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ADDITION OF A LOW ALTITUDE TETHYS FLYBY TO THE NOMINAL CASSINI TOUR

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ABSTRACT

Of the eight Saturnian icy satellites, all but Mimas and Tethys have low altitude targeted flybys during the 4-year nominal Cassini spacecraft tour. In November 2004, the existence of a potential low-altitude Tethys flyby was discovered; this low-altitude Tethys flyby, added to the nominal tour in March 2005, corresponds to a 1500 km non-targeted periapsis altitude on September 24, 2005 and requires a Δv cost of 8 m/s. This paper details the methods used to determine the Tethys non-targeted flyby altitude, driven by navigational requirements and operational constraints, in addition to several trajectory modifications implemented to reduce total Δv costs, and in some cases, simultaneous increases in scientific return.

INTRODUCTION

The 4-year nominal Cassini spacecraft tour of the Saturnian system, the most complex gravity-assist tour ever flown, consists of 45 targeted Titan flybys and eight targeted icy satellite flybys (including a pre-Saturn Orbital Insertion (SOI) Phoebe flyby) [1]. In addition to scientific importance, Titan flybys are needed to manipulate the Cassini spacecraft orbital geometry to meet varying scientific objectives. This stems from the fact that Titan is the only Saturnian satellite sufficient in mass to provide useful gravity-assists. As a result, targeted icy satellite flybys must be incorporated in Titan-to-Titan transfers if and when desirable icy satellite periapsis distances coincide [2]. This constraint renders targeted icy satellite flybys difficult to obtain, and based on nominal reference trajectory statistics, requires an average Δv cost of approximately 18 m/s per encounter.

Of the eight Saturnian icy satellites, (Mimas, Enceladus, Tethys, Dione, Rhea, Hyperion, Iapetus, and Pheobe), all but Mimas and Tethys have low altitude targeted flybys in the nominal primary mission. Hence, one of the primary goals to meet icy satellite scientific objectives [3] in the extended mission would be to perform low altitude flybys of Tethys and/or Mimas.

While investigating the feasibility/existence of low Δv cost trajectory options to reduce the September 23, 2005 E-ring crossing impact probability (most dangerous ring crossing during the Cassini spacecraft's 041210 nominal reference trajectory), the existence of a potential low-altitude Tethys flyby was discovered [4]; This low-altitude flyby (1500 km) could be added to the nominal tour for approximately 8 – 20 m/s depending on how localized the trajectory deviations.

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This paper details the methods used to determine the minimum Tethys non-targeted flyby altitude, driven by navigational requirements and operational constraints, in addition to several modifications implemented to reduce total Δv costs, and in some cases, simultaneous increases in scientific return.

ANALYSIS

A simplified graphical depiction of the T7 – T8 localized sequence of events are illustrated in Figure 1 (also listed in Table 1). As can be seen in Fig. 1, there is a non-targeted Tethys flyby located between OTM-034 (last opportunity to correct B-plane aim point variations in order to meet H1 pointing requirements) and the outbound 1000 km Hyperion flyby (H1). Originally, the Tethys flyby occurred on September 24, 2005 01:3713 ET having a periapsis altitude of 29,800 km. It was found this periapsis altitude could be arbitrarily lowered while incurring reasonable Δv costs (Fig. 2).

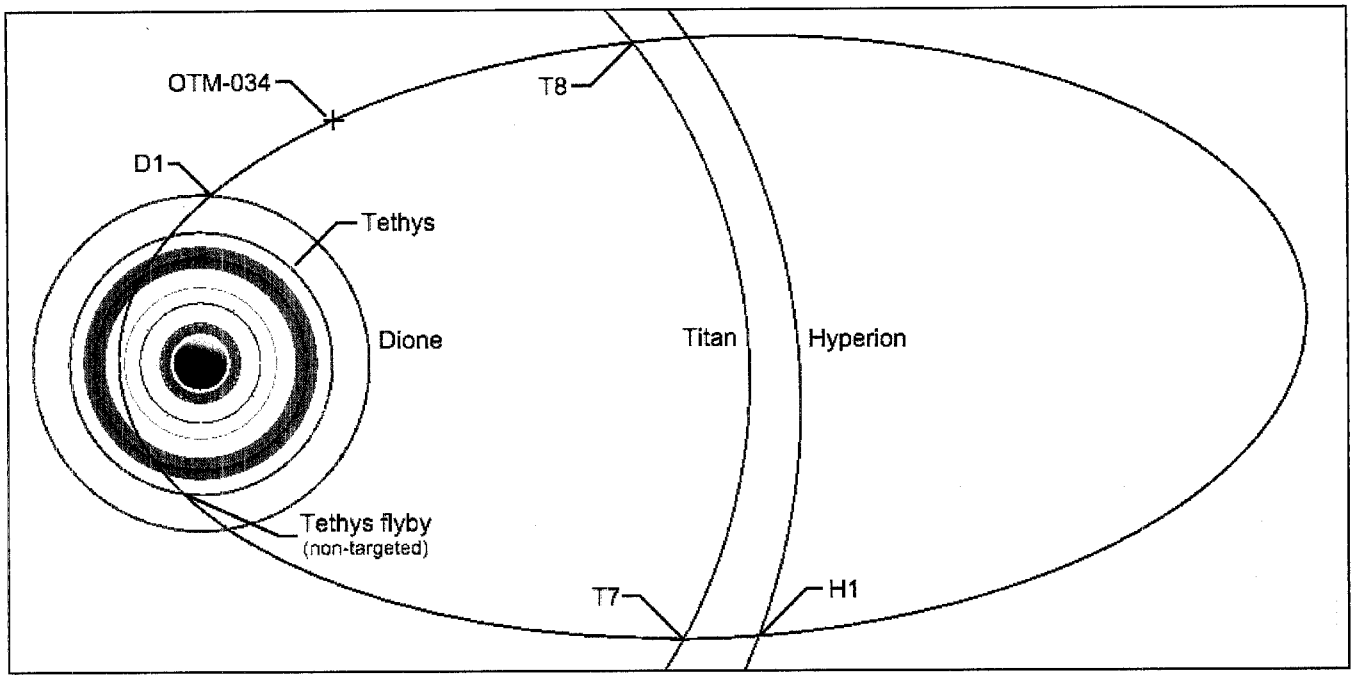

Figure 1: Graphical representation of T7 – T8 local sequence of events summarized in Table 1.

Table 1: T7 – T8 local sequence of events.

Event	Rev	Date (ET)	Description
T7/14Ti		**07-Sep-2005 08:01:50**	**Outbound 1025 km targeted Titan flyby**
OTM-032	14	10-Sep-2005 17:10:04	T7 Clean-up maneuver (T7 + 3d)
OTM-033		19-Sep-2005 16:41:04	Rev-14 apoapsis maneuver
OTM-034		*23-Sep-2005 07:46:04*	*Statistical H1 approach maneuver*
H1/15Hy	15	**26-Sep-2005 01:47:14**	**Outbound 1000 km targeted Hyperion flyby**
OTM-035		28-Sep-2005 16:12:04	H1 Clean-up maneuver (H1 + 3d)
OTM-036		01-Oct-2005 13:32:04	Rev-15 apoapsis maneuver
D1/16Di		**11-Oct-2005 18:00:44**	**Inbound 500 km targeted Dione flyby**
OTM-038	16	12-Oct-2005 16:46:04	D1 Clean-up maneuver (D1 + 1d)
OTM-039		21-Oct-2005 14:59:04	Rev-16 apoapsis maneuver
T8/17Ti	17	**28-Oct-2005 04:05:01**	**Inbound 1458 km targeted Titan flyby**

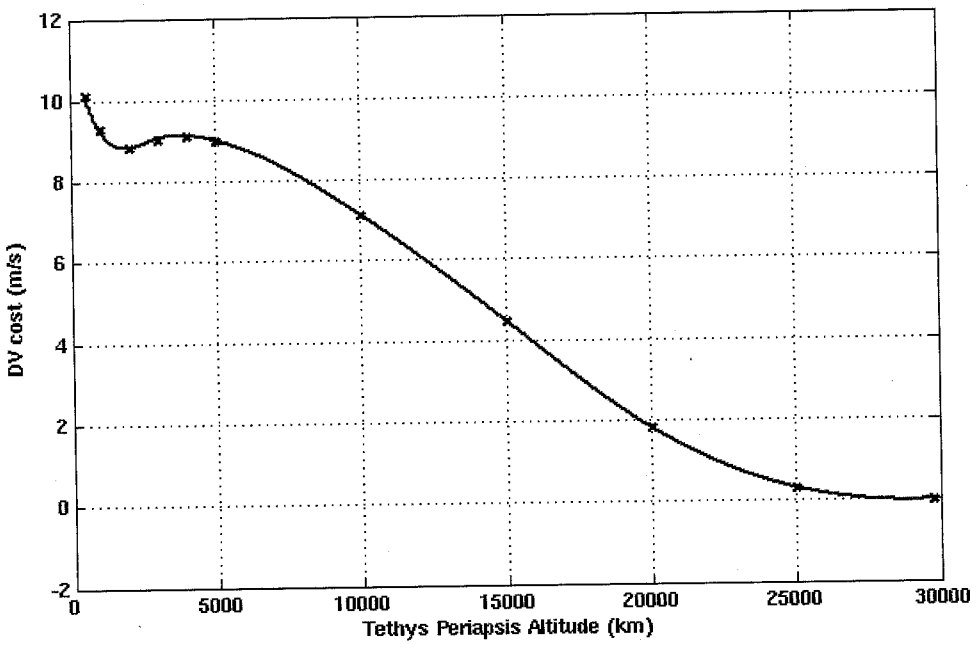

Figure 2: Δv cost associated with lowering Tethys periapsis altitude.

From here the paper will explain in detail a first-order preliminary determination of the minimum Tethys flyby periapsis using OTM-034 covariance analysis for B-plane uncertainties mapped to H1 corresponding to the nominal trajectory, estimates of H1 B-plane uncertainties associated with the Tethys gravity-assist (due to flyby altitude deviations), and H1 pointing requirements. The minimum Tethys flyby altitude will then be verified with an updated (most current satellite, planet, and spacecraft ephemeredes) high-fidelity covariance analysis.

The paper will also address targeted flyby altitude and timing shifts along with Saturn periapsis time shifts associated with the addition of the low altitude Tethys flyby, and additional Δv costs associated with minimizing downstream effects, essentially localizing major trajectory deviation from T6 thru T9.

Lastly, additional T7 – T8 trajectory variations will be addressed which helped minimize total Δv costs while also increasing the scientific return.

ACKNOWLEDGEMENTS

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