Extended Abstract

Cassini Tour Redesign for the Huygens Mission

Nathan J. Strange,* Troy D. Goodson,† and Duane C. Roth‡

Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109-8099

The Cassini spacecraft will arrive at Saturn in 2004 carrying the Huygens probe which will descend into the atmosphere of Saturn's moon Titan. The beginning of the Cassini tour has been redesigned in order to work around the probe relay problem that was discovered during tests in February 2000. An extra 32-day orbit has been inserted at the beginning of the tour, and the orbiter altitude has been increased during the probe delivery flyby. This paper details the changes to the tour, including the mission design, maneuver analysis, and orbit determination for the tour.

Introduction

Cassini-Huygens was launched October 15, 1997 and is currently enroute to arrive at Saturn in 2004, having flown by Jupiter on December 30, 2000. Cassini will be the first spacecraft to orbit Saturn and carries the Huygens probe which will be the first spacecraft to descend through the atmosphere of Saturn's moon Titan.

In February 2000, it was discovered that the bit synchronizer of the Huygens receiver onboard the Cassini orbiter has a bandwidth that is too small to accommodate the Doppler shift of the relay signal. In order to recover the probe mission[1], the Cassini tour at Saturn has been redesigned to reduce the Doppler shift between the orbiter and the Huygens probe. The altitude of the orbiter on the probe delivery encounter is raised so that the radial component of the orbiter's velocity relative to the probe is reduced, and hence the Doppler shift of the relay signal is also reduced.

Changes to The Tour

The previously-baselined tour[2,3] (T18-5) has largely been maintained with changes limited to the beginning of the tour. The first two flybys of the T18-5 tour (T1 and T2) have been replaced with three new flybys (Ta, Tb, and Tc). The probe delivery was

* Engineering Staff, 818.393.1165, nathan.strange@jpl.nasa.gov, FAX: 818.393.4215, Member AIAA
† Engineering Staff, 818.393.7887, troy.goodson@jpl.nasa.gov, FAX: 818.393.4215, Member AIAA
‡ Engineering Staff, 818.393.0613, duane.roth@jpl.nasa.gov, FAX: 818.393.4215

originally on the 1200 km altitude T1 flyby and has now been moved to a distant flyby (with an altitude of 50,000 km to 65,000 km) on Tc. Figure 1 compares the beginning of the original tour to the beginning of the new tour:

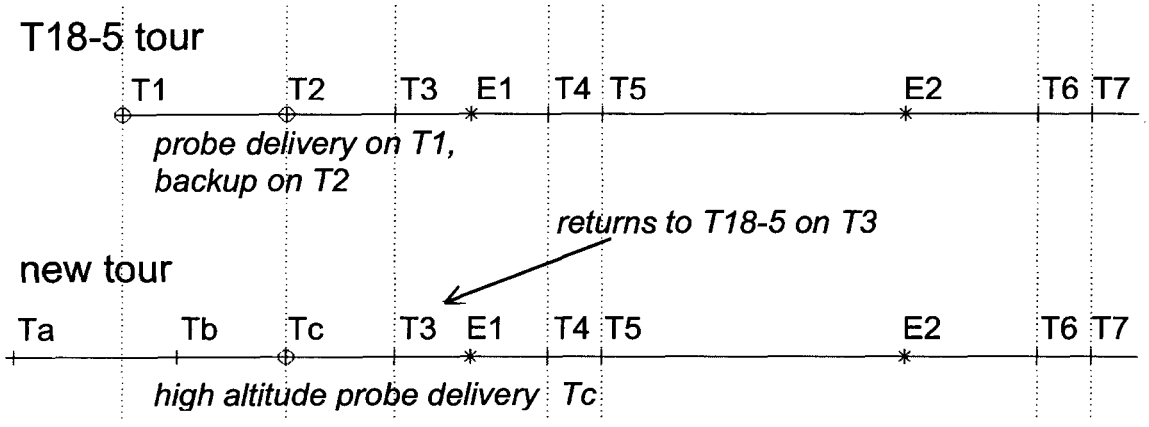

Figure 1: Comparative Timelines

The distant probe delivery flyby (i.e. Tc) does not provide sufficient ΔV to change the Saturn relative orbit period after the flyby. So the orbit after Tc must be the same period as the orbit before, 32 days. The new tour arrives at the first flyby 32 days earlier than the T18-5 tour and allows time to insert an extra 32 day orbit from the distant flyby and still return to the T18-5 tour by the third flyby of T18-5, T3. The first Titan encounter, Ta, is moved earlier by increasing the size of SOI (Saturn Orbit Insertion) and PRM (Periapsis Raise Maneuver) to reduce the orbit period before the Ta encounter.

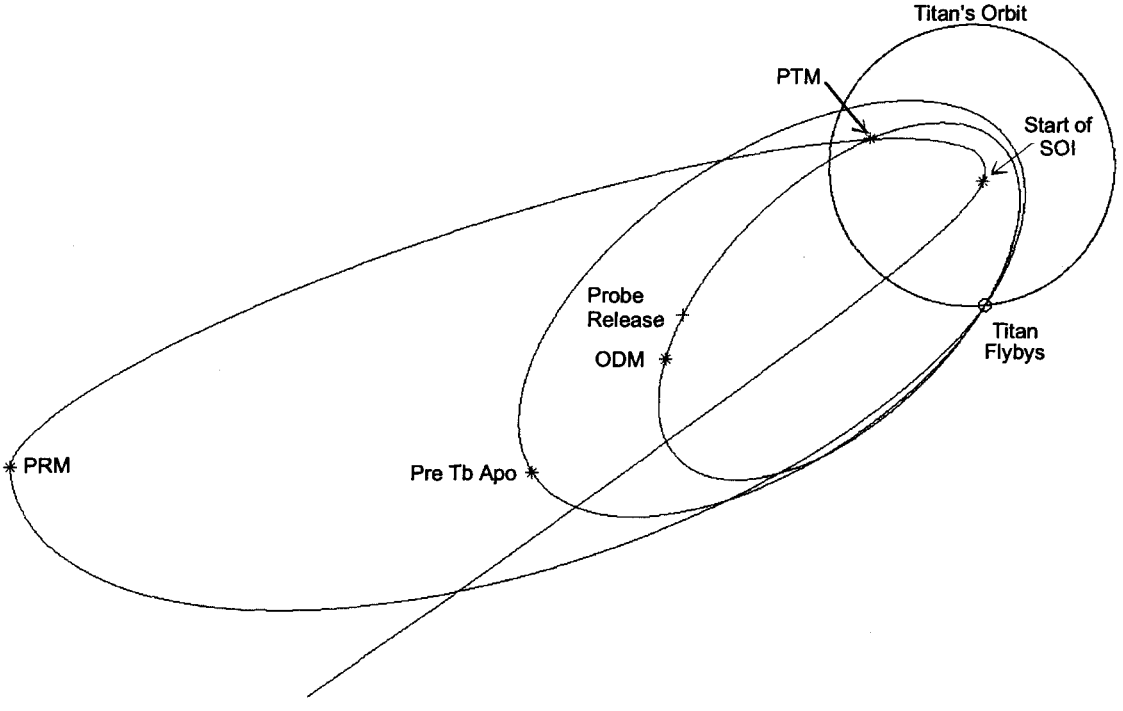

Figure 2: First Three Orbits of New Tour

Figure 2 illustrates the first three orbits of the new tour leading up to the probe delivery on the Tc flyby. The SOI and PRM maneuvers capture Cassini at Saturn and set up the Ta flyby. A small maneuver at the apoapsis of the 48 day period orbit after Ta then targets the Tb encounter which reduces the orbit period around Saturn to 32 days for the probe delivery orbit.

Analysis

The paper will detail the design and analysis of these changes to the Cassini tour. We will discuss the mission design process and the trades involved in coming to the current tour design. We will also discuss the design and placement of the maneuvers in the new tour, and we will discuss the impact of the placement of these maneuvers on orbit determination of the spacecraft and the fuel budget.

Although the general shape of the tour and the strategy for recovering from the probe relay link problem has been chosen, several details of the probe mission are to be finalized this spring. The paper will report on the changes to the tour as of this summer and will discuss any options still being reviewed.

References

[1]"Huygens Recovery Task Force Final Report," ESA Report: HUY-RP-12241, July 27, 2001, (Internal Document).

[2]Smith, J. C., "Description of Three Candidate Cassini Satellite Tours," Paper AAS 98-106, Monterey, CA, Feb.9-11, 1998.

[3]Wolf, A. A. and Smith, J. C., "Design of the Cassini Tour Trajectory in the Saturnian System", Journal of International Federation of Automatic Control (IFAC), Vol. 3, No. 11, pp. 1611-1619, 1995.