

DIVISION A AND F / FUNCTIONAL WORKING GROUP
CARTOGRAPHIC COORDINATES AND ROTATIONAL ELEMENTS
COORDONNÉES CARTOGRAPHIQUES ET ÉLÉMENTS DE ROTATION

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TRIENNIAL ACTIVITIES REPORT TO THE IAU FOR 2019–2021

1. Introduction and Plans for Current Work

The main activity of the IAU Working Group on Cartographic Coordinates and Rotational Elements (hereafter, WG) is to make recommendations to the international planetary community regarding the creation and maintenance of cartographic planetary coordinate systems. The agreed-upon recommendations are produced roughly in conjunction with each IAU General Assembly (GA) 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. 2018; 54 citations) with corrections published in 2019 (Archinal et al. 2019).

Although delayed by the pandemic and other issues, we have begun work to compile the next report in the series. We expect to include 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 bodies such as Mercury, Venus, Jupiter, Saturn, Saturnian satellites, Ceres, 67P/Churyumov–Gerasimenko, Arrokoth, Bennu, and Ryugu.

Although lunar ephemerides currently 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. Identifying any needed updates in 2021 was recently recommended by a NASA panel in preparation for future human exploration (Artemis III Science Definition Team, 2020, Recommendation 8.2–1).

For Mars, the Kuchynka et al. (2014) orientation model recommended by the WG could be updated to that of Konopliv et al. (2016), which is based on additional data and improved modeling. However, a separate issue is that these models seem to have at the equator a 100 m offset in longitude at J2000.0 relative to the previous recommended system (Archinal et al., 2020, Section 5). We continue to seek clarification 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 and History

The WG currently consists of 16 members from 5 countries, with membership duration from 3 to 45 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 (EC), 2016). According to the IAU Rules (IAU EC, 2020), the status of such Working Groups should be

revisited by the EC every 6 years. Given its long history, its active work, and the demonstrated international community need for the WG's recommendations and advice, the WG does plan to make a request to Divisions A and F and the EC to continue operation.

Membership in the WG is open and the group is always looking for volunteers to join. Several scientists have recently expressed a wish to become members, but more are needed. Adding members is necessary to combat attrition and broaden the expertise of the group, but primarily to assist with the preparation of triennial reports and other work.

3. Community Inquiries

The WG Chair and many of the WG members spend significant time answering questions from NASA, space missions and 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 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) assessment group. The WG cooperates with other IAU components, such as IAU Commission A3 Fundamental Standards and the X2 Cross-Division A-F Commission Solar System Ephemerides. More frequently relative to coordinate system issues, WG members have been asked to review papers and plans for data archives.

4. Concern About the Future of the WG

In recent years, there has been concern that the WG is becoming overextended 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. Because several people have retired and left the WG in recent years, we hope that this issue can be addressed in part by recruiting new members and increasing our membership numbers to a level higher than in the past. However, it may be appropriate to consider whether an actual service (perhaps analogous to the International Earth Rotation and Reference Systems Service, though at least initially on a smaller scale) is needed to perform some of the community support functions of the WG. The WG Chair 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 space agencies, to continue to address community requests and increased demands for input.

During 2020 and early 2021, the WG reached out to the international planetary community on this topic. An abstract (Archinal and WGCCRE, 2020a) was submitted to the Lunar and Planetary Science Conference (LPSC), which unfortunately was cancelled. A paper (Archinal et al. 2020) was submitted to the ISPRS and a presentation made at their September virtual meeting. An abstract (Archinal and WGCCRE, 2020b) was submitted to COSPAR and a presentation made at their January hybrid virtual/in person meeting. A white paper (Paganelli et al. 2020) was submitted to the NASA Planetary Science and Astrobiology Decadal Survey. The common theme of these submissions was asking for input on the WG's current operation, the recommendations the WG has made in its reports, and what the long-term structure of the WG should look like. Unfortunately, due to the pandemic and the virtual structure of these meetings, little input was received. We plan to continue to ask for such input, particularly as in-person meetings resume, and will look at other options (e.g., surveys) to obtain input.

5. Publications and Meetings

The WG makes its efforts and activities known via its website (<https://astrogeology.usgs.gov/groups/IAU-WGCCRE>) and by various publications and community presentations and will continue to do so. Specifically:

- We will continue, on a roughly triennial basis, to publish our main report to the planetary community following each IAU GA. We anticipate releasing our next report in 2021.

- The WG will make brief annual reports to Divisions A and F on our activities. We will continue to make oral reports at GA Division meetings as requested.
- We will provide occasional reports on items of interest for submittal as an IAU News Announcement, such as that shown in IAU (2018).
- In 2019, the WG, along with other components of the IAU, submitted a proposal to hold an IAU Symposium at the 2021 IAU GA on the topic of “Reference systems and their ties with the rotation of the Earth and other Solar System bodies.” Unfortunately, the proposal was not accepted by the IAU; however, given the perceived need for such a meeting, it may be submitted again in the future.
- 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 WG’s activities and reports.
 - Past examples of such events 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), NASA MAPSIT Town Hall meetings (Archinal and Hare, 2020), and various international meetings (Archinal and WGCCRE, 2018, 2019b, 2020b; Archinal et al. 2020; Heinkelmann et al. 2019).
 - We may extend these activities to other NASA Analysis Group meetings (<https://www.lpi.usra.edu/analysis/>).

Our presentations will focus on describing the WG’s functions and soliciting community input on how its operations might be improved in the future.

6. Closing remarks

We are currently working on our next main report with the goal of submitting it to *Celestial Mechanics and Dynamical Astronomy* later in 2021. 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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