APPROACH SCIENCE PHASE PLAN

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

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 PHASE FUNCTION OBSERVATIONS (PART 1)

Full Rotation Phase Function	***Daily Phase Function***
Sept 27, Oct 16	Oct 2 - Nov 9
MapCam	*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

1,800 km/h
Spacecraft speed relative to Bennu

ASTEROID APPROACH MANEUVER 1
Oct 1
Main Engine

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

520 km/h
Spacecraft speed relative to Bennu

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

1.9 mil | 1.8 mil | 1.7 mil | 1.6 mil | 1.5 mil | 1.4 mil | 1.3 mil | 1.2 mil | 1.1 mil | 1 mil | 900k | 800k | 700k | 600k | 500k | 400k | 300k | 200k | 100k | 7k

AUGUST | SEPTEMBER | OCTOBER

SPACECRAFT RANGE (KM)

520 km/h
Spacecraft speed relative to Bennu

ASTEROID APPROACH MANEUVER 2
Oct 15
Main Engine

Deterministic burn to continue approach and compensate for potential AAM-1 execution errors.

19 km/h
Spacecraft speed relative to Bennu

BENNU PHASE FUNCTION OBSERVATIONS (PART 2)

Full Rotation Phase Function	***Daily Phase Function***
Sept 27, **Oct 16**	Oct 2 - Nov 9
MapCam	*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

TAGSAM COVER EJECTION & SAMPLE MASS MEASUREMENT 3
Oct 17
TAGSAM & Spacecraft

• Eject the protective cover that shields the TAGSAM head.

• Spin the spacecraft to test sample mass measurement procedure.

SAMPLE MASS MEASUREMENT 4
Oct 18
TAGSAM & Spacecraft

• Spin the spacecraft to test sample mass measurement procedure.

ASTEROID APPROACH MANEUVER 2A
Oct 22
TCM Thruster

Contingency maneuver to cleanup potential AAM-2 execution errors.

NATURAL SATELLITE SEARCH OBSERVATIONS
Oct 24, 25, 27, 28
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.

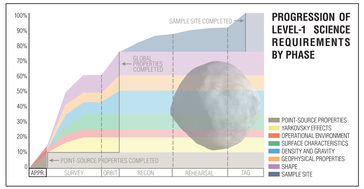
Data Products: Astrometry of Confirmed Satellites, Photometry of Confirmed Satellites, Map of Region around Bennu with Faint Detectable Satellites

TAGSAM ARM DEPLOYMENT
Oct 26
TAGSAM

• Deploy the TAGSAM arm to test mechanism.

BENNU VISIBLE AT 30 PIXELS ACROSS
Oct 28
PolyCam

7,000 | 6,650 | 6,300 | 5,950 | 5,600 | 5,250 | 4,900 | 4,550 | 4,200 | 3,850 | 3,500 | 3,150 | 2,800 | 2,450 | 2,100 | 1,750 | 1,400 | 1,050 | 700 | 350



PROGRESSION OF LEVEL-1 SCIENCE REQUIREMENTS BY PHASE

ASTEROID APPROACH MANEUVER 3
Oct 29
TCM Thrusters

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

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 3A
Nov 5
ACS Thrusters

Contingency maneuver to cleanup potential AAM-2 execution errors.

SAMPLE MASS MEASUREMENT 5 & 6
Nov 7, 8
TAGSAM & Spacecraft

• Spin the spacecraft with the TAGSAM arm deployed to test sample mass measurement procedure.

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

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

350 | 340 | 330 | 320 | 310 | 300 | 290 | 280 | 270 | 260 | 250 | 240 | 230 | 220 | 210 | 200 | 190 | 180 | 170 | 160 | 150 | 140 | 130 | 120 | 110 | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30

NOVEMBER | DECEMBER

DERIVED FROM APPROACH SPPv9c