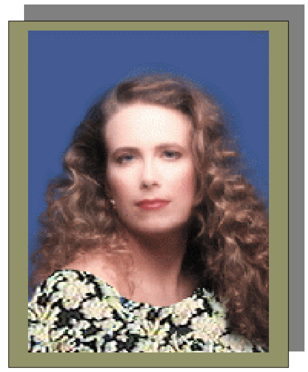
NASA's Deep Impact Mission: Decision Making

Dr. Karen Meech

APPENDIX C: 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. Karen J. Meech
Job Title: Astronomer
Institution: University of Hawaii-Honolulu Institute of Astronomy
Interviewer: John Ristvey
Date: July 10, 2001
Conducted by phone at her hotel in Washington, D.C.



Dr. Karen J. Meech
Astronomer

My involvement with the Deep Impact mission is that I am the coordinator of all of the ground-based observing for the mission. Comets are really neat to look at in part because they are always changing. The comets I tend to focus on are very faint and distant objects in our solar system. Because of this, the comets I observe are very challenging to find each time. By studying comets, we can learn about the earliest part of our solar system. Like an archeological tool, with comets, we can dig back into the past history and find out what it was like at the beginning of our solar system. The Deep Impact mission gives us the first chance to look inside of a comet. All of the other cometary studies look at the materials that flow off of the outside of a comet. But the outside of comets have been heated and altered since they were first formed. So, if we want to sample what the early solar system was like, we have to look at fresh comet material and the only way to do that is to get inside of one.

I have been working on a very long-term program of watching about 60 comets as they move closer to the Sun or farther from the Sun to see how they change as a function to their position in orbit. The comets I look at are sometimes only a few kilometers across and darker than charcoal. We can see the reflective light of these comets that are 30 AU away; that is the distance to the planet Neptune. The brightness of the comets I study is about 30^{th} magnitude. * Because I have this unique data set of Charge-Coupled Device (CCD) images of comets, many space missions dealing with comets come to me for information about particular comets to support their missions. I have spent a lot of time with the Stardust mission in order to help them develop dust models from my data, so that they can decide whether or not the Stardust spacecraft will survive when it passes through comet Wild 2's tail. They used the brightness measurements from ground-based observations to figure out how much dust is in the comet as well as the size of the dust grains. I have also provided information about comet Encke for the Contour mission, which resulted in some surprising findings that were interesting for that mission. In 1991, I co-discovered a huge outburst in comet Haley. It was moving away from the Sun, cooling and losing its tail when at about 12 AU away from the Sun it had a huge outburst that formed a dust cloud 200,000 kilometers across! These are examples of some of the exciting things that have cropped up during this long-term methodical study of comets. My current work with Deep Impact is to determine the rotation period, nucleus size and dust environment of Comet 9P/Tempel 1.

We have been making observations of Comet 9P/Tempel 1 for Deep Impact ever since the mission was accepted. We had a huge observing campaign in 1999 and 2000. We use many ground-based observatories to get data about Comet 9P/Tempel 1 prior to impact. The goals of this campaign are to understand how much dust the comet puts out and when it starts to make this dust. We need to have very good knowledge of the amount of dust that is in the tail so that when the Deep Impact spacecraft passes near the comet, we can say with certainty that it will be safe. Particles as large as one centimeter could destroy camera optics if it hits it at high speed. If the dust hits the edge of the spacecraft it might cause it to tumble, so that the spacecraft could not talk to the Earth. In order get this information we will need many pictures of Comet 9P/Tempel 1 with a CCD camera. We will begin from the time it is farthest from the Sun (aphelion) when it has no tail at all and as moves toward the Sun and develops its tail, to see how fast the dust comes off. We also need to know the size of the comet's nucleus and how dark it is. To do this we need to have simultaneous measurements from two telescopes. One telescope looks at the reflected sunlight in the visible wavelengths and another looks at the heat emitted from the nucleus. This will give us information about targeting the comet for impact. The darker the nucleus, the more we would have to increase the exposure times on the spacecraft. The size of the nucleus would also tell us what the gravity might be in order to determine the mass of the comet.

We need to measure the chemical composition of the gases coming from the nucleus prior to impact. Because the mission is going to create a large crater, we will measure the change in the types of gas after impact, in order to have a starting point for comparison. We do this by using spectroscopy or breaking the light into its various wavelengths. Because this reduces the amount of light available at any particular wavelength, the comet has to be bright and therefore close to the Sun when we use spectrographs.

We need to measure how fast the comet spins, which is important for targeting the impactor. We want to target the impact on the large side of the comet. In order to time the impact, we will need to time the rotation of Comet 9P/Tempel 1 to within a minute before the spacecraft is launched. If the comet rotates too fast, then the impact crater may rotate away from our field of view. It is challenging to measure the rotation. If you think of the comet as a large potato, it is very uneven, and would reflect light differently depending on the side you are facing. The rotation is determined by looking at a time series of images of the comet and looking at the brightness variation due to different surfaces being reflected off of different surfaces. If there is a large dust cloud around the comet it is very difficult to see this variation in brightness. Yet when there is no dust cloud surrounding the comet, it is very faint, requiring very large telescopes. In order to determine the rotation period of Comet 9P/Tempel 1, we have determined we will need six nights of large telescope time, for four months in the fall of 2001 at four different observatories around the world in order to get maximum coverage. Based on all of the proposals we have submitted we should get somewhere between 30 and 50 nights in fall 2001, which is absolutely unheard of, since obtaining time on large telescopes is very competitive.

Much of this information that we are searching for prior to launch will help inform mission science and mission planning. There are many factors that we need to consider in deciding on a time of impact. If you think about public appeal, we would like to have as many people in the United States able to see the impact while the comet is above the horizon at night. This would provide the biggest "Ooh! Aah!" factor. From a scientific point of view, we would like to have as many observatories in the world as possible to be looking at the event at the time of impact so we can maximize the science. Every observatory specializes in something different. We have a lot of telescopes in Chile that could be used. Since Chile is a little further east than Florida, it would be night time on the U.S. East Coast at the same time as it would be night in Chile. We have a nice concentration of telescopes at Kitt Peak National Observatory, in Arizona, and of course here in Hawaii. We have observatories at other longitudes, but after you take into account the weather statistics at various observatories in July, some observatories are completely unacceptable. For example, it is monsoon season in India, and since they only have a 10% chance of clear skies, we eliminated them very quickly. It boils down to two questions, "Do we pick having the impact during night time in Chile and get a huge amount of ground-based coverage? Or do we choose night time in Hawaii, where there are not as many telescopes, but it is a superb observing site?" Since the telescopes are spread out in Chile, we would have more options, if weather were bad in one location. If the spread of telescopes was the only consideration, it would be an easy decision, but we also need to get data from the spacecraft via the largest network of radio telescopes called the Deep Space Network (DSN). If we use Chile, we only are able to use one Deep Space Network site. If we use Hawaii, we would get an overlap of two DSN sites. Having redundant DSN sites greatly reduces the chance of failure of getting data from the spacecraft. There was a huge amount of discussion between scientists and engineers to which scenario to pick. With any decision, there will have to be a compromise somewhere.

Using orbiting telescopes like Hubble makes it even more difficult to schedule things, because Hubble has a 90-minute orbit and we would like to pick a time of impact when we can get as much of that 90-minute orbit as possible. There are certain periods when Hubble is not available because it passes through the South Atlantic Anomaly, which is when the telescope passes through Earth's radiation belts. This does not hurt the telescope, but the data from the telescope becomes so "noisy" that it becomes useless. An advantage to using orbiting telescopes both prior to impact and during impact is that there are certain molecules which emit light at wavelengths that are not accessible from the ground. Water is an example of a molecule that is not easily seen through our atmosphere. We will certainly use Hubble Space Telescope as well as any other orbiting telescopes that we can. So we have a 90-minute time frame for Hubble, the need for redundant DSN sites and the best ground-based viewing with sometime around July 4, 2005 since the holiday is ideal for public viewing. It has been a challenge to mesh everything together to make sure it works when we want it to.

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*The ancient Greeks developed the magnitude system that is used today. They basically looked at the sky and said that the brightest stars were the first importance, slightly dimmer stars were second importance. So as the magnitude increases the brightness decreases. Your eye is a logarithmic detector. For every five magnitudes there is a factor of 100 in brightness. The human eye can detect magnitudes as high as 6. At a magnitude of 30, the comets Karen Meech studies are about 10 billion times fainter than you could see with the naked eye.