NASA's Deep Impact Mission: Decision Making

# Deep Impact Spacecraft

## STRATEGY INFORMATION SHEET

### BACKGROUND INFORMATION

Deep Impact

The Deep Impact spacecraft is launched as a single spacecraft. About one day before the scheduled impact, the impactor is separated from the flyby spacecraft. Determining the timing of the impact is important to optimize the data that is obtained from Deep Impact. For this observation strategy, an important criterion for timing the impact is to do so such that the impact is made on the lighted side of the comet.

An onboard camera is used to target the impactor and to provide the highest resolution of the surface. The resulting crater is expected to form in 200 seconds after impact. The crater is expected to have a 120-meter diameter and be 28-meters deep. The flyby spacecraft has a number of instruments for making observations of the impact and resulting crater. High- and medium-resolution telescopes are mounted on the spacecraft's body. The spacecraft rotates in order to follow the nucleus and crater during the flyby. Other instruments include an optical imager and a near infrared mapping spectrometer.

The Deep Impact spacecraft observations must be carefully managed in order to stay within certain constraints. The spacecraft observational sequence must be designed to fit within the capabilities of the spacecraft memory and downlink data rate. Pictures that are taken must either be sent immediately to Earth over the telemetry link or stored in the spacecraft computer for later relay. Critical images might be sent immediately to Earth and stored in the spacecraft memory for backup. Since the survival of the flyby spacecraft through the orbital path of the comet, where dust and debris is concentrated, cannot be assured, it is planned to return as much data as possible before the spacecraft passes through this potentially dangerous region.

Deep Space Network

The Deep Space Network is an international network of antennas that supports interplanetary spacecraft missions. They conduct radio and radar astronomy observations for the exploration of the solar system and the universe. The network is a NASA facility and is managed and operated by the Jet Propulsion Laboratory. The Deep Space Network is used for all space missions is the largest and most sensitive scientific telecommunications system in the world. Three locations currently make up the network including: Goldstone in California's Mojave Desert; Madrid, Spain; and Canberra, Australia. These facilities are approximately 120 degrees apart on the globe. The placement of the network in these locations allows constant observation as the Earth rotates. However, many missions need to access the network during the impact. For more information about the Deep Space Network, visit the Web site at: http://deepspace.jpl.nasa.gov/dsn/

The downlink data rate is 175,000 bits per second using Deep Space Network's 70-meter antennas and 25,000 bits per second using the 34-meter antenna. A full frame image is about one megabyte. How long would it take to download one full frame picture using the 70-meter antennas? How long would it take to downlink one full frame picture with the 34-meter antennas? (One megabyte is equal to one million bytes and there are eight bits in one byte.) There are about 300 megabytes of memory in the spacecraft computer to store images. How many full frame images can be stored on the spacecraft? How does knowing this affect mission planning? (See Procedure #1 below.)

Determining the best time for impact will optimize the data collection during the following Deep Impact flight system objectives:

1. Hit nucleus of 9P/Tempel 1 with sufficient kinetic energy to form a crater with a depth greater than twenty meters.
2. Observe nucleus for more than 10 minutes following impact.
3. Image nucleus impact, crater development and inside of crater.
4. Obtain spectrometry of nucleus and inside of crater.
5. Acquire, store, format, and downlink imagery and spectrometry data.

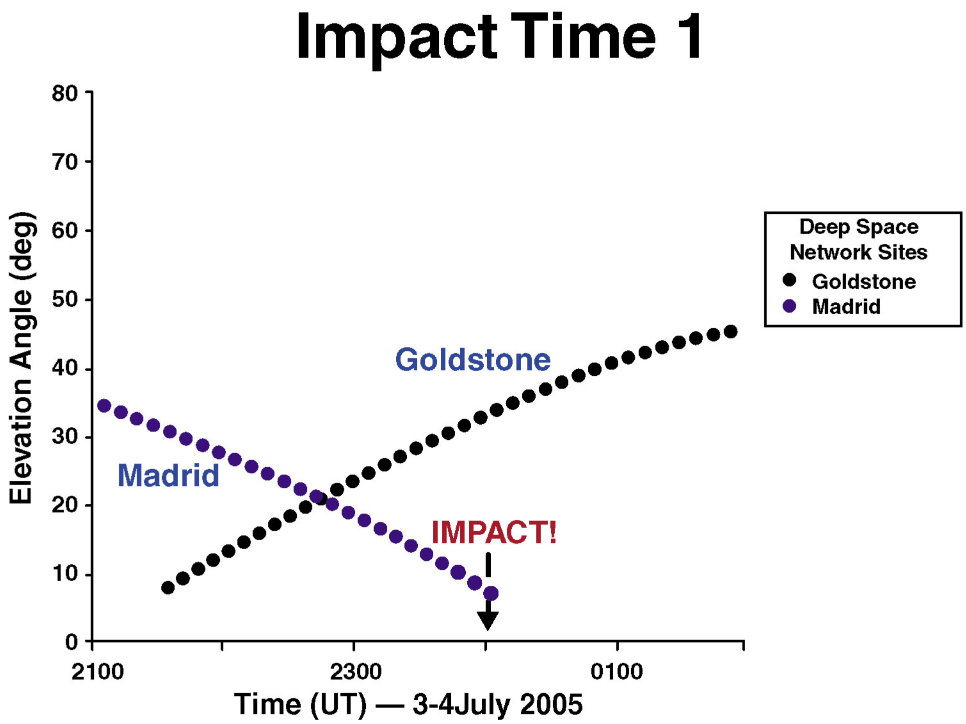
9P/Tempel 1 is in a 5.5-year orbit and next reaches its closest point to the Sun (perihelion) on July 5, 2005. The best date to reach the comet is when it is close to crossing the orbit plane of the Earth (the Ecliptic plane), which occurs on July 7, 2005**.** These events are fortuitously close together, so the Deep Impact mission first looked at days in early July 2005 for the impact date, since this minimizes the energy we need from the rocket that launches the spacecraft (the Delta II launch vehicle). Reducing the launch energy for the rocket allows it to carry the heaviest possible impactor in order to make a bigger crater.

## PROCEDURE

1. Complete the calculations in the background section as noted above.
2. Your job in this expert group will be to analyze all of the possible times of impact and determine the best option for obtaining data from the flyby spacecraft. Read the information that follows and prepare a recommendation to your group. Which option would you recommend and why? Ideally, the impact should be planned to take place when two of the Deep Space Network antennas are covering that area of the sky. For the information below, the science value of Earth-based observing is shown as well.

**Option1: Impact Time 1**

This option has an impact time of **0000 UTC on July 4, 2005**. With this option, the impact time will be 5 p.m. Pacific Daylight time on the west coast on July 3, and 8 p.m. Eastern Daylight time on the east coast. During this time many people in the United States will be awake during the impact. This option involves Earth-based observing primarily from high-altitude sites in Chile, which are favored by the southern declination of the comet at impact, and DSN coverage through the Goldstone, California tracking site. Substantial functional redundancy for receiving data at Goldstone would be possible using multiple antennas (70 meter, and 34-meter array). However, this option does not provide DSN backup in case of bad weather (thunderstorm, winds) or a major power outage that would disable all of the antennas at Goldstone.

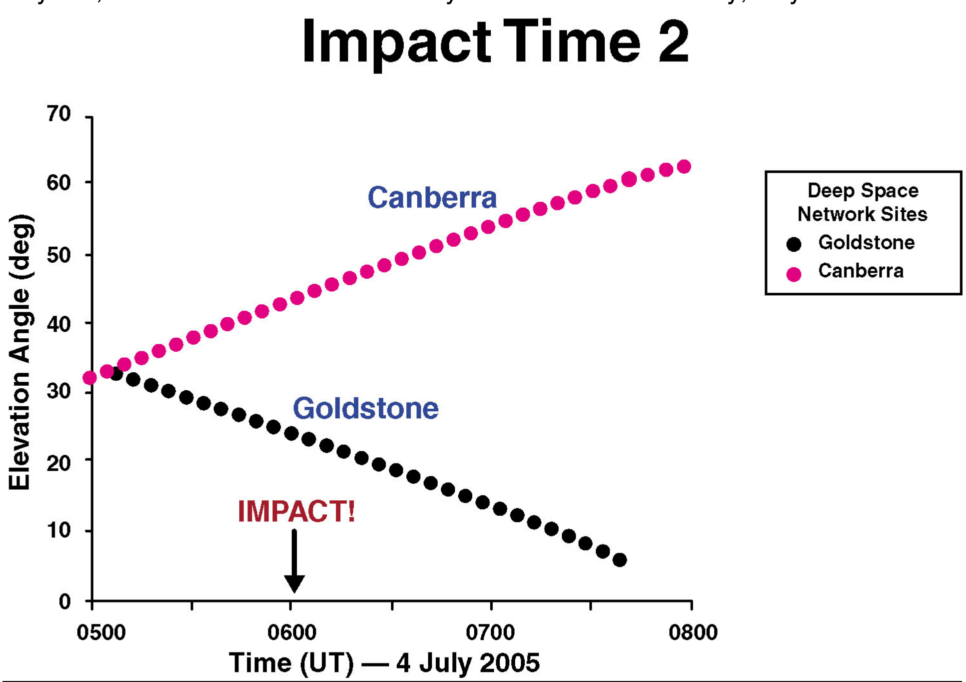


**Option 2: Impact Time 2**

The impact time for this option is set so that it will be first seen on the Earth at **0600 Hours Universal Time on Monday July 4th, 2005**. For people in the United States the time will be 11 p.m. Pacific Daylight Time on the west coast (actually Sunday, July 3rd) and 2 a.m. Eastern Daylight Time on the east coast.

0600 UTC puts the impact event in overlapping coverage between the DSN tracking stations at Goldstone, California and Canberra, Australia so that we have the highest confidence of receiving all the telemetry even if one tracking site has a problem, such as bad weather or a major power outage. This time represents some compromise in the observatory coverage of the impact event in order to maximize the probability of telemetry return. 0600 UTC puts the comet over the Pacific Ocean at impact, with overlapping coverage from the Mauna Kea, Hawaii observatories, just after sunset, and west coast observatories, primarily Palomar.

This scenario has the added benefit of similar public attention that was focused on the Pathfinder landing on July 4th, 1997. Most Americans will see the events before impact on TV on the evening of Sunday, July 3rd, but it should be the lead story in the news on Monday, July 4th.




**Additional Information from the mission planners:**
*Not everything is perfect for the dates in early July 2005. A compromise must be made, choosing between several factors. The two primary factors are the launch energy and the approach phase angle, which determines what percent of the nucleus is illuminated as the flyby S/C and impactor are targeted for the encounter. July 4 is approximately the best encounter date when considering all the mission parameters, as it allows us to carry the most mass in the impactor. Later arrival dates don't provide much more mass, while the approach phase angle and Earth range are degraded. Earlier arrival dates provide a better approach phase angle and Earth range (for better telecom rates and Earth-based observing), but the mass capability falls off significantly and the encounter speed is increasing, producing more smear in the images. A large illumination or small phase angle is important because we need sunlight to image the impact.*

*The science team and, in particular, the principal investigator still want to review the implications of your decision. This is because some compromises have been made in the observations of the impact from astronomical observatories in order to maximize the probability of receiving all the radio telemetry from the flyby spacecraft with the most important images.*