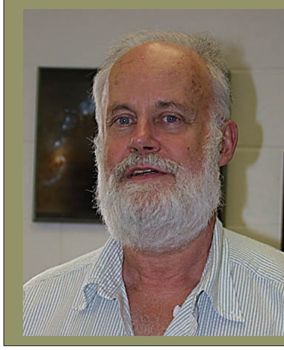
NASA's Deep Impact Mission: Decision Making

Dr. Michael A'Hearn

APPENDIX A: INTERVIEW SHEET

Question: Please tell us about your involvement with the Deep Impact mission and your thoughts about optimizing the data being received during the impact of Comet 9P/Tempel 1 in July of 2005.

Interview of: Dr. Michael A'Hearn
Job Title: Deep Impact Principal Investigator
Institution: University of Maryland
Interviewer: John Ristvey
Date: July 6, 2001
Conducted by phone at the University of Maryland in College Park, Maryland



Dr. Michael F. A'Hearn

Dr. Michael A'Hearn
Deep Impact Principal Investigator

My name is Michael A'Hearn. I am a professor of astronomy at the University of Maryland. My interest in comets goes back at least thirty years. I first did some work with comets when I was in graduate school. I was interested in comets because they provide clues to the origin of the solar system, and they were not being well studied at that time. The field has changed dramatically since then. There are now huge numbers of people studying comets. I am interested in all aspects of comets. The most unknown part of a comet is its nucleus. We have a huge amount of data on the gas and dust that make up the head and the tail of the comet, but our knowledge of the nucleus is based on theoretical inference. So Deep Impact is intended to probe the interior of a comet's nucleus for the first time. The original idea to propose a mission like this came from two members of the science team, Mike Belton and Alan Delamere, when they were serving on a review panel for another mission. Mike Belton asked me to take over as the principal investigator a couple of years later and I have been running the project during the selection phase of the mission since it has been selected.

Comets are very black. This makes it very difficult to study them. Questions that the science team is asking include, "Is there ice on the surface of the comet?" and, "Is there ice deep within a comet?" Belton and Delamere realized that because of the uncertainties of the nature of the comet's nucleus, trying to land on a comet is extremely challenging. One challenge of landing on the comet would be to figure ways to hold the spacecraft down. Gravity is weak on a comet, yet we don't know for sure how weak. Plus we do not know how to attach to the surface, because we don't know what the surface is like. The Rosetta mission developed by the European Space Agency (ESA) is scheduled to launch in 2003 and land on Comet 46P/Wirtanen in 2011. The challenge to land on a comet is so huge that a safer approach is to use brute force to see what the internal structure is like before trying to land. Deep Impact is a first step, a relatively simple mission, attempting to find out about a comet's interior and surface before trying to land on one.

The final decision on the timing of the impact for Deep Impact has not been made. We have baseline data that we are working from now, but this decision is one that will be made just prior to launch. There are several issues involved in this decision. We will have data coming back from the spacecraft through the Deep Space Network (DSN). In one sense, the data we get from the spacecraft are the most valuable. It is certainly the most expensive data because we built special instruments to fly on the spacecraft for the sole purpose of gathering these data. We would like to have redundancy in the Deep Space Network to make sure we get these data from the spacecraft. On the other hand, the variety of data we get from the spacecraft are relatively small compared to the variety of data we can get from Earth-based facilities, both on the ground and in orbit around the Earth. We can get a much wider physical understanding of the characteristics of the Comet 9P/Tempel 1, if we get a wide selection of data from Earth-based facilities as well. Since it is not dark everywhere on Earth, the question that must be answered is "From what observatories can we get the largest possible amounts of data with the greatest diversity and the highest probability of success?" Some observatories are in locations where it is likely to be rainy, and others don't have the instrumentation in order to make a wide variety of measurements. So we must think very carefully about which ground-based observatories are the most important from the viewpoint of instrumentation and a probability of clear weather. This information is used for deciding the best time for impact. The two prime Earth-based sites with a large variety of instrumentation and telescopes are in Chile and in Hawaii.

The real choice is how much weight do we put in having redundancy in the Deep Space Network? Is it important to have redundancy in two different sites or is it adequate to have redundancy between a large dish and an array of small dishes at the same site? This requires more analysis of the typical failures of the Deep Space Network to determine whether the failures are typically equipment failures or weather failures. This choice will also require an analysis of the instrumentation aboard the spacecraft. If these instruments are a lower reliability than the DSN, then perhaps it will be more valuable to get the Earth-based data than to have redundancy in the DSN. If the instrument is faulty, it will give us nonsense data anyway. We would like to make this choice after launch, since we would have a better idea of how the instruments are working. However, due to fuel constraints we will probably have to make this decision before launch.

Earth-based observations are a consideration for collecting data from the impact. For some types of observations, it may be possible to observe from both Chile and Hawaii. Depending on the location of the comet in the sky, and the time of year, the comet is not both above the horizon and in darkness at both observatories at any given time. So we have to pick one or the other. Ideally we would like to have backup observatories. California and the Canary Islands may serve this role as they have a better probability of clear weather than either Chile or Hawaii during July. However, these backups have a much narrower set of telescopes that can be used for observing the impact.

We have to make a small adjustment using the Hubble Space Telescope (HST) because it is in a 90-minute orbit around the Earth, and if it is on the wrong side of the Earth, it will not be able to see the event. We need to be able to shift the impact time by plus or minus forty-five minutes to optimize the observability from the space telescope. This is hard because the people that keep track of the space telescope do not know where it will be in its orbit until about two months in advance. They know where the space telescope's orbit will be, but this could change if they apply another boost to the orbit during the next servicing mission. The drag that slows the space telescope down slightly in orbit is unpredictable. This means we have to carry fuel on the Deep Impact spacecraft to make a big change two months before the impact. If there are other satellites in low-Earth orbit that are more important than HST, then we would optimize for those. The Far Ultraviolet Spectroscopic Explorer (FUSE) is an example of this. The FUSE observes the portion of the electromagnetic spectrum (90 – 120 nanometers) which is unobservable with other telescopes. For the time being, the HST is the most important for our purposes.

Costs of these scenarios are very difficult to assess. We do not pay for ground-based observations at all. The way space telescopes work, the institute gives us grants to make observations. We have to make competitive proposals. The projects that are chosen based on science merit then get funded to cover the observing and the data analysis. There is no doubt that due to the cost of flying the instruments, getting data from the spacecraft itself is the single most expensive part of this mission.

The challenge with Earth-based observatories is getting clear weather. In July 2005 it is winter in Chile, so some of the observatories could have poor weather. The further north in Chile we try, the better the possibility of good weather will be. Hawaii has moderately good weather during this time, but the telescopes in Hawaii are so close together that the weather would be the same from one site to another. Using Tucson, Arizona as a backup might not work since July is the start of their rainy season and many of their telescopes are shut down at that time. The biggest challenge with the spacecraft instruments is getting the timing of the observations right so we get the specific images that we most want. Predicting when to start a particular sequence of images is the biggest challenge beyond getting the instruments to Comet 9P/Tempel 1. The challenges of space telescopes are relatively small compared to the spacecraft and Earth-based methods.

Ultimately the decision for which scenario we will use is mine with the advice of the science team and key mission planners. We have a tentative decision on this for the mission review process. There is no need to reaffirm this decision or change it until a few months before launch.

The science objectives of the Deep Impact mission are to understand as much as we can about the cometary nucleus. In order to do this, we need the widest possible selection of measurements of the material ejected from the impact crater, and the details of the outer layers of the comet's nucleus. Any way we can study these ejecta, will give us more insight of what the structure of the nucleus is. The data we will get ranges from spectroscopy of the gases, to measuring the heat of ejected materials in the infrared. We will be getting images of the ejecta, finding out how long ejecta takes to come out, how long it takes to form the crater and whether the ejecta will orbit around the nucleus, or immediately fall back to the comet, or escape. These data will help us to understand what the nucleus is really like. The decisions we make for deciding the best scenario for optimizing our data collection will impact the extent to which we are able to meet these mission science objectives.