

INTERNATIONAL ASTRONOMICAL UNION  
DIVISION A AND F / WORKING GROUP  
CARTOGRAPHIC COORDINATES AND ROTATIONAL ELEMENTS

MEMBERSHIP            B. A. Archinal (Chair), A. Conrad (Vice-Chair), C. H. Acton, T. Duxbury,  
D. Hestroffer, J. L. Hilton, L. Jorda, R. L. Kirk, S. A. Klioner, J.-L. Margot,  
K. Meech, J. Oberst, F. Paganelli, J. Ping, P. K. Seidelmann, D. J.  
Tholen, I. P. Williams

REPORT TO IAU FOR 2019

1. Introduction

The main activity of the IAU Working Group on Cartographic Coordinates and Rotational Elements (hereafter, WG) is to make recommendations regarding the creation and maintenance of cartographic planetary coordinate systems. The agreed-upon recommendations are produced roughly in conjunction with each IAU General Assembly and are published as a report in the journal *Celestial Mechanics and Dynamical Astronomy*. Our most recent report was published in February 2018 (Archinal et al. 2018a) with corrections published in 2019 (Archinal et al. 2019c).

We are beginning work to compile the next version of that report. We expect there will be routine updates (Archinal and WGCCRE, 2020a) to recommended orientation and size models resulting from processing or reprocessing of various planetary datasets, e.g. with improvements possible for various bodies such as Mercury, Venus, Jupiter, Saturn, Saturnian satellites, Ceres, 67P/Churyumov–Gerasimenko, Arrokoth, Bennu, and Ryugu.

Although lunar ephemerides currently seem to provide the orientation of the Moon with an accuracy of several meters, improved ephemerides solutions continue to be made based on new lunar laser ranging (LLR) from various groups. Therefore, changes in the lunar orientation model should be considered. Another issue is whether to finally base the mean Earth/polar axis lunar system directly on no-net rotation-based LLR solutions for retroreflector coordinates rather than on a specific lunar ephemeris as is done currently.

For Mars, the orientation model previously recommended by the WG could be updated to a newer model. However, a separate issue has been raised that the new models seem to have a ~100 m offset in longitude at the fundamental epoch of J2000.0 relative to the previous recommended system. Clarification is needed as to the cause of this offset and based on community input a decision must be made as to whether some correction in longitude is needed in these newer models.

2. Membership

The WG currently consists of 16 members from 5 countries, with membership lengths from 2 to 44 years. Brent Archinal (U. S. Geological Survey) serves as the current Chairman, and Al Conrad (Large Binocular Telescope Observatory) serves as the Vice-Chairman. The WG began operation in 1976. In recognition of the continued need for the WG, in 2016 it became a "Functional Working Group" of the IAU, with an institutional scope and purpose in providing a service that naturally extends beyond the IAU triennial cycle (IAU Exec. Committee, 2016).

The WG is always looking for volunteers to join, particularly to help with each new report. Our membership is open to all who wish to help with our work. Some individuals have recently expressed an interest in joining the WG and we plan to follow up with them and others likely interested, but additional members are welcome. This may help to increase our membership, expertise, and available time to work on our main report and community inquires.

### 3. Community Inquiries

The WG Chair and many of the WG members spend significant time answering questions from NASA, missions, mission instrument teams, journal editors, individual researchers, and the public, on various issues related to planetary coordinate systems. Because of new data and improvements in data returned from active missions, there are ongoing questions about the coordinate systems for the Moon and Mars, and regular questions from various NASA Planetary Data System personnel. Some of our members have provided information to international archiving organizations such as ESA's Planetary Science Archive, JAXA's and IKI's archiving arms, as well as the International Planetary Data Alliance; and to planning organizations such as the NASA Mapping and Planetary Spatial Infrastructure Team (MAPSIT) advisory group. The WG cooperates with other IAU components, such as IAU Commission A1 Astrometry and the X2 Cross-Division A-F Commission Solar System Ephemerides. More frequently relative to coordinate system issues, WG members also have been asked to review papers and plans for data archives.

### 4. Concern About Support as a Functional WG

In recent years there has been concern, particularly due to the greatly increasing number and complexity of community inquiries, that the WG is becoming overextended. The time needed to respond to such inquiries have resulted in delays of our most recent reports relative to the preferred triennial schedule of IAU activities. We plan to address this partly by increasing membership, especially as experienced personnel retire and are not replaced. However, it also may be necessary to consider whether an actual service (perhaps analogous to the International Earth Rotation and Reference Systems Service, even if not initially at the same scale) is needed to perform some of the community support functions of the WG. One of us (Archinal) receives NASA funding for a portion of his work, but it may be necessary to seek additional funding and help in planning, perhaps from sources such as international space agencies, to continue to address community requests and increased demands for input. The WG plans to consider this overall issue but community input is welcome as we proceed.

### 5. Publications and Meetings

The WG has continued to make its efforts and activities known via its website (<http://astrogeology.usgs.gov/groups/IAU-WGCCRE>) and by various publications and community presentations. Specifically:

- We will continue to publish our main report to the planetary community, to be published approximately triennially, following each IAU General Assembly. Since our previous report was delayed, we tentatively plan to issue our next report in late 2020.
- The WG will make brief annual reports to Divisions A and F on our activities. We are also willing to continue to make oral reports at the General Assembly Division meetings.
- We will provide occasional reports on items of interest for submittal as an IAU News Announcement, such as that shown in IAU (2018).
- To make our work better known and encourage adherence to the recommendations in our main report, we will continue to submit abstracts to and make presentations at various planetary science meetings, describing the activities of the WG and our reports. Such events would include the Lunar and Planetary Science Conference and the Planetary Data Workshops (Archinal and WGCCRE, 2019a, 2020a; Conrad and WGCCRE, 2019), the Planetary Science Informatics and Data Analytics Conference (Archinal and WGCCRE, 2018c), various international meetings (Archinal and WGCCRE, 2018b, 2019b, 2020b, 2020c; Heinkelmann et al. 2019), and possibly other meetings such as NASA MAPSIT and other Analysis Group meetings (<http://www.lpi.usra.edu/analysis/>).

- In 2019, the WG, along with other components of the IAU, submitted a proposal to hold an IAU Symposium at the 2021 IAU General Assembly on the topic of “Reference systems and their ties with the rotation of the Earth and other Solar System bodies.”

## 6. Closing remarks

We plan to complete a new version of our main report by late 2020. We will continue to address questions from the planetary community regarding planetary coordinate system issues and continue to further increase community awareness of our work with abstracts and presentations at appropriate scientific meetings. Inquiries from the community have increased greatly in recent years from individuals, editors, instrument teams, missions, and space agencies. We expect to accommodate this increased workload in part by moving forward with an increased WG membership.

## References

Archinal, B. A., Acton, C. H., A'Hearn, M. F., Conrad, A., Consolmagno, G. J., Duxbury, T., Hestroffer, D., Hilton, J. L., Kirk, R., Klioner, S. A., McCarthy, D., Meech, K., Oberst, J., Ping, J., Seidelmann, P. K., Tholen, D. J., Thomas, P. C., and Williams, I. P. (2018a). “Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements: 2015,” CMDA, 130:22, <https://doi.org/10.1007/s10569-017-9805-5>.

Archinal, B., and the IAU Working Group on Cartographic Coordinates and Rotational Elements (2018b). “International coordination of coordinate systems of Solar System bodies by the IAU Working Group on Cartographic Coordinates and Rotational Elements,” 42nd COSPAR Scientific Assembly 2018, July 14-22, Pasadena, CA. #PEX.1-0021-18.

Archinal, B., and the IAU Working Group on Cartographic Coordinates and Rotational Elements (2019a). “Updating Solar System Reference Frames for Cartography in 2019,” 4th Planetary Data Workshop, Flagstaff, Arizona, June 18-20. #7062.

Archinal, B., and the IAU Working Group on Cartographic Coordinates and Rotational Elements (2019b). “Planetary Coordinate System Recommendations by the IAU Working Group on Cartographic Coordinates and Rotational Elements,” IAG Symposium G01 - Reference Systems and Frames, 27th IUGG General Assembly, Montréal, Québec, Canada. #IUGG19-1604. July 8-18.

Archinal, B. A., Acton, C. H., Conrad, A., Duxbury, T., Hestroffer, D., Hilton, J. L., Jorda, L., Kirk, R. L., Klioner, S. A., Margot, J-L., Meech, K., Oberst, J., Paganelli, F., Ping, J., Seidelmann, P. K., Stark, A., Tholen, D. J., Wang, Y., and Williams I. P. (2019c). “Correction to: Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements: 2015,” CMDA, 131, 12, <https://doi.org/10.1007/s10569-019-9925-1>.

Archinal, B., and the IAU Working Group on Cartographic Coordinates and Rotational Elements (2020a). “Update for 2020 from the IAU Working Group on Cartographic Coordinates and Rotational Elements,” Proceedings of the 51th Lunar and Planetary Science Conference, 2020 March 116-20, The Woodlands, Texas, Abstract #2385.

Archinal, B., and the IAU Working Group on Cartographic Coordinates and Rotational Elements (2020b). “Coordination of Planetary Coordinate System Recommendations by the

IAU Working Group on Cartographic Coordinates and Rotational Elements – Status and Future”, XXIVth ISPRS Congress, <http://www.isprs2020-nice.com/>, #326, accepted, March 2.

Archinal, B., and the IAU Working Group on Cartographic Coordinates and Rotational Elements (2020c). “Planetary Coordinate System Recommendations by the IAU Working Group on Cartographic Coordinates and Rotational Elements – Status and Future”, 43rd COSPAR Scientific Assembly, Sydney, Australia, Presentation #PSD.1-0003-21.

Conrad, A., Archinal, B., and the IAU Working Group on Cartographic Coordinates and Rotational Elements (2019). “Update for 2019 from the IAU Working Group on Cartographic Coordinates and Rotational Elements,” Proceedings of the 50th Lunar and Planetary Science Conference, 2019 March 18-22, The Woodlands, Texas, #2110.

Heinkelmann, R., Hilton, J. L., Stewart, S. G., Hohenkerk, C., and Archinal, B. (2019). “IAU activities on standards – interactions with IAG and GGOS BPS,” Global Geodetic Observing System Days, Rio de Janeiro, Brazil, November 12-14.

IAU Executive Committee (2016). “Summary of IAU Executive Committee Meeting in May 2016.” Available as <https://www.iau.org/static/archives/announcements/pdf/ann16029a.pdf>.

IAU (2018). “New Coordinate Systems for Solar System Bodies,” an18010 - announcement, 27 February. Available at <https://www.iau.org/news/announcements/detail/ann18010/>.