WORKING WITH PLANETARY COORDINATE REFERENCE SYSTEMS. T. M. Hare, R. L. Kirk, B. Archinal, K.L. Tanaka, U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ, 8600; thare@usgs.gov.

Introduction: Since the advent of satellite technologies for planetary research, images have been returned in a digital format. Researchers have always struggled to format this data into a usable format for their investigations. And now that digital cartographic programs including geographic information systems (GIS) and photogrammetric systems are widely used, the disparate datasets must also be formatted such that they accurately overlay [1]. For a digital mapping package, this usually means that the data must be translated to the same map projection using a matching coordinate reference system (CRS). While planetary CRSs are well defined [2], when mixing different map projections, datasets, and software packages, there are many potential pitfalls. Accurate documentation of the dataset's CRS and map projection is even more vital with the advent of on-line or streamed databases [1]. This abstract will try to list a few of the problematic issues in the current environment and also report on an emerging standard which may help software packages to interface more successfully, whether the software is locally run or via the Internet.

Part I: Issues

Issue 1 - Planetary Projections: In order to successfully use planetary imagery in a cartographic package, researchers must have a practical understanding of map projections. Map projections, in short, define the mathematical transformation from a CRS or 3D globe to a 2D X, Y Cartesian coordinate system [3]. The researcher may not need to intimately know the mathematics behind the projection but the characteristics and the suitability of the projection are extremely important. This also applies to understanding how the cartographic package handles the projection used. For example, not realizing if the package employed uses a sphere or ellipse in the projection's equation can lead to kilometers of errors in simple distance calculations. It is also extremely important to document these aspects of the software for distribution of the dataset to the community. Fortunately for planetary mappers, many of the datasets are eventually map-projected and released to the PDS (Planetary Data Systems) nodes. However, many parameters needed to accurately define the map projection may be missing from the dataset label, like the particulars of the projection's equation or the latitude type (as described next).

Issue 2 - Ographic and Ocentric Martian Woes: A major point of confusion in dealing with Martian datasets are the two competing coordinate systems that exist for Mars. In 1970, Commission 16 of the International Astronomical Union (IAU) defined these systems and approved their use. One combines longitude measured positive east with latititude measured from the equatorial plane to a point through the center of the planet, so-called planetocentric (areocentric for Mars, geocentric for Earth) latitude. This is simply a right-handed spherical-polar coordinate system. The other system uses longitude measured in such a direction that the sub-Earth longitude increases with time; for Mars, this means positive west. The second system also uses planetographic latitude, which is measured as an angle between the local vertical at a point and the equatorial plane. Because the shape of Mars is flattened relative to a sphere, the planetographic latitude of any point is greater in magnitude than the corresponding planetocentric latitude (except at the equator and poles, where the two types of latitude are equal). The maximum difference between the two types of latitude on Mars is about 0.3 degree or 20 km, at 45 degrees north and south.

To be fair, the IAU has approved these two systems for all bodies, but Mars has been more difficult because there has been extensive use of both systems and the fact that Mars is defined on an ellipse. The different latitude types only become an issue for elliptical bodies. Luckily, most planets and satellites are defined as a sphere. A commonly used "fix" for Martian data is to define a spherical reference, but this does lead to scale discrepancies over the elliptical approach. As with the projection, researchers must recognize the details of the coordinate system and whether or not their software system can handle the defined system.

Issue 3 – Cartographic Software: To continue the thread above, a major consideration is the compatibility of software with the projection type and, for Mars, the two types of coordinate systems. The two main planetary cartographic packages, ISIS and VICAR, were originally written to use the aerographic latitude type [4]. Both these applications had always calculated aerocentric coordinates and converted to the other system on output, so the required modification is relatively trivial. ISIS incorporated this modification in 2001 and also allows the user to work with aerocentric coordinates on an ellipsoidal reference system. The ISIS team is also working on the ability to generate

a uniform geometric database for all Mars orbital remote sensing data using the IAU/IAG 2000 east planetocentric coordinate system [5].

Third-party GIS and photogrammetric software systems pose more of a problem, in that their code is not accessible for modification. This does not favor either of the IAU/IAG-approved coordinate systems. However, most systems (i.e. ESRI's ArcGIS, Generic Mapping Tools, BAE's SOCET SET) use a mixed east/planetographic system not approved for Mars by the IAU/IAG. Thus, one must convert data for use with these packages in either case.

Part II: Solutions

Background: The Open Geospatial Consortium (OGC) was built to help establish and promote a series of Internet protocols for sharing GIS resources (i.e. geospatial data). The OGC works with a variety of technology hardware and software companies so that diverse GIS and remote sensing technologies can easily communicate. Some of the goals are (1) to make geospatial information easy to find, (2) to allow easy access and acquisition of datasets, and (3) to permit data from different sites to integrate, register and be analyzed [6]. Most GIS and remote sensing software manufacturers are working on adding support for Open Geospatial standards.

A key aspect of sharing live or streamed data on-line is the requirement to synchronize the different data providers to a single map projection and included CRS, as chosen by the user, such that datasets properly register. By utilizing a standards body like the OGC, in-house software applications as well as existing commercial application can be better integrated.

Projects from the USGS, Jet Propulsion Laboratory, Arizona State University, and eventually the PDS are already in motion to utilize these data serving standards for the planetary community [7]. It is an opportune time to cooperate with the Open Geospatial Consortium to make sure their standards have enough flexibility for planetary datasets. Currently, we are putting together a planetary working group within the OGC to make sure the community's concerns are heard. The next meeting in mid-January of 2005 should solidify the creation of this working group.

OGC/CRS Standard: Currently, the OGC is using the CRS definitions and coordinate transformation descriptions as defined by the European Petroleum Survey Group (EPSG) [8]. If the CRS is not part of the EPSG database, which no planetary definitions are, there is the option to explicitly define custom settings. However, using these custom settings is rarely supported in software packages. While folding planetary CRS definitions into the EPSG standard is an option, it is not ideal. A more flexible alternative would be to generate a new standard just for planetary CRSs and then reference it within the OGC. The IAU and IAG continue to update the report for planetary CRSs but it is not a recognized, properly formatted standard. This planetary CRS standard should also become part of the PDS as well as the OGC. Lastly, it is important to note that the OGC and EPSG groups are also working with the ISO/TC 211 Geographic information/Geomatics, which is responsible for the ISO geographic information series of standards [9].

Planetary CRSs in GML: Once the planetary CRS is formalized, users could easily define a planetary CRS and coordinate system transformation that would be recognized by numerous software packages. The main method to encode the information would be to use the geospatial Extensible Mark Language (XML) protocol called Geography Markup Language (GML) [10,11]. GML is quickly becoming a standard for geospatial data to not only hold the CRS and the transformation but also the data itself.

References: [1] Hare T., Tanaka K., Skinner J., GIS 101 for Planetary Research, ISPRS WG IV/9: Extraterrestrial Mapping Workshop, Advances in Planetary Technology, LPI, Houston, 2003. [2] Seidelmann, P. et al. (2002) Celest. Mech. Dyn. Astron, 82, 83-110. [3] Snyder, J. P. Map Projections--A Working Manual. USGS Professional Paper 1395. Washington, DC: U. S. Government Printing Office, 1987. [4] Gaddis, L., et. al., 1997, LPSC. XXVII, abstract #1226. [5] Becker, K.J., et. al., Unified Planetary Coordinate System, *this volume*. [6] http://www.opengis.org/ogcFaqs.htm#q5. [7] Hare T., Tanaka K., LPSC XXXV, abstract #1765. [8] Coordinate Reference System Definition, European Petroleum Survey Group (EPSG) website: http://www.epsg.org/. [9] International Organization for Standardization (ISO) TC 211, website: http://www.isotc211.org/welcome.htm [10] Open Geospatial Geography Markup Language (GML) Implementation Specification, OGC 03-105r1, 2004. [11] Recommended XML encoding of coordinate reference system definitions, OGC 03-010r9, 2003, http://www.opengeospatial.org/specs/?page=recommendation.

Additional Information: The PIGWAD website, which houses information on topics discussed in this abstract, can be found at the following address: http://webgis.wr.usgs.gov. To learn more about using planetary datasets in various GIS applications please visit our Planetary GIS Discussion site at:

http://webgis.wr.usgs.gov/pgis_discussion

Swine on Harvest Moon