



# APPROACH

## SCIENCE PHASE PLAN • AUGUST–DECEMBER 2018

The primary goals of Approach Phase are to optically acquire Bennu from approximately 2 million km away, to collect imagery to begin deriving the first shape model (75 cm), the coordinate system and Bennu's spin state, and to search the space immediately surrounding Bennu for dust/gas plumes and natural satellites.

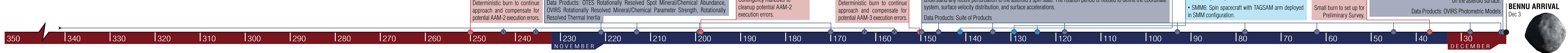
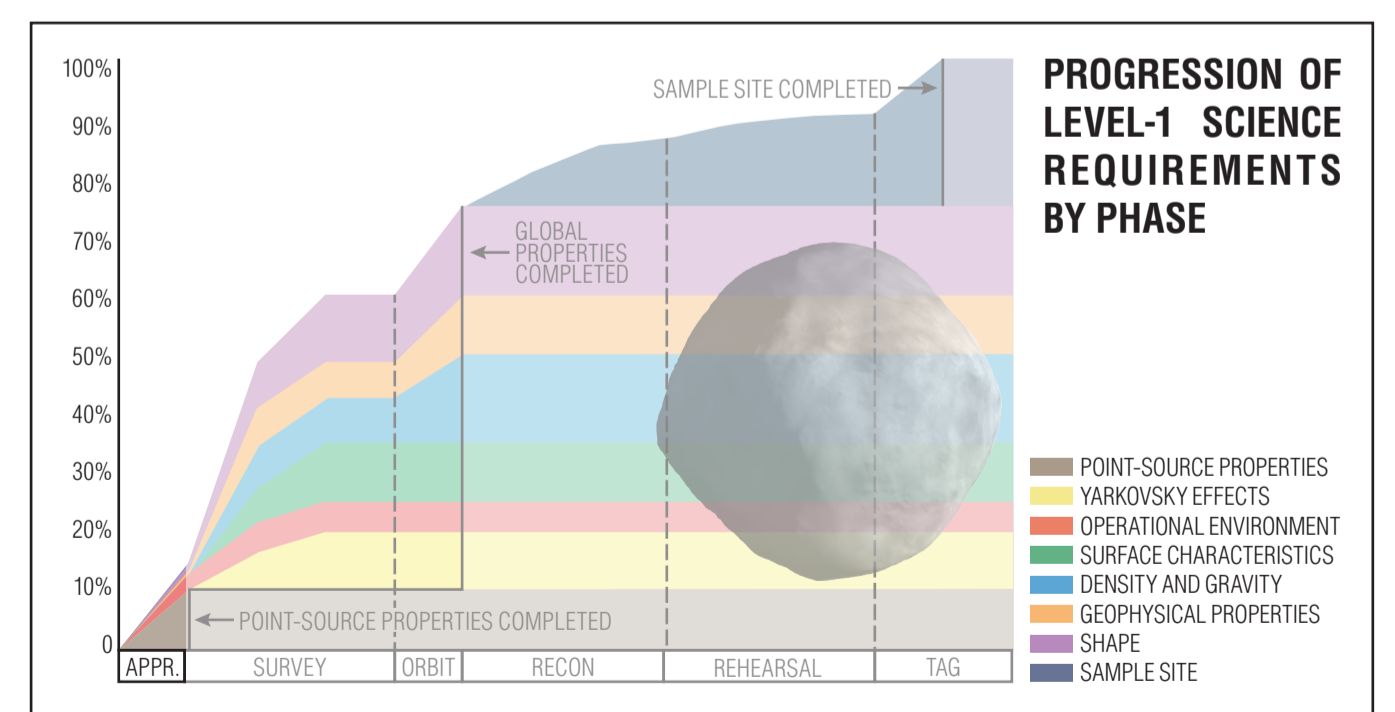
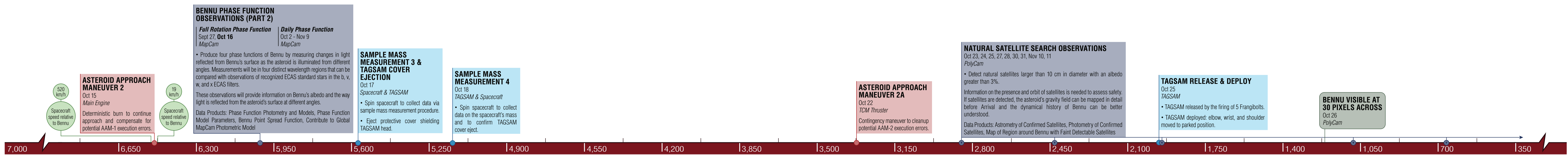
### APPROACH PHASE BEGINS

Aug 17

**FIRST IMAGE OF BENNU**  
Aug 17  
PolyCam



SPACECRAFT RANGE (KM)  
Dates subject to change



**BENNU PHASE FUNCTION OBSERVATIONS (PART 1)**

**Full Rotation Phase Function**  
Sept 27, Oct 16  
MapCam

**Daily Phase Function**  
Oct 2 - Nov 9  
MapCam

- Produce four phase functions of Bennu by measuring changes in light reflected from Bennu's surface as the asteroid is illuminated from different angles. Measurements will be in four distinct wavelength regions that can be compared with observations of recognized ECAS standard stars in the b, v, w, and x ECAS filters.

These observations will provide information on Bennu's albedo and the way light is reflected from the asteroid's surface at different angles.

Data Products: Phase Function Photometry and Models, Phase Function Model Parameters, Bennu Point Spread Function, Contribute to Global MapCam Photometric Model

**DUST PLUME SEARCH OBSERVATIONS**

Sept 11, 12  
PolyCam & MapCam

- Search for dust and gas plumes originating from the asteroid surface, and characterize their source regions and column densities.

Information on the presence and location of dust and gas plumes is needed to assess safety, understand the geologic and dynamic history of the asteroid, and inform sample-site selection.

Data Product: Dust Plume Image

**BENNU LIGHT CURVE OBSERVATIONS**

Oct 11, 12  
MapCam

- Produce four light curves of Bennu by measuring changes in the asteroid's brightness during two rotation periods. Measurements will be in four distinct wavelength regions that can be compared with observations of recognized ECAS standard stars in the b, v, w, and x ECAS filters.

These observations will increase understanding of Bennu's rotation state and variations in its longitudinal albedo – and will allow comparison to known asteroid taxonomies.

Data Products: Bennu Photometry, Temporal and Phased Light Curve Parameters, Light Curve Parameters

**ASTEROID APPROACH MANEUVER 1**

Oct 1  
Main Engine

Deterministic burn to slow the spacecraft and begin final Bennu approach.

Spacecraft speed relative to Bennu: 1,800 km/h

**BENNU PHASE FUNCTION OBSERVATIONS (PART 2)**

**Full Rotation Phase Function**  
Sept 27, Oct 16  
MapCam

**Daily Phase Function**  
Oct 2 - Nov 9  
MapCam

- Produce four phase functions of Bennu by measuring changes in light reflected from Bennu's surface as the asteroid is illuminated from different angles. Measurements will be in four distinct wavelength regions that can be compared with observations of recognized ECAS standard stars in the b, v, w, and x ECAS filters.

These observations will provide information on Bennu's albedo and the way light is reflected from the asteroid's surface at different angles.

Data Products: Phase Function Photometry and Models, Phase Function Model Parameters, Bennu Point Spread Function, Contribute to Global MapCam Photometric Model

**SAMPLE MASS MEASUREMENT 3 & TAGSAM COVER EJECTION**

Oct 17  
Spacecraft & TAGSAM

- Spin spacecraft to collect data via sample mass measurement procedure.
- Eject protective cover shielding TAGSAM head.

Spacecraft speed relative to Bennu: 19 km/h

**SAMPLE MASS MEASUREMENT 4**

Oct 18  
TAGSAM & Spacecraft

- Spin spacecraft to collect data on the spacecraft's mass and to confirm TAGSAM cover eject.

**ASTEROID APPROACH MANEUVER 2A**

Oct 22  
TCM Thruster

Contingency maneuver to cleanup potential AAM-2 execution errors.

**NATURAL SATELLITE SEARCH OBSERVATIONS**

Oct 23, 24, 25, 27, 28, 30, 31, Nov 10, 11  
PolyCam

- Detect natural satellites larger than 10 cm in diameter with an albedo greater than 3%.

Information on the presence and orbit of satellites is needed to assess safety. If satellites are detected, the asteroid's gravity field can be mapped in detail before Arrival and the dynamical history of Bennu can be better understood.

Data Products: Astrometry of Confirmed Satellites, Photometry of Confirmed Satellites, Map of Region around Bennu with Faint Detectable Satellites

**TAGSAM RELEASE & DEPLOY**

Oct 25  
TAGSAM

- TAGSAM released by the firing of 5 Frangibolts.
- TAGSAM deployed: elbow, wrist, and shoulder moved to parked position.

**BENNU VISIBLE AT 30 PIXELS ACROSS**

Oct 26  
PolyCam

**FULL-DISK INTEGRATED SPECTROSCOPY OBSERVATIONS**

Nov 2, 3, 5, 9  
OVIRS & OTES (PolyCam Ride-Along)

- Measure the integrated spectral properties of Bennu over one rotation period to detect spectral features with > 5% absorption depth.
- For one Bennu rotation period, measure fluxuations in thermally-emitted radiation to derive the thermal inertia of Bennu.
- PolyCam imaging for context.

These observations on spectral variation over time provide information on longitudinal surface variations and allow for direct comparison with telescope data. Bulk thermal inertia data inform the Yarkovsky model and provide a reference point for measurements from specific locations.

Data Products: OTES Rotationally Resolved Spot Mineral/Chemical Abundance, OVIRS Rotationally Resolved Mineral/Chemical Parameter Strength, Rotationally Resolved Thermal Inertia

**ASTEROID APPROACH MANEUVER 3**

Oct 29  
TCM Thrusters

Deterministic burn to continue approach and compensate for potential AAM-2 execution errors.

**ASTEROID APPROACH MANEUVER 3A**

Nov 5  
ACS Thrusters

Contingency maneuver to cleanup potential AAM-2 execution errors.

**ASTEROID APPROACH MANEUVER 4**

Nov 12  
ACS Thrusters

Deterministic burn to continue approach and compensate for potential AAM-3 execution errors.

**POLYCAM SHAPE MODEL OBSERVATIONS**

Nov 12, 13, 16, 19, 23, 25, 27, 29, Dec 1, 2  
PolyCam

- Produce a 75cm center-of-figure shape model with greater than 1 million vector resolution
- Designate a prime meridian and define the coordinate system
- Determine the rotation pole and its wobble to within 1°
- Measure the rotation period to within 10 seconds
- For more than 80% of the asteroid surface, produce a set of digital terrain models that informs the 75cm shape model.

The center of figure is needed to define the coordinate system and to determine variations in density. The prime meridian and the rotation pole location are also needed to define the coordinate system, which is used to co-register all data products. Pole orientation is critical to determine surface acceleration distribution. Pole wobble is needed to understand any recent perturbation to the asteroid's spin state. The rotation period is needed to define the coordinate system, surface velocity distribution, and surface accelerations.

Data Products: Suite of Products

**TAGSAM ARM DEPLOYMENT & IMAGING**

Nov 14  
TAGSAM, SamCam, NavCams

- TAGSAM articulated through its full range of motion. SamCam and NavCams execute both pre- and post-TAG imaging campaigns. Sequence ends with TAGSAM in parked position.

**SAMPLE MASS MEASUREMENT 5 & 6**

Nov 17, 18  
TAGSAM & Spacecraft

- SMM5: Spin spacecraft with TAGSAM arm deployed in sampling configuration.
- SMM6: Spin spacecraft with TAGSAM arm deployed in SMM configuration.

**MANEUVER 0 PRELIMINARY SURVEY**

Nov 30  
ACS & LTR Thrusters

Small burn to set up for Preliminary Survey.

**OVIRS PHASE FUNCTION OBSERVATIONS**

Dec 2  
OVIRS & OTES

- For at least 80% of the asteroid surface, map differences in spectral properties in regions where the albedo is at least 1%. These spectra will help assess the effects of space weathering on the asteroid surface.

Data Products: OVIRS Photometric Models

**BENNU ARRIVAL**

Dec 3