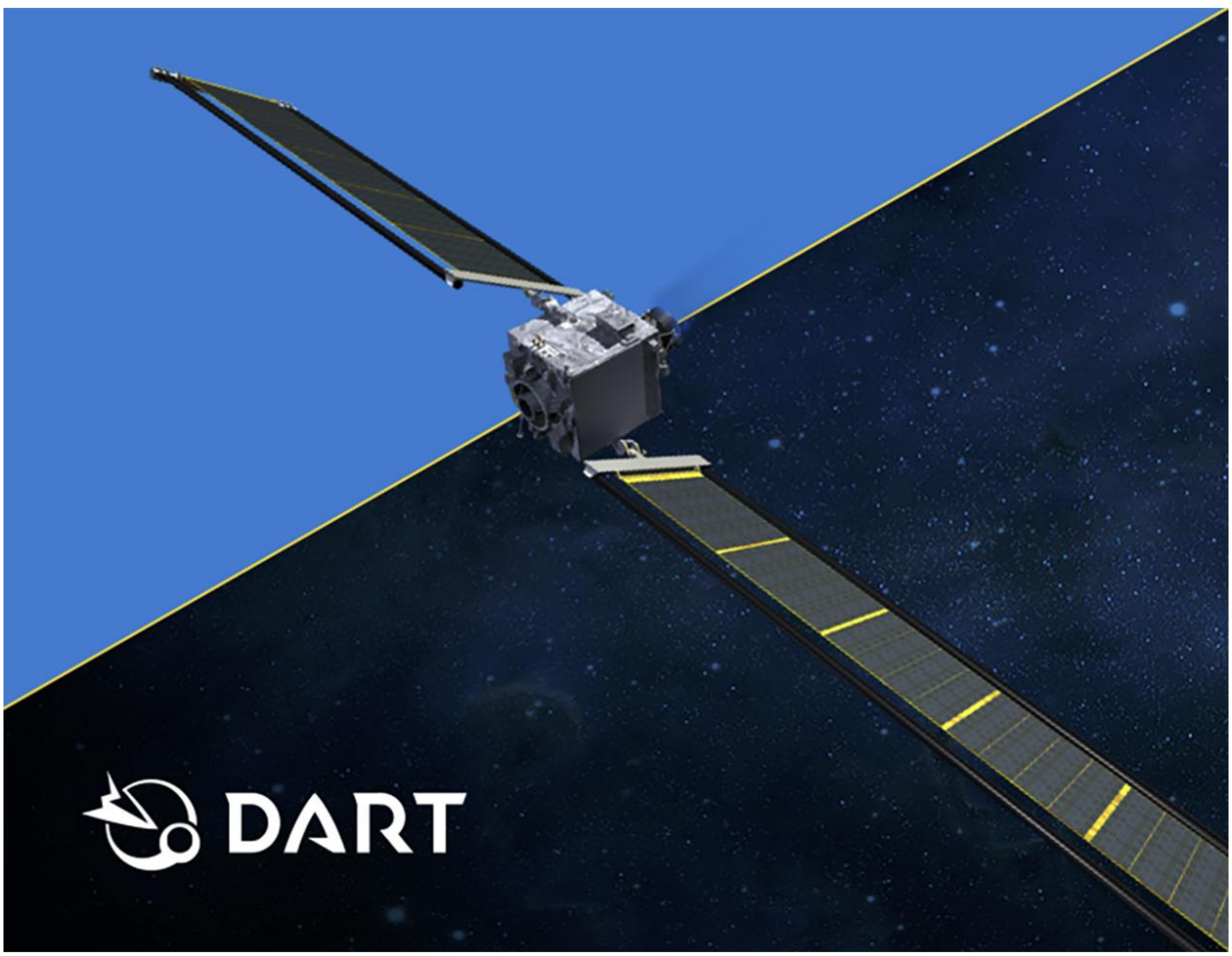
Dimorphos Coordinate System Description



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Revision Log

Version	By	Description	Date
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1. Introduction

This document defines and describes the coordinate system of the asteroid Didymos, which is the primary asteroid in the binary Didymos asteroid system. The secondary asteroid of the Didymos system, Dimorphos was the target of NASA's Double Asteroid Redirection Test (DART). The DART spacecraft carried an imager, the Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO). The DART spacecraft was accompanied by a Cubesat called LICIACube that was provided by the Italian space agency and carried the Liciacube Unit Key Explorer (LUKE).

The coordinate system of Didymos is newly defined based on a shape model derived from DRACO and LUKE images (Palmer et al., 2023) and a pole and rotation rate determined from ground-based observations made by members of the DART Observations Working Group.

2. The prime meridian

For an asteroid like Didymos, the Prime Meridian (PM) is usually defined by an easily recognized surface feature when resolved imaging is available. The location of the PM is preferable chosen to be near where existing radar and telescopic observation have already defined the PM. Because the resolution of the imaging from DRACO and LUKE of Didymos was limited (≥3.7m), we follow the approach taken at Mercury [Davies and Batson, 1975], and use a surface feature that can be well recognized in DRACO images to anchor the prime meridian, and assigning it a longitude consistent with where existing radar and telescopic observation assign 0 longitude. We assume that when Hera visits Didymos in 2026, because of better imaging(<1 m/pix), it will find a better feature for defining the PM.

We considered two main factors in selecting a feature to use to anchor the prime meridian. First, we used a feature that was large enough and easy enough to identify, usually via by patterns relative to other surface features that make it easily recognized. Second, we selected a feature near the equator to minimize correlation of the Prime Meridian with the pole orientation.

Figure 1 shows the boulder chosen to anchor the prime meridian of Didymos in unprojected DRACO images. LICIAcube did not readily see the PM anchor feature. A yellow arrow points to the chosen boulder. Table 1 gives the pixel-line location (with pixel [0,0] as the origin) of this anchor rock. Figure 2 shows the boulder in DRACO images projected on the Palmer et al (2023) shape model, along with lines of latitude and longitude. A crest near the middle of anchor boulder defines the center of the feature. The prime meridian anchor feature is located at 1.9±0.3E, 5.8±0.3S.

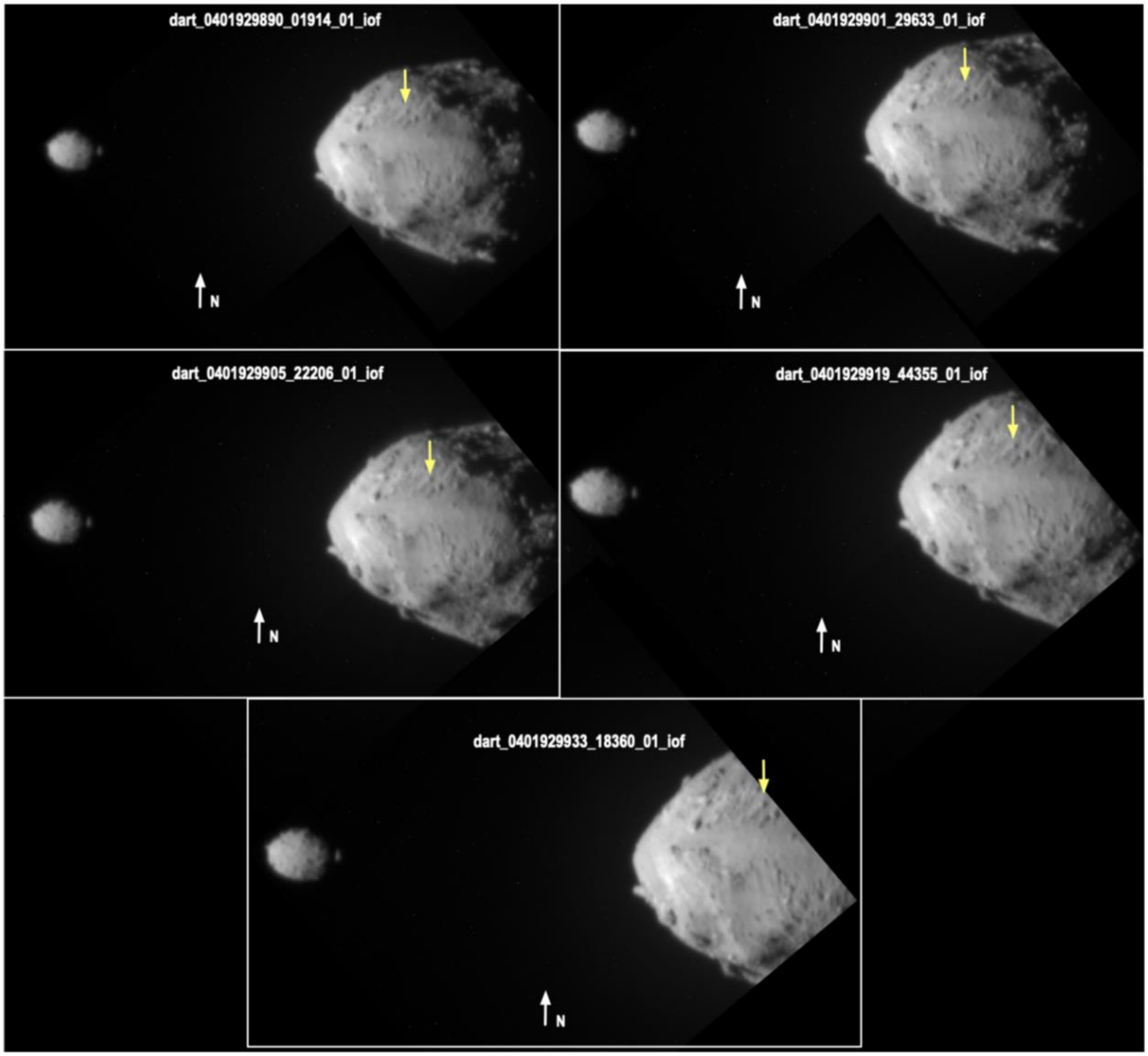

Figure 1. The boulder used to anchor the prime meridian of Dimorphos. This figure shows the chosen boulder (yellow arrow) in several unprojected DRACO images. The white arow indicates the direction of Dimorphos' north pole. See Table 1 for the pixel-line location of the boulder in these DRACO images.

Table 1: Pixel-line location of feature used to define prime meridian.

Image name	Pixel	Line
dart_0401929890_01914_01_iof.fits	407	616
dart_0401929901_29633_01_iof.fits	202	562
dart_0401929905_22206_01_iof.fits	216	534
dart_0401929919_44355_01_iof.fits	349	514
dart_0401929933_18360_01_iof.fits	339	330

The chosen PM anchor is defined as the top of a ~ 22 m boulder that is the most northward (+Z direction of the shape model) of a set of 4 boulders located just northward of the equator, which together create a diamond. This diamond feature is easy to spot in low to moderate-resolution images and will aid identification of the anchor rock in images taken by future spacecraft with different lighting conditions. The largest boulder lies to the South-East (where N is in the +Z direction of the shape model) of the anchor rock and is ~22m in diameter. The center of this boulder is located at ~6.07 °E, 1.79 °N. The boulder defining the southern tip of the diamond is ~17m in diameter and is located at ~2.98°E, 0.417 °S. The last of four boulders defining the diamond shape is ~ 19 m in diameter and is located at ~359.02°E, 2.064 °S.

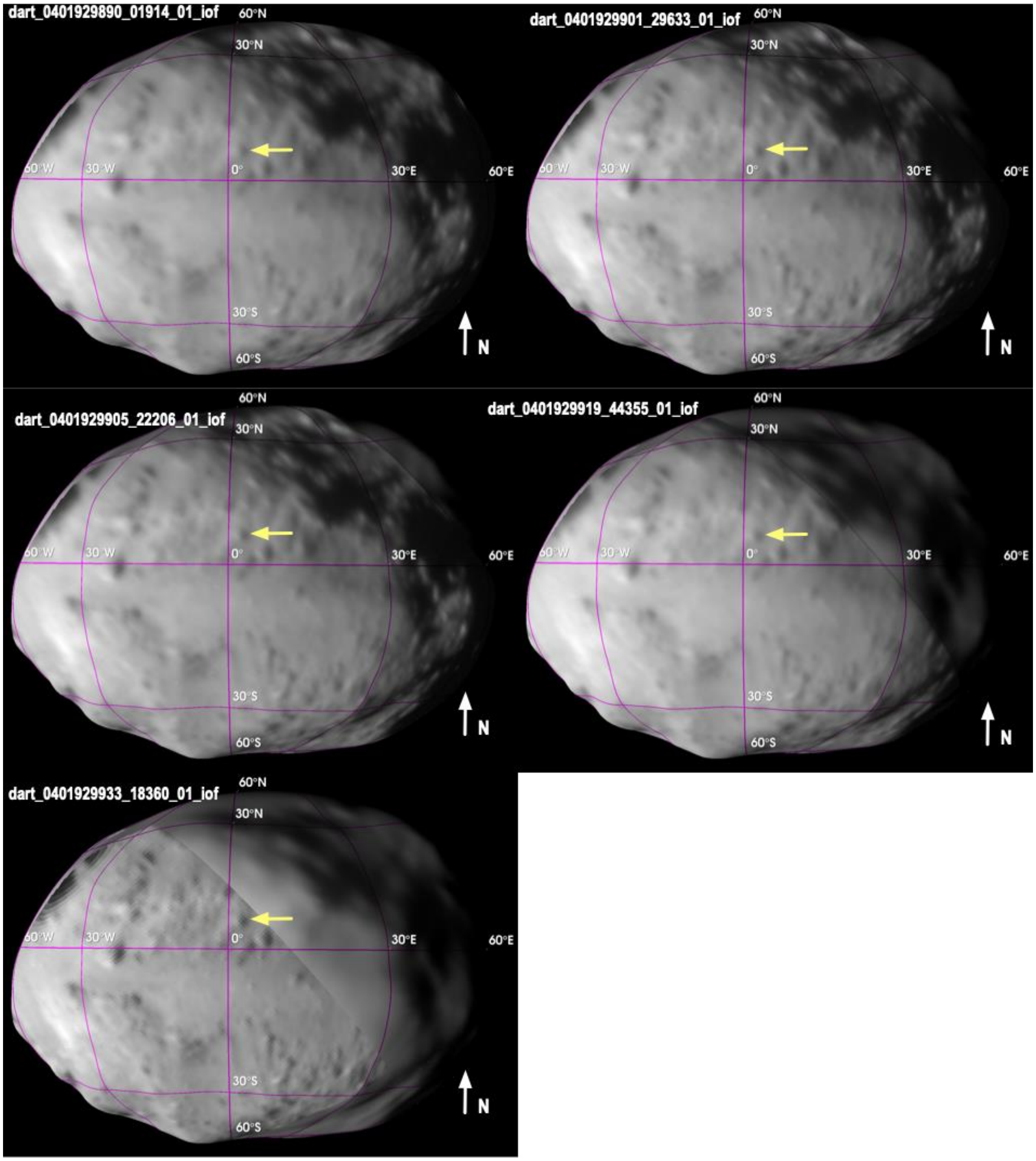

Figure 2. Location of Prime Meridian anchor rock for Didymos, located at 1.9±0.3E, 5.8±0.3S. in several DRACO images projected onto the Palmer et al. (2023) global shape model. The Prime Meridian anchor rock is at the top (most northward; +Z direction of the shape model) of a diamond delineated by four larger boulders. The diamond is easy to identify with its four boulders at its points: the PM anchor to the north (+Z direction of the shape model), a smaller 17 m boulder to its south (-Z direction of the shape model), a Optima

3. Pole Description

Using the International Celestial Reference Frame (ICRF; Archinal et al., 2018) Dimorphos' rotation state is modeled with $\{\alpha, \delta, W_0 + W_1 \Delta t + W_2 \Delta t^2\}$, where α represents the spin pole right ascension, δ represents the spin pole declination, W_0 represents the prime meridian angle, W_1 represents the rotation rate, and Δt represents the time elapsed since J2000 = JD 2451545.0,i.e. 2000 January 1 12 hours TDB (Barycentric Dynamical Time).

The initial set of pole parameters of Didymos are given in Table 2. They are the result of data collected from ground-based telescopes between 2016 and 2023. Table 2 also reports the equivalent spherical body radius, R, of Didymos, and its best fit ellipsoid, with semi-major a, b and c extends along the shape model's X, Y, Z axes, respectively**.** These constants along with their history are archived in the PDS in the DART SPICE archive as a Planetary Constants Kernel (PCK; didymos_system_14.tpc).

Table 2. Dimorphos coordinate systems for the DIDYMOS-MODEL-v003 shape models.

α [deg]	δ [deg]	W_0 [deg]	W_1 [deg/day]	W_2 [deg/day^2]	R [km]	a [km]	b [km]	c [km]
66.83 ±0.05	-73.0 ±0.3	0.0	3823.00±0.17	0.0	0.365 ±0.0085	0.4095 ±0.007	0. 4005 ±0.007	0.03035 ±0.007

4. References

Archinal, B.A. et al., 2018. Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements: 2015. *Celestial Mechanics and Dynamical Astronomy*, 130(3), pp.22–46.

Davies, M.E., Batson, R.M., 1975. Surface coordinates and cartography of Mercury. J. Geophys. Res. 80, 2417–2430. doi:10.1029/JB080i017p02417.

Palmer, E.E., et al., 2023 Digital Elevation Model of Didymos from DART and LICIACube, Asteroid, Comet and Meteorite Conference, LPI Contrib. No. 2851, Abstract #2466.