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Orbit Determination of Stardust from the Annefrank Asteroid Fly-by through the Wild 2 Comet Encounter

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ABSTRACT

Stardust, the fourth mission flown under the National Aeronautics and Space Administration's Discovery Program, was launched on February 7, 1999 from Cape Canaveral, Florida. The primary objective of the Stardust mission is to collect comet dust particles during encounter with the comet Wild 2 in January 2004, and return these samples to Earth in January 2006. Stardust will perform additional science measurements during the comet fly-by, which include composition analysis of the comet particles in real-time, keeping count of the number of particles the spacecraft encounters, and taking pictures of the comet nucleus throughout the encounter. Stardust was designed, built, and is operated by Lockheed Martin Astronautics (LMA), Denver, CO. The California Institute of Technology's Jet Propulsion Laboratory (JPL) is responsible for mission management and spacecraft navigation. After executing a fly-by of the asteroid Annefrank in November 2002, Stardust is currently completing its second orbit around the Sun, heading for its main science mission target Wild 2. Spacecraft attitude-maintenance thruster firings and 2 solar conjunctions during this part of the trajectory introduce two navigation challenges to the orbit determination task.

Stardust is a 3-axis stabilized spacecraft and maintains its attitude by firing its 0.2 lb reaction control system thrusters (RCS thrusters) or by firing its 1.0 lb trajectory correction maneuver thrusters (TCM thrusters). The spacecraft has eight of each type of thruster and all are mounted on its bottom side, in four sets of clusters. Each cluster contains two RCS thrusters and two TCM thrusters; one thruster serves as the primary thruster and the other serves as the backup. This arrangement of having all thrusters on one side of the spacecraft causes Stardust to create unbalanced torques each time a pair of thrusters fire to maintain attitude. Thus, the spacecraft experiences a perturbing acceleration, which cannot easily be cancelled in the spacecraft Z-axis direction. The cumulative effect of these small forces is non-negligible and must therefore be modeled, estimated, and predicted. This acceleration is non-deterministic and is difficult to predict

accurately given the method by which the attitude is to be maintained; i.e., the method depends on which thrusters are firing, the duration of the pulses, and the degree tolerance to which attitude is maintained.

The second challenge, which must be overcome during this inbound leg to the comet Wild 2, is the 2 solar conjunctions of Stardust with respect to the Earth. During the 14-month period from the asteroid Annefrank fly-by to the comet encounter, Stardust has a Sun-Earth-Probe (SEP) angle of less than 10 degrees for over 56% of the time; i.e., the spacecraft is within 10 degrees of the Sun as viewed from the Earth over a consecutive 240 days out of 426 days. Having an SEP angle of less than 10 degrees causes the radiometric data to be noisier than usual, thus degrading the accuracy of the data. During the periods when the SEP angle is less than 3 degrees, the solar conjunction prevents playback of the telemetry data, which contains the spacecraft attitude-maintenance thruster firings. This occurrence of 2 solar conjunctions within a 1-year span is due to the orbit geometry of the spacecraft with respect to the Earth. A more detailed description of this geometry, the navigation challenges and their resolutions will be provided in the paper, as well as a discussion of the orbit determination estimation procedure, models and performance assessment.

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Stardust is a 3-axis stabilized spacecraft that maintains its attitude by firing a pair of its one-sided thrusters. This thruster arrangement causes Stardust to produce unbalanced torques at each thruster firing, which yields an undesired perturbing force and makes navigation a challenge. In addition to this perturbing force, Stardust experiences 2 solar conjunctions during its inbound leg to the Wild 2 encounter, which is another major challenge to overcome. Descriptions of the Stardust mission, the spacecraft trajectory and discussion of the navigation challenges will be provided, as well as discussion of the orbit determination estimation procedure, models and performance accuracies.

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