A Working Coordinate System for Bennu (Discussion CLOSED)

A Bennu coordinate system

Michael C. Nolan and Daniel J. Scheeres

(Editors note: This proposal suggests that a submission be made to the IAU Working Group on Cartographic Coordinates and Rotational Elements. Further discussions with the Brent Archinal [the WG lead], the authors, and the PI office have led to a conclusion not to propose at this time. Please limit your suggestions to the technical merits of the proposed coordinate system to be used through development, launch, and cruise phases.)

This report will a) propose a body-fixed coordinate system for Bennu and b) propose that this system be submitted as the formal coordinate system for Bennu.

The IAU Working Group on Cartographic Coordinates and Rotational Elements issues recommendations for minor planet coordinate systems are contained in Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements. The recommendations here are based on their most recent published report (Archinal et al., 2011). Their recommendations are to choose a surface feature as the longitude reference. They state that this is "potentially arbitrary, but there is precedent (e.g. with (433) Eros) for choosing it so it aligns with the longest axis (or minimum moment of inertia, if this can be estimated)."

Based on radar and optical lightcurve measurements from 1999 and 2005, Bennu is a roughly spherical asteroid. It rotates in approximately 4.3 hours, with no evidence for non-principal-axis rotation. We therefore believe that any non-principal axis rotation will be in a "short-axis mode", where the spin vector makes modest excursions from the direction of minimum moment of inertia, and can thus be ignored in a body-fixed system. We propose a coordinate system with the origin at the center of mass and the +Z axis of the coordinate system defined as the axis of the minimum moment of inertia, aligned with the time averaged spin axis in the body-fixed frame, and chosen in a right-handed sense. This is consistent with the published shape model (to within the resolution of the model). Because the rotation is retrograde with respect to the plane of the Solar System, this axis is formally referred to as "positive" rather than "North" by the IAU, so latitudes are signed rather than referred to as North or South. The shape is nearly axisymmetric, with a ratio of moments of inertia of about 4%, so that the uncertainty in the direction of maximum moment of inertia is large: It includes the entire azimuth circle at the 3-sigma level. Thus there is no clear choice for a prime meridian based on the moments of inertia of the asteroid. These moments of inertia will eventually be known, but not until the gravity maps are complete, long after we will need a coordinate system that we will then not want to change.

We therefore provisionally choose as a prime meridian the highest point (above the local mean surface) of the "boulder" feature located at 125 degrees longitude and -45 degrees latitude. This point is clearly visible in the "October 2012" shape model delivered to the project. This feature appears to be unique in the radar imaging, and should be easily identifiable in optical images.

Because of the ambiguity inherent to radar imaging, it is possible (5-10% probability) that the hemisphere has been misidentified, but the longitude is unaffected by that uncertainty. The +X axis is then perpendicular to the Z axis in the direction of the prime meridian, and the +Y axis perpendicular to the other two such that $Z \propto X \times Y$. If this proposal is accepted, we will distribute a new version of the "October 2012" shape model, rotated so that the axes are aligned with this prime meridian.

Because of disagreements between the IAU and the Dawn team, there has been much discussion about the decision to choose a formal coordinate system for Bennu at this time. The longitudes chosen by the Dawn team and the earlier authors differ by 155 degrees. Having two such different systems has led to chaos. There are two arguments (of which I am aware) put forth for choosing the "newer" system: 1) the feature chosen was not well determined, and 2) the quadrangles come out better (Li, 2012). 1) is clearly a solved issue: A reference feature can be chosen to be at any longitude, as demonstrated by the IAU-accepted reference feature on Mercury being at 20 degrees longitude and by the IAU-approved coordinate system used for Vesta PDS submissions that places the reference feature at 146 degrees longitude. 2) could be relevant, but again, we will need to choose a coordinate system long before we will be doing quadrangle-style maps. It would be numerically convenient for quadrangles to start at 0 longitude, but does not appear to be a requirement.

We plan to publish further papers on the structure of Bennu before encounter and will need to describe the location of features on the surface. In addition, the IAU gives weight to the first published coordinate system, so if we do not choose now, another group is free to make the final decision. At encounter, we will need to choose a reference feature that is clear in both optical/IR and lidar data. We expect that the boulder will be a good choice in that all of these systems will be able to identify it, but it is probably too large of a feature to make a good final reference. We will not be able to choose a good final reference until well into the encounter, long after we will need to be using a coordinate system. Two simple ways to resolve this issue are either to make a small correction to the zero longitude or to set the reference feature to a non-zero longitude (like Mercury).

Since we will need to choose a system before we have final information, and because there will be no new relevant data before encounter, and because any other group is free to define the system based on the existing published shape mode, there is nothing to be gained by delaying. We therefore recommend that the boulder be formally proposed as the prime meridian of Bennu as soon as practicable.

We propose that this feature be given the name "Benben", after the stone upon which the Bennu bird sits.

Archinal, B. A. et al. (2011). Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements: 2009. Celest. Mech. Dyn. Astr. 109:101-135. DOI 10.1007/s10569-010-9320-4

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