The Flyby of Asteroid Annefrank by STARDUST for Wild 2 Testing

The NASA Discovery STARDUST spacecraft is set to flyby the vicinity of the main belt asteroid Annefrank in November of this year on its way to encounter the comet P/Wild 2 in January 2004. Plans are being put in place to target a close flyby of Annefrank as an operational test for the comet P/Wild 2 encounter. The spacecraft is carrying the JPL Aerogel Dust Collector, the Max Planck Institute Cometary and Interstellar Dust Analyzer (CIDA), the University of Chicago Dust Flux Monitor Instrument (DFMI), the JPL camera and radio science. The mission will implement approach camera operations for targeting a close flyby and then execute the P/Wild 2 encounter sequence involving all instruments and radio science during the Annefrank flyby. The flyby speeds between Annefrank and P/Wild 2 are similar while Annefrank will be viewed at much lower phase angles during approach. The flyby will occur when the aerogel collector is already deployed, collecting interstellar dust at that time. Details of this flyby and expected activities will be given.
Flyby of Asteroid Annefrank by STARDUST for Wild 2 Testing

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STARDUST

- 4th NASA Discovery Project
  - Mars Pathfinder, NEAR, Lunar Explorer prior Missions
- 1st NASA Unmanned Planetary Sample Return Mission
- NASA, Univ of WA, JPL and LMA Partnership
- Prof. Donald Brownlee, University of Washington, PI
  - Co-I's
    - Drs. Martha Hanner, JPL, Fred Horz, JSC,
    - Tony McDonald, UK, Scott Sandford, ARC,
    - Zdenek Sekanina, JPL, and Mike Zolensky, JSC
  - Co-I's with Payload Instruments
    - Aerogel Collector - Dr. Peter Tsou, Deputy PI, JPL
    - CIDA - Dr. Jochen Kissel, MPI fur Kernphysik,
    - DFMI - Dr. Anthony J. Tuzzolino, U of Chicago
    - NavCam - Dr. Ray Newburn, JPL
    - Radio Science - Dr. John Anderson, JPL
    - High Rate Attitude - Dr. Benton Clark, LMA
Primary Requirement: Collect 1000 Comet particles >15 μm at encounter velocity < 6.5 km/sec and return to Earth

Secondary Requirements: Collect 100 Interstellar particles >0.1 μm and return to Earth.
Provide ≥ 65 images of P/Wild 2, having a resolution of at least 67 μrad per pixel, taken within 2000 km of the comet nucleus through selected filters;
Provide in situ particle analysis for comet coma flythrough capable of resolving abundant elements in cometary solids

Tertiary Requirements: Provide in situ particle analysis for interstellar and interplanetary dust;
Measure dust mass fluence, large particles and comet mass upper limit
Provide dust flux measurement of $10^{-9}$ g to $10^{-4}$ g particles
**Trajectory Overview**

- **Launch**: 02/07/99
- **Earth Gravity Assist**: 01/15/01
- **Earth Return**: 01/15/06
- **Comet Wild-2 Orbit**

**Event Details**

- **Wild-2 Encounter**: 01/02/04
  - $V_{inf}=6.1$ km/s
  - $R_{sun}=1.9$ AU
  - $R_{Earth}=2.6$ AU

- **Interstellar Particle Stream**
- **Loop 1**
- **Loops 2 & 3**

**Key Events**

- **Earth Orbit**
- **Comet Wild-2 Orbit**
- **Ecliptic J2000**

**Additional Information**

- **Annefrank**: 11/02/02
  - $V_{inf}=7.2$ km/s
  - $R_{sun}=2.3$ AU
  - $R_{Earth}=2.3$ AU

- **Heliocentric Loops 1, 2 and 3**: Feb 99-Jan 01, Jul 03-Jan 06

- **Interstellar Particle Collection**
  - A-B: Feb-May 00, Jul-Dec 02

- **Deep Space Maneuvers**
  - 1: Jan 2000, 2: Jan 2002
  - 3: Jul 2003, 4: Feb 2004

- *Second day of launch period*
Annefrank

- Main Belt Asteroid
- C - Type
- ~1 km Radius
- Discovered by French, et al., 1983
- 3.3 yr Period
- Near Circular orbit with Semi-major Axis - 2.3 AU
ENCOUNTER OBJECTIVES

- Perform Flight Test of Wild 2 Encounter Operations
  - Full Approach and Departure Navigation
    - Radio and Optical Navigation
    - Trajectory Correction Maneuvers
    - Fast Computation Turn Arounds
  - Implement Go / No Go Procedures for Contingency Maneuver
  - Implement Full Wild 2 Encounter Sequence
    - Closed-loop Nucleus Tracking
    - Areogel Dust Collector Deployed
    - Full Image Sequence
    - U of Chi Dust Flux Monitor On
    - MPI Dust Mass Spectrometer On
    - Safe Mode Entry Inhibited
  - Full DSN Tracking Schedule for Uplink / Downlink with Contingency
- Use Lessons Learned to Increase Probability of Success at Comet P/Wild 2, the Primary Science Target
Annefrank Flyby Geometry
closest approach: 11/02/2002 04:44:47 UTC [010926 SPK]

radius ~ 6-8 km
Approach Phase Angle 150 deg

3000 km Flyby on Sunside

150 deg

V₀ = 7.23 km/s

C/A-20 min
Sun-Probe-Anne = 48.9 deg &
Mirror Angle = 19.1 deg

Sun-Probe-Earth angle
25 deg

Earth 2.25 AU

Sun 2.34 AU

Earth is 24.6 degrees from XS and 3.2 degrees above the flyby plane
Vinf points 5.0 degrees above the ecliptic
Annefrank heliocentric speed is 18.9 km, s/c is 16.7 km/s

Flyby plane coordinates (xs,ys,zs) defined by Vinf and Sun Vector
**Wild-2 Encounter Geometry**

Closest approach: 01/02/2004 19:18:56 UTC

- **Radius**: ~2 km
- **Approach Phase Angle**: 73 deg
- **Sunside**: 150 km Flyby
- **V\(_\infty\)**: 6.12 km/s
- **C/A-20 min**
  - Sun-Probe-Wild = 107.7 deg & Mirror Angle = 0.9 deg

**S/C Attitude**
+\(x\) // \(V_{\text{inf}}\)
+\(z\) to Earth
+\(y\) out of page

**Flyby Plane Coordinates**
(xs,ys,za) defined by \(V_{\text{inf}}\) and Sun Vector

- Sun: 1.86 AU
- Earth: 2.60 AU
- SPE Angle: 17 deg
- XS Earth is 16.7 degrees from XS and 1.9 degrees above the flyby plane
- \(V_{\text{inf}}\) points 2.8 degrees below the ecliptic
- Wild-2 heliocentric speed is 26.4 km, s/c is 21.7 km/s
## ENCOUNTERTIMELINES

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<thead>
<tr>
<th><strong>WILD 2</strong></th>
<th><strong>ANNEFRANK</strong></th>
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<tbody>
<tr>
<td>TCM @ E-30d</td>
<td>TCM @ E-45d</td>
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