

Olivier Barnouin JHUAPL, Mike Nolan UA

The Bennu coordinate system is newly defined. No prior study has explicitly defined a coordinate system for the asteroid. After completing a reconnaissance of the Bennu from November 1, 2018 to January, 17 2019, the OSIRIS-REx team has now identified a surface feature that can be used to define the prime-meridian (Figure 1). The surface feature was chosen to be near what researchers had used as a prime meridian during preparations for the OSIRIS-REx mission (e.g. Nolan et al., 2013; Lauretta et al., 2017), to within the resolution of those models. The choice of the prime meridian was somewhat difficult, as there were limited distinctive features near the “planning” prime meridian. The presented pole orientation is sufficiently stable for the purposes of surface product development. We do anticipate updates to the pole, as we proceed further, and obtain enhanced gravity measurements, surface topography and imaging. The surface feature used to define the location of the prime-meridian, however, will remain unchanged. The location of the prime meridian and pole were obtained from imaging collected by OSIRIS-REx CAMera System (OCAMS) which include a narrow (POLYCAM) and wide (MAPCAM) angle imager, and the development of shape model using the stereophotoclinometry (Gaskell et al, 2008). The shape model accuracy was verified with data collected by the OSIRIS-REx laser altimeter (Barnouin et al., 2019).

Prime Meridian Feature Description

The prime meridian feature is located on the surface of a distinctive boulder located at (Figure 1.) This boulder is the third largest on the asteroid and is easy to identify in images of Bennu. The boulder looks like a tent, with a near triangular face on the side of the boulder facing the equator. At the top of a longish crack that extends from the base of the rock, near an indentation, there sits a plateau-like structure with a little central mound, delineated by two nearly parallel structures. This feature is currently located at latitude -26.38° but is subject to change pending possible updates to Bennu’s pole orientation. The exact location in this plateau of this mound is pixel-line location (815, 209) in the OCAMS PolyCam image collected on March 21, 2019 at UTC 21:01:31 (Figure 1d and e). The mound is also visible in PolyCam image collected on March 7, 2019 at UTC 18:33:15 (Figure 1g) at pixel-line location (378, 906). Note that the image coordinates start in the lower left-hand corner of each image.

Pole Description

Using the International Celestial Reference Frame (ICRF; Archinal et al., 2011) Bennu’s pole is modeled with $\{\alpha, \delta, W + W_1\Delta t + W_2\Delta t^2\}$, where α represents the spin pole right ascension, δ represents the spin pole declination, W_0 represents the prime meridian angle, W_1 represents the rotation rate, and Δt represents the time elapsed since J2000 = JD 2451545.0, i.e. 2000 January 1 12 hours TDB. In the case of Bennu, an acceleration of the rotation rate by Yarkovsky–O’Keefe–Radzievskii–Paddack (YORP) effect, has been measured (Nolan et al., 2019, Hergenrother et al., 2019) and is included in the presented results for the rotation rate as W_2 . The pole parameters were estimated while solving for the topography within the stereophotoclinometry (SPC) processing pipeline. The initial set of pole parameters and body axes derived from the OSIRIS-REx data are given in Table 1. We present the feature defining the prime meridian in Figure 1. Table 1 also reports the equivalent spherical body radius, R , of Bennu, and its best fit ellipsoid, with semi-major a , b and c along its x , y , z axes, respectively. The OSIRIS-REx project’s configuration-controlled Planetary Constants and Models Document archives the updates to the PCK.

Table 1. Bennu preliminary coordinate systems derived from data collected between Nov 1, 2018 and Jan 17, 2019.									
	α [deg]	δ [deg]	W_0 [deg]	W_1 [deg/day]	W_2 [deg/day ²]	R [km]	a [km]	b [km]	c [km]
Initial coordinate system	85.46 ± 0.11	-60.36 ± 0.15	135.8156 ± 1.6	2011.14645095 ± 0.001	1.815e-06 $\pm 2.6e-7$	0.2449 ± 0.00012	0.2524	0.2463	0.2294

References:

Archinal, B. A., M. F. A'Hearn, E. Bowell, A. Conrad, G. J. Consolmagno, R. Courtin, T. Fukushima, D. Hestroffer, J. L. Hilton and G. A. Krasinsky, G. Neumann, J. Oberst, P. K. Seidelmann, P. Stooke, D. J. Tholen, P. C. Thomas, I. P. Williams, 2011. Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements, 2009. *Celes. Mech. & Dyn. Astron.* **109**, 101-135.

Barnouin, O.S. et al., 2019. Shape of (101955) Bennu indicative of a rubble pile with internal stiffness. *Nature Geoscience*, **12**(4), pp.247–252.

Gaskell, R. W., et al., Characterizing and navigating small bodies with imaging data. *Meteorit. Planet. Sci.* **43**, 1049–1061 (2008).

Hergenrother, C.W. et al., 2019. The operational environment and rotational acceleration of asteroid (101955) Bennu from OSIRIS-REx observations. *Nature Communications*, **10**(1), p.1291

Nolan, M. et al., Shape model and surface properties of the OSIRIS-REx target asteroid (101955) Bennu from radar and lightcurve observations. *Icarus* **226**, 629–640 (2013).

Nolan, M.C., et al. Detection of Rotational Acceleration of Bennu using HST Lightcurve Observations. *Geophysical Research Letters*. Accepted. DOI:10.1029/2018GL080658, (2019).

Figure:

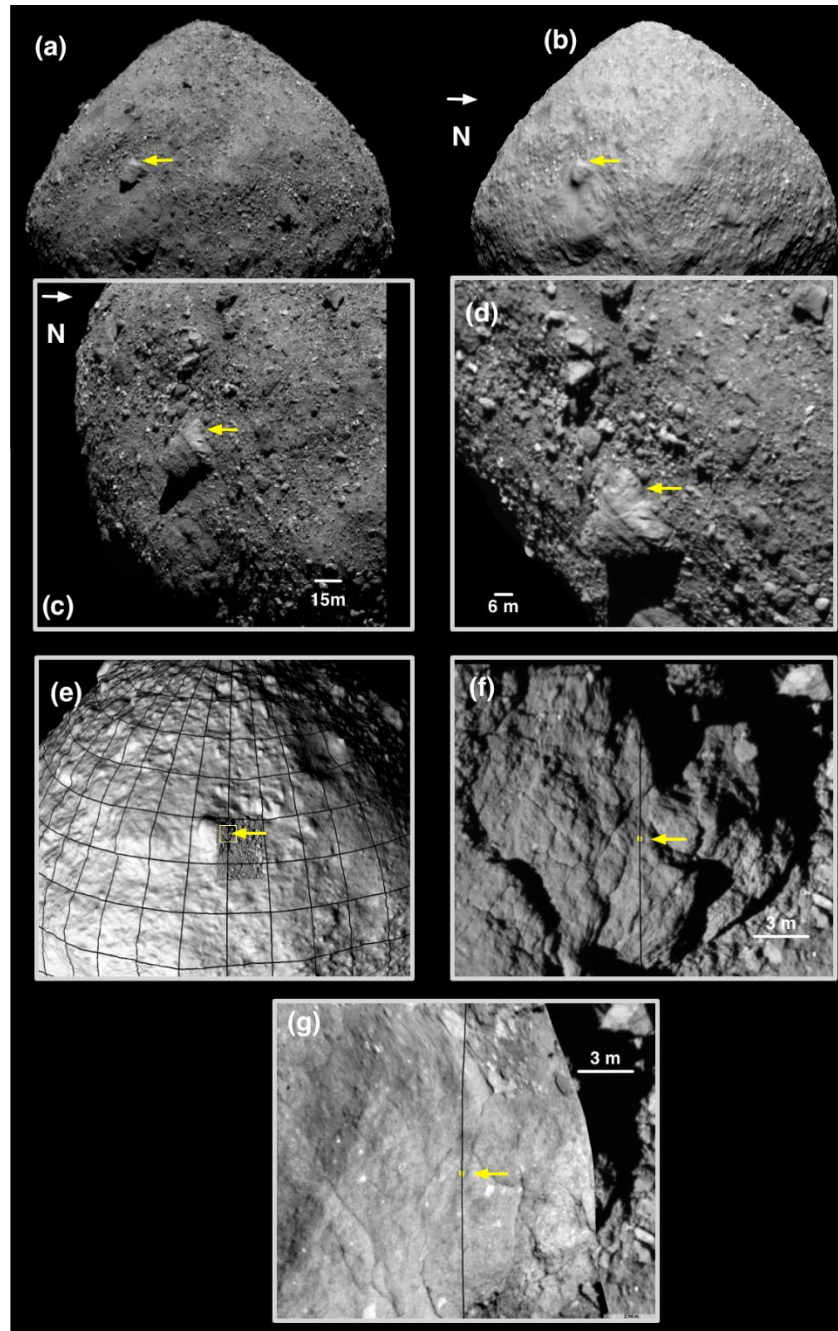


Figure 1: The definition of the prime meridian for Bennu: The yellow arrows in the OCAMS images (**a**, collected on 13 December 2018 at 03:39:07 UTC; **c** and **d**, 02 December 2018 at 06:07:44 UTC) and (**b**) the Bennu GDTM (in same orientation and illumination as OCAM's image collected on 13 December 2018 at 03:39:07 UTC) indicate the location of the prime meridian rock that includes the position of the prime median identified by the OSIRIS-REx science team. The exact location of the prime meridian is a small mound, located between two cracks that delineate a small plateau (**e** and **f**, March 21, 2019 at UTC 21:01:31 2018) on the prime-meridian rock. This feature is also visible in (**g**) OCAMS image collected on March 7, 2019 at UTC 18:33:15.