1-AU CALIBRATION ACTIVITIES FOR STARDUST EARTH RETURN

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Abstract

In January of 2006, the Stardust spacecraft will deliver a Sample Return Capsule to the recovery sight in northern Utah. Stardust will return dust samples from comet Wild 2 collected in January 2004, as well as interstellar dust collected at earlier epochs in heliocentric orbit. During Earth return, the trajectory will be perturbed by small firings of the spacecraft reaction control thrusters. Calibration of such activities is essential to ensure meeting Earth entry requirements. This paper will describe such calibrations performed between superior conjunctions in June-July 2003 when Stardust was about 1 AU from the Sun.

Extended Abstract

Stardust was selected as part of NASA's Discovery Program. The objective of Stardust is to collect interstellar and comet dust particles, the latter during an encounter with the comet Wild 2 in January 2004. An overview of the Stardust trajectory is shown in Figure 1. The design of the Stardust spacecraft, shown in Figure 2, utilizes a three-axis attitude control system (ACS), which includes star trackers, backup analog sun sensors and an inertial measurement unit (IMU) with gyros and accelerometers allowing for some closed-loop control of propulsive maneuvers. Thrusters are located on the opposite side of the space vehicle from sample collectors to minimize contamination of samples. Since thrusters so positioned do not produce balanced torques, all attitude control maneuvers contribute a translational Δv in addition to intended propulsive maneuvers. These must be accounted for orbit determination purposes and in terms of designing propulsive maneuvers.

During this Earth Return phase of the mission, it is expected that the spacecraft trajectory will be perturbed by small firings of the reaction control subsystem (RCS) thrusters incurred during three activities:

First, there is attitude limit cycling or deadband control, achieved exclusively through thrusting to maintain attitude within deadbands of various sizes. During Earth return use of ±0.25 degree deadbands, with the IMU activated, is planned to provide accurate attitude control for release of the Sample Return Capsule (SRC). This tighter deadband also maximizes the predictability of acceleration achieved over time from RCS thruster firings.

Second, attitude changes will be necessary for maneuver execution using deadband walks or slews. The former are achieved by slowly moving deadbands relative to an initial attitude to the attitude required for the trajectory correction maneuver (TCM). The latter are achieved via a "bang-bang" controller which entails accelerating to a maximum turn rate near the initial attitude and corresponding deceleration and settling near the target attitude. Slews have proven to be far less accurate and predictable from the standpoint of delta-v expenditure than deadband walks. It is desired, and possibly necessary for mission success, that attitude changes during Earth approach be performed using deadband walks almost exclusively.

Finally, execution of final trajectory correction maneuvers themselves entail some RCS activity required in conjunction with a pre-burn accelerometer calibration and post-burn settling. Some off-pulsing of the TCM thrusters used for the main burn itself may also occur.

In order to characterize these activities sufficiently to ensure successful SRC entry, descent and landing, a series of calibrations were performed in June-July 2003, as shown in Table 1. At this time, Stardust was at about 1 AU from the Sun between superior conjunctions in April and August-September 2003. The 1-AU tests were undertaken as a means of assessing the magnitudes of these three activities, and qualifying their impact on the return phase of the mission. The spacecraft at 1-AU solar distance must respond to similar solar pressure and thermal influences that it would be experiencing during the return phase. At issue is the breakdown of the spacecraft behavior before, during and after the execution of an entry TCM, and an attempt to characterize the effects of the velocity uncertainties present in each phase. Once these errors are understood, it is expected that they will allow us to assess what direction our efforts should take us in order to do what is required to achieve a safe Earth Entry.

This paper will discuss in more detail the planning, analysis and findings of the 1-AU calibration activities for Stardust.

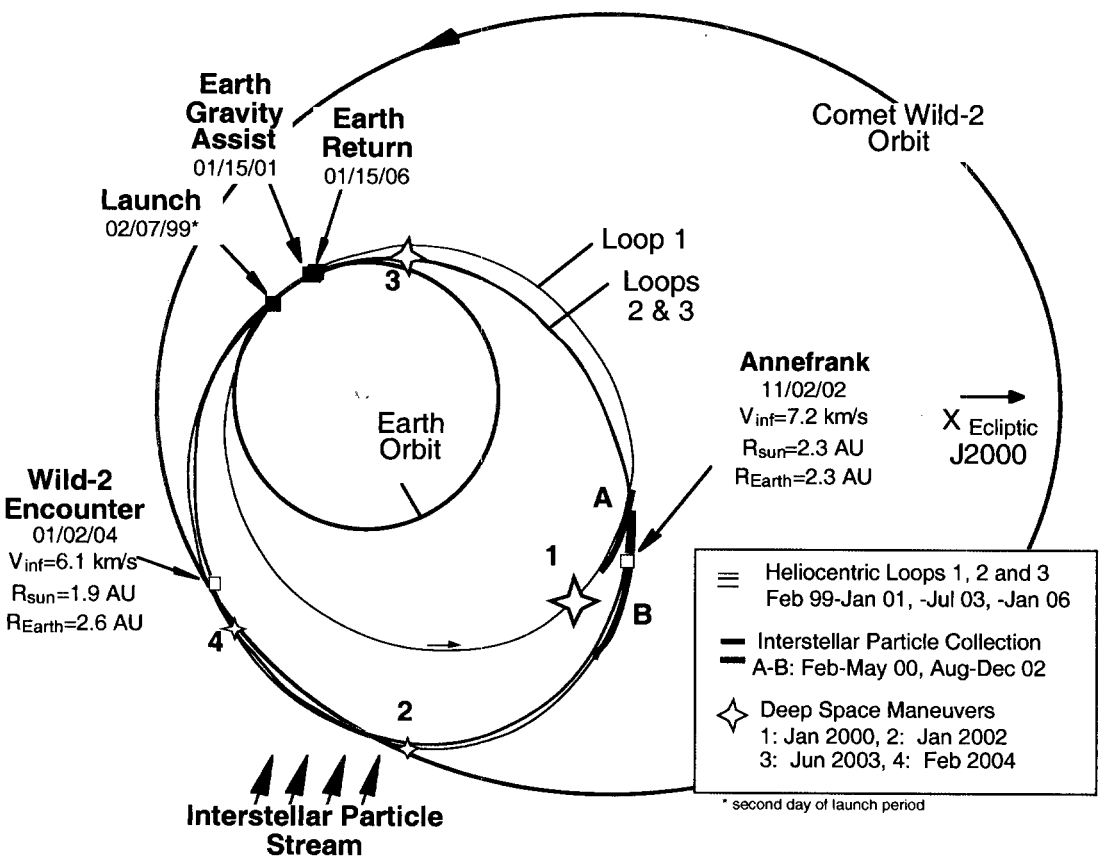

Figure 1. Stardust Mission Trajectory

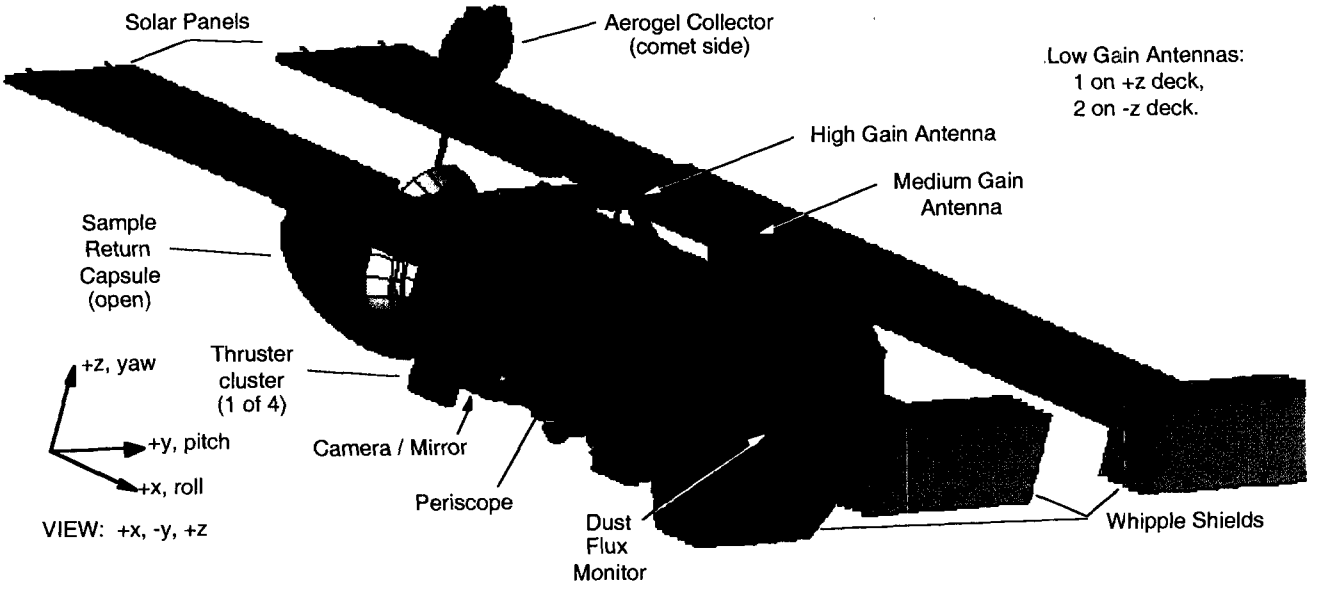

Figure 2. Stardust Spacecraft (+z Axis Normally Pointing Toward Sun or Earth)

Table 1. Overview of 1-AU Calibration Activities

Start (UTC)	End (UTC)	1-AU Test Activities
2003 JUN 23 19:05	2003 JUN 24 01:30	Entry Maneuver Demonstration (EMD-1 ~22:00 ET); all EMDs 0.25 m/s at HGA Earth point followed by playback
2003 JUN 24 10:00	2003 JUN 24 17:20	5-deg DBW test sets (7 roll, 8 pitch); walks usually start at least one hour into pass from MGA Earth point followed by playback at HGA Earth point
		40-deg DBW test sets (4 pitch) from MGA Earth point
2003 JUN 25 01:25	2003 JUN 25 05:30	Return to HGA Earth point for playback
2003 JUN 25 19:45	2003 JUN 26 01:30	EMD-2 (~22:00 ET)
		Limit Cycle Test #1 (Simulated SRC Release Attitude)
2003 JUN 27 01:25	2003 JUN 27 05:25	Return to HGA Earth point for playback
2003 JUN 27 12:05	2003 JUN 28 01:30	More 5-deg (3 roll and 2 pitch) and 15-deg (1 roll and 1 pitch) DBW test sets
		Limit Cycle Test # 2 (Simulated SRC Release Attitude)
2003 JUN 28 12:00	2003 JUN 28 17:20	15-deg DBW test sets (1 roll, 2 pitch)
		Limit Cycle Test #3 (Simulated SRC Release Attitude)
2003 JUN 29 15:55	2003 JUN 30 05:30	Backup for EMD and/or additional playback
2003 JUN 30 08:10	2003 JUN 30 17:35	EMD-3 (~14:00 ET)
		Limit Cycle Test #4 (Simulated TCM-20 Attitude)
2003 JUL 01 16:00	2003 JUL 02 05:30	15-deg DBW test sets (5 roll, 5 pitch)
2003 JUL 02 17:40	2003 JUL 03 01:35	Final 15-deg DBW test sets (3 roll, 2 pitch, last 4 in opposite direction from previous tests)
		Limit Cycle Test #5 (Simulated TCM-20 Attitude)
2003 JUL 03 17:30	2003 JUL 04 00:15	Return to HGA Earth point for playback