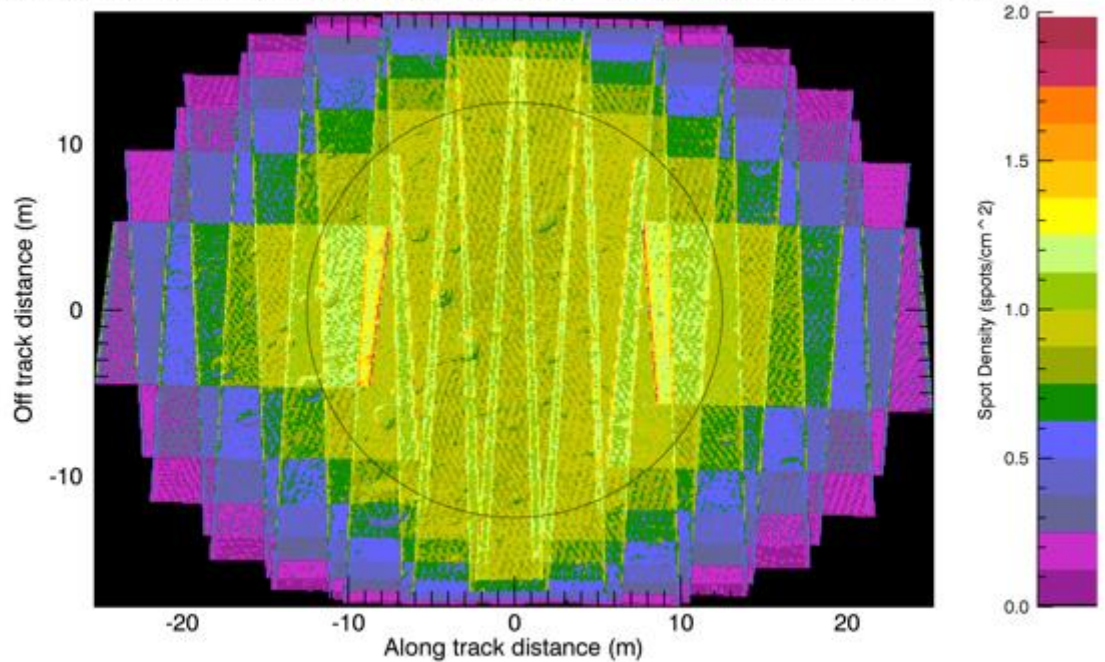
# Recon Phase spot density

5 million points within  
12.5 m radius target area

1 point/cm<sup>2</sup> average shot  
density in target area

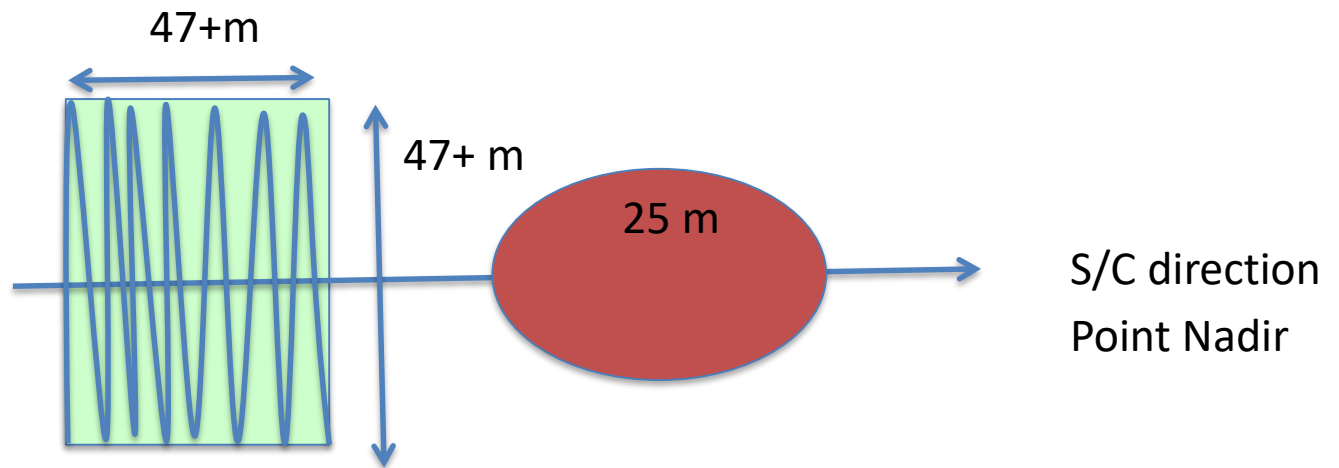
Concerned that  
overlapping spots wont  
overlap that well because  
of spacecraft trajectory  
and pointing knowledge  
issues.

525 m Recon - Spot Density - 0.10 mRad spot spacing - 30 mRad FOR 12.5 m radius - HR BENNU





# Alternative recon phase observation



Generate multiple 2min long overlapping raster scans.

Each return center separated by 0.1 mrad

Each return 0.1 mrad