

# Chapter 2. Cartographic Standards

The following cartographic data standards were developed through an iterative process involving both the NASA Planetary Cartography Working Group (PCWG) and the PDS. Members of the PCWG also serve on the key International Astronomical Union (IAU) committee that formulates these standards for international adoption. It is the intention of the PDS to keep its own cartographic standards in line with those of the PCWG, and in turn the IAU.

The cartographic standards used in any particular data set should be identified and, where helpful, documented on the archive volume.

## 2.1 Inertial Reference Frame, Time Tags and Units

The Earth Mean Equator and Equinox of Julian Date 2451545.0 (referred to as the J2000 system) is the standard inertial reference frame. The Earth Mean Equator and Equinox of Besselian 1950 (JD 2433282.5) is also supported because of the wealth of previous mission data referenced to this system. (The transformation between the two systems is well defined.)

The standard format for time tags is UTC in year, month, day, hour, minute and decimal seconds, although Julian dates are also supported.

The standard units are SI metric units, including decimal degrees.

## 2.2 Spin Axes and Prime Meridians

The IAU-defined spin axes and prime meridians defined relative to the J2000 inertial reference system are the standard for planets, satellites and asteroids where these parameters are defined. For other planetary bodies, definitions of spin axis and prime meridian determined in the future should have the body-fixed axis aligned with the principal moment of inertia, with the North Pole defined as lying along the spin axis and above the Invariable Plane. Where insufficient observations exist for a particular body to determine the principal moment of inertia, coordinates of a surface feature will be specified and these used to define the prime meridian. Note that some small, irregular bodies may have chaotic rotations and will thus need to be handled on a case-by-case basis.

## 2.3 Reference Coordinates

There are three basic types of coordinate systems: body-fixed rotating; body-fixed non-rotating; and inertial. A body-fixed coordinate system is one associated with the body (e.g., a planet or satellite). The body-fixed system is centered on the body and rotates with the body (unless it is a non-rotating type), whereas an inertial coordinate system is fixed at some point in space.

To support the descriptions of these various reference coordinate systems, the PDS has defined the following set of data elements (See the *Planetary Science Data Dictionary* for complete definitions.):

COORDINATE\_SYSTEM\_TYPE  
 COORDINATE\_SYSTEM\_NAME  
 LATITUDE  
 LONGITUDE  
 EASTERNMOST\_LONGITUDE  
 WESTERNMOST\_LONGITUDE  
 MINIMUM\_LATITUDE  
 MAXIMUM\_LATITUDE  
 POSITIVE\_LONGITUDE\_DIRECTION

Currently, the PDS has specifically defined two types of body-fixed rotating coordinate systems: planetocentric and planetographic. However, the set of related data elements are modeled such that definitions for other body-fixed rotating coordinate systems, body-fixed non-rotating and inertial coordinate systems can be added as the need arises. Contact a PDS data engineer for assistance in defining a specific coordinate system.

The definition of planetographic longitude is dependent upon the rotation direction of the body, with longitude defined as increasing in the direction opposite to the rotation. That is to say, the longitude increases to the west if the rotation is prograde (or eastward) and vice versa. Table 2.1 lists the rotation direction (prograde or retrograde) of the primary planetary bodies and the Earth's Moon. It also indicates the valid longitude range for each body. In order to accommodate different traditions in measuring longitude, the *Planetary Science Data Dictionary* defines a broad longitude range: (-180, 360). Table 2.1 indicates which part of that range is applicable to which body.

**Table 2.1: Primary Bodies and Earth's Moon: Rotation Direction and Longitude Range**

<b>Planet</b>	<b>Rotation Direction</b>	<b>Longitude Range</b>
Earth	Prograde	(0, 360) (-180, 180)*
Mars	Prograde	(0, 360)
Mercury	Prograde	(0, 360)
Moon	Prograde	(0, 360) (-180, 180)*
Jupiter	Prograde	(0, 360)
Neptune	Prograde	(0, 360)
Pluto	Retrograde	(0, 360)
Saturn	Prograde	(0, 360)
Sun	Prograde	(0, 360) (-180, 180)*
Uranus	Retrograde	(0, 360)
Venus	Retrograde	(0, 360)

\* The rotations of the Earth, Moon and Sun are prograde, however it has been traditional to measure longitudes for these bodies as increasing to the east instead of the west. The PDS recommends that the planetographic longitude standard be followed, but also supports the

traditional method. Specifically, the longitude range of (-180, 180) is supported for the Earth, Moon and Sun

## **2.3.1 Body-Fixed Rotating Coordinate Systems**

### **2.3.1.1 Planetocentric**

The planetocentric system has an origin at the center of mass of the body. Planetocentric latitude is the angle between the equatorial plane and a vector connecting the point of interest and the origin of the coordinate system. Latitudes are defined as positive in the northern hemisphere of the body, where north is in the direction of Earth's angular momentum vector, i.e., pointing toward the hemisphere north of the solar system invariant plane. Longitudes increase toward the east, making the planetocentric system right-handed.

### **2.3.1.2 Planetographic**

The planetographic system has an origin at the center of mass of the body. The planetographic latitude is the angle between the equatorial plane and a vector through the point of interest, where the vector is normal to a biaxial ellipsoid reference surface. Planetographic longitude is defined as increasing with time to an observer fixed in space above the object of interest. Thus, for prograde rotators (rotating counter clockwise as seen from a fixed observer located in the hemisphere to the north of the solar system invariant plane), planetographic longitude increases toward the west. For a retrograde rotator, planetographic longitude increases toward the east.

## **2.4 Rings**

Locations in planetary ring systems are specified in polar coordinates by a radius distance (measured from the center of the planet) and a longitude. Longitudes increase in the direction of orbital motion, so the ring pole points in the direction of right-handed rotation. Note that this corresponds to the IAU-defined North Pole for Jupiter, Saturn and Neptune, but the South Pole for Uranus.

Longitudes are given relative to the ascending node of the ring plane on the Earth's mean equator of J2000. However, the Earth's mean equator of B1950 is also supported as a reference longitude because of the wealth of data already reduced using this coordinate frame. The difference is generally a small, constant offset to the longitude. All longitude values fall between 0 and 360 degrees.

Note that ring coordinates are always given in an inertial frame, as it is impossible to define a suitable rotating coordinate frame for a ring system where features rotate at different rates. When it is necessary to specify the location of a moving body or feature, the rotation rate and epoch must be specified in addition to the longitude.

To support the description of locations in a planetary ring system, the PDS has defined the following elements:

RING\_RADIUS  
 MINIMUM\_RING\_RADIUS  
 MAXIMUM\_RING\_RADIUS

RING\_LONGITUDE  
 MINIMUM\_RING\_LONGITUDE  
 MAXIMUM\_RING\_LONGITUDE

B1950\_RING\_LONGITUDE  
 MINIMUM\_B1950\_RING\_LONGITUDE  
 MAXIMUM\_B1950\_RING\_LONGITUDE

RING\_EVENT\_TIME  
 RING\_EVENT\_START\_TIME  
 RING\_EVENT\_STOP\_TIME

RADIAL\_RESOLUTION  
 MINIMUM\_RADIAL\_RESOLUTION  
 MAXIMUM\_RADIAL\_RESOLUTION

The radius and longitude elements define an inertial location in the rings, and the ring event time elements define the time at the ring plane to which an observation refers. If desired, the radial resolution elements can be used to specify the radial dimensions of ring features that can be resolved in the data. See the *Planetary Science Data Dictionary* (PSDD) for complete definitions of these elements.

In general, the above elements refer to locations in an equatorial ring. However, under certain circumstances it is necessary to define these values for an inclined ring, in which case the interpretations are slightly more complicated. Here longitudes are measured as a “broken angle” along the planet’s equatorial plane to the ascending node of the ring plane, and thence along the ring plane. In these circumstances, it is also necessary to define the orbital elements of the ring in question via the following elements in the PSDD:

RING\_INCLINATION  
 RING\_ASCENDING\_NODE\_LONGITUDE  
 NODAL\_REGRESSION\_RATE  
 POLE\_RIGHT\_ASCENSION  
 POLE\_DECLINATION  
 COORDINATE\_SYSTEM\_ID

The ascending node longitude refers to the moment defined by the RING\_EVENT\_TIME. The ring inclination is given relative to the planet’s equator, as specified by the spin pole’s right ascension and declination. The COORDINATE\_SYSTEM\_ID can be either “J2000” or “B1950”, with “J2000” serving as the default. See the PSDD for further details.

## 2.5 Reference Surface

Two standard reference surface models are supported: the digital terrain model (DTM) and the digital image model (DIM). Note, however, that Mars is an exception for which planetographic latitude is used.

The digital terrain model defines body radius as a function of cartographic latitude and longitude in a sinusoidal equal-area projection. Spheroids, ellipsoids and harmonic expansions giving analytic expressions for radius as a function of cartographic coordinates are all supported.

The digital image model (DIM) defines body brightness in a specified spectral band or bands as a function of cartographic latitude and longitude in a sinusoidal equal-area projection, and associated with the surface radius values in the corresponding DTM. DIMs registered to spheroids, ellipsoids and harmonic expansions are supported.

## 2.6 Map Resolution

The suggested spatial resolution for a map is  $1/2^n$  degrees. The suggested vertical resolution is  $1 \times 10^m$  meters, with  $m$  and  $n$  chosen to preserve all the resolution inherent in the data.

## 2.7 References

The following references provide more detail on the cartographic data standards:

Davies, M. E., et al (1991) "Report of the IAU/IAG/COSPAR Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites: 1991," *Celestial Mechanics*, 53, 377-397.

Batson, R.M., (1987) "Digital Cartography of the Planets: New Methods, its Status and Future", *Photogrammetric Engineering & Remote Sensing*, 53, 1211-1218.

Greeley, R. and Batson, R.M. (1990) *Planetary Mapping*, Cambridge University Press, Cambridge, 296p.

- body coordinates
  - prime meridians, 2-1
  - spin axes, 2-1
- map resolution, 2-5
- reference coordinates, 2-1
  - body-fixed, 2-2, 2-3
  - data elements, 2-2
  - planetocentric, 2-2, 2-3
  - planetographic, 2-2, 2-3
  - ring systems, 2-3
  - ring systems, data elements, 2-4
- reference frames
  - B1950, 2-1
  - standard inertial (J2000), 2-1
- reference surface models, 2-5
  - digital image model (DIM), 2-5
  - digital terrain model (DTM), 2-5
- rotation direction
  - of Solar System bodies, 2-2
- time tags
  - format, 2-1