

Extended Abstract – 10<sup>th</sup> AAS/AIAA Space Flight Mechanics Meeting  
January 23-26, 2000  
Clearwater, FL

## **Cassini Orbit Determination From First Venus Flyby to Earth Flyby**

Mark D. Guman  
Duane C. Roth  
Rodica Ionasescu  
Troy D. Goodson  
Anthony H. Taylor  
Jeremy B. Jones

*Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, CA*

The Cassini spacecraft was launched on October 15, 1997, on a mission to study the Saturnian system. The spacecraft's trajectory is characterized by a number of trajectory correction maneuvers (TCMs) along with gravity assists from two Venus flybys, an Earth flyby, and a Jupiter flyby before arriving at Saturn in July 2004 (Figure 1). After arrival at Saturn, the Huygens Probe will separate from the orbiter and descend through the atmosphere of Titan, Saturn's largest moon, and land on its surface. The orbiter will begin a four year tour of the Saturnian system, with multiple close encounters of Titan and other satellites. A previous paper [Ref. 1] addressed Cassini orbit determination conducted from launch through the first Venus flyby. This paper covers the period from just past the first Venus flyby through the Earth flyby – from May 1998 to September 1999.

Accurate orbit determination is necessary to maintain the nominal trajectory of the spacecraft. It also facilitates efficient usage of spacecraft propellant, allows for safe navigation during flybys of solar system bodies, and helps characterize maneuver execution performance. Three maneuvers were executed between the first and second Venus flybys, four were executed between the second Venus flyby and the Earth flyby, and one was executed just after the Earth flyby. These maneuvers were implemented either as part of the trajectory design (deterministic maneuvers) or to correct significant deviations from the nominal trajectory (statistical maneuvers). Nominal and reconstructed values of these maneuvers will be presented along with the associated uncertainties.

# CASSINI INTERPLANETARY TRAJECTORY

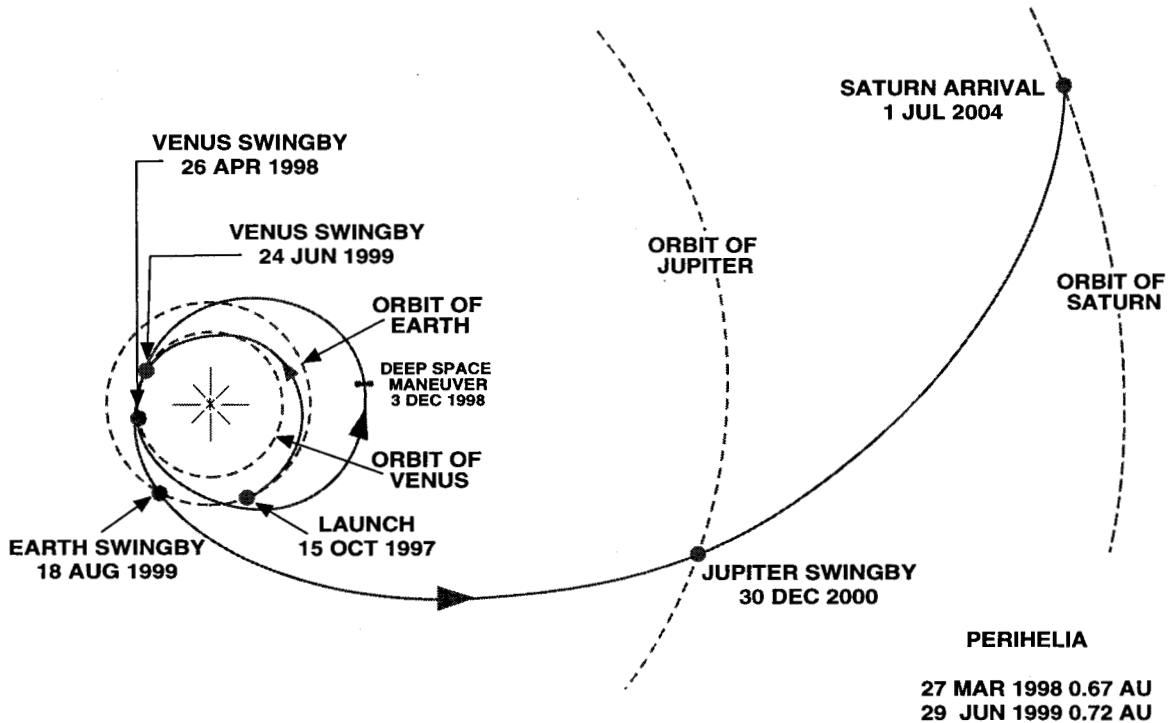


Figure 1. Cassini Interplanetary Trajectory

Two planetary flybys occurred within the period covered in this paper – one of Venus and the other of Earth. Orbit determination reconstruction of each encounter resulted in estimates of time and location of the closest approach events. The Venus flyby was determined to occur at 24 June 1999 20:29:29 UTC at an altitude of 387 km above the surface. The Earth flyby was estimated to be 18 August 1999 03:28:26 UTC at an altitude of 1175 km. The flyby locations and times of these encounters were well within mission delivery requirements.

Orbit determination during this leg of the Cassini mission may be characterized by refining estimates of the spacecraft state and dynamical model parameters using *a priori* information, telemetry, and X-band Doppler and range tracking data. The accuracy of these refinements depends upon the geometry of the trajectory and the quality and quantity of radiometric data measurements. Many of these improved models will allow the spacecraft to be navigated more efficiently in future phases of the mission.

Spacecraft telemetry has been used in the orbit determination process to identify the presence and nature of increased attitude control thrusting immediately following

maneuvers. In observing telemetry data associated with uncoupled thruster activity on the spacecraft, the duration and profile of such accelerations have been modeled more accurately. Correlation between post-maneuver accelerations and maneuver characteristics such as turn angle and burn magnitude will be addressed. Characterization of smaller  $\Delta V$  events such as reaction wheel assembly (RWA) exercises and attitude control deadband tightenings will also be presented.

Finally, conclusions concerning orbit determination performance will be addressed. Discussion will center primarily on orbit solutions made in operational support of maneuver designs. These solutions and their associated uncertainties will be compared with the best-determined spacecraft orbit reconstructed with radiometric data from the first Venus flyby through the Earth flyby.

### **Acknowledgments**

The research described in this paper was performed by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

### **References**

1. Roth, D. C., M. D. Guman, R. Ionasescu and A. H. Taylor, "Cassini Orbit Determination From Launch to the First Venus Flyby", AIAA 98-4563, AIAA/AAS Astrodynamics Specialist Conference, Boston, MA, August 10-12, 1998.