**LUNAR GEOGRAPHIC INFORMATION SYSTEMS (GIS) FOR DATASET SYNTHESIS AND ANALYSIS.** T. M. Hare, M. R. Rosiek, B. A. Archinal, R. L. Kirk, and L. R. Gaddis, U. S. Geological Survey, Astrogeology Team, 2255 N. Gemini Drive, Flagstaff, AZ 86001, USA, thare@usgs.gov.

**Introduction:** GIS is a valuable technology for researchers in the planetary sciences and continues to become more essential as the number and complexity of the data sets increase. It allows researchers to efficiently amass, manipulate, capture, update, analyze, and display all forms of geographic data. Use of GIS applications allows planetary scientists to perform comprehensive mapping and analyses, share information, and aids in landing site selection for robotic missions. This abstract will briefly describe why GIS technologies should be used to support future lunar planning and scientific research, and most importantly as a tool for a safe, efficient and effective human return to the Moon and for eventual operations at Mars.

**Data:** For any GIS to be successful, datasets must be well designed and accurately gathered, processed, and georeferenced. Thus we cannot stress enough that a well organized and planned cartographic research program among closely cooperating facilities is an essential component of the development of an effective lunar GIS database. The abstract ***"Urgent Processing and Geodetic Control of Lunar Data"*** also submitted to this workshop addresses this topic in more detail [1].

**Data Accessibility:** Dataset accessibility will always be a challenge for any field. In addition, multiple applications will require access to the same datasets to support the diverse activities needed for a planetary mission. The aim is to standardize the formats and/or data distribution mechanisms to allow many applications to utilize the same data in different ways. For online data distribution, there are currently many excellent planetary mapping sites. A few of the facilities producing these applications are the Planetary Data System (PDS), U.S. Geological Survey (USGS), Jet Propulsion Laboratories, NASA Ames Research Center, and many universities. The ultimate goal for all of these facilities is to achieve interoperability for their online datasets. This will allow the end-user to load different co-registered layers from different facilities into the various specialized applications. For example, the PDS Imaging Node, using common standards, is developing a unified location database for planetary images to facilitate data access [2].

Fortunately, the planetary community – and in particular the planetary geoscience community – can benefit greatly from work already completed by the Earth geospatial community. The Open Geospatial Consortium (OGC) [3] has developed a broad complex of specification and implementation that plays an increasingly important role in linking the similarly huge distributed reservoirs of Earth related geospatial data. With provenance dating from the early 80s, the OGC is now comprised of over 200 international government, university, and commercial organizations. In particular, NASA's Earth Science Enterprise – what is now the Geospatial Interoperability Office – has supported and been active in OGC development since 1994. A term used on the OGC website that describes this process is to "geo-enable" the Web.

Researchers at the Jet Propulsion Laboratory (JPL) and USGS, with cooperation from other planetary facilities, are adapting the fast developing and well-supported Open Geospatial standards and technologies for the access, processing, and display of geospatial data to the planetary domain [4, 5]. The basic motivation is that investigators need a unified methodology for accessing higher-level products that serve as substrate, background, and currently known detail pertinent to their ongoing work. The goal and promise is that anyone can build specialized access points or 'clients' with the assurance that data stored and archived online will be available at a single point of access.

**Proposed Infrastructure:** Currently, the USGS has proposed to the NASA Planetary Geology and Geophysics Cartography Program to support lunar mapping and science data analysis, with the intent to develop a GIS compatible global lunar database. This task was funded for FY07. A variety of digital data for the Moon will be made available for download and hosted in an online mapping viewer. The assembly and distribution of these co-registered data in a consistent map-projected format will also help other facilities and research centers that are supporting upcoming lunar missions and targeting tools. We will initially incorporate these data sets:

- Global Lunar Orbiter mosaic at 60 m/pixel
- Selected Lunar Orbiter frames at high- and very high-resolutions
- Lunar Prospector global maps of derived elemental abundances
- Clementine UVVIS and NIR bands (individual and color-ratios)
- Clementine derived parameter maps (e.g., FeO, TiO2, optical maturity)
- Clementine lidar products, current versions
- Apollo topographic maps produced by USGS
- USGS ULCN2005 control network maps
- Galileo SSI bands and color-ratio mosaics
- Apollo Metric and Pan camera coverage maps
- Apollo historic 'Lunar Consortium' data (e.g., Al, Si, Fe, Ti maps from Apollo)
- Georegistered LAC charts and hotlinks to digital LAC charts (as scanned by the Lunar and Planetary Institute)
- Hotlinks to LPI images, including digital Apollo metric/pan images, Ranger images, Consolidated Lunar Atlas images, etc.

An additional proposal to NASA may allow us to provide these datasets:

- Photogrammetrically-derived topography of a Shackleton crater analog
- Galileo SSI bands and color-ratio mosaics
- Apollo Metric and Pan camera coverage maps
- Cook, T., et al. and ULCN2005 merged DEM

**GIS Tools for Manned Missions:** It has long been recognized that geospatial technologies, such as

those proposed in developing a lunar GIS, can provide invaluable tools for future lunar exploration. Toolkits and decision support systems designed to support manned missions to the Moon have been funded by NASA. Tools such as these are crucial for building lunar and Martian bases to help ensure safe habitats. We are hopeful that NASA will recognize the value of such products and tools and take steps in the near future to continue their development.

As with the datasets, the tools to support manned missions should also be made readily available to this community. For experts in various fields, this becomes more important when several techniques could be run together to help, for example, select safe landing sites and possible habitat locations.

Lastly, some type of quality control and accuracy assessment is needed to ensure the results are reliable. Applying a technique to a dataset can be made very easy. The difficulty might be evaluating if the result is meaningful. As an example, it is possible to run slope analysis against a topographic dataset, but if the length of the slope distance is shorter than the spacing of the topographic data, the results are meaningless. Similarly, with the availability of multiple data sets from different eras and countries, we must have the ability to ensure that they are co-aligned and that we understand the potential errors for each layer [1].

**Final Recommendations**: Our recommendations for immediate use and development of a GIS capability for lunar data are:

- Missions must have a cartographic planning component, and a consistent cartographic coordinate system should be used for data products.
- Planetary data should be systematically processed in a coordinated way and made available in an easily accessed form (e.g., a GIS).
- Expand and/or connect planetary GIS-ready (OGC compliant) servers to broaden and coordinate data access.
- Develop toolkits and decision support systems to support further exploration and a human return to the Moon.
- The current effort to create a Lunar GIS needs to be continued and greatly expanded in the future, and coordinated among multiple facilities.

While many of these recommendations are obvious, we hope to stress their importance and urgency to workshop participants, the NASA Advisory Council, and the lunar science community at large.

**References:** [1] Archinal, B. A., et al. (2007), submitted here. [2] Becker et al. (2007), LPSC, XXXVIII, #2022. [3] Open Geospatial Consortium, website: http://www.opengeospatial.org/ [4] Plesea, L., et al. (2007), ISPRS WG IV/9: Extraterrestrial Mapping Workshop, "*Advances in Planetary Mapping 2007*", Houston, TX. [5] Hare, T. M., et al. (2007), LPSC, XXXVIII, 2364.

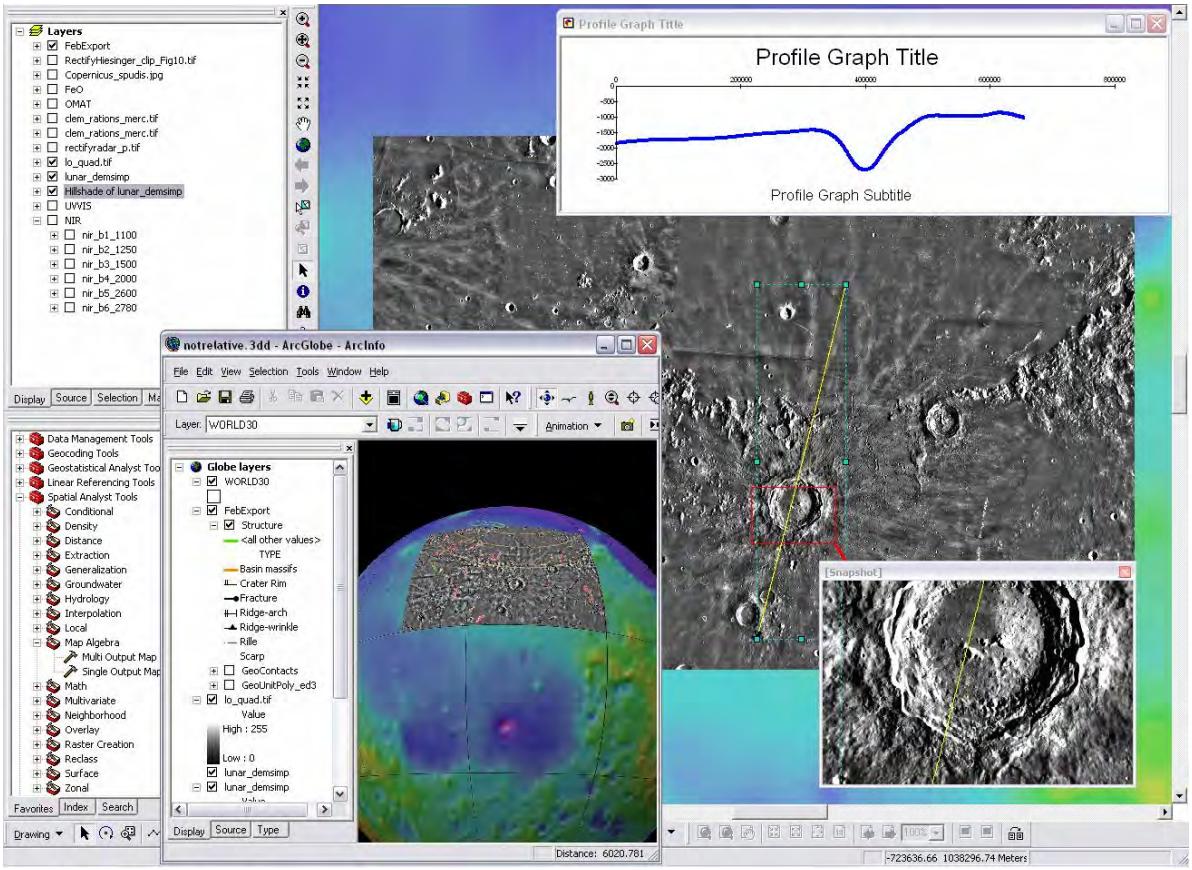


Figure 1. Image showing the ULCN2005 shaded topography and a preliminary Lunar Orbiter mosaic of Copernicus Crater in the GIS applications ArcMap and ArcGlobe by ESRI©. The profile shown is just one of the basic tools available.