

**UPDATE ON THE IAU WORKING GROUP ON CARTOGRAPHIC COORDINATES AND ROTATIONAL ELEMENTS AND ITS UPCOMING 2015 REPORT.** Brent Archinal<sup>1</sup> and the IAU Working Group on Cartographic Coordinates and Rotational Elements. <sup>1</sup>U. S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001, USA [barchinal@usgs.gov](mailto:barchinal@usgs.gov).

**Overview:** Approximately every 3 years since 1979, the Working Group on Cartographic Coordinates and Rotational Elements (hereafter the “WG”) of the International Astronomical Union (IAU) has issued a report recommending coordinate systems and related parameters (body orientation and shape) that can be used for making cartographic products (maps) of solar system bodies. These recommendations, which are open to further modification when indicated by community consensus, are intended to facilitate the use and comparison of multiple datasets by promoting the use of a standardized set of mapping parameters. This abstract is intended to draw attention to the WG’s efforts, our previous reports (e.g. [1]), [and the 2015 report now nearing completion. In this abstract we are providing updated material to our previous 2013 abstract, \[2\] with new items highlighted in dark blue font.](#) The WG encourages input and is available to assist users, instrument teams, and missions. See our website [3] for additional information.

**Operation of WG:** The Working Group consists of 19 volunteers, including C. Acton, M. A’Hearn, B. Archinal (Chair), A. Conrad ([Acting Vice Chair](#)), G. Consolmagno, T. Duxbury, D. Hestroffer, J. Hilton, L. Jorda, R. Kirk, S. Klioner, D. McCarthy, K. Meech, J. Oberst, J. Ping, K. Seidelmann, D. Tholen, P. Thomas, and I. Williams. This includes members from 6 countries, including China, France, Germany, UK, USA, and Vatican City State. Following nomination, volunteers are elected at the IAU General Assembly (GA) to serve for a three year term, which may be renewed. The WG looks at new determinations of coordinate systems (e.g., body sizes and orientations) that preferably have been published in refereed papers, and makes recommendations as to which to use, based where possible on consensus decisions. As a volunteer organization, the WG has no resources to verify results or conduct its own research so it relies only on published results and community input. For that reason it is sometimes not possible to recommend one set of results over another. The WG cannot verify or “bless” any particular results. The WG has no “enforcement” powers, but tries, in reflecting the long term planetary community consensus, to make persuasive recommendations. The WG does not deal with issues related to the formats of mapping products. Such issues have largely been left to individual map developers, archiving organizations such as the NASA Planetary Data System (PDS), the IPDA (International Planetary Data Alliance), or the NASA Mars Geodesy and Cartography and Lunar Geodesy and Cartography Working Groups (MGCWG[4], LGCWG[5]) and individual missions (e.g., the Cassini Icy Satellites Cartography

Working Group). Input from such organizations has been welcomed by the WG and the frequency of interaction highlights the strong need for such organizations at mission, space agency, and international levels. [We also look forward to working with and receiving input from two new related organizations, IAU Commission A3 on Fundamental Standards \[6\], and the NASA Mapping And Planetary Spatial Infrastructure Team \(MAPSIT\) \[7\].](#)

In discussions at the IAU GA in August 2012 there was agreement [8] to remind authors, journal editors, instrument teams, missions, and space agencies that a substantial body of IAU recommendations exist that have been developed over many decades of input by IAU members, national space agencies, and other institutions. Care should be taken to follow such recommendations or to present well-reasoned arguments why they should be changed. The IAU and its Working Groups stand ready to help authors, journal editors, and missions understand and follow IAU recommendations.

**Defining Longitude:** One recent issue is the question of how the definition of longitude should be updated on Solar System bodies. The WG addressed this issue in its first report [9] and reiterates in the recent report [1] that once an observable reference feature at a defined longitude is chosen, the longitude definition origin should not change except under unusual circumstances (such as perhaps a change in or loss of the feature). Given that our definition of longitude is primarily tied to data related to the surface of the body (e.g., direct imaging or altimetry) than to dynamical data (e.g., the principal axes of inertia for resonantly or synchronously rotating bodies such as Mercury [10], the Moon, or Jovian or Saturnian satellites). Once such a feature has been adopted, changing to a longitude system defined by some other method should be avoided. Note that this recommendation does not preclude the use of smaller or more precisely determined features, multiple features, or even human artifacts to define longitude, as long as the original definition is maintained to the level of precision at which the feature can be located in new data. Some shift in longitude of previously identified features may occur whenever new data are available and processed, but this is minimized at least in the vicinity of the defining feature.

**Coordinate System for (4) Vesta:** In 2011 August, the NASA/DLR/ASI Dawn mission proposed using a longitude system with a large (~155°) rotation from the previous [11] system. Many reasons were expressed for this new system, but the WG replied in

both 2011 September and 2012 March, after careful and extensive consideration, that the arguments were not compelling enough to ignore previous usage by the planetary community and the WG's previous recommendations. Unfortunately, the mission began publishing results using only their rotated system [e.g., 12]. This resulted in substantial confusion. Fortunately, the NASA Planetary Data System requires that data products archived to it follow various international and NASA standards, including those of the IAU. The mission therefore proposed a new system, which the PDS did accept as agreeing with IAU recommendations. This system is as described in the archive [13] (with  $W_0=285.39^\circ$ ). The WG ultimately formally accepted this system and recommended it for general use [14].

**General Changes:** Following extensive discussion, the WG has developed a list of changes and updates for the next report. Some details of these changes are still under final consideration as we continue work on our report, but this and the following section provide an overview. *First*, based on the experience with Vesta, the WG will reword and clarify its recommendations regarding updating longitude. *Second*, mission and community input indicates a need for the WG to differentiate between planetary body shapes and sizes for image projection and scientific modeling vs. a reference surface for elevation and map scale. In particular, long-accepted values for the latter will be documented for the Moon, Mars, and Titan. *Third*, after considerable input from the community, including from New Horizons mission personnel, the discussion of terminology for the poles (hemispheres) of small bodies will be modified, e.g. to indicate that following community practice, cardinal directions can still be used informally or as shorthand for directions on small bodies (which formally have only positive and negative directions). *Fourth*, updates to the orientation models of Jupiter and Saturn will not be recommended at this time, as we await community consensus on a model for Jupiter and further results from the Cassini mission regarding the orientation of Saturn.

**Changes for Specific Bodies Under Discussion:** Formulas for the Earth's orientation (which were previously given for comparison purposes only) will be removed in order to avoid confusion over their accuracy. For the Moon's orientation, a new JPL lunar ephemeris is expected in the near term (W. Folkner, personal comm.). However for now, the report will continue to recommend the use of the DE421 lunar ephemeris rotated to an ME frame. Coordination is expected so that the next JPL ephemeris and lunar ephemerides from other sources (e.g. INPOP [15] will match each other and the DE421 ME frame within some stated (few meter) level of uncertainty. The MGCWG has recommended for use a new orientation model for Mars [16], which the WG in turn will recommend for use. Neptune's rotation model will be updated based on new results from Karkoschka [17]. New or updated values will likely be adopted for (2)

Pallas, (21) Lutetia, (52) Europa, and (511) Davida. An updated orientation model will be adopted for (2867) Šteins. The size of (25143) Itokawa will be corrected to show semi-axes sizes (rather than axes sizes). The declination of the pole of (243) Ida will be corrected (to  $-87^\circ.12$ ). Data will be added for comet 9P/Tempel 1 based on the Stardust NExT flyby [18], for 19P/Borrelly based on the DS1 flyby and subsequent ground-based measurements [19], for 103P/Hartley 2 based on the EPOXI flyby [20], and for 67P/Churyumov-Gerasimenko based on the pre-perihelion approach mapping from the Rosetta orbiter [21]. Data for Mercury, (1) Ceres, and Pluto and Charon may also be updated based on recent mission results and papers currently being published. Individual members of the WG worked with Dawn mission personnel to arrive at a suitable way to update the existing orientation model for Ceres.

**Request for Input:** The WG desires continued input from the planetary community, especially regarding the systems for specific bodies, the operation of the WG, and the need for and/or usefulness of the WG's efforts. The lead author of this abstract should be considered the primary point of contact.

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