ACTIVITIES OF THE NASA LPRP LUNAR GEODESY AND CARTOGRAPHY WORKING GROUP. B. Archinal[1] (Chair) and the Lunar Geodesy and Cartography Working Group. [1]U. S. Geological Survey, Astrogeology Team, 2255 N. Gemini Drive, Flagstaff, AZ 86001, USA, barchinal@usgs.gov.

Introduction: With the acquisition of large volumes of new imaging data for the Moon and the resurgence of lunar mapping programs worldwide, there is an urgent need for adoption of international lunar cartographic standards. Use of uniform cartographic standards facilitates and enhances both the creation and use of lunar data products. Because such uniform products are coregistered into common reference frames and can more readily be analyzed and compared, they are essential for both efficient lunar mission operations and scientific investigation of the Moon. The NASA Lunar Precursor Robotic Program (LPRP) established a Lunar Geodesy and Cartography Working Group (LGCWG) with international membership to examine and recommend uniform lunar cartographic standards for use by all lunar data providers.

The NASA Lunar Geodesy and Cartography Working Group (LGCWG):

Purpose. The LGCWG helps to ensure that lunar products created for the NASA Constellation program or by NASA missions in general adhere to fundamental cartographic standards. Many such products have been identified for creation as part of the LPRP Lunar Mapping and Modeling Project [1]. The LGCWG further provides a forum for cooperation and coordination with the international lunar exploration community.

Operation. The LGCWG accepts recommendations from experts in the U.S. and international lunar exploration communities, and makes decisions by consensus of a core membership (see list at end) representing data providers and users as well as NASA management. LGCWG meetings are occurring primarily by teleconference, supplemented by regular e-mail communication. Teleconferences and meetings include presentations on mission and instrument teams' data processing and product plans, as well as reports on newly available lunar cartographic products.

Participation in telecons and our e-mail list is open to any interested lunar investigator funded by NASA or other space agencies. Presentations to the broader community (such as this) are also being made to increase awareness of our work.

The LGCWG will follow – or, as necessary, recommend changes to – the basic lunar standards of the International Astronomical Union Working Group on Cartographic Coordinates and Rotational Elements (WGCCRE, the international advisory group that sets high-level cartographic standards for all solar system bodies) [2]. Further, the LGCWG will define and extend geodetic and cartographic requirements and recommendations to lower levels than considered by the WGCCRE. The LGCWG thus provides the essential level of detail for development of new cartographic products from lunar data that are necessary to support ongoing and future lunar exploration.

Activities. Since its inception in late 2007, the LGCWG has addressed the following: a) worked with the Lunar Reconnaissance Orbiter (LRO) mission to update the LRO Lunar Coordinates White Paper into a general set of lunar coordinates recommendations [3]; b) defined the mean Earth/polar axis (ME) coordinate system for the Moon to be used in the creation of cartographic products (per recommendation of the WGCCRE); c) established use of the new JPL DE 421 ephemeris [4] to initially locate the lunar body-fixed frame in the principal axes system, which with 3 associated small rotation angles then establishes a ME frame; d) developed recommendations for a standard for creating lunar mosaics and map products [5]; e) developed draft recommendations for verifying and publishing lunar topographic products (e.g. digital elevation models); and f) planned establishment of a web site for distributing information and recommendations on lunar mapping standards and conventions [6]. The LGCWG has also communicated with personnel from the Chandrayaan-1, Chang'E-1, and Kaguya (SELENE) missions, asking for input on these recommendations and encouraging their adoption by those missions. For example, the Kaguya/RISE team and apparently most other teams from these missions have at least adopted the use of the DE 421 based ME frame.

Future plans. The LGCWG will: a) continue to update the general LGCWG/LRO Lunar Coordinates standards as needed, for use by NASA-funded data providers and recommended for use by international missions and space agencies; b) recognize and make recommendations on the use of updated lunar reference frames; c) define gravity field standards and updates as needed; d) recommend a new model for the lunar reference shape [sphere radius and perhaps elevation (potential)] when results from new missions are available; e) possibly develop recommendations for image processing such as image file formats, camera/sensor calibration and modeling, and lunar control networks; f) possibly develop recommendations for controlled, semi-controlled, uncontrolled, mosaicked, and/or projected image products; g) assist the NASA Planetary Data System (PDS) and/or the International

Planetary Data Alliance (IPDA) with development of data archiving requirements, including formats, mapping conventions, scales and projections for digital images and mosaics; and h) continue to encourage international space agencies, missions, instrument teams, and individuals to collaborate with us.

Registration of Lunar Data for Exploration and Science: Proper registration of lunar data, including use of the densest and most accurate geodetic control network available, is essential to lunar exploration and science. Fine-scale coregistration is the only way to connect and compare data at known levels of precision and accuracy. This need was recognized at the 2007 Tempe Lunar Exploration Architecture Meeting and by the NASA Advisory Council, with their recommendation to NASA that [7]:

Lunar orbital data sets should be geodetically controlled and accurately co-registered to create cartographic products that will enable fusion, integration, and manipulation of all past and future data relevant to lunar exploration.

Adherence to uniform cartographic standards for lunar data will provide simulation and operational (exploration) support for all current and future missions, affecting the mapping and characterizing of future landing and surface operational sites and determination of precise and accurate landing site coordinates in three dimensions relative to navigational coordinates in inertial space. Spacecraft development, landing maneuvering costs, and risk (including the loss of a mission) rise significantly with position uncertainty.

Uses of coregistered data in planetary science are numerous and include:

- Geologic mapping and study of the morphology and distribution of surface features. The sizes and relative two- and three-dimensional locations of features (e.g. craters, volcanoes, structures, and stratigraphic layers) and visualization and integration of all available datasets provide critical information.

- Color and compositional analyses, maturation or evolutionary processes, and resource identification and location. Single band (albedo), multi-band (color) and hyperspectral data must be accurately registered at the sub-pixel level to topography so that photometric corrections (based on incidence, emission and solar angles) can be made and relative mineral abundances evaluated.

- Qualitative or quantitative analysis of data where precise, clean mosaics and/or accurate placement of data onto topography (i.e., orthometric registration) are necessary for proper visualization and characterization.

- Change detection studies where comparison of "before" and "after" datasets are made to identify temporal variations (e.g., for use in determination of impact cratering rate). Monochromatic and color (indicating maturity) image data must be directly compared at the sub-pixel level for such work. Repeat radar data, if similarly registered, can be used to interferometrically detect small cm scale changes that can then be examined with imagery to assess what the changes have resulted from. Such studies directly address the issue of the impact history of the Earth-Moon system.

Lastly, the LGCWG recommendations on the format of lunar mosaics and map products [5] also facilitate transfer and use of lunar datasets as well as comparison of these (now often quite large) data sets (e.g., within Geographic Information Systems), for exploration and science purposes.

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