COMPARING THE RADAR SHAPE MODEL OF (101955) BENNU WITH GROUND TRUTH FROM OSIRIS-REX. M. C. Nolan[1], M.M. Al Asad[2], O. S. Barnouin[3], L.A.M Benner[4], M. G. Daly[5], C. Drouet d'Aubigny[1], R. W. Gaskell[6], J.D. Giorgini[4], C. W. Hergenrother[1], E. S. Howell[1], C. Magri[7], J.L. Margot[8] E. Palmer[5], M. Pajola[9], M. E. Perry[3], B. Rizk[1], J. R. Weirich[5], D. S. Lauretta[1], and the OSIRIS-REx Team, [1]Lunar and Planetary Laboratory, University of Arizona (Tucson, Arizona 85721, USA, nolan@lpl.arizona.edu), [2]University of British Columbia (Vancouver, Canada), [3]The Johns Hopkins University Applied Physics Laboratory (Laurel, MD, USA), [4]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Dr., Pasadena, CA, 91109 USA), [5]York University (4700 Keele Street, Toronto, Ont., Canada, M3J 1P3), [6]Planetary Science Institute (1700 East Fort Lowell, Suite 106, Tucson, AZ, 86719 USA), [7]University of Maine at Farmington (173 High St, Preble Hall, Farmington, ME 04938, USA), [8]University of California, Los Angeles (595 Charles E. Young Drive East, Los Angeles, CA 90095 USA), [9]INAF-Astronomical Observatory of Padova (Vic. Osservatorio 5, 35122 Padova, Italy).

Introduction: Nolan et al. [1] presented a shape model and rotation state of (101955) Bennu using radar and lightcurve observations in 1999 and 2005. The rotation state was updated based on additional HST lightcurves obtained in 2012 [2]. We will compare that model with the "ground truth" imaging and shape model from the OSIRIS-REx mission. Bennu is only the fourth radar-imaged asteroid to be visited by a spacecraft.

Radar Shape Model: The shape model from [1] (hereafter, "radar shape model") consists of 2692 triangular facets, with a median edge length of 27 m. The radar imaging had 7.5-m (2005) and 15-m (1999) resolution, but to increase SNR the images were binned at 6-degree (~25 m at the equator) rotational resolution. The uncertainty of the overall dimensions of the radar shape model was 10 m in X and Y, but 52 m in Z, because of ambiguities in the radar observations. The radial uncertainty was not reported, but it was likely comparable to the uncertainty in X and Y of 10 m. They saw one "boulder" that they estimated to be 10-20 m in size based on its appearance in the radar images. The shape model reflects this feature because the model resolution was increased to ~5-m edge length in the region of the boulder.

The shape modeling process adjusts the shape of the model to match the data in a chi-squared sense, but also includes a number of "penalties" to enforce "reasonable" shapes. Because the radar data are typically quite noisy, these penalties are required for stability, but it is difficult to a priori decide what is "reasonable". These penalties tend to smooth the model. [3]

Comparison with OSIRIS-REx results: We compare the radar shape model to the OSIRIS-REx images and a stereophotoclinometry (SPC) shape model produced from those images. [4]

The initial images of Bennu in October 2018 looked quite similar to the rendering from the radar shape model (Fig. 1). The dimensions are well within 1-sigma. The asteroid appears to be slightly more flattened than the model. The obliquity of the rotation pole is approximately 1-sigma from the prediction, but the actual pole position is approximately 5 (1.5 sigma) degrees away.

The boulder feature in the radar shape model is the largest boulder visible, near latitude −45 and longitude 145, which is ~20 m in height and ~50 m across [5]. It has a flat eastward-facing face, which likely is why it was dramatically visible in the radar imaging. Even this boulder was not clearly visible from other viewing directions in the radar imaging. Another boulder at latitude −30 and longitude 0 is slightly shorter, and appears in the shape model as topography but not as a separate object. No smaller boulders were clearly distinguishable from noise in the radar imaging. Miller et al. [6] estimated that 20-m boulders should be visible, but smaller ones might not be. This estimate is apparently still optimistic.

Acknowledgements: This material is based upon work supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program.

References: [1] Nolan, M. C. et al. (2013) *Icarus, 226,* 629–640. [2] Nolan M. C. et al. (2018) *GRL,* submitted. [3] Magri, C. et al. (2007) *Icarus 186*, 152–177. [4] Barnouin, O. S. et al. (2019) 50th LPSC. [5] Jawin, E. R. et al. (2019) 50th LPSC. [6] Miller, K. J. et al. (2014) *DPS meeting*, 46, 213.13.

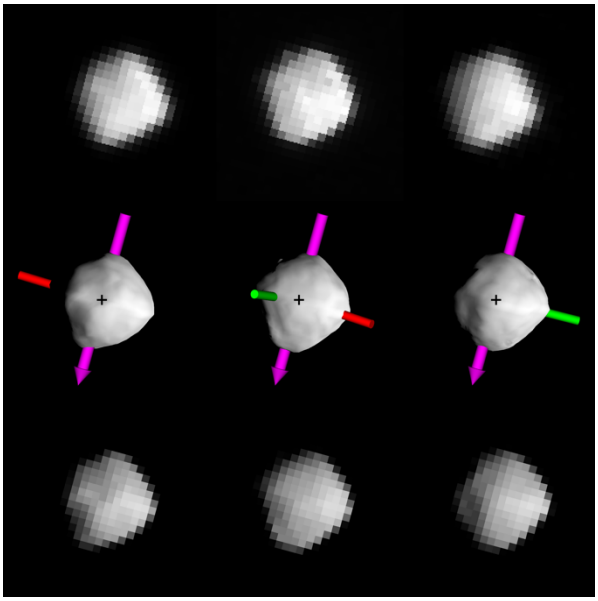

Figure 1. The top row contains three images of Bennu obtained by the PolyCam camera on October 23, 2018, each taken about two hours apart. The images were taken from a distance of 3,000 km from the asteroid and represent Bennu at 13 pixels in the camera's field of view. The middle row shows renderings of Bennu as predicted by [1]. The shape model representations are rendered as if they were observed by the spacecraft at the same time, distance, and lighting conditions as the images. The bottom row pixelates the shape model renderings to be similar to the observed images to make comparison easier. The images show overall agreement between the observations and the radar model predictions, including some of the large-scale features on the asteroid.