STANDARDS PROPOSAL FOR 2021 TO SUPPORT PLANETARY COORDINATE REFERENCE SYSTEMS FOR OPEN GEOSPATIAL WEB SERVICES. T. M. Hare[1], Malapert J-C.[2], [1]U.S. Geological Survey, Astrogeology, Flagstaff, AZ, 86001 (thare@usgs.gov), [2]Centre National d'Etudes Spatiales (CNES).

Introduction: This abstract outlines an updated proposal to encode planetary map projections for open geospatial consortium (OGC) web services. The update leverages the recent availability of the International Organization for Standardization (ISO) 19162 standard, also known as WKT2. ISO 19162 standard defines a well-known text (WKT) definition for coordinate reference systems (CRS) and has been improved to support nearly all planetary CRS needs. These codes are needed to allow streaming mapping applications to recognize a defined planetary CRS and give them the capability to overlay multiple data sets from different sources and implement accurate measures and calculations.

Background: Hare et al. in 2006 [1] originally proposed methods to support planetary CRSs within existing OGC web mapping standards. Within a typical OGC web mapping session, the server must define a minimum set of information such that the client application understands not only the data layer but also the current CRS and/or map projection. Generally, web mapping servers only support the numeric European Petroleum Survey Group (EPSG) codes to define the CRS also referred to as the Spatial Reference System (SRS). For example, code "4326" is the EPSG identifier for Earth's "WGS 84" geographic CRS. The client relays this code to the map server by passing an in-line SRS request using the string "SRS=nameSpace:code" (e.g., "SRS=EPSG:4326"). Additional EPSG codes catalog the most widely used cartographic map series from all countries (e.g., "32612" = WGS 84 / UTM zone 12N; "21413" = Beijing 1954 / Gauss-Kruger zone 13). However, if a CRS is not part of the EPSG database, and no planetary definitions are available, there is not an easy mechanism to explicitly define custom settings within the EPSG namespace.

To help solve this incompatibility among planetary clients and servers, the authors have proposed their own set of codes outside of the EPSG namespace, but for eventual adoption by the OGC. The proposed codes will leverage both the Navigation and Information Facility (NAIF, http://naif.jpl.nasa.gov) numeric code for extraterrestrial bodies and the IAU's publication date from the Report on Cartographic Coordinates and Rotational Elements [2].

In the original 2006 proposal, the publication year was part of the namespace (e.g., IAU2018). We now propose to use the publication date as method to version the codes, separating the date from the IAU namespace (e.g., IAU:2015, IAU:2018). We will continue to model our numeric codes after the planetary codes defined in existing NAIF system. NAIF codes define the barycenter (center of mass) of the Solar System as 0 and defines the Sun as 10. This allows the planets to be classified as 1 through 9 starting with Mercury out to Pluto (even though Pluto is now considered only a dwarf planet). The NAIF planet ID is then defined as the planet barycenter ID * 100 + 99. Thus Mars, in the NAIF system, is defined as "499". To build upon that value for our proposed planetary IAU codes, the new geospatial code for Mars is derived as follows:

- Mars IAU:2005 code = 499 * 100 = 49900
- Sample WMS call: "SRS=IAU:2018:49900"

The moons for each body, as defined by NAIF, start at planet barycenter ID * 100 + 1. For example, Phobos is defined as "401" and Deimos as "402". Thus, the new planetary IAU codes would be defined as:

- Phobos IAU:2018 code = 401*100 = 40100
- Deimos IAU:2018 code = 402*100 = 40200

To continue with the Mars example for the IAU codes, the first 10 numbers, 49900 to 49909, are reserved for geoid definitions (Table 1). Codes in the range of 49910 to 49959 are reserved for predefined projection definitions intended to capture the most popular projections used in the planetary community. Codes from 49960 to 49999 are for "AUTO" projections (Table 2). AUTO projections allow the user to submit the projection parameters also (e.g., SRS= "IAU:2018:49960,100,45,1.0", where 49964 is Transverse Mercator, center longitude=100º, center latitude=45º, and scale = 1.0).

Working with the OGC: As stated above, the WTK v2 standard currently supports most but not all planetary CRS needs. One update that is required, and already agreed to by OGC members, is the use of a two-parameter "spherical" definition for ocentric latitude systems. That update will be added in the coming months. Lastly, we will also submit for the creation of a planetary domain working group within the OGC.

Conclusion: While the proposal to support EPSG-like planetary codes is not ideal, we feel it is still required to support exiting OGC web protocols. We also plan to include these codes within the PROJ library for use within applications like GDAL and QGIS. And finally, we will continue to push the more robust WTK v2 standard for file-based and forthcoming streaming standards and continue to work with the IAU Working Group on Cartographic Coordinates and Rotational Elements to inform and coordinate these efforts.

References: [1] Hare, T.M., Archinal, B., Plesea, L., Dobinson, E., Curkendall, D. (2006) *LPSC XXXVII, Abs #1931*. [2] Archinal, C. H. Acton, M. F. A'Hearn, et al., (2018) *Celestial Mechanics and Dynamical Astronomy*, 130:22, doi: 10.1007/s10569-017-9805-5. https://rdcu.be/b32V4. [3] Tables for the codes and Python scripts to generate the codes are available at Github (https://github.com/PlanetMap/csvForWKT).

Table 1: List of the five options per body using the defined IAU radius value(s) and longitude direction [2].

xxx00	Ocentric on a sphere. If triaxial use IAU Mean radius. If elliptical use semi-major axis as a sphere, (always east longitude direction). This is to enable the most interoperable definition for the body.
xxx01	Ographic on ellipse, (east or west, depending on body rotation).
xxx02	Ocentric on ellipse, (always east).
xxx03	Ographic on triaxial, (east or west, depending on body rotation).
xxx04	Ocentric on triaxial, (always east). Note triaxial definitions are not generally supported in typical mapping applications but may be useful for more advanced applications like ISIS3, VICAR, etc.
xxx05 – xxx09	Reserved for special cases uniquely defined per body. For example, Mars 49905 can be used for the “truncated” Mars radius 3396000 (m) as defined by some instrument teams (e.g., MOLA and HRSC Team). In rare cases a reserved code may be defined to support using a polar radius as a sphere. This can be useful for a system defined in an ocentric latitude system within a polar stereographic map projection.

Table 2: Example planetary codes to support planetary OGC services for Mars using the “IAU:2018” namespace. Other bodies will follow similar definitions as derived from the NAIF planetary codes [3].

IAU:version	**IAU Codes**	**GEOIDS**
IAU:2018	**49900**	**Mars 2018, sphere, aerocentric latitudes, positive east longitudes**
IAU:2018	**49901**	**Mars 2018, ellipse, aerographic latitudes, positive west longitudes**
IAU:2018	**49902**	**Mars 2018, ellipse, aerocentric latitudes, positive east longitudes**
IAU:2018	**49903**	**Mars 2018, triaxial, aerographic latitudes, positive east longitudes**
IAU:2018	**49904**	**Mars 2018, triaxial, aerocentric latitudes, positive east longitudes**
IAU:2018	**49905***	**Mars 2018, Mars truncated sphere (3396000), aerocentric latitudes, positive east longitudes**
IAU:2018	**49906***	**Mars 2018, Mars polar radius (3376200), aerocentric latitudes, positive east longitudes**
IAU:2018	**49907 – 49909***	***Reserved for special cases
		Non-triaxial map projections
IAU:2018	**49910**	**Equirectangular (Simple Cyl.), clon=0º, sphere, areocentric, east longitudes**
IAU:2018	**49911**	**Equirectangular (Simple Cyl.), clon=0º, ellipse, aerographic, west longitudes**
IAU:2018	**49912**	**Equirectangular (Simple Cyl.), clon=0º, ellipse, areocentric, east longitudes**
IAU:2018	**49915**	**Equirectangular (Simple Cyl.), clon=180º, sphere, areocentric, east longitudes**
IAU:2018	**49916**	**Equirectangular (Simple Cyl.), clon=180º, ellipse, aerographic, west longitudes**
IAU:2018	**49917**	**Equirectangular (Simple Cyl.), clon=180º, ellipse, areocentric, east longitudes**
IAU:2018	**49920 – 49927**	**Sinusoidal (same pattern as above)**
IAU:2018	**499**	**North Polar Stereographic, clat=90º, clon = 0º, sphere, areocentric, east longitudes**
IAU:2018	**49931**	**North Polar Stereographic, clat=90º, clon = 0º, ellipse, aerographic, west longitudes**
IAU:2018	**49932**	**North Polar Stereographic, clat=90º, clon = 0º, ellipse, areocentric, east longitudes**
IAU:2018	**49935**	**South Polar Stereographic, clat= -90º, clon = 0º, sphere, areocentric, east longitudes**
IAU:2018	**49936**	**South Polar Stereographic, clat= -90º, clon = 0º, ellipse, aerographic, west longitudes**
IAU:2018	**49937**	**South Polar Stereographic, clat= -90º, clon = 0º, ellipse, areocentric, east longitudes**
IAU:2018	**49940 – 49947**	**Mollweide (same pattern as Equirectangular)**
IAU:2018	**49950 – 49957**	**Robinson (same pattern as Equirectangular)**
		AUTO map projection (parameter order)
IAU:2018 or Auto	**49960 – 49962**	**Auto Transverse Mercator, areocentric, (clon, clat, scale)**
IAU:2018 or Auto	**49965 – 49967**	**Auto Orthographic, spherical equation, areocentric, (clon = 0 [default], clat)**
IAU:2018 or Auto	**49970 – 49972**	**Auto Orthographic, spherical equation, areocentric, (clon = 180 [default], clat)**
IAU:2018 or Auto	**49975 – 49977**	**Auto Lambert Conic Conformal, areocentric, (clon, clat, 1st std. par, 2nd std.)**
IAU:2018 or Auto	**49980 – 49983**	**Auto Lambert Azimuthal Equal Area, areocentric, (clon, clat)**
IAU:2018 or Auto	**49985 – 49987**	**Auto Albers Equal Area, areocentric, (clon, clat, 1st std. par, 2nd std. par)**