

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

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REPORT TO IAU FOR 2021-2022

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 approximately in conjunction with each IAU General Assembly and are published as a report in the journal *Celestial Mechanics and Dynamical Astronomy*. Our most recent main report was published in February 2018 (Archinal et al., 2018) with corrections published in 2019 (Archinal et al., 2019).

2. Main Report

We are beginning work to compile the next version of that report. We expect routine updates (Archinal and WGCCRE, 2021a and 2021c) 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, the Saturnian satellites, Ceres, 67P/Churyumov–Gerasimenko, Arrokoth, Bennu, and Ryugu.

Although lunar ephemerides currently provide the orientation of the Moon with an accuracy of a few meters, improved ephemerides solutions continue to be made based on new lunar laser ranging (LLR) from various groups, and recommendations have been made to NASA to update the lunar reference frame in preparation for upcoming missions (Joint LEAG-MAPSIT SAT, 2021). Therefore, changes in the lunar orientation model should be considered. Another issue is whether to finally base the mean Earth/polar axis lunar frame directly on a no-net-rotation-based LLR solution for retroreflector coordinates rather than on a specific lunar ephemeris as is done currently. An abstract on this topic has been submitted to the upcoming Planetary Science Informatics and Data Analytics Conference (Archinal and WGCCRE, 2022).

For Mars, the orientation model previously recommended by the WG could be updated to a newer model. However, a separate issue is 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 a decision must be made based on community input as to whether some correction in longitude is needed in these newer models.

3. Membership

The WG currently consists of 16 members from 5 countries, with membership lengths from 4 to 46 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, it became a "Functional Working Group" of the IAU in 2016, 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 will help to increase our membership, expertise, and available time to work on our main report and community inquiries.

4. 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 open questions about the coordinate systems for the Moon and Mars, and other questions from various NASA Planetary Data System personnel. Some of our members have provided information to international archiving organizations such as the European Space Agency's Planetary Science Archive, the Japan Aerospace Exploration Agency's and Russian Space Research Institute'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. WG members also have often been asked to review papers and plans for data archives regarding coordinate system issues.

5. Concern About Support as a Functional WG

In recent years the WG has been concerned that it is becoming over-extended, particularly due to the greatly increasing number and complexity of community inquiries. 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. 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 support, perhaps from international space agencies, to continue to address community requests and increased demands for input. The WG is considering these issues, but community input is welcome as we proceed. A discussion of the overall issues involved has been presented as input to the NASA Planetary Science and Astrobiology Decadal Survey (Paganelli et al., 2020) and at other venues (Archinal and the WGCCRE, 2020a, 2020b, 2021a, 2021c; Archinal et al., 2020).

6. Publications and Meetings

The WG has continued to make its efforts and activities known via its website (<https://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, and due to delays due to pandemic issues, we tentatively plan to issue our next report in late 2022. A separate triennial report on our activities is also prepared for the IAU (Archinal et al., 2021).
- The WG will make brief annual reports such as this to the IAU and Divisions A and F on our activities. We are also willing to continue to make oral reports at the General Assembly Division meetings, such as in 2021 for Division F (Archinal and the WGCCRE, 2021b).

- 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. See the various references here for examples of those submissions and presentations.
- Members of the WG and others, such as from the International Cartographic Association Commission on Planetary Cartography, have worked to make our recommendations more accessible via software packages and other standards (Hare et al., 2022).

7. Closing remarks

We plan to complete a new version of our main report by late 2022. 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.

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