Stardust Mission – Summary

*Editor’s Note: The descriptions given here were originally copied from the “Stardust Mission Plan” document and its addenda (used with permission from the Stardust project). To reflect the completion of the primary mission, the information has been updated by Tony Farnham using the weekly status reports, press releases and informational bulletins released by the Stardust mission.*

# Mission Overview

The primary science goal of the STARDUST mission was to collect Wild 2 coma samples, plus bonus interstellar dust samples, in aerogel, and return them to Earth. On January 2, 2004, the spacecraft successfully flew by the comet, obtaining dust samples that were returned to the Earth on January 15, 2006. Additional science return was obtained in the form of images of the comet coma and nucleus obtained with the NAVCAM, in situ dust composition measurements obtained with the Comet and Interstellar Dust Analyzer (CIDA) and dust impact counts from the Dust Flux Monitor (DFMI).

## Trajectory

The STARDUST mission was designed for a low velocity (6.1 km/s) flyby of comet Wild 2 during a time when the comet was moderately active (at a heliocentric distance of 1.9 AU). The spacecraft was then designed to have a low energy Earth returning trajectory so that dust samples obtained at the comet could safely be returned to Earth.

The launch on February 7, 1999 put Stardust into a two year orbit, which would bring it back to Earth for a gravitational assist in 2001. Deep Space Maneuver #1 (DSM1), broken into three separate burns, was executed on January 18, 20 and 22, 2000, when Stardust was near aphelion. This maneuver imparted a 170 m/s deterministic delta-V to set up the orbit for the Earth flyby, which occurred on January 15, 2001. The Earth flyby increased the spacecraft's semi-major axis so that Stardust could reach comet Wild 2. The new orbit had a 2.5 year period. A small, 2.65 m/s, deep space maneuver (DSM2) was executed on January 24, 2002 to correct for minor trajectory errors from the previous Earth flyby. On June 17-18, 2003, the third deep space maneuver (DSM3) was performed to properly target Wild 2. It imparted a Delta-V of 69 m/s. On January 2, 2004, Stardust encountered Comet Wild 2 (98.5 days after the comet's perihelion passage), passing at a distance of 237 km. The last deep space maneuver, DSM4, was performed in the first week of February 2004. It was a small maneuver (5 m/s) and adjusted the orbit to target the spacecraft back to Earth so the Sample Return Capsule could reenter the atmosphere and parachute to the recovery site in Utah.

## Asteroid 5535 Annefrank Encounter

On November 2, 2002 04:50:20 UTC, Stardust encountered the asteroid 5535 Annefrank. The encounter distance was 3079 km and the solar phase angle ranged from 130 deg to 47 degrees during the period of observations. This encounter was used as an engineering test of the spacecraft and ground operations in preparation for the encounter with comet Wild 2.

## Comet Encounter

On January 2, 2004, 19:21:28 UTC, Stardust encountered Comet Wild 2 (98.5 days after the comet's perihelion passage). The spacecraft passed the comet on the sunward side with a relative velocity of 6.1 km/sec. The closest approach distance was 237 km (+/- 1km). (The original encounter distance was planned to be 150 km, but this was changed after a safety review board decided to increase the closest approach distance to minimize the potential for catastrophic dust collisions.)

The relative velocity between the comet and the spacecraft was such that the comet actually overtook the spacecraft from behind as they traveled around the Sun. During the encounter, the spacecraft was on the sun-lit side of the nucleus, approaching at a solar phase angle of 70 degrees, reaching a minimum angle of 3 degrees near closest approach and departing at a phase angle of 110 degrees.

## Interstellar Dust Collection

The interstellar dust particle (ISP) collection periods occurred near the first and second aphelion portions of the spacecraft's orbit, when the relative velocity between the spacecraft and the ISP streams is at a minimum. In addition to the favorable velocity alignment, these collection periods are further defined by the need to avoid large off-Sun pointing of the solar panels, collection of beta meteoroids, and deep space maneuvers.

The first ISP collection period lasted from February 22 through May 1, 2000. The second collection period was from August 5 through December 9, 2002. Although the opportunity existed for additional ISP collection on the third orbit, this would have been after the Wild 2 encounter, and it was decided that it was undesirable to re-open the SRC after the comet encounter.

## *In Situ* Particle Analysis

CIDA and DFMI experiments were executed at every available opportunity during the mission. The main constraints on their operation were the availability of spacecraft power and conflicts with other mission activities. Prime experiment periods were defined as those where the interstellar particle (ISP) streams are oriented to fall within the CIDA field-of-view.

## Earth Return

On January 15, 2006 the Sample Return Capsule (SRC) successfully separated from the Stardust spacecraft. After separation, the spacecraft executed a divert maneuver that put it into a heliocentric orbit, while the SRC re-entered the Earth's atmosphere and parachuted to the ground. The SRC was recovered at the Utah Test and Training Range (UTTR) and transported to the staging area at UTTR for the retrieval of the sample canister. The canister was then transported to the planetary materials curatorial facility at Johnson Space Center in Houston.

# Mission Phases

Six mission phases were originally defined for significant spacecraft activity periods. These were the Launch, Cruise 1, Earth Gravity Assist, Cruise 2, Wild 2 Encounter, Cruise 3, and Earth Return. One more mission phase -- Annefrank Encounter, -- completely nested inside the Cruise 2 phase was added in 2002 when the asteroid flyby was approved as a full scale Wild 2 encounter test.

## Launch

Mission Phase Start Time : 1999-02-07

Mission Phase Stop Time : 1999-03-08

The launch phase began as the launch vehicle lifted-off and ended with the completion of the activation and checkout of most of the spacecraft subsystems. Included in this phase were spacecraft separation from the launch vehicle, establishment of attitude and communications, tracking of the spacecraft and the execution of the first trajectory correction maneuver (TCM-1) to correct the injection error. The duration of this phase was 30 days.

## Cruise 1

Mission Phase Start Time : 1999-03-08

Mission Phase Stop Time : 2000-11-14

The Cruise 1 phase of the first part of the STARDUST mission, nearly six years long, was a period of relatively low activity. This part spanned from launch through the Earth flyby. Within this phase are embedded the first ISP collection period and the CIDA and DFMI experiments. The ISP collection period during this phase of the mission started 380 days after launch and continued for 69 days.

## Earth Gravity Assist

Mission Phase Start Time : 2000-11-14

Mission Phase Stop Time : 2001-02-14

The Earth flyby was performed primarily to provide a gravity assist to the STARDUST spacecraft thus reducing the delta-V requirements of the mission. The flyby changed the orbital period from 2 years to about 2.5 years. The spacecraft approached Earth from the dark side with a velocity of 6.5 km/s and receded back into the dark side having flown by the sunward side at a closest approach altitude of 6008 km. During the flyby the Sun-Earth-spacecraft angle cycled from ~130 degrees to ~28 degrees at closest approach to a minimum of ~19 degrees (8 minutes after closest approach) and back up to ~90 degrees toward the end of the EGA phase. The Earth flyby time was 15 January 2001 11:14:28 UTC.

## Cruise 2

Mission Phase Start Time : 2001-02-14

Mission Phase Stop Time : 2003-09-24

The Cruise 2 phase was the second part of cruise, spanning the time between the Earth flyby and the Wild 2 encounter. Within this phase are embedded the second ISP collection period and the CIDA and DFMI experiments. The ISP collection period during this phase of the mission started 1275 days after launch and continued for 126 days.

## Annefrank Encounter

Mission Phase Start Time : 2002-10-31

Mission Phase Stop Time : 2002-11-05

This phase was the part of the mission, during which STARDUST flew by the S-type, main belt asteroid Annefrank. The Annefrank flyby occurred with just over one month (out of four) remaining in the second ISP collection period and was fully embedded with Cruise 2 phase of the mission.

This encounter was not present in the original mission plan and was added in 2002 as a full scale Wild 2 encounter test. The main objective and supporting rationale for this test was to implement the entire Wild 2 encounter sequence in flight at Annefrank.

The spacecraft flew past Annefrank on 2 November 2002 at 4:51:20 UTC at a closest approach distance of 3079 km. The imaging sequence encompassed a solar phase angle range from 130 deg to 47 deg.

## Wild 2 Encounter

Mission Phase Start Time : 2003-09-24

Mission Phase Stop Time : 2004-02-21

The most important mission phase of STARDUST ranged from 100 days before the encounter with comet Wild 2 to 50 days after. Encounter occurred on January 2, 2004, 19:21:28 UTC.

The primary goal of obtaining comet coma samples during the encounter flyby was accomplished by a navigation plan that delivered the spacecraft to a close approach distance of 237 km from the nucleus. Near the closest encounter, the spacecraft +x-axis was aligned with the S/C velocity vector relative to Wild 2 so that the dust shield protected the S/C. In this flyby configuration, the Earth was located in the direction of the spacecraft +z-axis (also HGA direction). The spacecraft approached Wild 2 from above and receded below the comet's orbit plane.

Although the collection of cometary dust samples was the primary goal of the mission, it is totally passive, enabled by deployment of the aerogel collector and the setting of the spacecraft / collector attitude perpendicular to the dust stream. The collector was deployed on December 24, 2003 and remained deployed until five hours after the encounter, at which time the spacecraft should have exited the coma. The majority of the dust was believed to have occurred in the few hours around closest approach.

## Cruise 3

Mission Phase Start Time : 2004-02-21

Mission Phase Stop Time : 2005-10-17

The Cruise 3 phase was the third part of cruise, spanning from the Wild 2 encounter to the return to Earth. During this period, no dust collection took place. The dust collectors were stowed to protect the comet particles and to prevent any potential problems that might endanger their return to the Earth.

## Earth Return

Mission Phase Start Time : 2005-10-17

Mission Phase Stop Time : 2006-01-16

This phase of the mission began 90 days before Earth Return (ER) and ended when the SRC was transferred to the ground handling team. Earth approach contained three TCM's and a final divert maneuver, performed after SRC separation, to prevent the spacecraft from following the SRC into the Earth's atmosphere. Prior to separation, the spacecraft was placed at the separation attitude and the SRC was spun up using a spin release mechanism. This provided the spin stabilization that the SRC required for successful atmospheric entry. The SRC entered the atmosphere at 09:57 UTC on January 15, 2006.

The SRC aeroshell protected the sample canister against the extreme aerodynamic heating experienced during atmospheric entry. The aeroshell also removed over 99 percent of the initial kinetic energy thus allowing the parachute system to place the SRC within the allowable touchdown requirements.