Deep Impact Cratering Research

APPENDIX C: SCIENTIFIC MODELING IN ACTION

In science, we work to develop methods of describing and understanding what is going on around us in ways that allow us to make useful predictions about how the world works. We call these descriptions "models." Think for a minute about a model airplane. In some ways, the model airplane is just like the original aircraft, and you can learn a lot about the original by building the model. However, in other ways, the model is significantly different from the original. You can adjust the model or build new models that are more and more like the aircraft, but a model is still not the aircraft itself. In a similar way, scientific models can be useful in allowing us to learn about a physical phenomenon or to test our theories about a phenomenon, but they are not the actual phenomenon itself. Scientific models can take the form of graphic descriptions of how the pieces of something are arranged or how they interact, such as in the Bohr and electron cloud models of atoms. They can take the form of mathematical formulas, such as those used for calculating speed, acceleration, force, etc. Or, scientific models might take the form of simulations; smaller scale events that recreate some, but not all, of the factors involved in the actual event. Modeling is a useful way to understand the world around us. To make it really work for us, however, we need to be aware of the limitations of what our models can show us as well as their strengths.

Modeling is particularly useful in studying events that are difficult to get to or to recreate. Cratering is just such an event and scientists interested in cratering rely on modeling as a regular part of their research. You have just modeled cratering in your classroom. You designed and conducted experiments that explored the effects of a variety of factors, and then used your results to create some quick mathematical models for making predictions. Your experiments gave you some ideas about how some factors, such as impactor mass and velocity, can affect crater diameter and depth. However, as you examined in class today, your experiments modeled low energy impacts, which do have some significant differences from the high energy impact the Deep Impact mission plans to carry out on Comet Tempel 1. Deep Impact scientists are also modeling cratering using both numerical and laboratory models to find out more about what to expect in the actual cratering event.

The Ames Vertical Gun Facility

LABORATORY TESTS

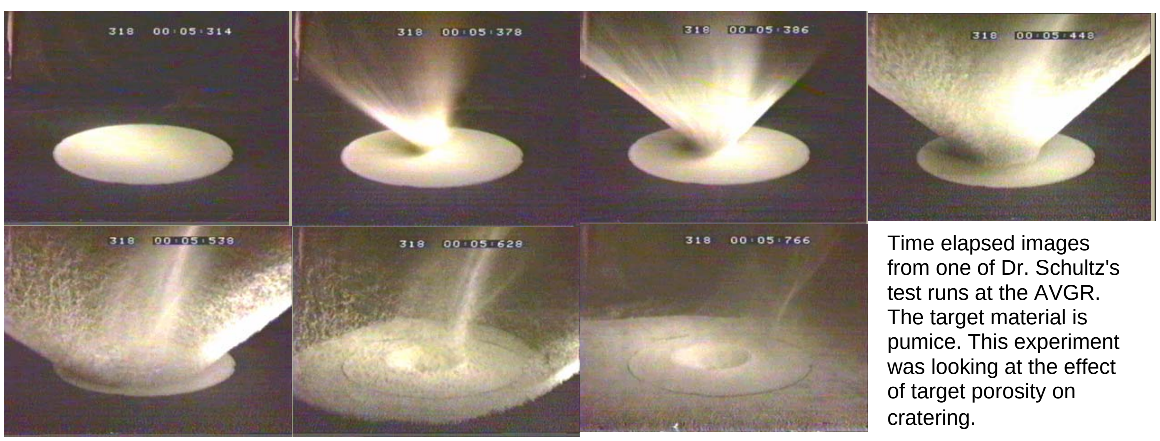
Dr. Peter Schultz is a member of the Deep Impact Science Team and a professor at Brown University. He conducts laboratory cratering experiments using the AVGR (Ames Vertical Gun Range) at the NASA Ames Research Facility in California.

The AVGR consists of a large gun barrel on a hinge that allows the angle of impact to be varied from 0 to 90 degrees in 15 degree intervals. There are three available launchers at the facility: an air gun, a powder gun, and a gun that uses a combination of hydrogen and gun powder.

The guns can fire a number of differently shaped projectiles, such as spheres, cylinders, irregular shapes, and even collections of particles, which are made of a number of materials, such as metal, glass, or minerals. The equipment at AVGR allows Dr. Schultz to achieve impact speeds much greater than those we were able to achieve in the classroom. "Our gun can shoot up to 7.5 km/s for small (1/8 inch) projectiles," says Dr. Schultz. The guns are fired into a 2.4 m vacuum chamber. A large variety of surfaces and atmospheres can be placed within the chamber.

Dr. Schultz is interested not only in the final size of the crater, but in the entire process of cratering. He uses a variety of high-speed imaging devices that allow him to examine cratering events in slow motion. Some of the devices capture images of the cratering event at a rate up to 35,000 frames per second. Other devices allow for measurement of the brightness of the light produced in the impact. He also uses spectrometers, which allow him to break the light into its different components, like a prism, and examine the effect cratering has on the chemical signature of materials that can be found in light. His equipment also allows him to measure the velocity of the excavated particles as they are thrown away from the crater.

Dr. Schultz will conduct a large number of experiments in the course of preparing for the Deep Impact mission, looking for the effects of different projectile mass and densities on a variety of different targets. Currently, he is conducting experiments looking at the effect of the porosity of the target surface on the growth of the crater. Porosity is a measure of the amount of empty space in a material. A highly porous material is one in which there are lots of empty cavities. Think about a sponge and a brick as an example. The sponge is more porous or has a higher porosity than the brick. We don't currently know much about the porosity of comets and hope to learn more from the results of the Deep Impact cratering event. Dr. Schultz is exploring the effect of porosity on crater growth so that by examining the growth of the Deep Impact crater on Tempel 1, we will be able to learn something about the porosity of comets.



Time elapsed images from one of Dr. Schultz's test runs at the AVGR. The target material is pumice. This experiment was looking at the effect of target porosity on cratering.

MATHEMATICAL MODELING

In activity three (or the Predict section) of this module, "Looking for Patterns and Making Predictions," you examined your classroom data for patterns and put together a rough mathematical formula to make predictions about cratering results for previously untested masses, impact velocities, and other factors. These were fairly rough estimates based on only a few measurements taken over a narrow range of possible values. Imagine how much better your predictions would be if you had a greater number of measurements taken over a larger range of variables. Over the course of the last century, scientists have put together a large collection of data about the process of cratering. These data come from laboratory tests like those mentioned above, studies of impact craters on Earth and elsewhere in the Solar System, and the study of craters produced by explosive weapons tests. Scientists have examined this base of data and put together mathematical models of cratering known as scaling laws.

Dr. H. Jay Melosh of the University of Arizona is another member of the Deep Impact Science Team. Dr. Melosh works with computer programs originally developed to model nuclear explosions. "These (computer) codes simulate all of the physical processes that occur in a real impact and have successfully reproduced many small-scale impact experiments. We are making simulations of the Tempel 1 impact to explore the range of possible outcomes of the actual experiment and decide how to distribute the mass in the impactor to make the biggest possible crater in spite of not knowing the exact physical properties of the comet," says Dr. Melosh, describing his work for the Deep Impact mission.

While there are quite a number of unknowns about the comet, many of the questions about cratering center on the comet's density, porosity, and strength. Thus many of the numerical simulations run by Dr. Melosh are designed to explore these variables. The focus of his work at this point is to use the test results to make decisions about the design of the impactor.

LIMITS TO DEEP IMPACT MODELING

While the scientists on the Deep Impact team are working with some of the best impact laboratory facilities and the most complete numerical code information, there are limits to these models just as there are to any scientific modeling process. The biggest hurdle to modeling the Deep Impact event is the information that we don't have about the nature of the target body - Comet Tempel 1. In fact, we are hoping to learn much of what we don't know from watching the formation of the actual crater. If we could model the event exactly, then we wouldn't need to make the crater!

The scientists involved in cratering research on the Deep Impact team explore a variety of possible conditions and compositions for the comet. Their goal is to choose an impactor design that is highly likely to give us a large enough crater to allow us to measure and learn what we would like to know about the interior of comets. By examining the effect of different conditions on crater size and formation in the laboratory and in numerical simulations, the Deep Impact scientists are developing an understanding of cratering that will allow them to discover some of the unknown traits of the comet by examining the Deep Impact cratering event.