STARDUST

MISSION PLAN

POST LAUNCH SUPPLEMENT B

Wild-2 Encounter Test: Annefrank Flyby

October 23, 2002

Jet Propulsion Laboratory
California Institute of Technology

SD-75000-100-Revision A - Supplement B

JPL D-300-1-Revision B - Supplement B

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Change Log

Change Letter	Date	Affected Sections
Draft	11 Oct 2002	First review version
Final	23 Oct 2002	Added 2.5 Bonus Science, integrated extensive review comments.

1.0 Introduction

1.1 Purpose

The purpose of this document is to provide a high-level description of the Wild-2 Encounter Test. This test entails a flyby of the asteroid Annefrank, which occurs approximately 14 months prior to the comet Wild-2 flyby.

The addition of this test to the Stardust Mission Plan was approved by MCR 1450 (see Appendix 4.1) and is being performed to minimize the number of first time events occurring during the Wild-2 encounter.

1.2 Scope

This document presents the baseline Wild-2 Encounter Test plan, also referred to interchangeably throughout this document as the Annefrank Flyby. It describes the high-level integration of flyby activities with the background interstellar dust collection period, and more detailed planning for the week of the Annefrank closest approach passage.

Interstellar dust collection period #2 spans from August 5, 2002 through December 9, 2002, or Annefrank closest approach –98 days to +37 days. A trajectory correction maneuver is planned in support of Annefrank as late as December 20, 2002 (AF+48 days) [TBR]. The week of the Annefrank flyby is October 28, 2002 (AF-5 days) to November 3, 2002 (AF+1 day).

This supplement is largely consistent with the reference trajectory that contains a 3200-kilometer, sun-side flyby of the asteroid at an encounter velocity of 7.2 kilometers per second. This trajectory is designated SDU_L_020925_010101_060401 and has an Annefrank closest approach time of November 2, 2002 04:50:10 UTC. The integrated time-ordered listing in Tables 4 through 9, and in Appendix 4.3, however, is consistent with the latest ephemeris at the time of publication, SDU_S_021010_020615_021105_V01, with a closest approach time of November 2, 2002 04:50:02 UTC.

This document assumes the reader is familiar with the Stardust Mission language.

1.3 Relationship to Other Documents

The information contained in this document has been gathered from multiple internal and external project reviews performed as a part of the design, development and approval of this activity. Two external reviews are worth noting: Wild-2 Encounter Test Design and Risk Review held January 9, 2002, and Wild-2 Encounter Test Critical Events Readiness Review held August 16, 2002.

This supplement, together with the Mission Plan document, and Supplement A, describes the intended implementation of the Stardust Project Plans. No attempt has been made to reflect historical deviations from the Mission Plan. Future major deviations, if known far enough in advance, will be documented in similar supplements to the Mission Plan document. For historical deviations from the Mission Plan, please refer to operations status reports and the Mission Management Office's Mission Change Control Board change request database. The latest Mission Plan documentation is:

Mission Plan, SD-75000-100-RevA, Feb. 1, 1999
Mission Plan Post Launch Supplement A, SD-75000-100-RevA-SupA, Dec. 1, 1999

2.0 Wild-2 Encounter Test Overview

2.1 Objectives and Rationale

The main objective and supporting rationale for the Wild-2 Encounter Test can be stated as follows:

- Implement entire Wild-2 encounter sequence in flight at Annefrank.
    - Maximizes the testing fidelity of Wild-2 operations.
    - More robust than spacecraft test laboratory simulations of the spacecraft
    - Uses an actual small planetary body

This main objective has the goal of minimizing the number of first time events at Wild-2, and breaks down to the following detailed objective listing.

- Image and acquire small body and perform image processing on the ground, including image co-addition to extract faint features.
- Obtain navigation solution by combining radiometric and optical data.
- Exercise fast maneuver design turn around (8 hr template, B-plane only correction maneuver).
- Exercise and implement, if needed, fast contingency maneuver go-selection/no-go (pre-canned maneuver).
- Exercise and implement late update to encounter flyby time and nucleus tracking parameters.
- Exercise autonomous nucleus tracking and associated spacecraft attitude roll turn.

The first four of these detailed objectives are key in demonstrating the ability to successfully navigate to a safe flyby distance and complete the primary mission objective of sample collection at comet Wild-2. The additional two objectives are key in demonstrating the ability to successfully complete the secondary mission objective, one of three, of safely acquiring optical images during the Wild-2 flyby.

The execution of these objectives is subject to the overriding constraint that the flyby activities be implemented safely, even if Annefrank is not acquired during approach imaging.

2.2 Mission Context – ISP Collection Period 2

The Annefrank flyby occurs with just over one month (out of four) remaining in the second interstellar particle (ISP) collection period. Dust impact velocities are at a minimum during this final month (~10 km/s) compared to the velocities at the start of the period (~15 km/s) making it desirable to minimize the interruption to ISP collection activities. The lower the impact speed, the higher the probability of capturing intact ISPs.

The overall allowed interruption of ISP collection is established by flight rule 705-E-SCI. This flight rule states: "The ISP side (-x) of the Aerogel must not be pointed directly into the sun for more than 5% of the collection time". While the flight rule speaks of pointing directly into the sun, mission operations has elected to evaluate this flight rule more strictly and interpret the flight rule as not allowing more than 5% of the collection time to be in a non-ISP collection orientation. Note that the 5% applies to the total collection time, i.e. total across collection period 1 and collection period 2.

Robust implementation of the Annefrank flyby establishes the need to perform two trajectory correction maneuvers in addition to the close Annefrank activities. The interstellar dust collection period runs from August 5, 2002 (AF-98 days) to December 9, 2002 (AF+37 days), and is open to impact not only from the additional specific activity, but also from the additional DSN tracking coverage required for the design, implementation and reconstruction of the maneuvers.

Successful navigation delivery of the spacecraft to Annefrank makes it unavoidable to place the pre-encounter maneuver outside of the ISP collection period. This pre-encounter maneuver is scheduled for October 9, 2002 (AF-24 days). The post-encounter maneuver, however, is not as tightly time constrained and it is possible to schedule it outside of the ISP collection period. It is currently placed on December 20, 2002 (AF+48 days) [TBR].

The preliminary estimate of non-ISP time based on normal levels of DSN tracking in support of the Annefrank activities was as high as 12%. A large contributing factor to this estimate was the fact that non-ISP time was allowed to be approximately 10% during ISP collection period 1. The high non-ISP time was due to the collection period's proximity to Deep Space Maneuver #1, and the DSN coverage associated with that very large, very important mission event (~170 m/s expended over the course of a week). Under the pre-Annefrank plan, ISP collection period 2 was expected to be much quieter, thus making up for ISP period 1.

While the risk reducing value of the Annefrank activities would have certainly justified the science impact of this high percentage of non-ISP time, navigation and sequencing strategies have been modified to minimize the amount of non-ISP time required to support the approach TCM and approach to Annefrank. In the navigation area, use of 2-way / 3-way Doppler tracking passes have allowed reduction of overall DSN coverage. In the sequencing area, the aerogel position management around the approach TCM has been changed from a day-prior/day-after strategy to a just-prior/just-after strategy. As a result of these changes, the total non-ISP time has been reduced to 8.5%. This is still in violation of 0705-E-SCI, but a bit more appealing. Waiver 35 (see Appendix 4.2) has been processed and approved to allow non-ISP time to be as high as 10% of the collection time.

It is worth noting that the project is required is to provide a minimum of 150 days for ISP collection. Current plans will provide 195 days. Sample contamination by solar beta meteoroids is the main driver for establishing the flight rule, but, from a minimum number of days perspective, 10% of the total ISP time (20 of 195 days) still provides some margin (25 days) over the 150 day total ISP requirement.

Figure 1 shows where the Annefrank flyby falls within the mission trajectory. Figure 2 illustrates how the Annefrank activities mesh with the ISP collection period activities. Table 1 is a companion to Figure 2, and a slightly more detailed description of the Annefrank and ISP collection period activities.

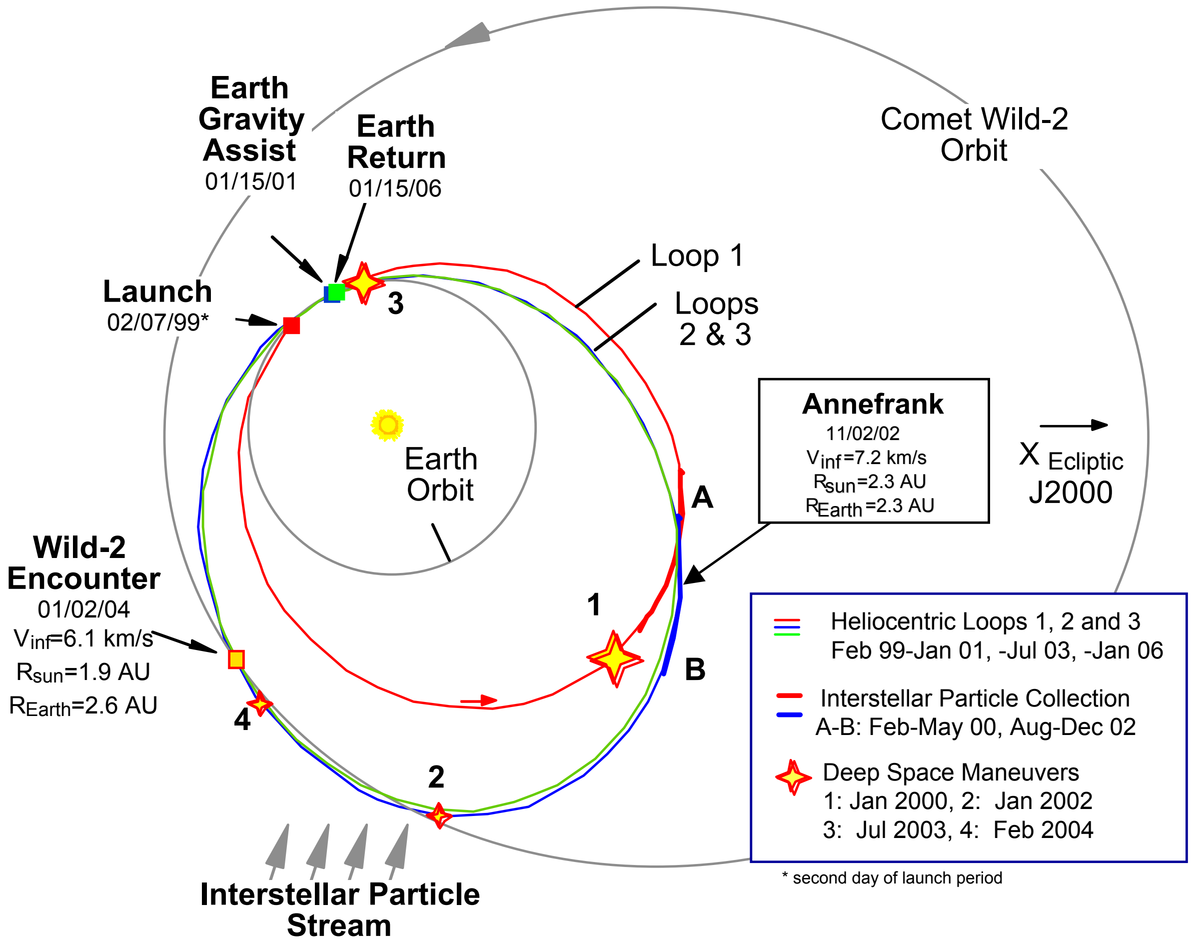

Figure 1. Stardust Trajectory Overview

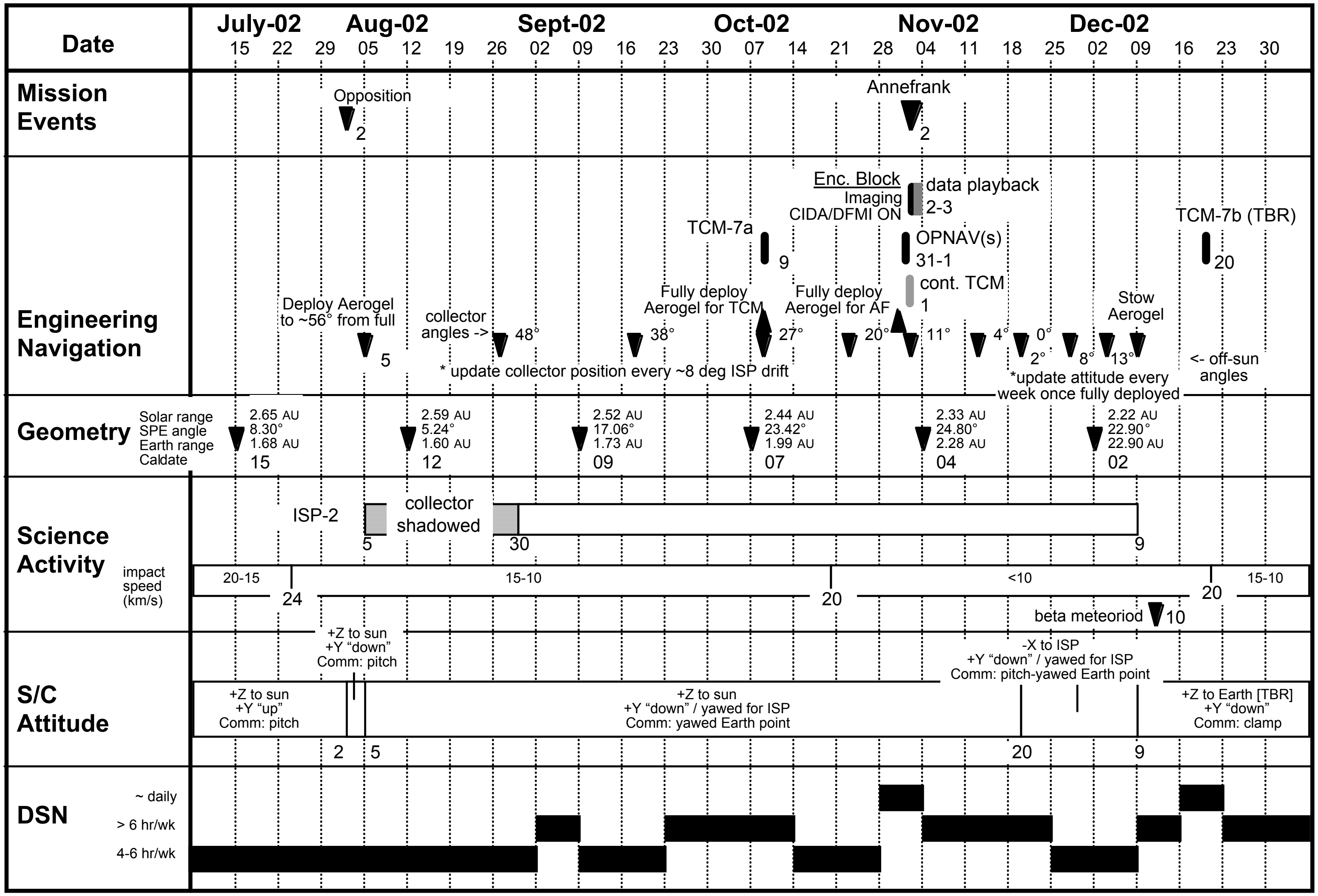

Figure 2. ISP-2 / Annefrank Overview

Table 1. High-Level Mission Plan Timeline

Date 2002	C/A	Activity
05 Aug (DOY 217)	-98 d	Start ISP-2 [MCR 1252], open SRC, deploy Aerogel grid 56° from full deployment, s/c attitude to ISP (30° yaw)
27 Aug (DOY 239)	-67 d	Update Aerogel grid (48° grid) and s/c attitude (24° yaw)
18 Sep (DOY 262)	-45 d	Update Aerogel grid (38° grid) and s/c attitude (22° yaw)
09 Oct (DOY 282)	-24 d	TCM-7a (includes full deployment of aerogel grid and grid update, 38° to 0° to 27°, s/c attitude to 20° yaw)
23 Oct (DOY 296)	-10 d	Update Aerogel grid (20° grid) and s/c attitude (20° yaw)
28 Oct (DOY 301)	-122 h	Uplink Annefrank sequence, approach image parameters, and default nucleus tracking parameters and flyby attitude
31 Oct (DOY 304)	-48 h -38 h -32 h -32 to –26 h	IMU On Full deploy aerogel (~20°), S/C flip (slew) from ISP attitude, Take and downlink Annefrank images Take and downlink Annefrank images Perform nucleus tracking and encounter attitude update
01 Nov (DOY 305)	-26 h -26 to –18 h -18 h -14 to –10 h -12 h -12 to –6 h -6 h	Take and downlink Annefrank images, Uplink nucleus tracking and encounter attitude update W2-18h TCM Template Operational Readiness Test Take and downlink Annefrank images Perform E-6h contingency TCM go-selection/no-go Take and downlink Annefrank images Perform nucleus tracking and encounter attitude update Execute contingency TCM and cancel AF flyby OR Uplink nucleus tracking and encounter attitude update
02 Nov (DOY 306)	-6 h to –20 m -20 to +5 m 0 +5 to +20 m +6 h +12 h +16 h	Re-configure spacecraft (CIDA On, other details TBR) Encounter closest approach sequence (includes DFMI On, nucleus tracking, bank maneuver, etc) Annefrank Closest Approach (7.2 km/s, 3200 km) Re-configure spacecraft (CIDA Off, DFMI Off, details TBR) Start Annefrank playback Continue Annefrank playback, deploy aerogel to ISP position (11°) S/C flip (walk) to Sun point ISP (19° yaw)
03 Nov (DOY 307)	+25 h +33 h	Continue Annefrank playback IMU Off
08 Nov (DOY 312)	+6 d	Continue Annefrank playback
13 Nov (DOY 317)	+11 d	Update Aerogel grid (4° grid) and s/c attitude (19° yaw)
20 Nov (DOY 324)	+18 d	Update Aerogel grid (grid fully deployed) and s/c attitude (2° off-sun, 19° yaw)
28 Nov (DOY 332)	+26 d	Update s/c attitude (8° off-sun, 18° yaw)
04 Dec (DOY 338)	+32 d	Update s/c attitude (13° off-sun, 18° yaw)
09 Dec (DOY 343)	+37 d	End ISP-2, Stow Aerogel grid, Close SRC, Attitude mode: +z-axis to Earth [TBR]
20 Dec (DOY 354)	+48 d	TCM-7b (As needed, date TBR)

2.3 Comparison to Wild-2 Flyby

The value of the Annefrank flyby is better understood when comparing it to the Wild-2 scenario. The geometrical and mission characteristics of the Annefrank encounter make it impossible to create an exact duplicate of the Wild-2 encounter scenario. However, this duplication does exist at a functional level, with one exception, fault protection.

When in the Wild-2 critical event fault protection mode, only hardware faults will be allowed to place the spacecraft into safe mode. In addition, the Wild-2 safe mode will have a special definition so that the spacecraft remains in a safe attitude (behind the whipple shields) as it flies through the Wild-2 dust cloud. Neither of these is put into place at Annefrank primarily because Annefrank is a test, and the main mission objectives should not be placed in jeopardy as a result of attempting Annefrank. Also, the Annefrank flyby attitude is not power or communications friendly (the Wild-2 attitude is). At Annefrank action must be taken to re-establish a positive power configuration if the spacecraft enters safe mode. There is no dust cloud at Annefrank, and spacecraft survival due to dust impacts is not a concern.

Table 2 illustrates a few general points of comparison between Annefrank and Wild-2. Table 3 illustrates the differences between the two encounters at a more detailed level. Figures 3 through 8 illustrate some geometrical differences between the two encounters

Table 2. General Context Comparison

Wild-2 Phase	09/24/2003 to 02/21/2004 (E-100d to E+50d)
Mission	Perihelion on 07/22/03, Exit Solar Conjunction on 10/06/03 Pre/post encounter NAVCAM checkout/calibration
Approach NAV	OPNAV campaign, TCMs (5), Comet detected days prior to C/A (73° phase)
Geometry	Spacecraft attitudes (image, comm, flyby) all very similar. Little slewing, on-Sun. Possible exception pending periscope viability.
Closest Approach	01/02/2004 19:20:00 ET (19:18:56 UTC)
Annefrank Test	10/31/2002 to 11/03/2002 (AF-2d to AF+1d)
Mission	ISP collection 08/05/02, Full deploy grid for slews, TCMs, flyby Waiver to 0705-E-SCI for non-ISP time.
Approach NAV	TCMs (2), Five OPNAV images on approach (not required), Asteroid detected hours prior to C/A (150° phase)
Geometry	Spacecraft attitudes (ISP, image, comm, flyby) significantly different. Images and flyby performed in the blind and on batteries. Limited communication with IMU on due to solar range.
Closest Approach	11/02/2002 04:51:14 ET (04:50:10 UTC)

Table 3. Functional Activity Encounter Comparison

Wild-2	Annefrank	First Time	N

TCM @ E-30d, E-10d, E-2d	TCM @ E-24d	Dec 1999	
SRC Open/Aerogel Deployed @ E-9d	SRC Open/Aerogel Deployed @ E-98d, Fully at E-38h	Feb 2000	
OPNAV E-88d to E–2d (wkly, daily) OPNAV to E-32h (hourly)	OPNAV @ E-38, 32h	Sep 2002	1
Update Nuc Tracking Files (ongoing)	Update Nuc Tracking Files @ E-26h	Annefrank	
OPNAV to E-26h (hourly)	OPNAV @ E-26h	Annefrank	1
TCM @ E-18h	E-18h TCM Design ORT	Sep 2002	2
OPNAV to E-12h (hourly)	OPNAV @ E-18h, 12h	Annefrank	1
Contingency TCM @ E-6h	Contingency TCM @ E-6h	Annefrank	3
Update Nuc Tracking Files @ E-6h	Update Nuc Tracking Files @ E-6h	Annefrank	
C/A E-30 to +5m @ 6.1 km/s, 150 km	C/A E-30 to +5m @ 7.2 km/s, 3200 km	Annefrank	4
Nuc Track @ E-20m, 1° off-periscope	Nuc Track @ E-20m, 20° off-periscope	May 2000	5
Aerogel Stowed/SRC Sealed @ E+5h	Aerogel to ISP @ E+16h, until E+37d	Dec 1999	6
TCM @ E+30d	TCM @ E+48d [TBR]		
Fault Protection for Critical Event	Fault Protection fully enabled	Wild-2	
Extensive DSN coverage, near-continuous comm, image playback with MCD-III, complete within 13 days	Limited DSN coverage, power constrained comm, image playback with MCD-III, complete within days with tight Earth point	MCD-III demo in Oct 2002	

Notes:
1. First pattern matching and windowing images in Sep 2002. Windowed images only at Annefrank due to stray light concerns (see section 3.3).
2. Roll only TCM. Sequence pre-built, populate flight software configuration files only.
3. Canned TCM, pre-built and tested.
4. Characteristics (power, stray light, etc) of Annefrank flyby attitude verified in Oct. 2001
5. Annefrank nucleus tracking starts off the periscope. A test will be performed prior to Wild-2 that will track a bright body (planet) through the periscope.
6. SRC will be “sealed” only one time, after Wild-2.

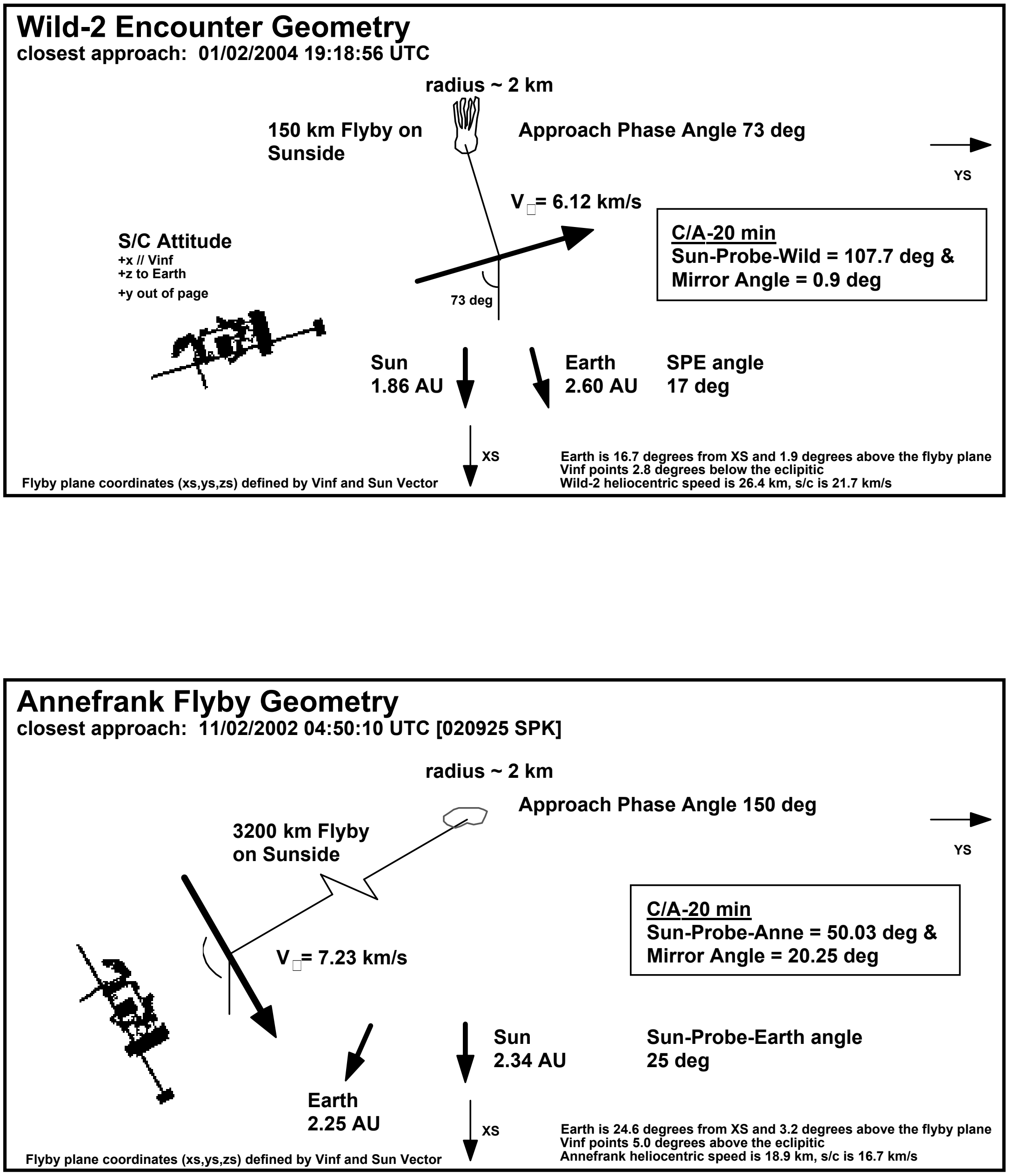

Figure 3. Encounter Geometry Comparison

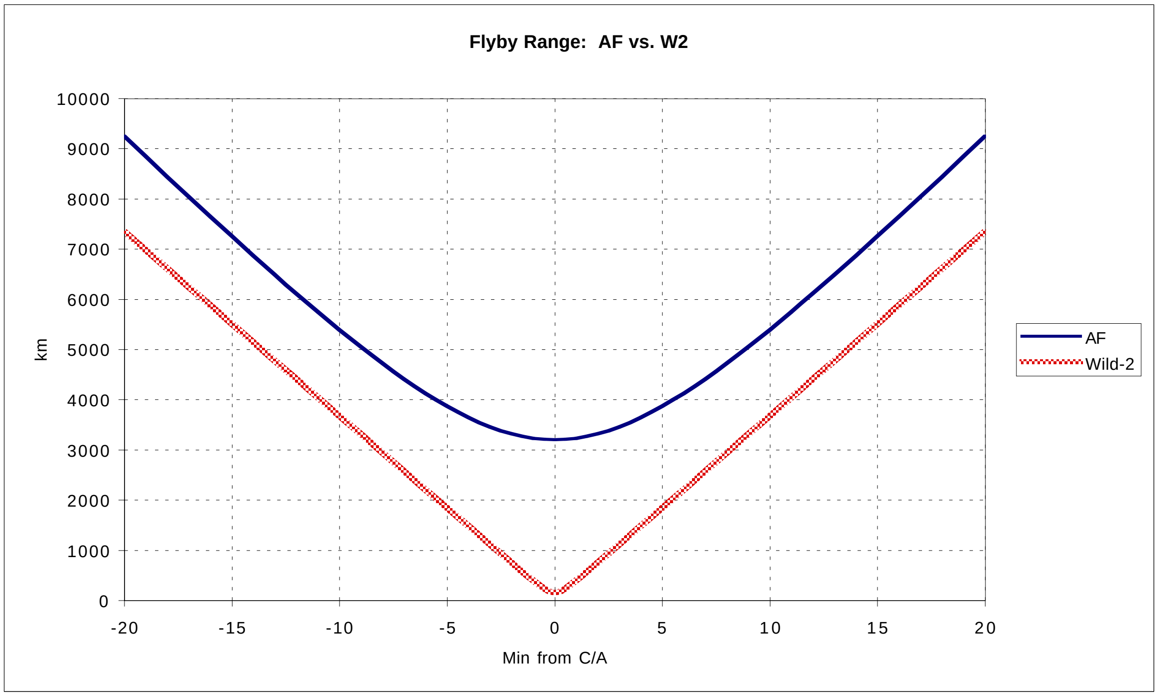

Figure 4. Comparison of Range Profile

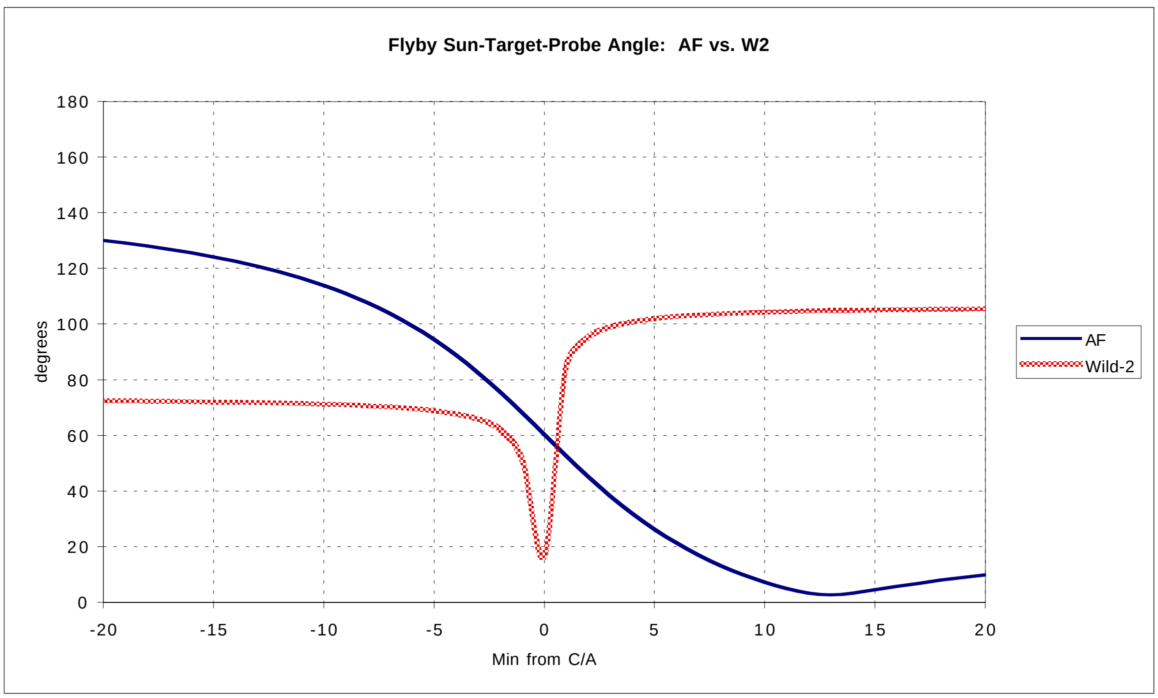

Figure 5. Comparison of Sun-Target-Probe Angle Profile

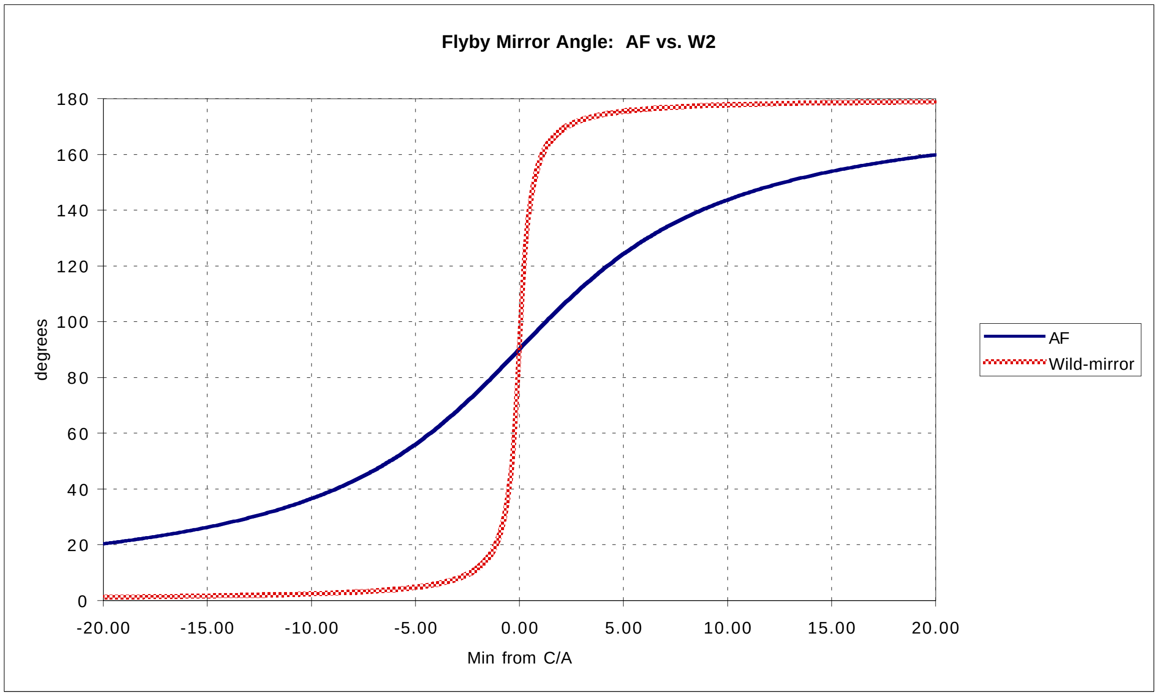

Figure 6. Comparison of NAVCAM Mirror Angle Profile

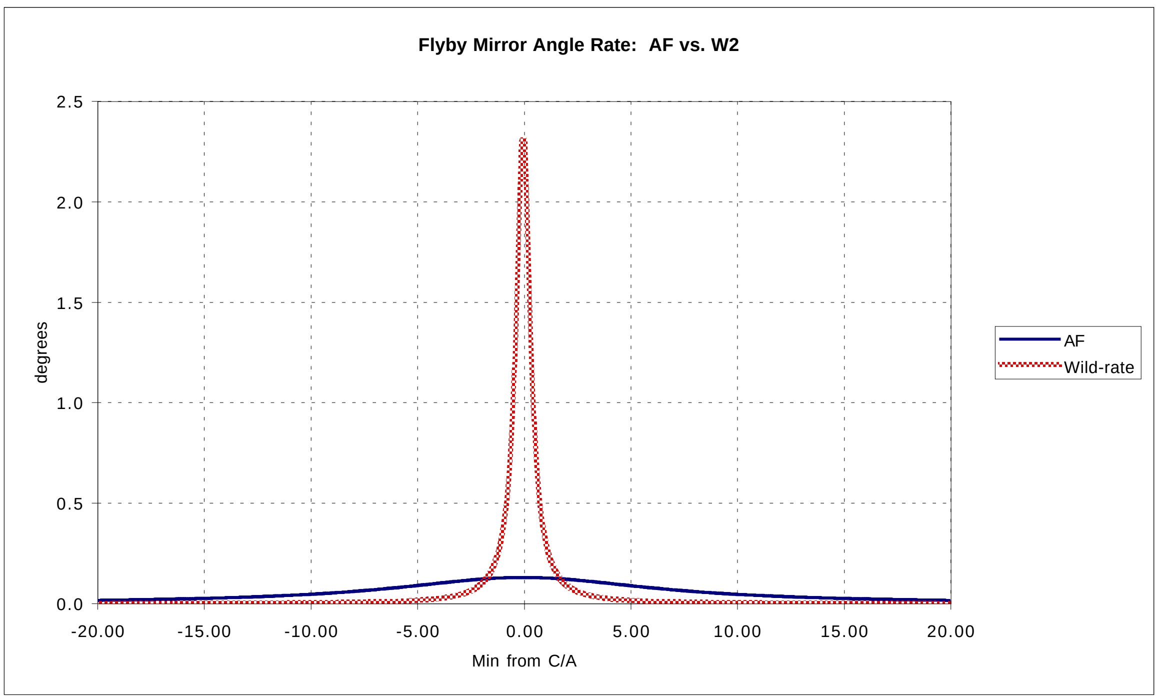

Figure 7. Comparison of NAVCAM Mirror Angle Rate Profile

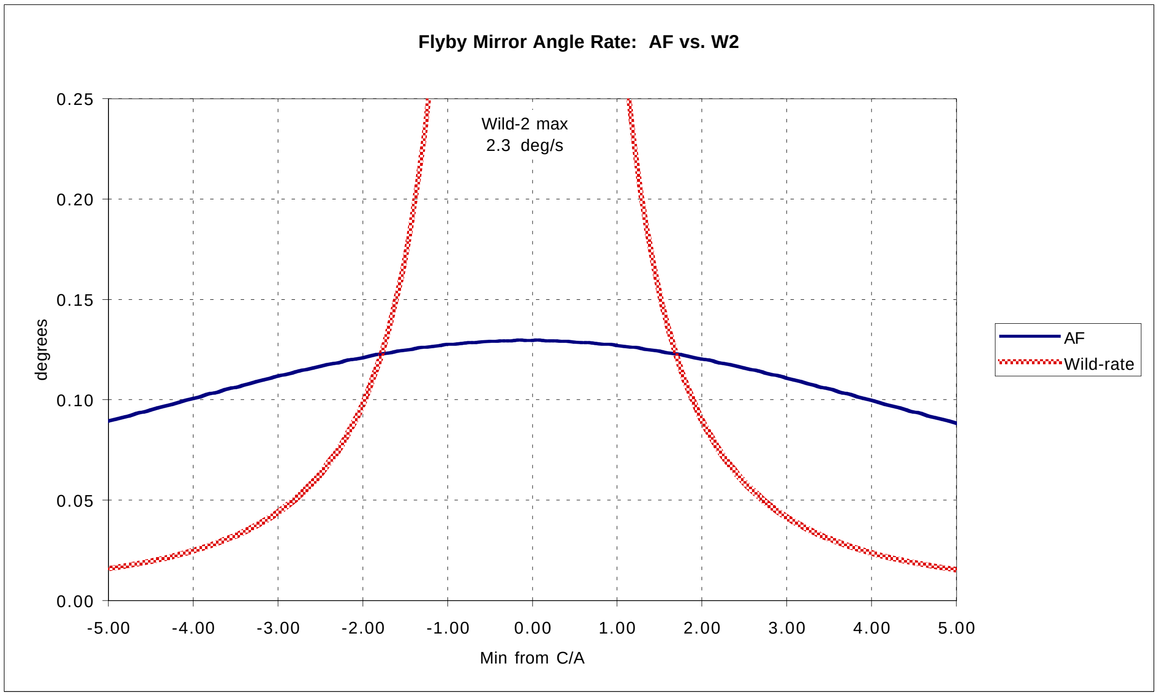

Figure 8. Zoomed Comparison of NAVCAM Mirror Angle Rate Profile

2.4 Nucleus Tracking and Lessons Learned from Deep Space-1

The navigation delivery of the spacecraft to comet Wild-2 using ground based radio and optical navigation is not sufficiently accurate to keep visual lock on the comet to a high probability for flyby science imaging. The cross-track uncertainty (19 km, 1σ) is not low enough to determine the flyby plane for the mirror to sweep as the comet goes by. The down-track uncertainty (215 km or 35 sec, 1σ) is too large to determine mirror angles needed to maintain lock through closest approach.

An improved knowledge of the target relative spacecraft trajectory in both cross-track and down-track directions is possible using images of the comet as the spacecraft approaches it, but the round trip light time (44 minutes at Wild-2, 38 minutes at Annefrank) prevents any ground-in-the-loop effort from being effective. As a result, the only option is the on-board closed-loop tracking algorithm loaded in the spacecraft's main computer.

The on-board tracking algorithm is initiated 20 minutes prior to the time of closest approach (E-20 min) with nominal values for the following parameters:

- Initial target-relative state (position and velocity), and associated covariance, at E-20 minutes. These values are based on results from ground-processed observations, processed in time for a final uplink at E-6 hrs.

- Camera characteristics.

- Predictions for camera pointing for all image opportunities based on a perfectly predicted comet-relative trajectory.

During nucleus tracking, images are taken every 6-10 seconds [TBR] to accomplish mission science objectives. Of these images, only every other [TBR] needs to be processed by the tracking algorithm.

Each image is processed to locate the nucleus "center-of-figure" (a centroiding process). Pixel and line values of the observed centroid are differenced with the predicted center location to produce a residual. These residuals are then processed using a least-squares filter to update the current state and associated covariance. The updated state is then used to generate new pointing predicts for future images, and these are decomposed into spacecraft attitude, mirror angles, and mirror angle rates.

A key component of the nucleus tracking function occurs at E-3 minutes (E-5 minutes for Annefrank). At this time, the updated comet-relative state is used to determine and execute a spacecraft roll maneuver. This maneuver places the spacecraft X-Z axis plane (which is the same as the mirror slew plane) in the correct orientation for the closest approach passage. An opposite roll is executed at E+3 minutes (E+5 minutes for Annefrank). Closed loop tracking is terminated several minutes past encounter.

The Deep Space 1 nucleus tracking software shares the same heritage as the software that is being used on Stardust. In preparation for the DS1 Braille encounter, onboard encounter rehearsals and numerous testbed simulations executed successfully prior to encounter. During the encounter itself, however, the closed-loop tracking algorithm failed due to poor characterization of asteroid and camera characteristics. The signal from Braille barely made it above background noise, and never above the detection threshold, so the software was unable to lock onto the target. In addition, a noise spike of unknown origin triggered a false acquisition. A key assumption had been that the asteroid would be the brightest object in the camera field-of-view, no signal discrimination had been built into the algorithm.

Changes were made to the nucleus tracking software as a result of the Braille experience. The processing filter was changed from sequential to a batch mode. This allows for more robust data editing, and blunder point detection. It also allows for better flight system control when the loop is closed for tracking. In the initial design, the system immediately responded to the data being acquired. The second improvement was to change the signal detection from a simple brightness centroider to a "blob" detector. In the "blobber", regions of signal meeting threshold criteria are lumped together to form "blobs". This feature allows for discrimination of blobs based on expected size and brightness of the targets.

It is important to note that these improvements in the tracking software would not have made a difference for the Braille flyby due to the poor characterization of the target. If no signal matches the detection criteria, the tracking algorithm is not successful. Apriori characterization of the target to set detection thresholds is still critical. All of the lessons learned at Braille were incorporated in time for the DS1 Borelly encounter, including a better characterization of the camera and the comet. As a result, the closed-loop tracking algorithm performed flawlessly.

The software updates described above have now been integrated to the Stardust nucleus tracking software, and will be exercised at the Annefrank encounter.

2.5 Bonus Science

The science potential as a result of the Annefrank flyby is limited but significant. Given the test nature of the activities, no special accommodations have been made for science. However, the images obtained during the flyby will help address questions of asteroid diversity by providing the first information on a 4-kilometer diameter, S-type, main belt asteroid.

Annefrank is expected to be about 20 pixels across in the closest approach images. Even at this size, the images will help address questions of size, shape, albedo, albedo variation, phase function (150°-2°) and the photometric phase function.

3.0 Selected Details of the Annefrank Encounter

The purpose of this section is to describe a little more in depth the functional components of the Wild-2 Encounter Test, and the rationale behind how they are being executed.

Appendix 4.3 contains an integrated listing of spacecraft and ground events for Annefrank as of the publishing of this document. Although subsequent updates may occur prior to the actual flyby, the listing is sufficient to illustrate in slightly more detail the spacecraft events. A visual illustration of this time-ordered listing is provided in Figure 9.

3.1 Event Design – Selecting the Flyby Distance

A key component of the Wild-2 encounter will be the highly choreographed interaction between the spacecraft and ground activities. At Annefrank, however, ground-to-spacecraft interactions are designed to be a target of opportunity rather than a requirement. This feature is put into place given the test nature of the activity, to guard against the first time nature of many of the ground processing activities. An additional consideration for this design is the fact that the Sun-Target-Probe angle on approach to Annefrank is 150 degrees, only a sliver of Annefrank is to be illuminated by the Sun. Under this condition, optical detection is estimated to occur only a few tens of hours prior to closest approach. And under that scenario, the risk of failure in successful target acquisition by optical navigation and subsequent trajectory correction, as would be required to support a close distance flyby, is deemed unnecessary to accomplishing the test objectives.

This design characteristic of the Annefrank encounter is implemented by careful selection of the encounter flyby distance, 3200 kilometers. The goal is to select a flyby distance that will provide a greater than 3-sigma probability that Annefrank will be in the camera field-of-view at the start of nucleus tracking. This probability calculation is based on the apriori uncertainties in the Annefrank ephemeris and the navigation delivery to the Annefrank flyby point. No improvement in the ephemerides is assumed to come from the approach images. As a result, once the terminal approach phase begins, failure of a ground activity will not preclude successful testing of the on-board spacecraft functions. It is worth noting, however, that success of the certain ground events will improve the probability of success of certain spacecraft events. A clear example of this lies in the acquisition of Annefrank through optical navigation, and subsequent update to the nucleus tracking initial parameters.

Another consideration to selecting the flyby distance is the initial mirror angle at the start of nucleus tracking. The selected flyby distance provides an initial mirror angle that is greater than 20 degrees. At this mirror angle, the camera field-of-view is not projected through the camera periscope. Several images taken at a mirror angle of 15 degrees have resulted in a double image. Without fully understanding the characteristics or nature of this double image, it is deemed necessary to avoid use of the periscope during the Annefrank test. To this end, in parallel with each nucleus tracking parameter file update (see Section 3.7), navigation will make an assessment of the initial mirror angle given any additional information available at the time. Based on that estimate of initial mirror angle, they may recommend deleting the first few minutes of nucleus tracking images, where mirror angles would be below 20 degrees. Alternatively, when image deletion gets to the point of jeopardizing the success of nucleus tracking, the project will accept the risk of allowing the nucleus tracking algorithm to work with images taken through the periscope.

At first glance, this double image is not expected to provide significant difficultly at Wild-2. By the time the periscope is used for Wild-2 imaging, in particular, during nucleus tracking, the displacement of the double image will be small in comparison to the size of the comet image. Full characterization of the periscope is planned for Spring 2003, with a subsequent test of nucleus tracking through the periscope shortly after. A bright planetary body is planned as the target for those tests.

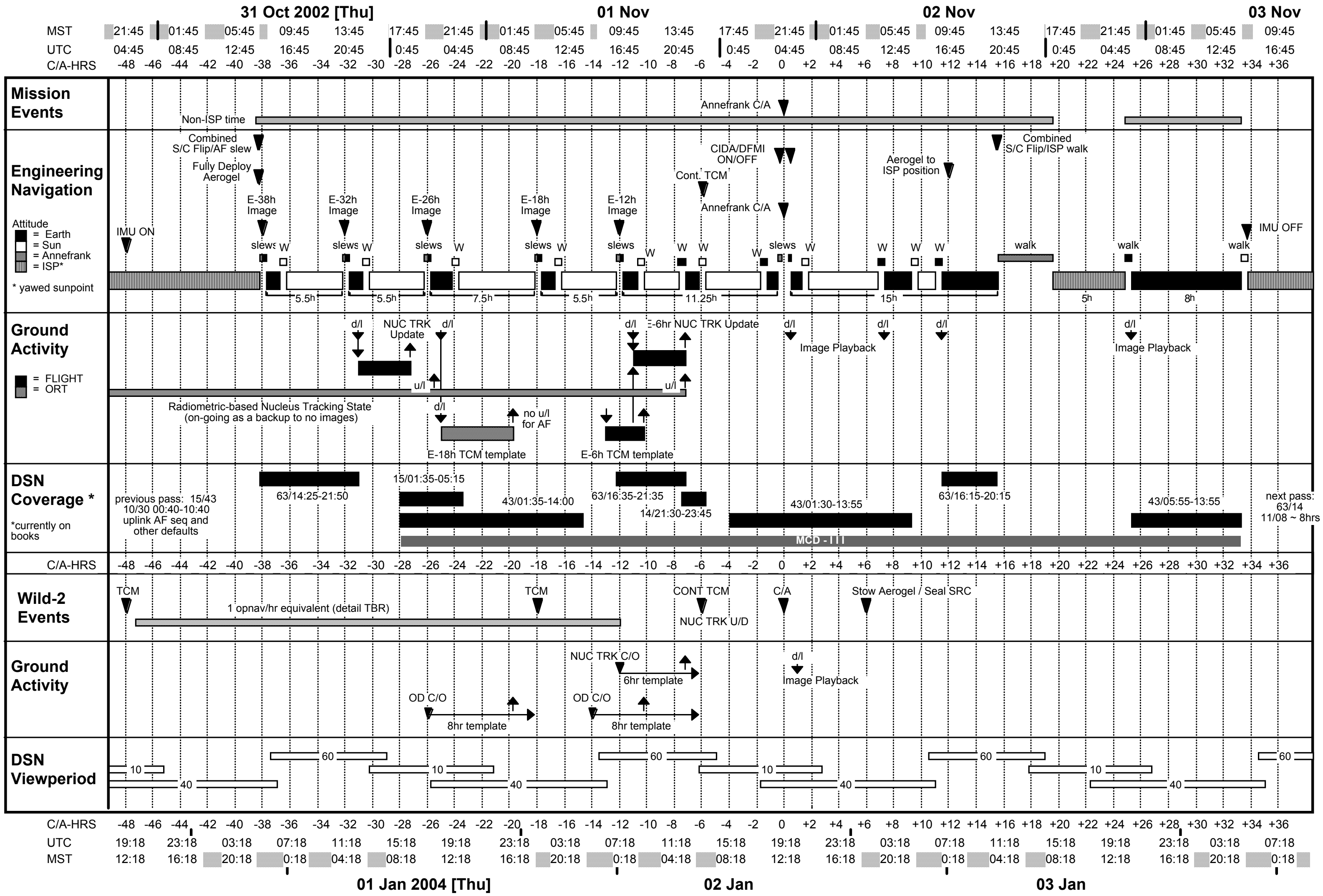

Figure 9. Annefrank Closest Approach Activities

3.2 Aerogel Grid Management and ISP Collection

Full deployment of the aerogel grid is required during any thruster activity beyond limit cycle pulsing and deadband walks. In addition, to more fully emulate the Wild-2 configuration, the grid is desired in a fully deployed position for the actual Annefrank closest approach passage. It is recognized, however, that there is no particle environment at Annefrank and as a result the spacecraft will not experience the full dynamics of particle impacts.

The requirement to fully deploy the aerogel grid during extensive thruster activity is driven by the concern that SRC mechanisms could move during thruster firings. This would lead to unpredictable mass properties, and as a result, unpredictable ACS performance. A flight software capability has been put into place to monitor (via microswitches) the fully deployed positions of not only the aerogel grid, but of the SRC backshell. Should microswitches indicate that the mechanisms have moved, motors will be activated to drive the mechanisms back to their fully deployed positions.

The off-sun nature of the Annefrank pre-encounter imaging, and encounter attitudes dictate the need to use slews (as opposed to deadband walks) to move the spacecraft from either Sunpoint or Earthpoint to the desired attitude. Transitioning the spacecraft from the ISP collection attitude to the Annefrank attitudes involves a 180-degree spacecraft flip to provide the required orientation to the spacecraft +x-axis. The initial flip from the ISP attitude to the E-38h Annefrank imaging attitude is being done as a slew, in the interest of time. After the flyby, the flip from Earthpoint to ISP Sunpoint will be done via deadband walk over the course of several hours.

To support the use of slews, the aerogel grid will be fully deployed just prior to the E-38 hr imaging opportunity. It will be left fully deployed, and returned to its ISP collection configuration only after the Annefrank flyby is completed. This second flip is currently planned at about 16 hours after closest approach, while re-deployment of the aerogel grid to its ISP position is anticipated to occur at about 12 hours after closest approach.

3.3 Approach Imaging

The main purpose of the approach imaging is to provide real images of a faint body for optical navigation to process, and navigation to combine with radiometric data to obtain a solution. An equally important, secondary objective, if Annefrank is acquired during these imaging opportunities, is to update the nucleus tracking initial parameters, thus improving the probability of a successful flyby. Combination of optical and radiometric data is a key component of the Wild-2 OPNAV campaign. Optical data will reduce the uncertainties in the spacecraft relative Wild-2 ephemeris to a point where a 150 kilometer flyby distance can be safely achieved.

Given the Annefrank approach geometry (150 degree phase angle) and a desire to avoid use of the periscope (see Section 3.1), there exists the possibility that stray light may affect image taking at the approach imaging attitudes. The mirror angle for these images will be 20 degrees, and the spacecraft +x-axis, as a result, will be 10 degrees off the spacecraft-sun line to get Annefrank in the camera field-of-view. In this configuration, light path modeling has identified the possibility of stray light making it to the camera CCD, but no quantative measure is available. This situation has slightly modified the intended image taking strategy for these opportunities. Where as full use of the pattern matching and windowing algorithms was desirable, the images will now be taken with deterministic windows only; the stray light would result in failure of the pattern-matching portion of the algorithm. It is felt that the overall Wild-2 test objectives are only slightly impacted by this change in strategy, in fact the strategy enables most of the test objectives to be exercised.

The optical navigation opportunities at Annefrank provide images for three types of ground activities: nucleus tracking parameter updates, E-18hr TCM development operational readiness test, and E-6hr Contingency TCM Go-Selection/No-Go. These will be discussed in more detail in subsequent sections.

The general sequence of events for one of the approach imaging opportunities is shown in show in Table 4. This specific example is extracted from the integrated time-ordered listing for the E-38 hr opportunity.

Table 4. E-38 hr Imaging Opportunity

C/A-hh:mm	dT-h:mm:ss	Activity
-38:44	0:24:26	S/C Htrs On (THRM_SET_PT_SEL)
-38:20	0:00:52	Fully Deploy Aerogel Grid (SRC_WRIST_GO)
-38:19	0:09:04	Slew from Sunpoint ISP to image attitude (ACS_MODE_SELECT)
-38:10	0:02:00	First Image in series (NAVC_TAKE_IMAGE)
-38:08	0:00:26	Last Image in series (NAVC_TAKE_IMAGE)
-38:07	0:02:12	Slew to Earth point (ACS_MODE_SELECT)
-38:05	0:14:43	Begin r/t only transmission (DOWNLINK_MODE, TLM_XBAND)
-38:00		E-38hrs
-37:50	0:40:17	Begin image transmission (FSW_OBJ_INITIAL, dpt_af_approach)
-37:10	0:05:10	Begin r/t only transmission (FSW_OBJ_INITIAL, dpt_rt_only)
-37:05	0:20:00	Walk to Sun Point (ACS_MODE_SELECT)
-36:45	3:48:38	Sunpoint

3.4 Power Scenario

Communications sessions are carefully planned to meet downlink and uplink requirements throughout the Annefrank scenario, while keeping the spacecraft in a power positive configuration. Notice the relatively short amount of time that is spent communicating with Earth after each imaging opportunity shown in Figure 9 (and Appendix 4.3).

Short communication sessions are characteristic throughout the Annefrank scenario due to the combination of the off-sun angle of the imaging and encounter attitudes, the solar distance, the need to have gyro-based attitude control (IMU On) for slews and the encounter, and having the telecom equipment powered on for communications. The telecom equipment is turned on and off in the power management scheme, but the IMU is left on to provide the stable performance required for image taking on approach, and during the encounter, and post-encounter for tight deadband playback (see Section 3.9). Table 5 summarizes the supportable communications plan as a function of Annefrank activity.

Table 5. Power-Constrained Communications Plan

Activity	Attitude (1)	Off-Sun (deg)	Comm. Duration	Post-Event Recharge
E-38, -32 hr imaging	S–A–E–S	0–60–25–0	1 hr	4 hrs
E-26 hr imaging	S–A–E–S	0–60–25–0	1.5 hrs	5.5 hrs
E-18, -12 hr imaging	S–A–E–S	0–60–25–0	1 hr	4 hrs
E-6 hr uplink	S–E–S	0–25–0	1 hr	2 hrs
Encounter (2)	S–E–A–E–S	0–25–60–25–0	45 m, prior & after	5 hrs
E+6 hr Playback	S-E-S	0-25-0	2 hrs	2 hrs
E+11 hr Playback	S-E-S	0-25-0	3.5 hrs	9 hrs

Notes:
1. S=Sunpoint, A=Annefrank, E=Earthpoint
2. Deeper state of charge of allowed, ~60%. IMU Off at post-encounter playback

3.5 E-18 hr TCM Operational Readiness Test

The approach TCM campaign at Wild-2 is designed to allow refinement of the flyby trajectory based on incremental knowledge of the comet ephemeris. Late improvements in this knowledge create the need for a quick response with a trajectory correction. The E-18 hr TCM provides the last opportunity to correct the flyby B-plane intercept point. Only 8 hrs are allocated between the final desired image (E-26hr), and the time of the main delta-V burn. During this time, images must be processed, combined with radiometric data, then delivered for maneuver design, implementation, and transmission to the spacecraft.

Restricting the maneuver design to a B-plane correction, given the characteristics of the flyby attitude, is equivalent to restricting possible attitude motion to the "roll" axis of the spacecraft. This is important at Wild-2 as the spacecraft may already be within the comet's dust cloud at E-18hrs, a roll-only TCM keeps the spacecraft behind the protection of the whipple shields. The maneuver sequence is pre-built for a worst-case roll, and 3-sigma expected delta-V magnitude such that during this 8 hr process, only the maneuver's flight software configuration files need be updated and verified.

The 8 hr maneuver design process is illustrated in Table 6. For the Annefrank flyby, the process will only be completed through what are considered the time-constrained portions, as indicated in Table 6.

Table 6. E-18 hr TCM Operational Readiness Test

C/A-hh:mm	dT-h:mm:ss	Team	Activity
-26:05	0:19:00		owlt
-25:46	0:14:43	DSN	lockup on signal + sweep time (dpt_rt_only)
-25:31	0:40:17	SC	transmit images
-24:51	0:30:00	GDS	data processing/delivery to OPNAV
-24:21	0:30:00	OPNAV	OPNAV image processing
-23:51	0:30:00	OD	OD process/deliver solution
-23:21	0:30:00	MNVR	MNVR design/deliver MPF to SCT
		NAV/ALL	E-18hr TCM Go / No-Go Assessment (if needed)
-22:51	1:00:00	ACS	ACS implement maneuver/design slews
-21:51	0:20:00	PROP	PROP Design
-21:31	0:40:00	ACS	ACS build/deliver MIF/config files to ALL
		END ORT HERE!!	
-20:51	0:30:00	ALL	Review Products
-20:21	0:30:00	ALL	E-18hr TCM Command Conference
-19:51	0:00:26		Margin
-19:51	1:51:00	RTO/SYS	Uplink Maneuver Files to S/C
-18:30	1:00:00		Start E-18hr TCM Maneuver Sequence

3.6 E-6 hr Contingency TCM Selection

The approach TCM campaign at Wild-2 is also designed to allow for sudden and late discoveries regarding the flyby trajectory, or more likely the dust environment surrounding Wild-2. The possibility of acquiring this knowledge very late creates the need to have a contingency maneuver pre-built and ready to implement should there be any indication that the spacecraft is in danger.

The contingency TCM is implemented as late as 6 hours from closest approach and is designed to increase the flyby distance by a pre-determined amount. For Wild-2, the flyby attitude is also conveniently an Earth pointed attitude, and as such is an excellent attitude for the contingency burn. However, the implementation strategies are yet to be refined for Wild-2, and the possibility exists of considering multiple pre-canned maneuvers to increase the flexibility of response to multiple different scenarios.
Given the apriori design of the Annefrank encounter, as described in Section 3.1, the probability of requiring this contingency maneuver during the Annefrank flyby is extremely small. Nonetheless, if even for the purposes of operational readiness testing, a contingency maneuver with a magnitude of about 5 meters per second will be ready to be implemented, if needed. The implementation attitude will be Earth pointed. Although that attitude is not the most efficient in terms of providing an increase in flyby distance as a function of delta-V (35° from being perpendicular to the approach asymptote), it is a safe attitude and effective enough for the purposes of Annefrank. This maneuver design will provide a change in flyby

distance of about 80 kilometers at the Annefrank closest approach point. Eighty kilometers corresponds to approximately the 1-sigma value of the navigation delivery knowledge for flyby distance.

The E-6hr contingency TCM selection process is initiated at the E-14 hr OPNAV opportunity during the Wild-2 scenario. The start of the process cannot wait for the final OPNAV opportunity at E-12 hrs because the results of this process, go or no-go, must be folded into the final nucleus tracking parameter file updates. There is no need to be concerned about this earlier cutoff, however, as it should be evident by E-14 hrs (if not sooner) whether the contingency is needed.

For Annefrank, delayed processing of the E-18 hr imaging opportunity will provide the starting point for the contingency TCM process. Table 7 illustrates the steps involved in said process. A ground rule for Annefrank is that if this maneuver is executed, something has gone very wrong and the close encounter events themselves will be canceled.

Table 7. E-6 hr Contingency TCM Selection

C/A-hh:mm	dT-h:mm:ss	Team	Activity
-14:05	0:19:00		owlt
-13:46	0:14:43	DSN	lockup on signal + sweep time (dpt_rt_only)
-13:31	0:40:17	SC	transmit images
-12:51	0:30:00	GDS	data processing/delivery to OPNAV
-12:21	0:30:00	OPNAV	OPNAV image processing
-11:51	0:30:00	OD	OD process/deliver solution
-11:21	0:30:00	ALL	E-6h TCM Go & Selection/No-Go
-10:51	0:30:00	ALL	Command Conference
-10:21	3:53:27		margin
-6:27	0:40:17	RTO/SYS	Uplink Files to S/C

3.7 Nucleus Tracking Parameter File Updates

The need for updates to the nucleus tracking parameter file suite is more fully described in Section 2.4. During Annefrank, the imaging opportunities from E–38 hrs to E–12 hrs provide the information that drives the file updates. The update process involves interaction between ground data system engineers, optical navigators, orbit determination analysts, the spacecraft team, and flight operations management.

Two opportunities to update the file suite are provided during the Annefrank exercise. The first is at 26 hours from closest approach and will incorporate whatever information was obtained from the E–38 hr and E–32 hr image opportunities. The final opportunity to update the nucleus tracking files is provided at E–6 hrs, and will include information from all imaging opportunities.

The time available from the last image opportunity prior to an update and the time of the command transmission is 6 hours. Table 8 illustrates the steps involved and the time allocated for each step. The illustration corresponds to the E–12 hr image opportunity that then leads to the E–6 hr uplink window.

Table 8. E-6 hr Nucleus Tracking Parameter Update Process

C/A-hh:mm	dT-h:mm:ss	Team	Activity
-11:55	0:19:00		owlt
-11:36	0:14:43	DSN	lockup on signal + sweep time (dpt_rt_only)
-11:21	0:40:17	SC	transmit images
-10:41	0:30:00	GDS	data processing/delivery to OPNAV
-10:11	0:30:00	OPNAV	OPNAV image processing
-9:41	0:30:00	OD	OD process/deliver solution

-9:11	0:15:00	SCT	Generate Image Time PEF
-8:56	0:15:00	OPNAV	OPNAV build config files, sasf
-8:41	1:00:00	SCT	SCT build uplink products
-7:41	0:30:00	ALL	Review uplink products
-7:11	0:30:00	ALL	Command Conference
-6:41	0:13:24		Margin
-6:27	0:40:17	RTO/SYS	Uplink Files to S/C

3.8 Close Encounter Sequence

The Annefrank close encounter block is not identical to the Wild-2, but as mentioned previously, it exercises all of the same activities at a functional level. The Wild-2 block commands cover a period of over 10 hours while the Annefrank block is approximately 25 minutes long. The Wild-2 block will also take science images at 3 and 2 hours from closest approach, the Annefrank block will take three images prior to the start of centroiding at E-22 minutes. Nucleus tracking and the bank maneuver are similar to Wild-2, with exception of the previously described difference in initial mirror angle. Table 9 provides a high-level description of the close encounter events.

The first time events exercised by the Annefrank block can be summarized as follows:

- Disable S/W fault protection entries: ACS faults will remain enabled, Battery State of Charge will remain enabled, Critical Event Fault Protection will not be enabled.
- Reallocation of HEAP Space (C&DH memory) to encounter configuration.
- Command ACS to Encounter Mode.
- Command CIDA to Encounter Mode.
- Command NAVCAM to Encounter Mode.
- Nucleus Tracking
- Perform Bank Maneuver
- Reallocation of HEAP Space to Cruise Configuration (post-playback).

3.9 Data Playback

Post–encounter data playback is a key component of the Wild-2 and Annefrank scenarios. The flyby data is stored in volatile memory that would not survive a hard reset of the spacecraft's computer. It is essential to downlink the acquired data as quickly as possible.

Data playback at Annefrank is similar to Wild-2 in that it makes use of specialized equipment at the DSN (MCD-III) to increase the convolutional encoding rate from 7-1/2 to 15-1/6. Use of this higher encoding allows the downlink data rate to be doubled from 3950 bps to 7900 bps. Also being implemented at Annefrank is the use of very tight deadbanding to further increase the downlink data rate. Standard high-gain antenna communications are performed at deadbands of 2 degrees (x-axis, y-axis, 10° on z-axis). At Annefrank, deadbands of 0.25 degrees, while relatively expensive in delta-V, will result in an additional tripling of the data rate, from 7900 bps to 22,120 bps.

Table 9. Closest Approach Activities

C/A-hh:mm	dT-h:mm:ss	Activity
-2:50	1:15:07	S/C Htrs On (THRM_SET_PT_SEL)
-1:34	0:20:01	Walk to Earth Point (ACS_MODE_SELECT)
-1:14	0:14:43	Begin r/t only transmission (DOWNLINK_MODE, TLM_XBAND)
-1:00	0:13:15	Begin data transmission (FSW_OBJ_INITIAL, dpt_af_approach)
-0:46	0:01:55	Reallocate Heap Memory (REALLOCATE_HEAP)
-0:44	0:04:59	Turn CIDA On (CIDA_MAIN_POWER)
-0:40	0:05:01	Begin r/t only transmission (FSW_OBJ_INITIAL, dp_rt_only)

-0:34	0:01:04	Turn NAVCAM On (NAVC_POWER)
-0:33	0:03:07	Turn NAVCAM Mirror On (NAVM_POWER)
-0:30	0:05:48	Slew from Earth point to AF attitude (ACS_MODE_SELECT)
-0:25	0:01:00	Configure Fault Protection (SEQ_ABORT_EN_DIS)
-0:24	0:01:00	Pre Nucleus Tracking Image (NAVC_TAKE_IMAGE)
-0:23	0:00:00	Turn DFMI On (DFMI_POWER)
-0:23	0:01:00	Pre Nucleus Tracking Image (NAVC_TAKE_IMAGE)
-0:22	0:02:01	Pre Nucleus Tracking Image (NAVC_TAKE_IMAGE)
-0:19	0:14:20	Start Nucleus Tracking (NAVC_TAKE_IMAGE, 20 sec sep.)
-0:05	0:03:39	Execute Roll Maneuver (ACS_MODE_SELECT)
-0:02	0:02:00	Continue Nucleus Tracking (NAVC_TAKE_IMAGE, 6 sec sep.)
		ANNEFRANK CLOSEST APPROACH
0:03	0:00:06	End Nucleus Tracking (last NAVC_TAKE_IMAGE)
0:03	0:00:20	Execute Roll Maneuver (ACS_MODE_SELECT)
0:03	0:01:02	Slew from AF attitude to Earth point (ACS_MODE_SELECT)
0:04	0:00:34	Begin r/t only transmission (DOWNLINK_MODE, TLM_XBAND)
0:05	0:00:02	Turn CIDA Off (CIDA_MAIN_POWER)
0:05	0:01:35	Turn DFMI Off (DFMI_POWER)
0:06	0:00:02	Turn NAVCAM Off (NAVC_POWER)
0:06	0:13:28	Turn NAVCAM Mirror Off (NAVM_POWER)
0:20	0:02:00	Begin image transmission (FSW_OBJ_INITIAL, dpt_af_approach)
0:22	0:00:13	Set command loss timer to 17 days (FSW_OBJ_INITIAL, hlfp_cpm)
0:22	0:23:46	Re-configure Fault Protection (SEQ_ABORT_EN_DIS)
0:46	0:05:10	Begin r/t only transmission (FSW_OBJ_INITIAL, dp_rt_only)
0:51	0:20:00	Walk to Sun Point (ACS_MODE_SELECT)
1:11	5:14:57	Sunpoint

The tight deadband configuration has not been previously used for extensive periods of time, as planned here. While no problems are anticipated, contingency commands will be available to open the deadbands to 2 degrees, and drop the data rate, should anomalous behavior be observed.

While extensive 70-m DSN coverage is available during the Wild-2 encounter, there is a plethora of non-Stardust mission activity planned for that period. An anomaly could ripple through the DSN network and jeopardize data return. At Annefrank, there is not extensive 70-m DSN coverage, which in itself is reason enough to increase the data rate to as high a value as possible and reduce the risk of data loss.

4.0 Appendix

4.1 MCR-1450: Add Wild-2 Encounter Test (Annefrank) to Mission Plan

4.2 Waiver 53: Allowance for Non-Interstellar Dust Collection Time

4.3 Integrated Time-Ordered Listing (separate Excel File: Aftol.r9.xls)

4.1 MCR-1450: Add Wild-2 Encounter Test (Annefrank) to Mission Plan

MMO CHANGE REQUEST
No. 1450

Date 10/11/2002

	MMO CHANGE REQUEST	**Change Request Type:** Mission Change Request **Change Classification** (●) 1 ( ) 2 ( ) 3
Title: Add Wild-2 Encounter Test (Annefrank) to Mission Plan (Keywords)		**S/C ID:** SDU
Initiator: Ed Hirst **Phone:** 4-4947 **LOC:** 264-580F **Date:** 10:38:34 AM 10/11/2002 **Type of Change:(n/a for CMD):** ☐ Hardware NASA ID: N/A H/W Location: N/A ☐ Software ☑ Documentation ☐ Sequence # N/A ☐ Block # N/A	**Team Affected by this Request:** ☐ GDS ☑ MP&S ☑ Science ☑ SCT ☐ DSMS ☑ NAV ☐ Facilities **Subsystems/Components Affected:** ALL **Disposition/Implementation required by (Date):** 10/21/02	**Project:** ☐ MGS ☑ STARDUST ☐ SIRTF ☐ ODYSSEY ☐ GENESIS ☐ MER ☐ MEX ☐ MMO - ALL
Criticality/Priority: ( ) 1. No Workaround exists (●) 2. Arduous Workaround exists ( ) 3. Acceptable Workaround exists ( ) 4. Desirable	**Document Affected (n/a for CMD):** ☑ Mission Plan ☐ Experiment Operations Plan ☐ Detailed Mission Requirments ☐ Flight Rules and Constraints ☐ SIS ☐ SRD ☐ ATP ☐ OTHER None	**Related (n/a for CMD):** Change Request : N/A Waiver : N/A PFR N/A ECR N/A

Change/Command Requested:

Add Wild-2 Encounter Test (Annefrank flyby) activties to Mission Plan as listed in Attachment 1.

Reason for Change/Command:

The test will allow reduction of the following risks for the Wild-2 encounter: (1) Limitations of STL fidelity to model all S/C, subsystem, payload activties and interactions, (2) Limitations of STL models of S/C, ACS, Nav Cam, mirror closed loop control, (3) Limited characterization of Nav Cam image / geometric performance, (4) Lack of small body initial acquisition and associated ground processing, (5) Simplicity of ORTs through STL and simulations (test as will be flown opportunity).

Impact if Not Implemented:

Wild-2 flyby becomes a first time in-flight event for many critical functions and components. Annefrank flyby affords the project a unique opportunity to test all activity that will be used during Wild-2 flyby. Disapproval squanders this unique opportunity.

Implementation Approach:
(Command Window)

Document further via supplement to the Mission Plan. Implement via CCR and background sequence planning as required.

Attachments: Attachment 1: AF-plan.ppt **Attachment 2:** No_Attachment.html **Attachment 3:** No_Attachment.html **Attachment 4:** No_Attachment.html

MCCB

STATUS	**Authorized By:**
Approved Rejected Withdrawn Pending	Mission Manager: Not Yet Reviewed - 00/00/00 Project Manager: Not Yet Reviewed - 00/00/00 Mission Management Office Manager: Not Yet Reviewed - 00/00/00
Comments:	
Action Items:	
Approximate cost Estimate: W/F $ 0	Mission Phase No.
ICA: 00000 Date Implemented 00/00/00 Closed Date: 00/00/00	

Back to View a Change Request Form or Back to MMO Main Page

Mission Plan Timeline

Bold Italics are new items. Times are approximate and subject to change during detailed planning.

05 Aug 2002 (DOY 217)	E-98 days	Start ISP-2 [MCR 1252], open SRC, deploy Aerogel grid
27 Aug 2002 (DOY 239)	E-67 days	Update Aerogel grid and S/C attitude
18 Sep 2002 (DOY 262)	E-45 days	Update Aerogel grid and S/C attitude
09 Oct 2002 (DOY 282)	***E-24 days***	***TCM-7a (includes full deployment of aerogel grid, approximately 65° total movement).***
23 Oct 2002 (DOY 296)	**E-10 days**	**Update Aerogel grid and S/C attitude**
28 Oct 2002 (DOY 301)	***E-122 hrs***	***Uplink Annefrank sequence, approach image parameters, and default nucleus tracking parameters and flyby attitude***
31 Oct 2002 (DOY 304)	***E-48 hrs***	***IMU on***
	E-38 hrs	***Fully deploy aerogel grid (~20°), S/C flip from ISP attitude*** ***Take and downlink Annefrank images***
	E-32 hrs	***Take and downlink Annefrank images***
	E-32 to -26 hrs	***Perform nucleus tracking and encounter attitude update***
01 Nov 2002 (DOY 305)	***E-26 hrs***	***Take and downlink Annefrank images*** ***Uplink nucleus tracking and encounter attitude update***
	E-26 to -18 hrs	***W2-18 hr TCM Template Operational Readiness Test***
	E-18 hrs	***Take and downlink Annefrank images***
	E-14 to -10 hrs	***Perform E-6hr contingency TCM No-Go/Go-Selection***
	E-12 hrs	***Take and downlink Annefrank images***
	E-12 to -6 hrs	***Perform nucleus tracking and encounter attitude update***
	E-6 hrs	***Execute contingency TCM and cancel AF flyby OR*** ***Uplink nucleus tracking and encounter attitude update***
02 Nov 2002 (DOY 306)	***E-6 h to -20 min***	***Re-configure spacecraft (CIDA On, other details TBR)***
	E-20 to +5 min	***Encounter closest approach sequence (includes DFMI on, nucleus tracking, bank maneuver, etc)***
	E+0	***Annefrank Closest Approach (7.2 km/s, 3200 km)***
	E+5 to +20 min	***Re-configure spacecraft (IMU Off, details TBR)***
	E+6 hrs	***Start Annefrank playback***
	E+10 hrs	***S/C Flip to Earth-point ISP***
	E+12 hrs	***Deploy aerogel to ISP position (~11°)***
	E+16 hrs	***Resume ISP collection***
03 Nov 2002 (DOY 307)	***E+25 hrs***	***Continue Annefrank playback***
08 Nov 2002 (DOY 312)	***E+6 days***	***Continue Annefrank playback***
13 Nov 2002 (DOY 317)	**E+11 days**	**Update Aerogel grid and S/C attitude**
20 Nov 2002 (DOY 324)	**E+18 days**	**Update Aerogel grid and S/C attitude (grid fully deployed)**
28 Nov 2002 (DOY 332)	**E+26 days**	**Update S/C attitude**
04 Dec 2002 (DOY 338)	**E+32 days**	**Update S/C attitude**
09 Dec 2002 (DOY 343)	E+37 days	End ISP-2, Stow Aerogel grid, Close SRC
20 Dec 2002 (DOY 354)	***E+48 days***	***TCM-7b (As needed, date TBR)***

4.2 Waiver 53: Allowance for Non-Interstellar Dust Collection Time

Mission Management Office
WAIVER REQUEST

Waiver# *53*
(Call CM for #)

Waiver Title *Allowance for Non-Interstellar Dust Collection Time* Keywords

Initiator: *E. Hirst (x4-4947)* Date: *10/11/02*	Teams Affected by this Change: *Science*	WAIVER INVOLVES: ☐ Project Policies ☐ Mission Plan ☐ Mission Sequence Plan ■ Flight Rules ☐ Mission Operations Spec ☐ Software Requirements ☐ Test & Training Plan ☐ Security ☐ Other *Mission Req.*
Rule Number: *0705-E-SCI*	Documents Affected: *N/A*	
Criticality Rating: *N/A*	External Interfaces Affected? ☐ YES ■ NO Specify:	
Sequence Load Affected: *SC046 thru SC051*	Related: MGSO CR,FR, WVR, PFR, MCR *MCR 1450 (approval to perform Annefrank flyby)*	

Original Requirement(s): (Cite specific requirements and/or indicate document title, no., para, page, etc.)
0705-E-SCI : The ISP side (-X) of the Aerogel must not be pointed directly into the sun for more than 5% of the collection time.

Waiver Requested: (Be Specific)
Allow non-ISP time to be as high as 10% of the total collection time.

Justification/Remarks:
Approval of MCR 1450 requires additional DSN tracking for successful, robust implementation ofAnnefrank flyby. The preliminary estimate of non-ISP time based on normal levels of DSN tracking was 12%. Efforts have been taken (e.g. 2-way/3-way tracking) to allow the non-ISP time to be reduced to approximately 8.5%, but this is still in violation of the flight rule. Note that rule applies to total ISP-1 (69 days) plus ISP-2 (126 days) time. During ISP-1, non-ISP time was allowed to be approximately 10% due to its proximity to Deep Space Maneuver 1. In addition, under the pre-Annefrank plan, ISP-2 was to be much quieter. The addition of Annefrank flyby reflects a Stardust Project trade with regards to Science objectives. Also note that 10% of the total ISP time (20 of 195 days), still provides some margin (25 days) over the 150 day total ISP requirement, against which, it could be argued, 0705-E-SCI is measured.

Impact if Disapproved:
Mission Operations unable to schedule required DSN tracking to perform Annefrank Flyby activities.

Date:	Approval : ☐ Yes ☐ No Date
Sequence Integration Engineer:	Mission Manager
Team Chief:	Required for Rules with Criticality A,B,C,D Approval: ☐ Yes ☐ No Date
MOA Manager:	Mission Management Office Manager

11/04/00
JAB