A Peek At *Cassini* After 7 Years In Saturn Orbit

After becoming humankind's first artificial satellite of Saturn on 1 July 2004, the *Cassini* orbiter shared headlines with its companion spacecraft *Huygens* until the latter reached the surface of Saturn's largest moon Titan on 14 January 2005. Since then, *Cassini* has continued to observe Saturn, its rings, its moons, and its magnetosphere. Mission status, together with a wealth of imagery and other discoveries enabled by these observations, can be accessed at http://saturn.jpl.nasa.gov/home/index.cfm.

Trajectory design strategy supporting *Cassini*'s tour of the Saturn system is driven by two astrodynamic precepts. First, node placement with respect to Saturn's equatorial plane is critical to orbiter survival and mission success. Both ring material and Saturn's retinue of major moons lie within a few degrees of this plane[1]. Consequently, the distances from Saturn at which *Cassini* crosses the equatorial plane must be chosen with care to avoid catastrophic collisions and to obtain close-up observations of major moons. Furthermore, one of the nodes must never stray very far from 1,221,870 km, the mean distance of Saturn's largest moon Titan from the planet's center. Only Titan has sufficient mass to provide gravity assists making *Cassini*'s tour possible with the orbiter's limited propulsive capability.

The second precept relating to *Cassini* tour strategy is the orbiter's inclination with respect to Saturn's equatorial plane. *Cassini*'s as-flown and planned inclination is plotted in Figure 1.

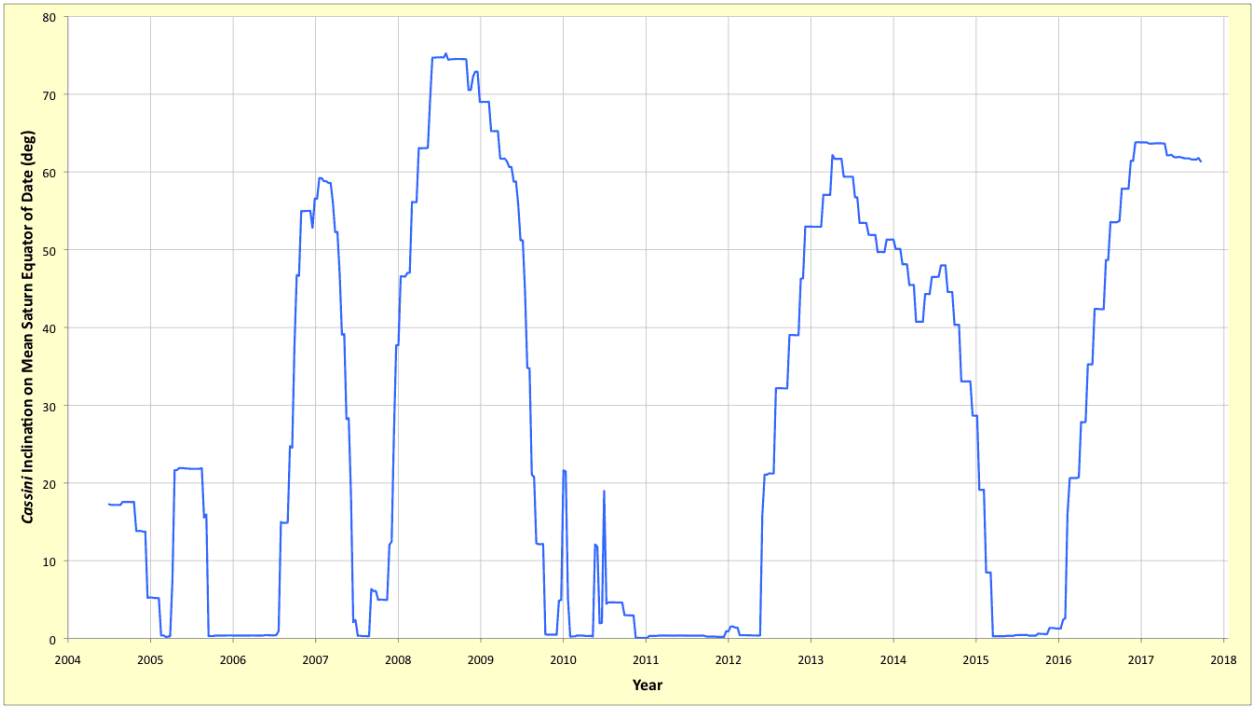

Figure 1. *Cassini* inclination with respect to Saturn's equatorial plane from Saturn orbit insertion in 2004 until planned mission termination in 2017. Each increment in inclination results from a Titan gravity assist.

[1] The most highly inclined major moons of Saturn are Mimas (inclination of 1.572°) and Iapetus (inclination of 7.489°). *Cassini* generally orbits between these two moons, whose mean distances from Saturn are 185,540 km and 3,560,840 km, respectively. All orbit and trajectory data supplied in this article are obtained from Jet Propulsion Laboratory's (JPL's) *Horizons* ephemeris computation system (accessible at http://ssd.jpl.nasa.gov/?horizons).

When *Cassini* inclination is nearly zero, encounters with moons other than Titan are practical. During close approaches to Enceladus, *Cassini* has determined this moon is continually spewing briny ice from its south polar region, as depicted in Figure 2.

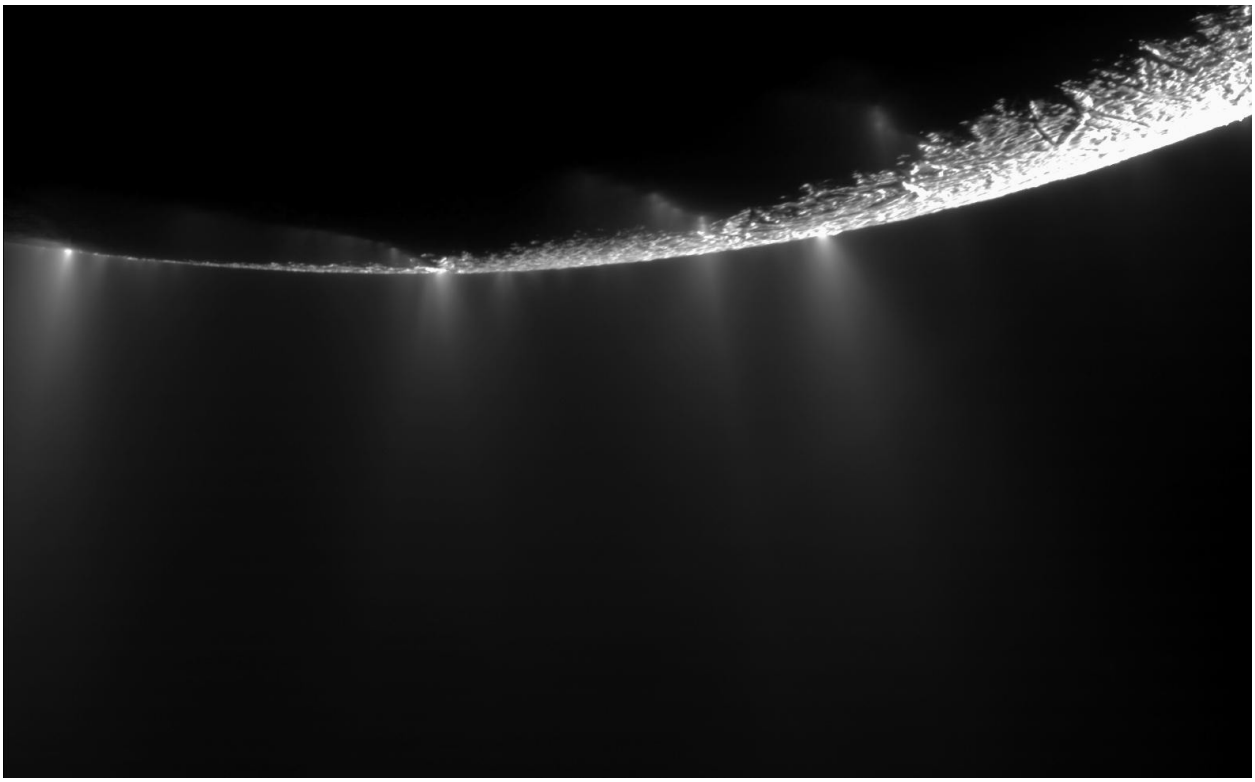

Figure 2. *Cassini* imaged briny ice plumes near the south pole of Saturn's moon Enceladus on 23 February 2010. Image PIA11688 credit NASA/JPL/Space Science Institute (SSI).

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From a perspective near Saturn's equator, major moons can undergo mutual transits per the Figure 3 *Cassini* image. These geometries are much more likely to arise at lower orbit inclinations. In addition to their aesthetic appeal, images of such transits contribute to improved accuracy associated with the moons' ephemerides.

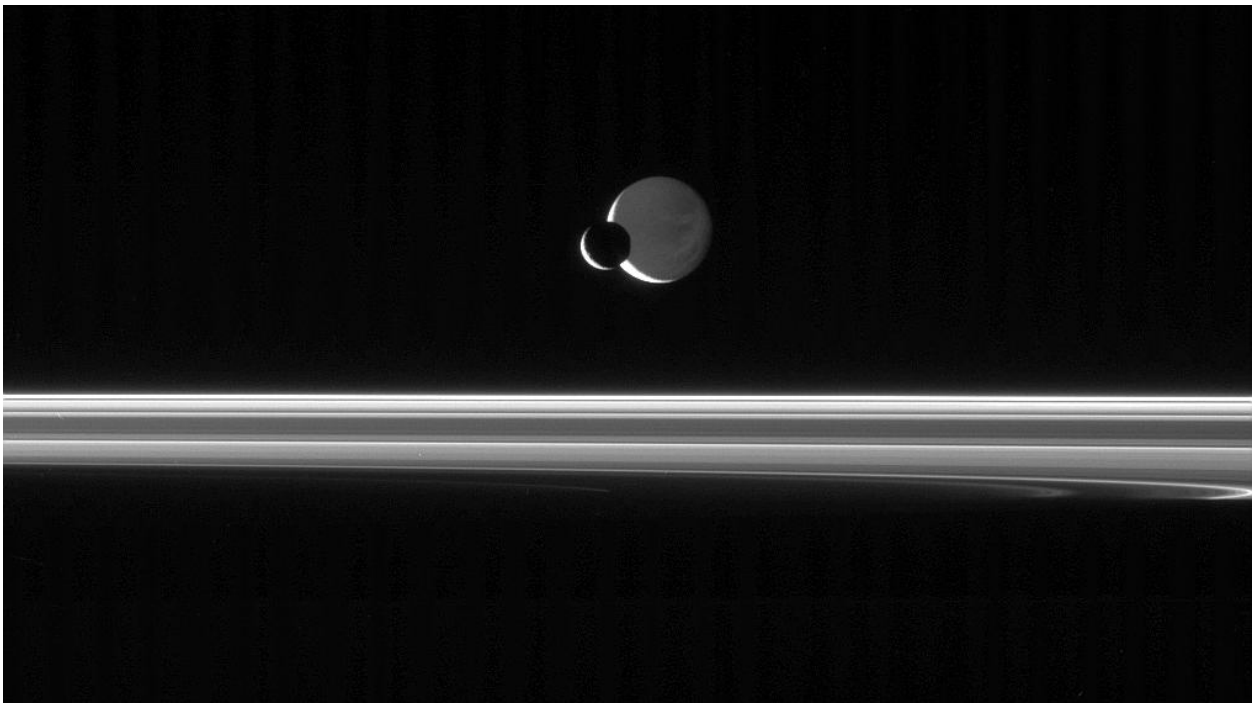

Figure 3. Mimas is seen transiting Dione from *Cassini* on 3 July 2006. Saturn's rings disappear into the planet's shadow at bottom. When this image was obtained, *Cassini* was located just "above" the rings' plane at 0.5° north latitude with respect to Saturn's equator. Because Mimas was located between *Cassini* and Saturn at this time, its nightside was only illuminated by starlight. In contrast, Dione was located across Saturn and its rings from *Cassini*, and its nightside was illuminated by reflected sunlight from the planet's dayside. Image PIA08228 credit NASA/JPL/SSI.

The Figure 3 perspective near Saturn's equatorial plane provides a nearly edge-on and highly foreshortened view of the planet's rings. In contrast, Figure 4 is an example of perspective from well south of Saturn's equator. Observations of polar regions and most ring dynamics are therefore only practical with *Cassini*'s orbit at higher inclinations.

Figure 4. *Cassini* obtained this true color Saturn mosaic on 6 October 2004 from 18° south latitude. Note Saturn's shadow on the rings, the rings' shadow on Saturn, and the blue tint in Saturn's atmosphere at high northern latitudes during local winter. These are features difficult or impossible to view from Earth. Image PIA06193 credit NASA/JPL/SSI.

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As the year 2011 draws to a close, Figure 1 indicates *Cassini* is about to end an extended period of low inclination observations. This orbit geometry enables a Dione encounter on 12 December, followed by a Titan encounter the next day, as illustrated in Figure 5. The Dione encounter is plotted relative to Dione in Figure 6, and the Titan encounter is plotted relative to Titan in Figure 7.

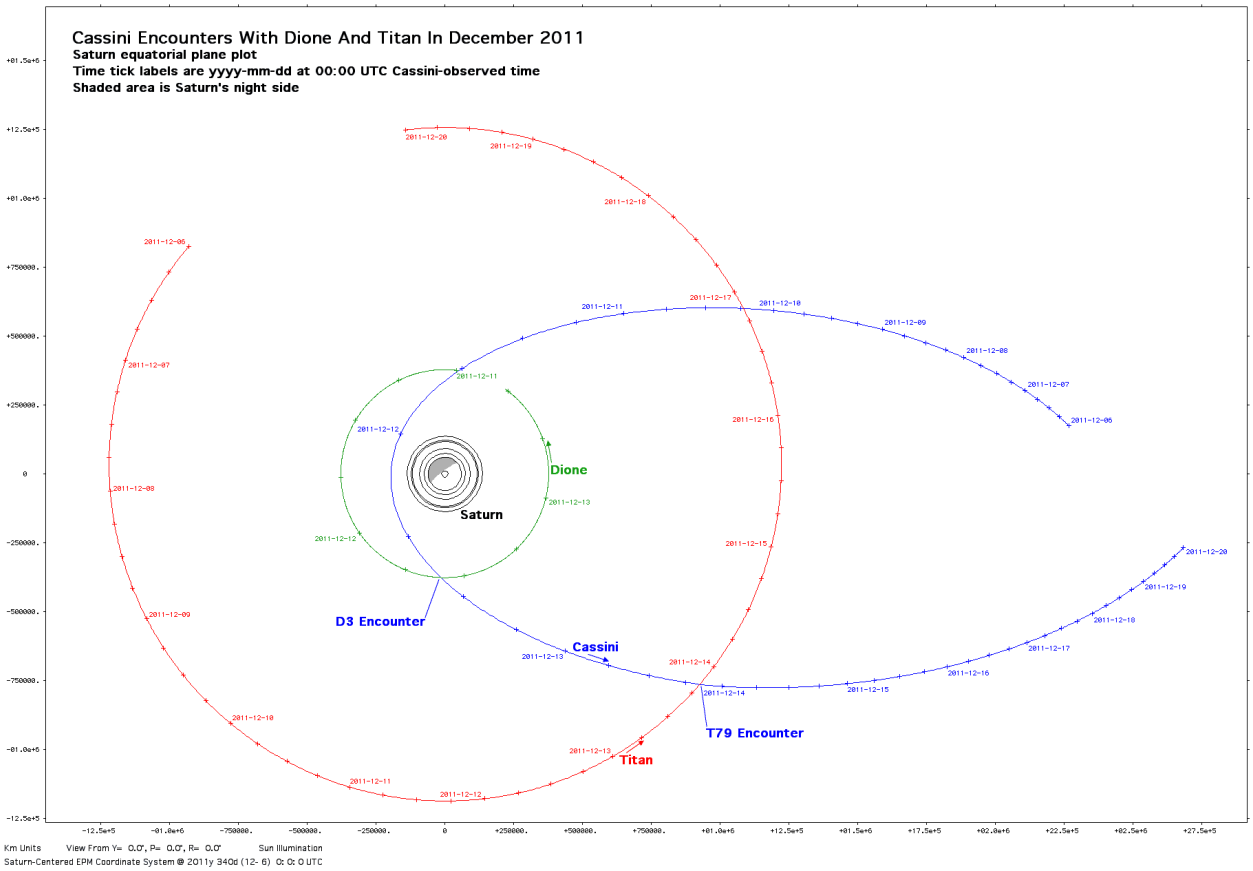

Figure 5. Mid-December 2011 *Cassini* encounters with moons Dione and Titan are plotted with respect to Saturn in the planet's equatorial plane. Although the Dione encounter has little effect on *Cassini*'s orbit, the Titan encounter noticeably raises apochrone (*Cassini*'s maximum distance from Saturn).

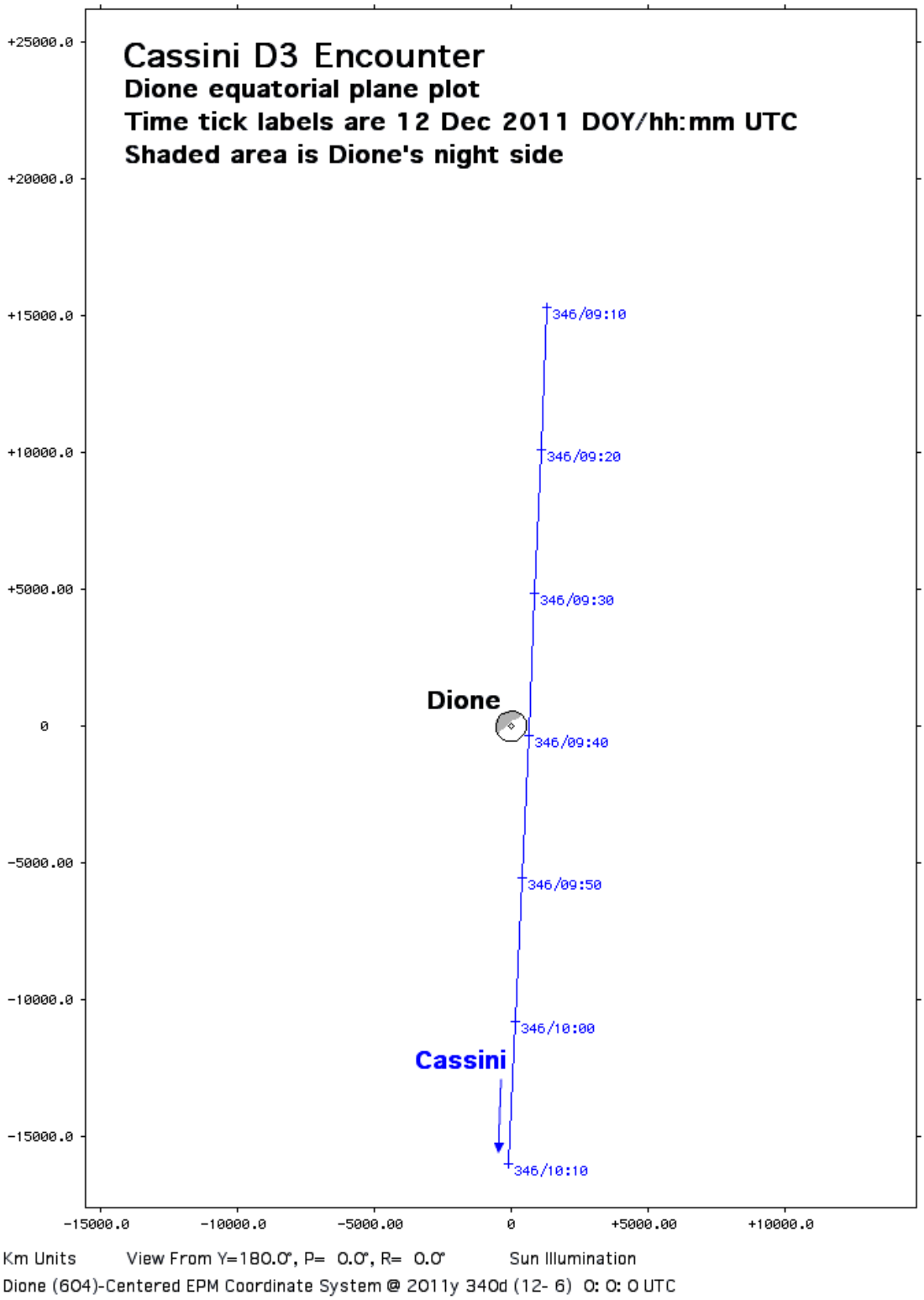

Figure 6. The "D3" Dione encounter is plotted relative to Dione in that moon's equatorial plane (parallel to that of Saturn) in nearly the same inertial orientation as Figure 5. *Cassini*'s trajectory is indistinguishable from a straight line, indicating Dione exerts very little gravity perturbation, even with *Cassini*'s periapsis height targeted at only 99 km.

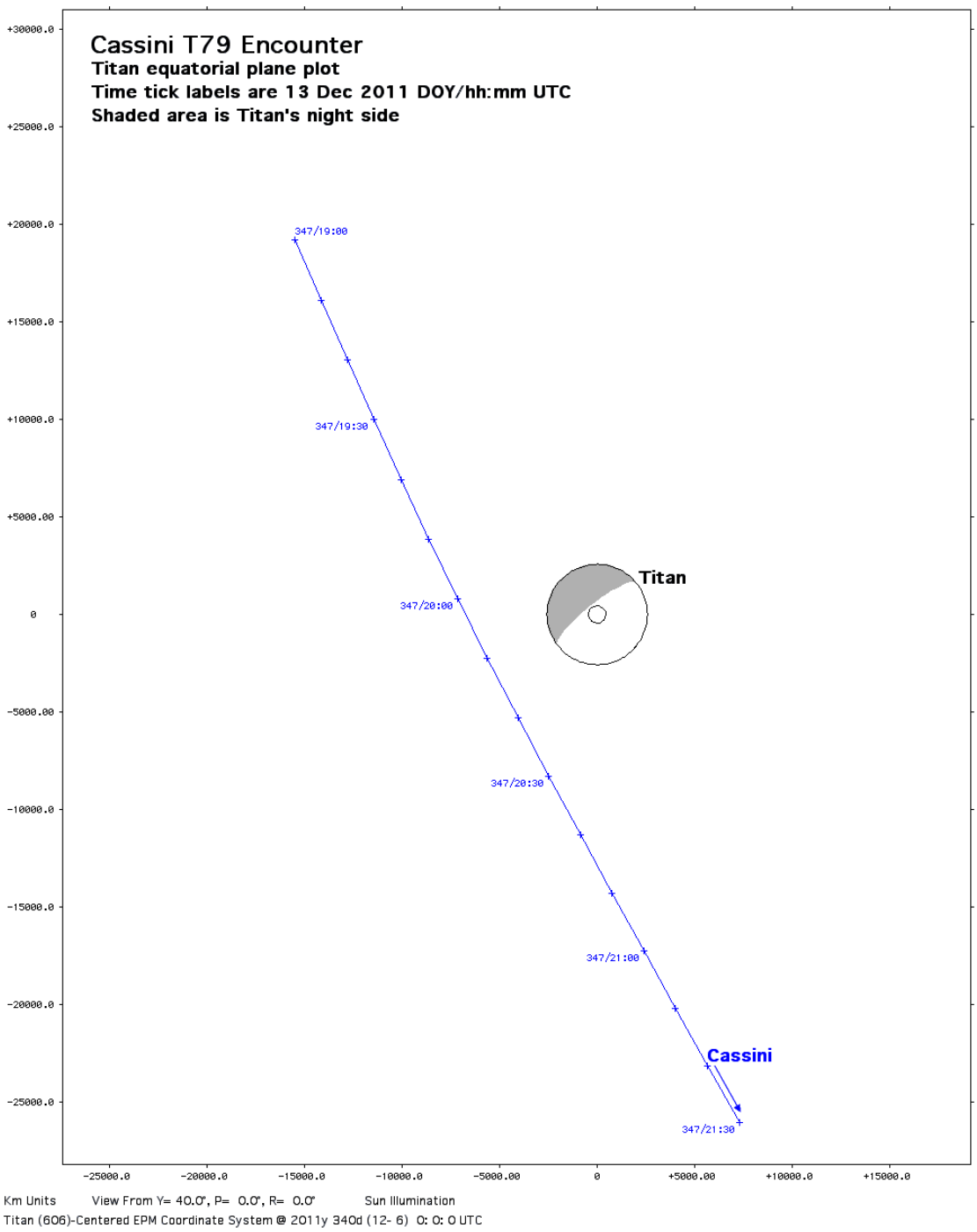

Figure 7. The "T79" Titan encounter is plotted relative to Titan in that moon's equatorial plane (parallel to that of Saturn) in nearly the same inertial orientation as Figure 5. Because *Cassini* periapsis is over the trailing hemisphere of Titan in its Saturn orbit, angular momentum is transferred from the moon to the orbiter, increasing its apochrone. This transfer is evident as a small deviation in *Cassini*'s heading in the direction toward Titan, resulting in greater speed with respect to Saturn immediately after the encounter than immediately before it. Since Titan periapsis falls very near Titan's equator, low inclination with respect to Saturn's equator is preserved throughout the Titan encounter.