Titan Atmospheric Density Estimation Results from Cassini's T107 Flyby

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This work explores the variation of Titan's atmospheric density using orbit determination results from Cassini's T107 flyby of Titan in December 2014. The Cassini-Huygens mission launched in 1997 and the Cassini spacecraft has been in orbit about Saturn since 2004. Exploration of the Saturn system is driven by gravitational flybys of Titan which alter the spacecraft trajectory. Flybys of Titan are generally "in-the-blind" for navigation, meaning no tracking data is collected during close approach. The spacecraft does experience acceleration from Titan's atmosphere during low flybys of less than 1400 km altitude and a scale factor is estimated in the orbit determination process to adjust the nominal atmosphere model. The T107 flyby is the second opportunity of the mission after T87 to receive two-way Doppler tracking between NASA's Deep Space Network and the spacecraft through close approach of Titan. These flybys were chosen for this experiment due to the orientation of the High-Gain Antenna being near Earth-point. This data allows the Navigation team to estimate an updated density profile for Titan through the orbit determination process.

The methodology of orbit determination is used to determine Titan's atmospheric density, in which a navigation filter minimizes the differences between observed and computed Doppler observations in a least-squares sense. A specialized version of the standard orbit determination setup for Cassini is implemented in the Monte software developed by NASA's Jet Propulsion Laboratory. A data arc with Doppler tracks before and after the flyby at sixty second count-time and data through Titan close approach at one second count-time is used to adequately resolve the acceleration due to the atmosphere. Telemetry from the Reaction Control Subsystem is incorporated during the flyby to account for the thruster firings that counteract the atmospheric drag experienced by the spacecraft. The a priori density model is taken from the results of the first Titan density estimation experiment produced by the T87 flyby. The density model is broken up into layers such that the accumulated acceleration between layers is equal to ten times the noise in the Doppler residuals. Separate layer profiles are implemented for the inbound and outbound portions of the flyby allowing different density estimates on either side of close approach. The base densities at these layers are updated in the iterative least-squares process and the density between layers is computed from an exponential profile which enforces continuity at layer boundaries.

This paper details the different filter cases applied to the tracking data and compares the resulting atmospheric density profiles. Plots of Doppler residuals and density variation with altitude are shown and discussed. Estimates of the layered base densities and their formal uncertainties are documented. The Ion and Neutral Mass Spectrometer instrument directly sampled the atmospheric density during the flyby and the Attitude and Articulation Control Subsystem team also produced density estimates based on the drag torque exerted on the spacecraft. These results and uncertainties are compared to the Navigation team's estimate of atmospheric density for the T107 and the previous T87 Titan flybys. The Navigation estimate of atmospheric density is used to calibrate the INMS instrument and provide a new best estimate of Titan's atmosphere for future orbit determination solutions.

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