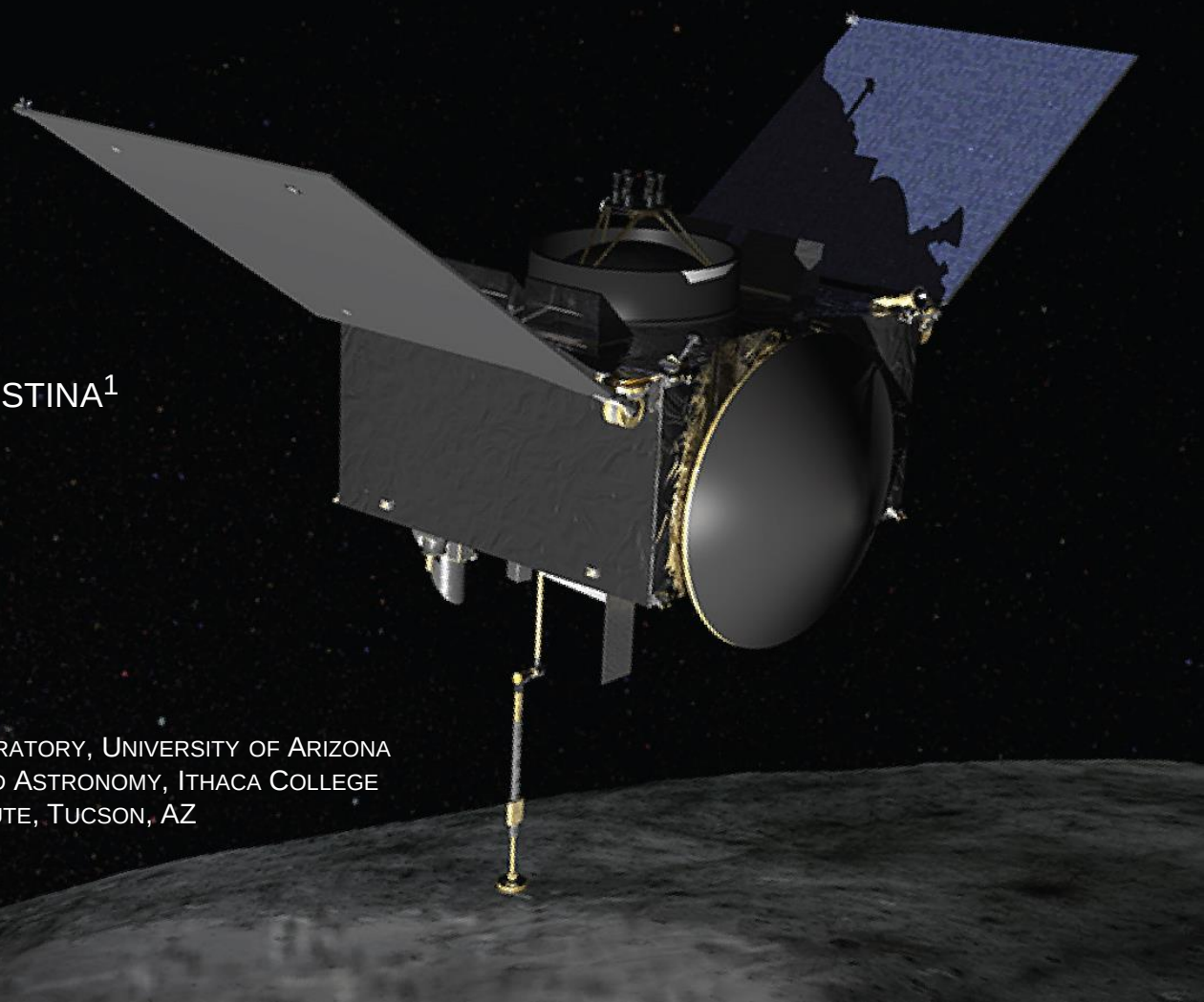
PHOTOMETRIC MODELING OF SIMULATED SURACE-RESOLVED BENNU IMAGES

OSIRIS-REX™
ASTEROID SAMPLE RETURN MISSION

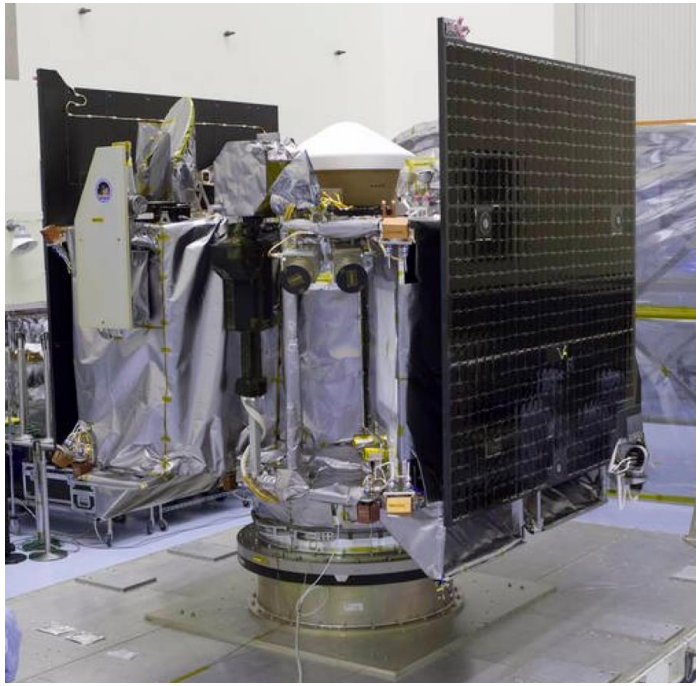


DATHON GOLISH[1]
DANIELLA DELLAGIUSTINA[1]
BETH CLARK[2]
CARINA BENNETT[1]
JIAN-YANG LI[3]
XIAO-DUAN ZOU[3]
DANTE LAURETTA[1]

[1]LUNAR AND PLANETARY LABORATORY, UNIVERSITY OF ARIZONA
[2]DEPARTMENT OF PHYSICS AND ASTRONOMY, ITHACA COLLEGE
[3]PLANETARY SCIENCES INSTITUTE, TUCSON, AZ

OSIRIS-REx

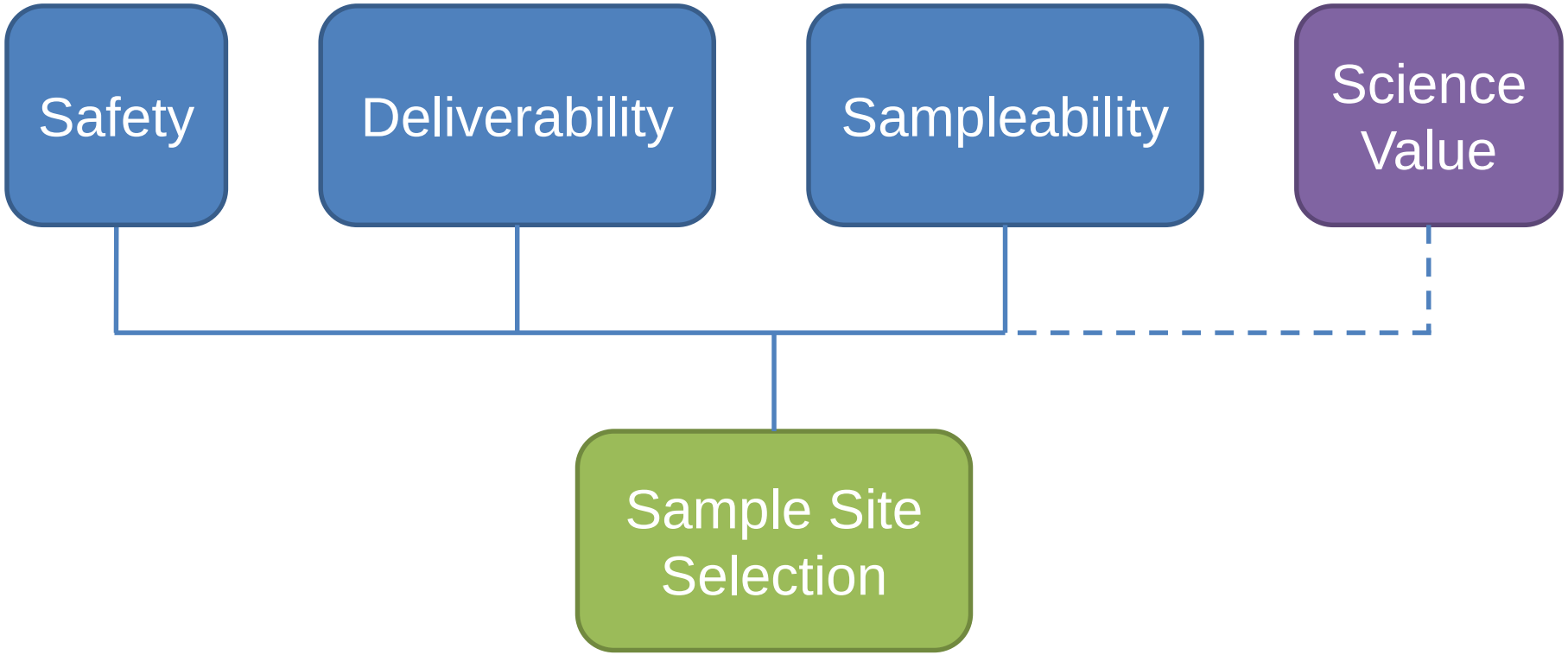
- Launched on September 08, 2016
- Arrives at Bennu in late 2018



Proximity Operations

- OSIRIS-REx is unique in that all of its data products are driven by sample site selection
- The pace of production is also driven by the timeline to prepare for sampling
- This emphasizes the need for robust and timely creation of the products that are inputs to the selection process

Top Level Maps



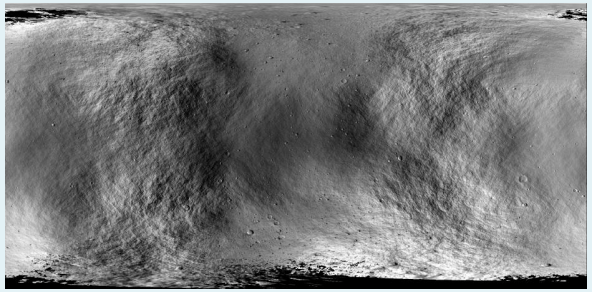
Top Level Maps

Safety
- Shape model
- Dust/gas plumes
- Albedo map
- Surface temperature

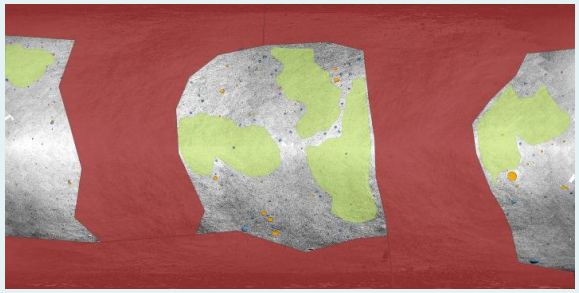
Sampleability
- Tilt map
- Grain size map
- Thermal inertia
- Hazard map

IPWG Data Products

Albedo map



Hazard map



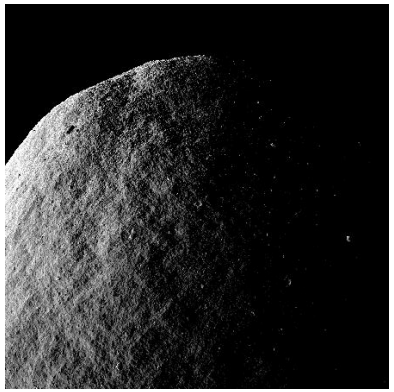
Top Level Maps

- 1064 nm albedo/reflectance map
  - IPWG will generate a global mosaic with MapCam's X filter, which is extrapolated to a 1064 nm reflectance map using photometrically corrected OVIRS data
  - The reflectance map is used by the Guidance, Navigation & Control LIDARs to ensure safe descent to the surface
- Hazard map
  - IPWG will produce a global map indicating regions of interest and regions of exclusion on the surface
- Both the albedo and hazard maps depend on an accurate photometric model

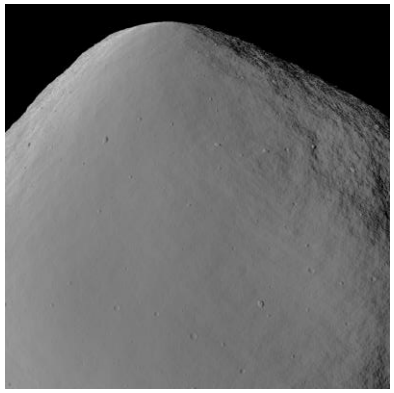
Simulated Data

- The observation plan and photometric modeling pipeline are tested with simulated data using planned observation kernels
- The Equatorial Stations observation campaign provides global coverage at four phase angles with MapCam in all filters

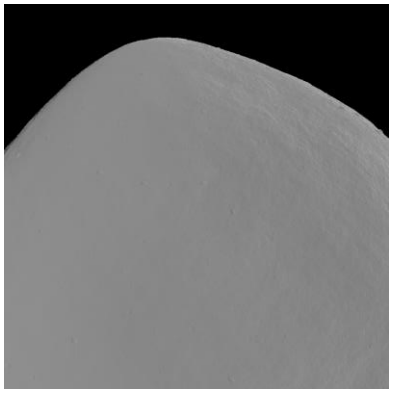
6 am



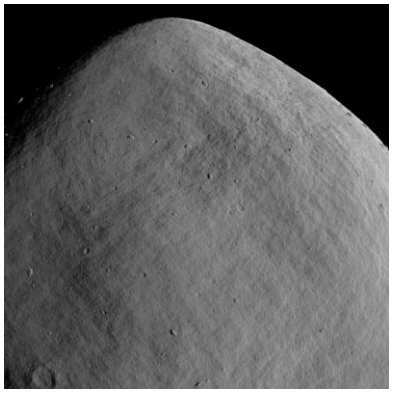
10 am



12:30 pm



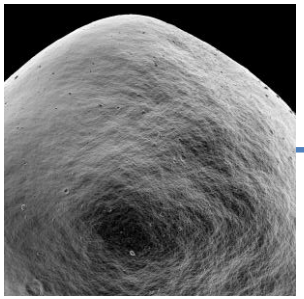
3 pm



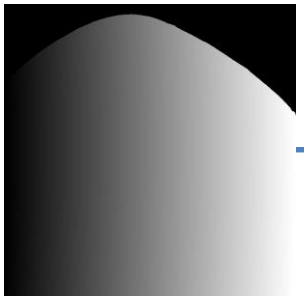
Simulated Data

- Simulated data is created using USGS ISIS

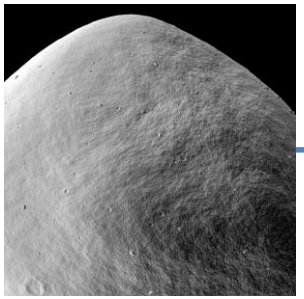
Emission Angle



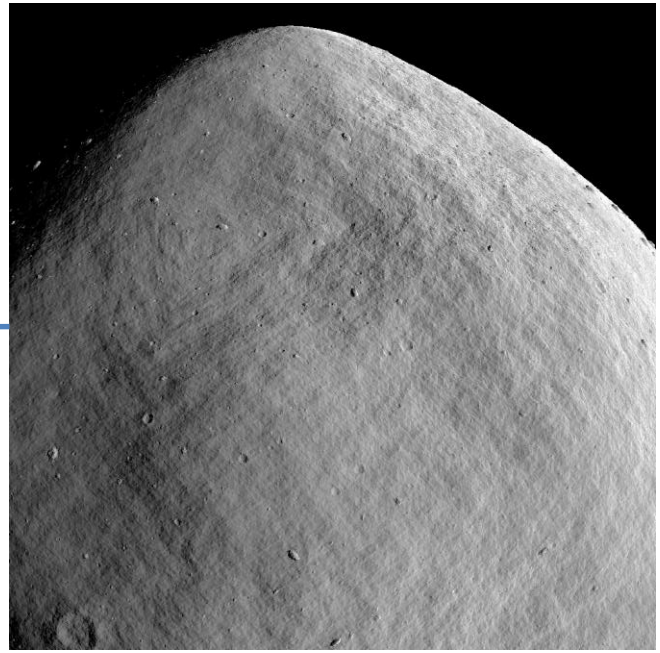
Phase Angle



Incidence Angle



Inverse photometric correction



Simulated Data

Limitations

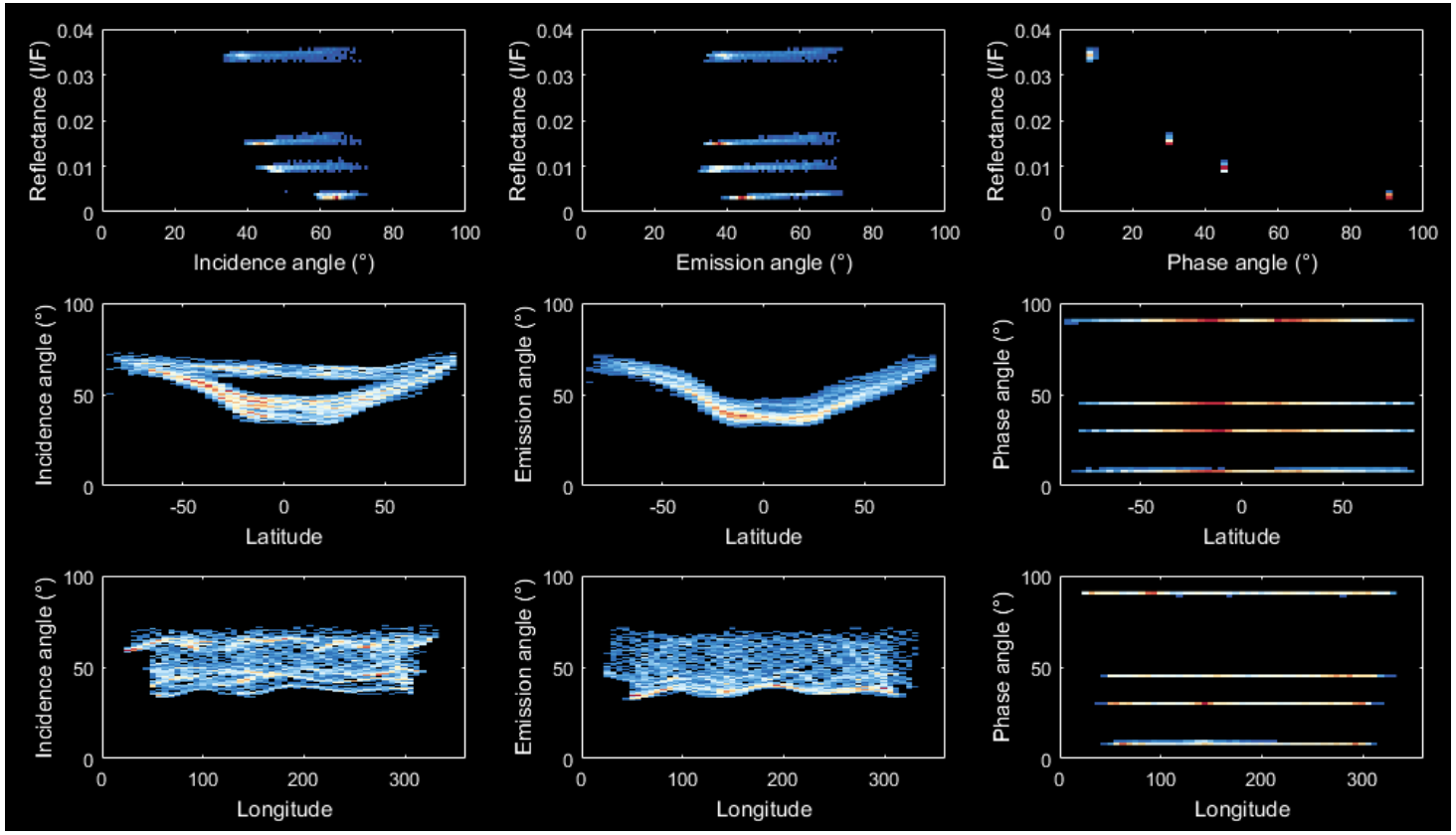
- Obscurations
  - Uses single-surface ray tracing – obscurations will not produce shadows
- Albedo
  - Uses one photometric model for the entire surface – i.e. no albedo variation across the surface
- Resolution
  - Uses the DSK shape model, which has a size limitation

Advantages

- Accurate
  - Produces photometrically and radiometrically accurate images
- Flexibility
  - Photometric models parameters are easily changed by editing a text file
  - New models also can be added with minimal bash/ISIS scripting
- Dynamic range
  - Images are created in 32 bits

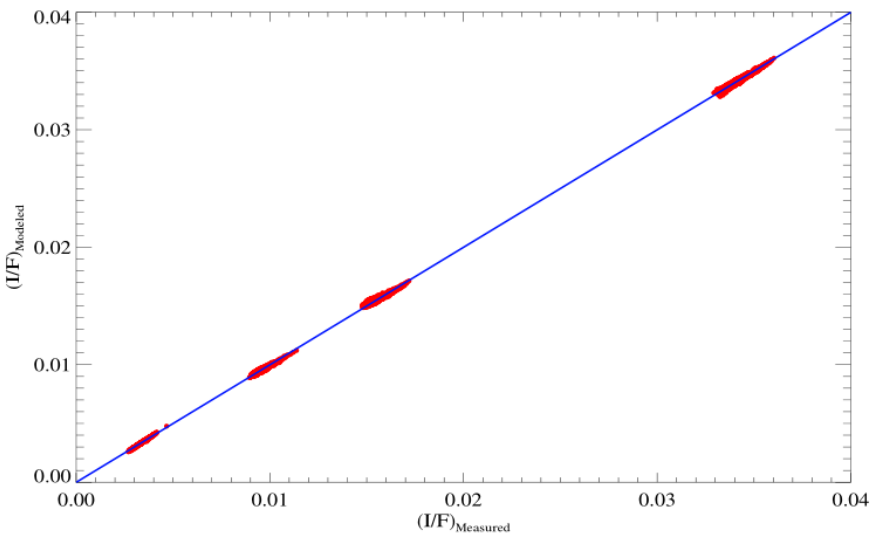
Simulated Data

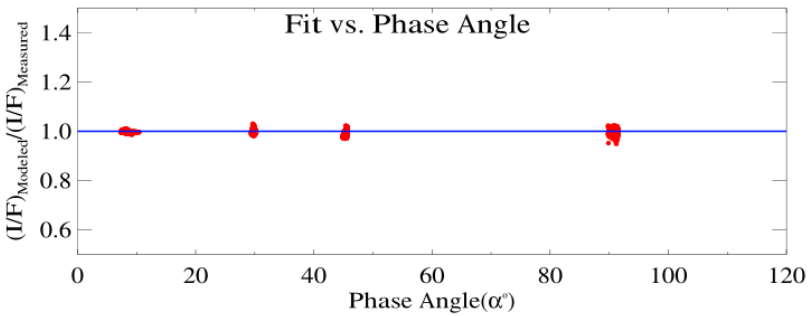
- Evaluate the photometric coverage achieved by the observation plan as designed

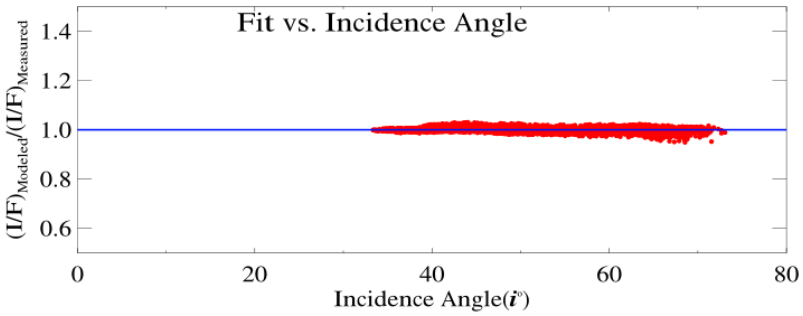


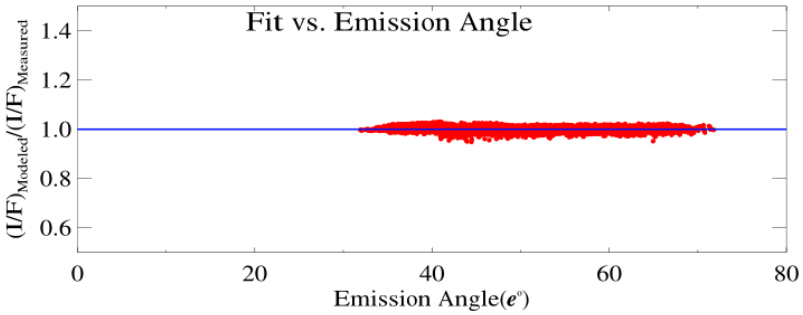
Photometric Modeling

- Modeling software is written in IDL
  - Fits several photometric models to the phase, emission, incidence, and reflectance data
  - Lommel-Seeliger shown in plots





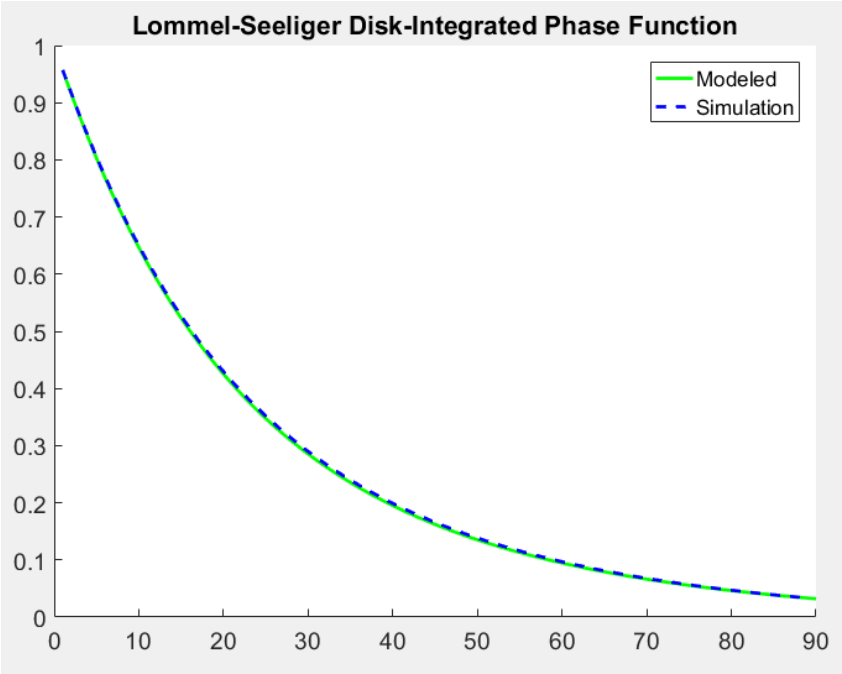




PHOTOMETRIC MODELING

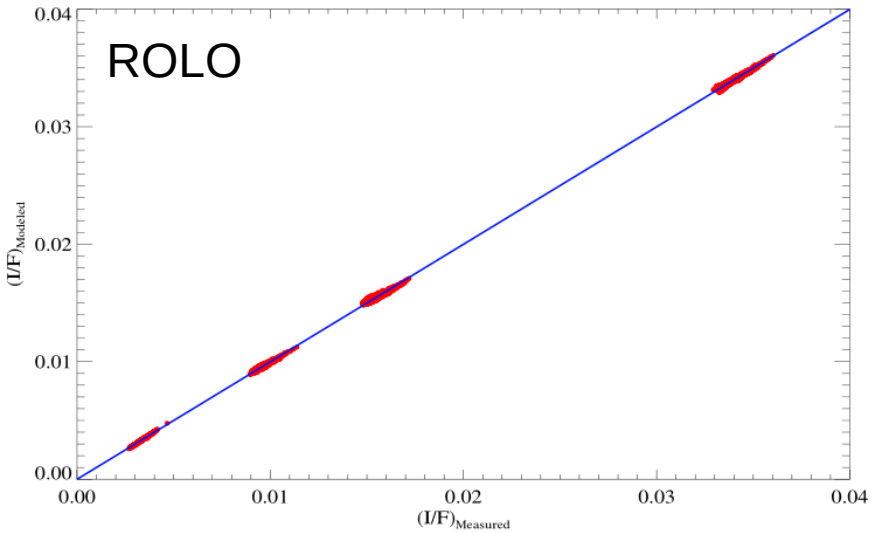
$$I/F(\alpha, i, e) = \frac{A_{LS}\cos(i)}{\cos(i)+\cos(e)} e^{\beta\alpha+\gamma\alpha^2+\delta\alpha^3}$$

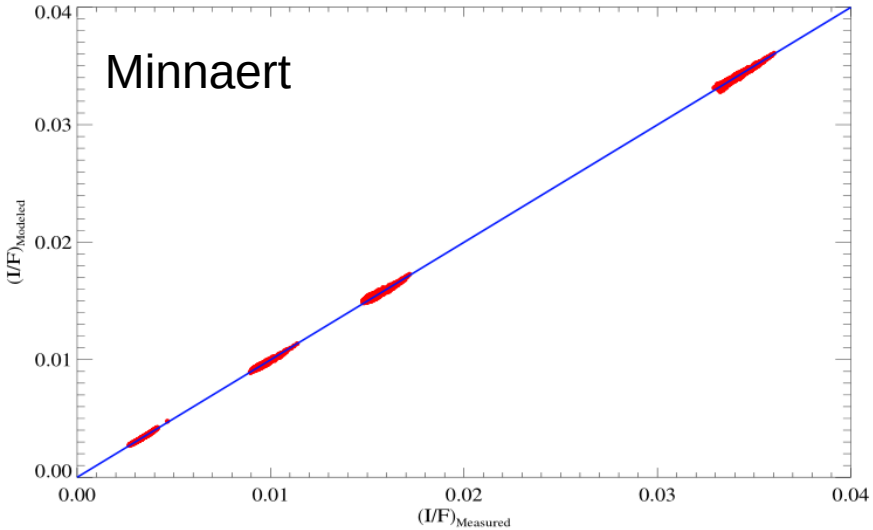
Simulation Parameters	Modeled Parameters
$A_{LS} = 0.030$	$A_{LS} = 0.0302$
$\beta = -0.0433$	$\beta = -0.0436$
$\gamma = 2.64 \times 10^{-4}$	$\gamma = 2.5408 \times 10^{-4}$
$\delta = -9.67 \times 10^{-7}$	$\delta = -8.1734 \times 10^{-7}$

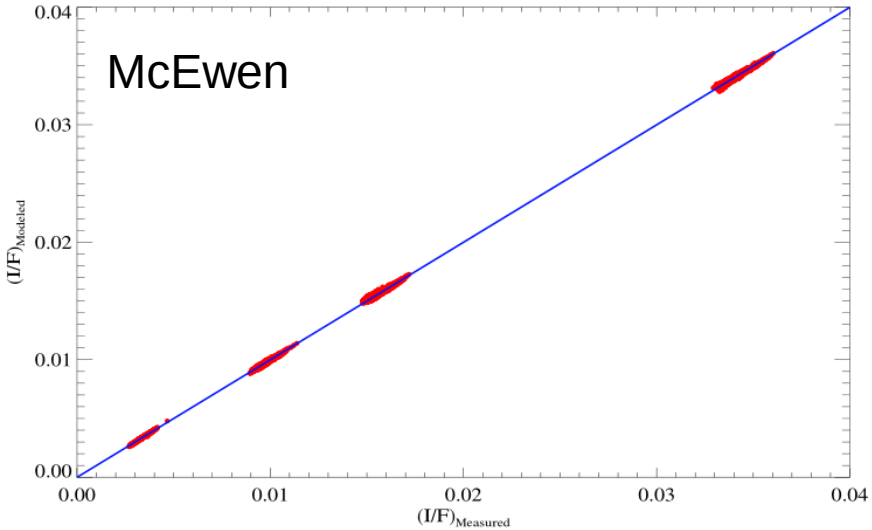


Photometric Modeling

- Though the images are simulated with Lommel-Seeliger, fitting to other common photometric models is also successful

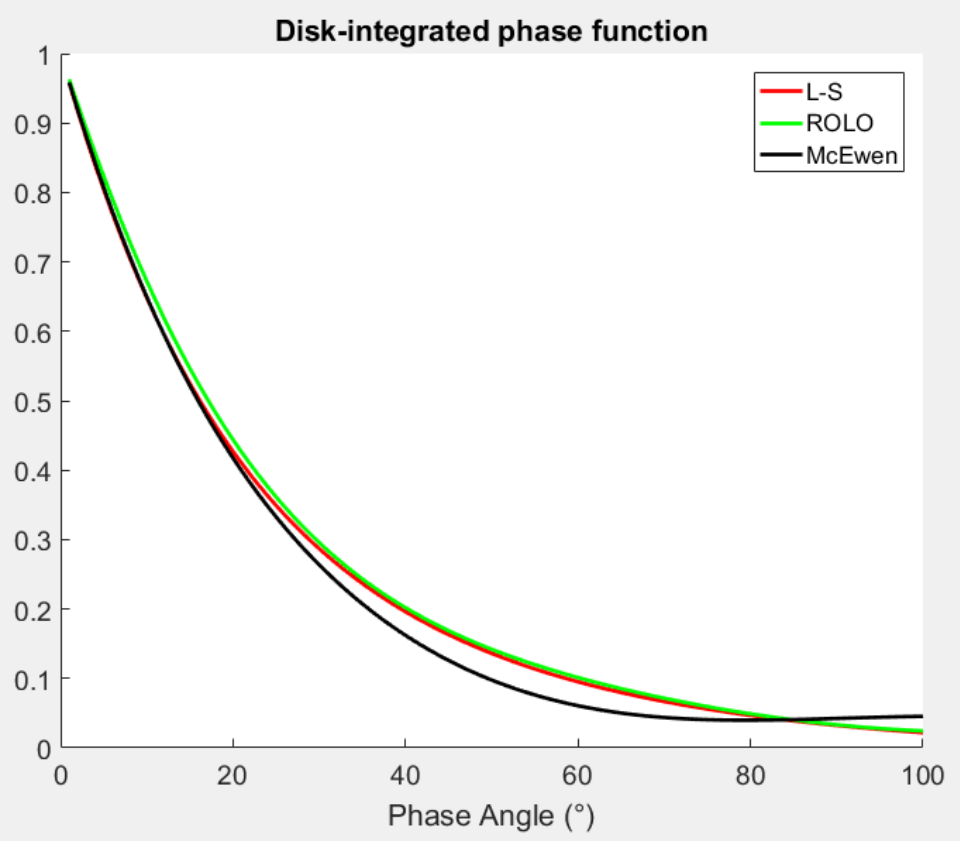






Photometric Modeling

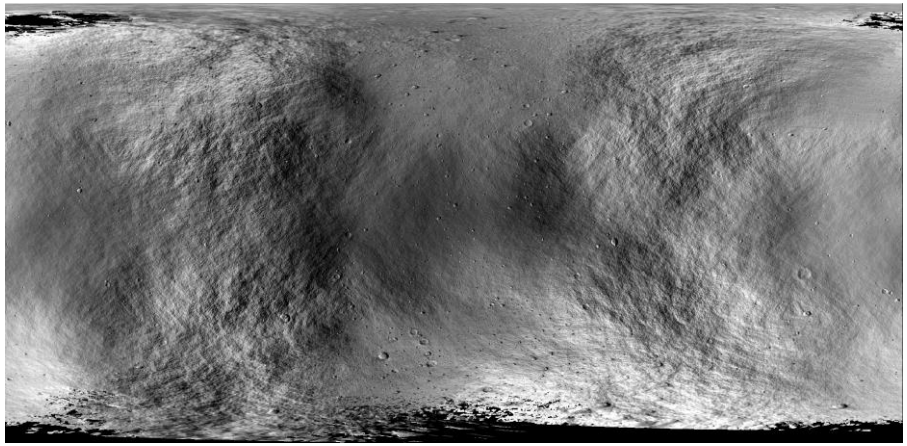
- The disk-integrated phase functions for the other models verify that they fit fairly well to the Lommel-Seeliger data
- McEwen deviates slightly at mid-phase angles, due to its two-part disk function



Photometric Correction

- Photometric correction is applied in ISIS
  - The error in correction is best judged by the uniformity of a mosaic of photometrically corrected images
  - A perfectly corrected mosaic will represent only the albedo of the surface (which is uniform), without any topography

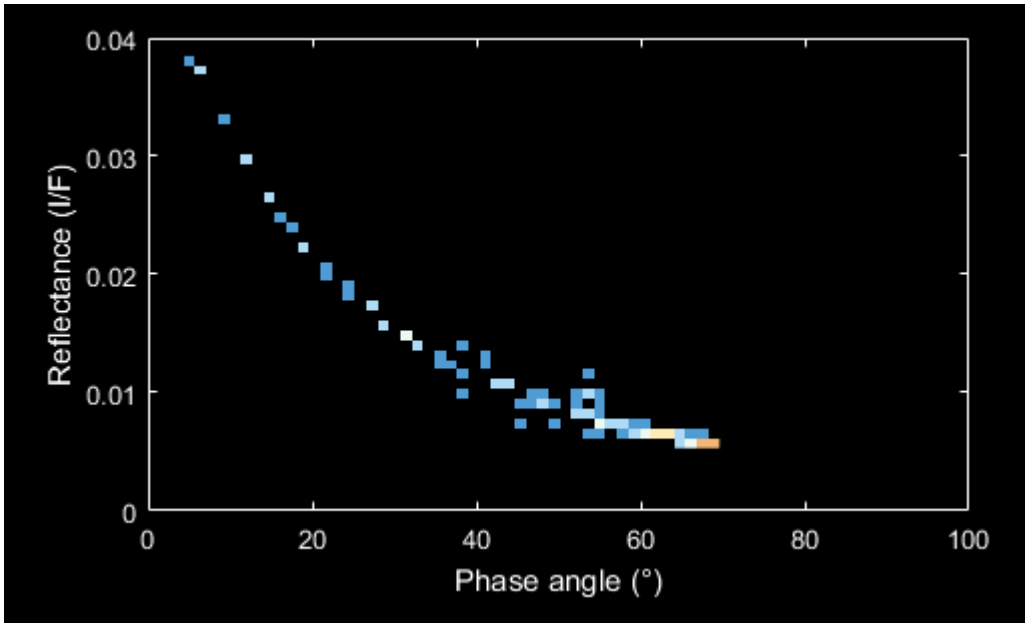
Uncorrected



Corrected

Future Work

- Additional data
  - Simulate potential contribution of additional observations during the mission to fill in gaps in the phase function

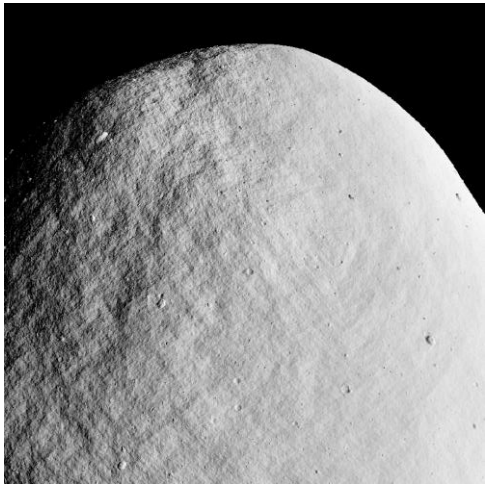


Add observations from Approach and Preliminary Survey

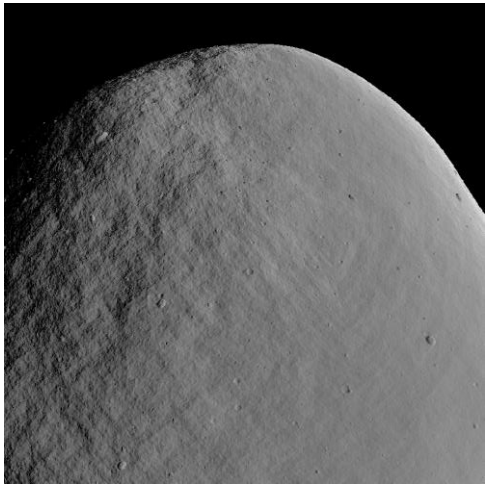
Future Work

- Photometric models
  - Add Akimov model to both simulation and modeling software

$$\underbrace{\left(A_1 * e^{-\mu_1 \alpha} + A_2 * e^{-\mu_2 \alpha} + A_3 * e^{-\mu_3 \alpha}\right)}_{\text{Phase Function}} \underbrace{\left[\cos\left(\frac{\alpha}{2}\right)\cos\left(\frac{\pi}{\pi-\alpha}\left(\gamma-\frac{\alpha}{2}\right)\right)\frac{\cos(\beta)^{\frac{.5\alpha}{\pi-\alpha}}}{\cos(\gamma)}\right]}_{\text{Disk Function}}$$



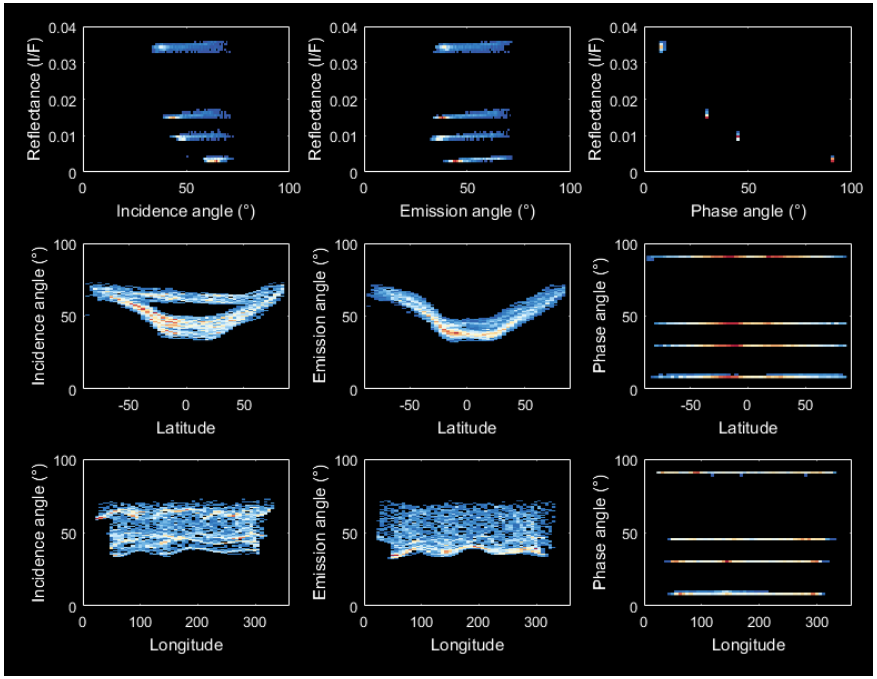
Akimov



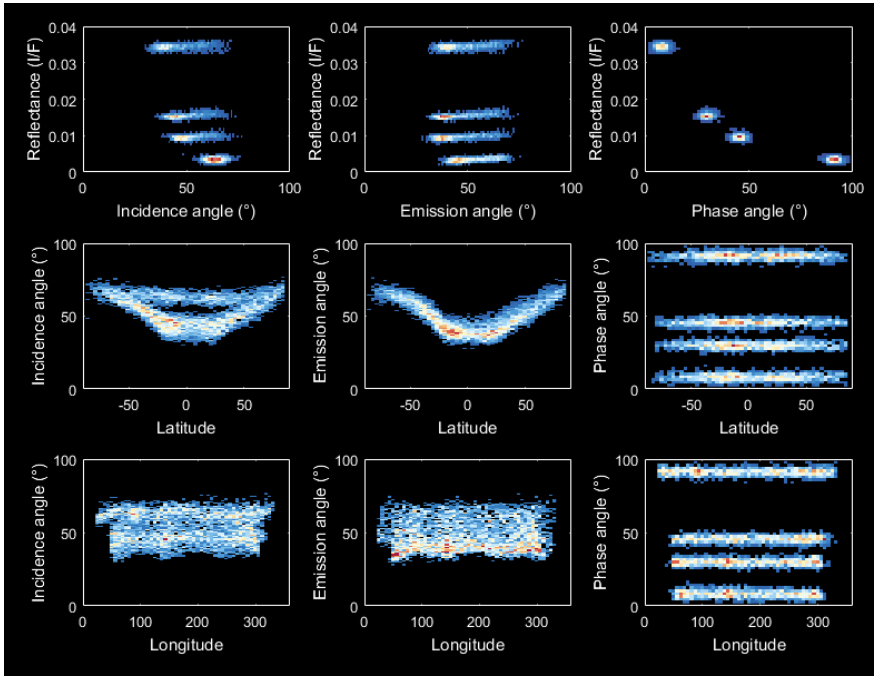
Lommel-Seeliger

Future Work

- Perturbed data
  - Simulated images are essentially perfect
  - Modeling software can be exercised by purposefully perturbing the photometric/reflectance data



Unperturbed



Perturbed

Future Work

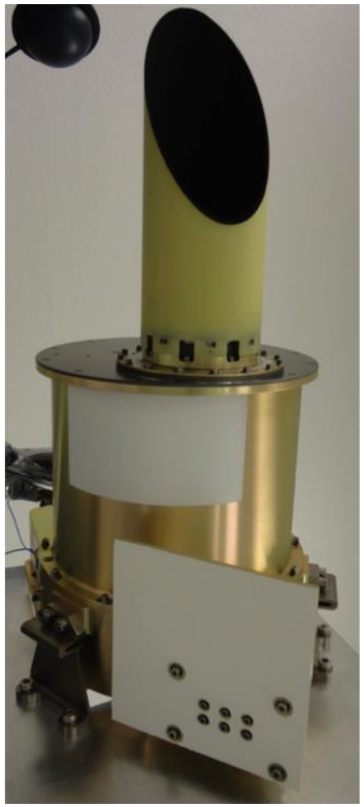
- Increase fidelity of simulator
  - Simulated images are limited by resolution of DSK
    - Investigate creation of a higher resolution DEM
  - There is no albedo variation in the simulation, leading to flat photometrically corrected mosaics
    - Explore options for adding large scale albedo variations to simulation

THANKS!

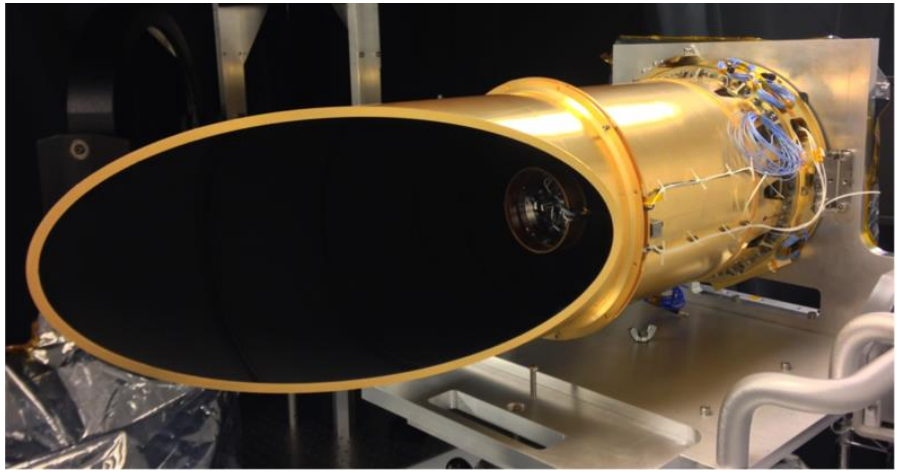
Backup slides

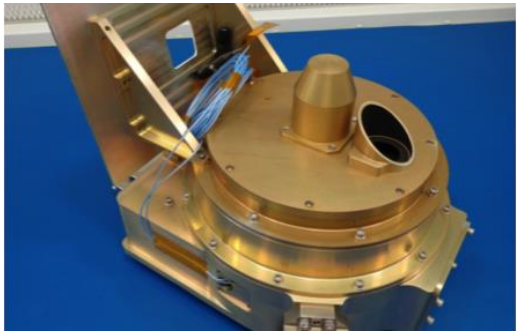
OSIRIS-REx Camera Suite (OCAMS)

MapCam



PolyCam





SamCam

HEADING