

STATUS OF THE IAU WORKING GROUP ON CARTOGRAPHIC COORDINATES AND ROTATIONAL ELEMENTS AND ITS UPCOMING REPORT. Brent A. Archinal, U. S. Geological Survey, Astrogeology Science Center, (2255 N. Gemini Drive, Flagstaff, AZ 86001, USA 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 (e.g. body orientation and shape) to be used for making cartographic products (maps) of Solar System bodies. These recommendations are based on community consensus as interpreted by a diverse international group of mapping experts, and 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 our 2015 report that is now being written (i.e., there will be no “2012” report). The WG encourages input and is available to assist users, instrument teams, and missions on cartographic issues. See our website [2] for additional information.

Operation of WG: The WG currently consists of 19 volunteer members from 6 countries: C. Acton, M. A’Hearn, B. Archinal (Chair), A. Conrad, 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, representing China, France, Germany, UK, USA, and the Vatican City State. Following nominations, 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 by independent research, and 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 mapping product formats. Such issues have largely been left to individual map developers, archiving organizations such as the NASA Planetary Data System (PDS), the International Planetary Data Alliance, or the NASA Mars Geodesy and Cartography and Lunar Geodesy and Cartography Working Groups (MCGWG[3], LGCWG[4]) and individual missions. 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. The WG looks forward to collaborating with the new NASA Cartography Research Assessment Group (CRAG) [5].

In discussions at the IAU GA in August 2012 there was agreement [6] to remind authors, journal editors, instrument teams, missions, and space agencies that a substantial number 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 such groups understand and follow IAU recommendations.

Defining Longitude: One continuing 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 [7] and reiterates in the recent report [1] that once an observable reference feature at a defined longitude is chosen, the alignment of the longitude system should not change. Given that our definition of longitude is primarily for mapping surface features, it is more logically 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 [8], the Moon, or Jovian or Saturnian satellites). Once such a feature has been adopted, changing the longitude system alignment 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 alignment is maintained to the level of precision at which the feature can be located in new data. An example is the redefinition of the origin for longitude for Mars from the large feature then known as Sinus Meridiani to the small crater Airy-0 [9]. 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 August 2011, the NASA/DLR/ASI Dawn mission proposed using a longitude system with a large ($\sim 155^\circ$) rotation from the previous [10] system. Many reasons were expressed for this new system, but the WG replied in both September 2011, and March 2012, 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., 11]. The change in system has resulted in substantial confusion. Fortunately, the NASA PDS requires that ar-

chived data products follow various 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 [12] (with $W_0=285.39^\circ$). The WG was asked by the mission for concurrence on the suitability of this latest system, and did so in November 2012. The WG also recommended that to avoid further confusion, maps and scientific publications should henceforth use the same primary system as the data archives. The Dawn mission has published data to the PDS using the new compliant system. The WG also explicitly recommended this system for general use for Vesta [13].

General Changes Under Discussion: Following extensive discussion, the WG has developed a working list of changes and updates for the next report. Details of these changes are still being addressed, 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 body shapes and sizes for image projection and scientific modeling versus 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. *Finally*, the WG will likely become a “Functional group” under the new IAU structure, where such groups would have the “main responsibility of [providing] state-of-the-art deliverables: standards, references; tools for education, related software (VO), etc., with an official IAU stamp, for universal use” [14].

Changes for Specific Bodies Under Discussion: Due to past confusion in their use, formulae for the Earth’s orientation (which had been given for comparison purposes only) will be removed. For the Moon, the availability of a new JPL lunar ephemeris (DE430) will be pointed out, but its adoption may not be recommended given that another JPL ephemeris is likely to be released in early 2016 (W. Folkner, personal comm.). The availability of the current INPOP ephemeris [15] will also be described. The recommendation of a new orientation model for Mars [16] by the MGCWG will be followed [17]. Cassini results will be considered regarding updates for the Saturnian satellites. Neptune’s rotation model will be updated based on results from Karkoschka [18]. New or updated values will likely be adopted for (2) Pallas, (21) Lutetia, (52) Europa, and (511) Davida. Correct values will be used for the size of (25143) Itokawa. Recent determinations of variable rotation rates for 9P/Tempel 1 [19] and 103P/Hartley 2 [20] will likely be recommended.

Outlook for Later Reports: Specific changes for the 2018 and later reports will depend largely on what new results are published. We can speculate regarding updates or new values in several areas including a) using human artifacts to define longitude, e.g. on the Moon with the lunar laser ranging retroreflectors

(LRRR) and on Mars with the Viking 1 or planned InSight landers; b) further improvements in the lunar ephemeris; c) updates for the orientation of Jupiter and Saturn; and d) updates due to new results from ongoing and new missions (e.g. missions to Mercury, Saturnian satellites, Pluto and Charon, (1) Ceres) and Earth-based observations (various asteroids). Consultation is needed within the IAU as to whether the WG should make any recommendations regarding extra-solar “planets.” The WG has been looking into establishing links to related organizations, such as the International Association of Geodesy and the International Society for Photogrammetry and Remote Sensing. The WG will continue to provide assistance on coordinate system and mapping issues to the planetary community (e.g., missions, product developers, the new NASA CRAG, etc.) on a best-effort basis.

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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