EDUCATION AND PUBLIC OUTREACH FOR NASA'S DEEP IMPACT MISSION

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Abstract. The Deep Impact mission's Education and Public Outreach (E/PO) program brings the principles of physics relating to the properties of matter, motions and forces and transfer of energy to school-aged and public audiences. Materials and information on the project web site convey the excitement of the mission, the principles of the process of scientific inquiry and science in a personal and social perspective. Members of the E/PO team and project scientists and engineers, share their experiences in public presentations and via interviews on the web. Programs and opportunities to observe the comet before, during and after impact contribute scientific data to the mission and engage audiences in the mission, which is truly an experiment.

Keywords: solar system exploration, education public outreach

1. Introduction

The Deep Impact mission sends a pair of spacecraft to study the interior of comet 9P/Tempel 1. An impactor spacecraft separates from the flyby spacecraft 24 h before impact. Traveling at a relative velocity of 10.2 km/s the comet overtakes the impactor at 5:53 UT July 4, 2005. The impactor carries an imaging system that will study the surface of the comet upon approach, relaying data to the flyby spacecraft and then back to the Earth. The flyby carries two imagers and an infrared spectrometer that will record the impact and its aftermath (A'Hearn *et al.*, this volume). Images and spectra will allow the science team to address questions related to the nature and structure of comets:

1. What are the basic properties of a cometary nucleus?
2. How do comets evolve?
3. What are the primordial ices in comets?

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4. Do comets become extinct or only dormant?
5. Are comets made of discrete cometessimals?
6. Do cometary nuclei have a discernable impact history?

The science team anticipates that answers to the above questions will contribute to understanding the formation of the solar system in its early stages and be useful to determining how one would mitigate a cometary impact on Earth today.

1.1. Deep Impact E/PO Program

NASA's Discovery Program is charged with sharing the excitement of space science with the public, contributing to the improvement of science, technology, engineering and math (STEM) education in the United States while inspiring the next generation of the 21st century scientific and technical workforce. To this end each mission plans and implements an Education and Public Outreach (E/PO) program. A series of three publications provide the guidelines and description of the infrastructure of E/PO programs for NASA missions (NASA, 1996, 2003, 2004). Rosendhal *et al.* (2004) provide a summary of the program, its history, philosophy and policy.

The E/PO team implemented a program built upon six principles comprising the Deep Impact's E/PO program philosophy:

1. Audiences will learn with opportunities to participate in many ways.
2. Partnerships with other education and outreach programs leverage the efforts of all programs.
3. Educators will respond to Deep Impact products and programs that meet the standards-based criteria to which they teach.
4. Learning is enhanced when inquiry and discovery are embedded in the process.
5. Educators look for real-world examples of teamwork and problem solving for their classrooms and mission work provides valuable lessons.
6. The internet enables delivery to targeted audiences.

The mission's E/PO program has four primary components: formal education, outreach programs including professional development, informal education and partnerships with other organizations, outreach products and the web. Two programs for undergraduate students were developed after the project was under way and were not in our original plan. They provide hands-on engineering and science opportunities for students in both high school and university.

1.2. Anticipated Outcome

The anticipated outcome of the E/PO program includes: providing access to the excitement of a NASA mission and to the scientific, engineering and mathematical themes of the mission. The team strives to engage students, teachers and the interested public in the mission in order to learn and understand scientific investigations, their nature, process and results. The expected outcome, in the long term, is to inspire the next generation of scientists, engineers and educators, and to promote scientific literacy among the general public. To this end, a program evaluation is conducted to evaluate the extent to which target audiences access and use the E/PO materials and to examine the experiences of teachers and students using them. (See Section 5).

2. Formal Education Products and Programs

Educational units for school-aged children from elementary, middle and high school have been developed. Materials for grades K-4 are called activities. For middle school and high school, we developed educational modules that consist of guides for both students and teachers, and include alignment with science and/or math educational standards. All materials can be used in both formal classrooms and informal settings such as community or after school programs. The modules were reviewed by scientists for scientific accuracy before being tested with the intended audience. They were reviewed by educators, revised and reviewed again and posted on the project's web site. Some of the materials were reviewed by the Solar System Education Review process and recommended for distribution through NASA's CORE program. Major distribution is via the world wide web. All materials described here are available at http://deepimpact.jpl.nasa.gov/educ/index.html.

2.1. Elementary School Activities

Two principles drove development of materials for K-4:

1. Younger children begin by being curious about the world, efforts were made to build on that curiosity to prevent their losing it.
2. Children have different learning styles and will engage differently in educational activities.

Activities were built around things in which children naturally engage in during their early years – singing, listening to stories, using their imagination, and making crafts. A brief description is given below.

2.1.1. *C-o-m-e-t-s*

A simple song, written by E/PO team member, Maura Rountree-Brown, contains some basic facts about comets. The song spells out the word "comets" with an easy tune. Actions such as hand gestures and clapping are included so that the brain is recording the information through three different modes, with music, rhythm, and kinesthetic action. After singing the song, the students and presenter go over it line by line and ask questions such as, "If the song says a comet is very, very cold, what might a comet be made of?" The children easily come up with the concept of ice. By repeating the lines from the beginning every time a new line is added, the information is worked deeper and deeper into a student's memory. Teachers report that children are heard singing the song on the playground weeks after it was initially introduced to them. http://deepimpact.umd.edu/educ/storysong.html#cometsong.

2.1.2. *Comet on a Stick*

A hands-on activity on comet modeling called Comet on a Stick works well with young students following the song activity. This activity has been used with all age groups, however. Background information is provided to students about the reasons for developing a model of the comet for planning and design purposes. The students then form teams. Using an $8'' \times 11''$ piece of paper, the team shapes a comet nucleus and attaches it to a stick. They choose two or three facts about comets to model them using re-cycled materials: tin foil, black paper, beads, fiber fill for pillows and other items that a teacher can collect. Once their models are built, each team has a chance to show them, while other teams determine the subject being communicated. Misconceptions can be caught because they are physically showing what they learned. Modifications to this activity include selecting a candy bar that best represents what might be found beneath the surface of a comet and defending the reason for choosing it (layers, homogenous, rocky). http://deepimpact.umd.edu/educ/CometStick.html (Figure 1).

Figure 1. Team member Jochen Kissel shows a version of a modeled comet.

2.1.3. *Comet Sisters*

M. Rountree-Brown also wrote a mythical comet story after taking a class at the International Storytelling Center on incorporating story into education. “I’m going to tell you a story,” she starts out. “Some of what I tell you is true about comets, some of it might be true and we will find out what happens when we execute the Deep Impact mission. Some of it – I just made up.” Students who listen to the story can either draw their impressions on paper or discuss it afterward to find out what they know to be true or to perhaps be true about comets.

2.1.4. *Make a Comet and Eat It*

This activity starts with a basic ice cream recipe and suggests that students put in foods such as peppermint, ground cookies, peanuts, gummy bears, all of which represent components of a comet. The teams trade ice cream bags and then start using their individual senses to research what is in the ice cream: look at it, smell it, feel a separate cup of it, taste it. The process is compared to that of a spectrometer in using different wavelengths to collect different kinds of information about what is in the comet. http://deepimpact.jpl.nasa.gov/educ/IceCream.html.

2.2. Middle and High School Modules

Materials for middle schools were built upon interdisciplinary themes combining social education (team work and communication) with science education. Workshops for teachers at the National Science Teachers’ Association were held during which these materials were introduced and feedback was collected and incorporated into revision of the materials. High school material focuses on physics and includes inquiry-based processes.

2.2.1. *Collaborative Decision-Making*

Collaborative Decision Making is designed to engage students in grades 7–12 in activities that focus on collaboration and communication strategies. These activities strengthen students’ understanding of and ability to use collaborative processes and communication practices to clarify, conceptualize, and make decisions. Students first consider cases in which they have to make decisions that are important in their life. They discuss how they arrive at a course of action or a decision. They are then presented with a problem that the Deep Impact team confronted, that of deciding the best time for the impactor to hit the comet. Students take on the roles of different project members, the principal investigator, the project manager, and engineer. After the risks are identified, they gather and convey evidence supporting and refuting the viability of these actions. The module’s strategies rely primarily on student investigation into the background information that is necessary to support arguments; make quantitative risk analyses; engage in debate, role-playing, and practice persuasive writing and communication processes; and practice group decision-making procedures. The material is aligned with national science education standards (Appendix I). It was selected by the OSS, peer review process for wide distribution throughout NASA Resource Centers. http://deepimpact.umd.edu/collaborative_ed_module/index.html.

2.2.2. *High Power Activity*

An activity that takes less time to research and is not as technically involved as Collaborative Decision Making is called High Power Activity. It focuses on the same decision-making processes forming the basis of Collaborative Decision Making. Students play the role of different members of the project and are confronted with a problem that is similar to one that arose in the course of the Deep Impact mission. A company offered to pay to place extra cameras on the spacecraft to watch the impactor separate from the flyby spacecraft. After the students consider the pros and cons of this proposal, they decide what to do. They can compare their decision making with that of the Deep Impact team. http://deepimpact.jpl.nasa.gov/high_power/index.html.

2.2.3. *Designing Craters*

Designing Craters is a two-to-three week inquiry-based module addressing the question: "How do you make a 7–15 stories deep, football stadium-sized crater in a comet?" The lessons are designed for students in grades 9–12 and provide them with experience in conducting scientific inquiries, making measurements, displaying data and analyzing it to gain a greater understanding of scientific modeling while involving students in the excitement of a NASA mission in development. This unit was designed as part of a Masters degree in Science Education at University of Maryland. After studying the physics of crater formation based on the work of Melosh (1996), the graduate student then developed guidelines for student-designed experiments. The activities are designed to model one path that a scientific inquiry might take. The students begin by brainstorming what factors might influence crater size and doing some initial experimentation and exploration. They evaluate each other's suggestions and describe their initial ideas about cratering phenomena. Next, they design their own experiments to test one of the possible factors influencing crater formation. Emphasis is placed on experiment design, limiting the test to one variable, and quantifying the experiment. After analyzing the data for patterns that might be used to predict crater size from initial variables, the students test those predictions, use the results to refine their methods of prediction, and try again. The students discuss the advantages and limits of scientific modeling as they compare their own low-energy simulations, the work of Deep Impact Science Team cratering experts, and cratering on a Solar System scale. Finally, the students use current information about comets and the patterns they derived from their own investigations to give their best answer to the initial question. These answers can be submitted to the Deep Impact Education and Outreach Team.

Science team members reviewed the material while it was being tested in the classroom. When science team member Jay Melosh pointed out that laboratory experiments in high schools do not represent hypervelocity impacts in space, a section was added in which students discuss and compare their experimental conditions to those in space. They are led to an understanding of the limitations of laboratory experiments as well as knowledge that conditions in space are different. Science standards addressed in this unit are available in Appendix II. This unit is available at: http://deepimpact.umd.edu/designing_craters/index.html.

2.2.4. *Math Challenges*

A series of math problems was developed from computations that are necessary to carry out the Deep Impact mission. Algebra and geometry are required. Called Mission Challenges, they have been aligned to National Math standards and can be found at: http://deepimpact.jpl.nasa.gov/disczone/challenge.html.

2.3. University Programs

Two higher education programs were developed after the initial planning of the Deep Impact E/PO program. Both programs offered undergraduate university students the opportunity to gain valuable research or engineering experience that will allow them to participate in the mission. The Deep Impact mission is a catalyst for long-term education and public outreach collaborations.

2.3.1. *Deep Impact Project Schools Technology Collaboration (DIPSTIC)*

DIPSTIC is a joint venture of the Jet Propulsion Laboratory (JPL), Los Angeles City College (LACC), University of Texas El Paso (UTEP), Digital Media Center (DMC) and the Deep Impact project at the University of Maryland. Participants in the program collect telescopic observations of 9P/Tempel 1 using a CCD camera built by the students and staff at LACC. This is a unique opportunity for undergraduates at a community college to participate in a NASA space mission. Data are gathered at Table Mountain Observatory (TMO) and analyzed by students. The results of their observations are distributed to the public through a web site built by students at the Digital Media Center (DMC) at UTEP. A cooled CCD detector system is built and operated by LACC students for comet spectroscopy.

The main goal of DIPSTIC is to provide a research experience for undergraduates. It is a focused effort reaching a small number of students and community college professors in an in-depth way. The team is on a journey to define the project's scientific goals, build the CCD camera, plan and execute novel astronomical observations, analyze data and finally, report results. NASA/JPL technology expertise has been transferred to LACC by developing the CCD.

Nine students between the ages of 19 and 25 have participated. They are physics, electrical engineering and computer science majors. None had previous experience in astronomy. Grades were not considered. Selection was based upon enthusiasm and interviews. In the CCD construction phase physics and engineering students were chosen. When the main task became software development, computer science students were selected. Physics and engineering students will observe the comet.

The educational benefits to students are several.

1. They learn that the real scientific world is about finding solutions to problems.
2. They learn to work independently and confidently.
3. They learn to set goals and meet them.
4. They learn to think “outside the box”.
5. They also learn teamwork.

Their experiences encouraged the students to ask more questions in class, which probably carried over into their other classes and benefited their academic studies.

DIPSTIC provided one LACC instructor (Mike Prichard) with first-hand experience with unusual devices like thermoelectric coolers and thermistors. He promptly replaced experiments using more mundane electrical components with these devices in his electrical engineering classes. This required considerable modification of his curriculum. Experience in the DIPSTIC program gave him a new experimental perspective from which to teach his electronics classes.

The DIPSTIC laboratory and fabrication facility at LACC is essentially a college physics experiment. LACC science professors conducted tours of the lab for their students. DIPSTIC provides an example of the real world to students to motivate their academics.

A large draw for prospective DIPSTIC students is the opportunity to work with a NASA/JPL scientist who worked at LACC every Friday between May 2002 and June 2004. The program is now sustained by instructors; Mr. Dean Arvidson, Physics, Ren Colantoni and Mike Prichard, custom CCD electronics, Mike Slawinski, CCD cooling system.

Results are reported on the DIPSTIC web site at http://dml.nmsu.edu/dipstic/. The DMC built and maintains the web site. This aspect of the program brought together the expertise of the Digital Media Center (DMC) with the students in need of presenting their results to the public. In 2003 the DMC team filmed video interviews with DIPSTIC students. They gave knowledgeable presentations, without scripts, after participating for less than a year. The web site also presents the student’s experimental logs and theoretical investigations on Microsoft^{TM} Excel spreadsheets, PowerPoint presentations to the LACC physics club by DIPSTIC students and an HTML version of a poster-paper reporting the experimental work of the first year on the construction of the CCD cooling system. There are also photos and biographical sketches of all the participants. The DMC also produced the paper as a laminated 44×44 inch poster. It was presented at the 2003 Southern California Conference on Undergraduate Research.

2.3.2. *Observing the Impact*

High School and undergraduate students around the country are preparing to observe the comet both before and after impact. Many school educators who have been participating in training workshops over the duration of the mission will be working with students to observe the comet as part of the Small Telescope Science Program (Section 3.4) which requires a CCD camera and a telescope, or the Amateur Observers Program (Section 3.5) which requires just a dark sky and the ability to describe and possibly draw, what is seen. Professional scientists at colleges and universities around the country will be participating with observers at telescopes around the world in monitoring the behavior of the comet before, during and after impact. There are opportunities for students to observe using remote telescopes such as those connected with the TIE program, and the Faulkes Telescope, http://www.faulkes-telescope.com/.

3. Outreach Programs

Outreach extends the reach of materials and programs from the formal classroom setting to community and professional organizations with common interests and objectives to the E/PO program. It includes professional development for teachers, museum coordinators, and amateur astronomers. The programs engage the public and interested community organizations in the excitement of the mission. This is accomplished through lectures conducted via teleconference, telescope observation programs and by providing informative materials that explain and engage people in the mission.

3.1. Professional Development

In 2000, Deep Impact, with other missions, partnered to provide professional development for educators through the Solar System Educator program (SSEP – see http://solarsystem.nasa.gov/ssep/) with as many as 75 teachers training 100 or more teachers each year. The program consists of training at JPL or another location, telecon updates providing the educators with information, written materials, videos and on-site training. In the final year of the Deep Impact mission, members of SSEP are forming their own programs and events for encounter (see Penny Kids http://deepimpact.jpl.nasa.gov/community/pennies.html). In addition, the Deep Impact outreach team has participated in professional development workshops and classes at NASA's Educational Resource Centers and other locations.

3.2. Informal/Public Programs

Beginning in 2000, Deep Impact also combined with other missions to bring comet science and the technology of the Deep Impact mission to families, adults and communities through the Solar System Ambassadors (SSA – see http://www2.jpl.nasa.gov/ambassador/usstates.html). These 450 speakers participate in public events across the country reaching millions with information on NASA missions including

Deep Impact. The outreach team provides materials, training via teleconference, and mentoring as needed to meet their needs for information and expertise. Many of these ambassadors are also partnered or employed by informal institutions, school systems or are amateur astronomers further leveraging the reach of the Deep Impact mission into those outreach areas. As Deep Impact partners with museums and informal institutions across the country through the Museum Alliance at JPL, there is another leveraging effort to combine these different partners with special events hosted at informal institutions during encounter in July 2005. Many of their plans are self-sustaining bringing to fruition the goal of the Deep Impact outreach plan to provide opportunity for real participation by others. Deep Impact has also participated in several national and regional training for the leads of the Challenger Centers, many of whom would like to host encounter events in July. It is a goal within the Deep Impact outreach plan to leverage new opportunities off existing materials or programs, ViewSpace and Discovery Channel are producing videos and exhibits to reach an even larger section of the public through television and informal institutions.

3.3. Underserved and Underrepresented Audiences

The Deep Impact outreach team focuses on the needs of several underrepresented and underserved audiences: young women, rural and inner city audiences, Native, Polynesian and Latin Americans, children with different learning styles. Efforts to reach these audiences are described below.

3.3.1. *Young Women*

The Deep Impact EPO team encourages young women to explore STEM careers by working with the Girl Scouts of the USA. Contributing comet materials to science kits, training Girl Scout master leaders who train other Girl Scout leaders in their council, participating in events for Girl Scouts in the geographical areas in which the outreach team is centered (California, Maryland and Colorado) the story of the mission and its scientific objectives are conveyed to girls and young women. In addition, the outreach team participates in conferences for young women interested in engineering and science careers. The Deep Impact mission also contributes to the Girl Scout/NASA Solar System Nights Kit bringing a traveling science discovery night to the families of an individual community.

3.3.2. *Rural and Inner City*

The outreach team has participated since 2000 in L.A.'s Best, an inner city after school program for middle school students. Mission team members visit schools teaching comet science, technology and using hands-on activities. Deep Impact team members have participated in the Challenger Center's Voyage through the Universe program, where scientists visit schools in the District of Columbia every year. Deep Impact supported a comet section and bulletin board exhibit distributed to the 900 rural and inner city libraries of the Space Place Program bringing knowledge to young people in informal settings (http://spaceplace.jpl.nasa.gov/en/kids/deepimpact/deepimpact.shtml). In addition, the outreach team participates in both video and on-site national trainings for the Explorer school educators (many of whom are from underserved schools) and will be engaging some of those teachers in encounter events, particularly those in Hawaii.

3.3.3. *Native, Polynesian and Latin Americans*

The Deep Impact plan focused in particular on Native, Polynesian and Latin American cultures, especially in building early relationships and combining the science of Deep Impact with their cultural past. The project funded the Native American Initiative while it was active at JPL from 2000 to 2003 and participated in trainings for Native American educators and students. In 2004, the Deep Impact project participated in the first conference for Native American colleges held at JPL in California. The outreach team participates in conferences for the underserved such as Society for the Advancement of Chicano, Native American Scientists (SACNAS) giving workshops and distributing educational materials.

Successful collaborations are the key to effective education and public outreach. In Hawaii and the Polynesian islands, partners working to promote the NASA Deep Impact Mission include the University of Hawaii's Institute for Astronomy in Hilo, the Maui and Kauai Community Colleges, the Hawaii Public Libraries and Aloha Airlines. Nationally, the Carnegie Science Education Center and the NASA Astrobiology central EPO office supported programs. International partners include the Faulkes Telescope Foundation in England and an educational consortium in Iceland.

The Deep Impact mission serves as a perfect venue to promote public interest in astronomy and astrobiology in Hawaii with Deep Impact's Small Telescope Science Program (Section 3.4) since the impact will be visible in Hawaii. Information about the mission is incorporated into the Carnegie Institution of Washington, DC, traveling exhibit entitled: "Astrobiology: Discovering New Worlds of Life", on a 3-month tour to Oahu, Hawaii, Maui and Kauai, with support from Aloha Airlines. Lectures and teacher workshops were held in conjunction with this display. The exhibit introduced the local population to astrobiology and extremophiles living in hydrothermal vents. We transitioned to comets by using the University of Hawaii NASA Astrobiology Institute's (NAI) focus on water. The activities and materials on making observations of Comet Tempel 1 provide relevant applications at the workshops. We are recruiting teachers from the two NASA Explorer Schools on Kauai and Hawaii.

Since we have developed a cadre of master teachers through the NSF Toward Other Planetary System (TOPS) program, 1999–2003, these teachers served as instructors at our workshops. Deep Impact materials were presented and used at TOPS workshops. Having Karen J. Meech, a member of the Deep Impact science team, as well as the TOPS director, has given our Hawaii teachers extensive background for Deep Impact. Pacific Island teachers from Micronesia, Yap, Marshall Islands and Guam who were given 6″ Dobsonian telescopes through the TOPS program are encouraged to observe comet Tempel 1. Follow up with these teachers has been difficult, but will continue to be pursued for observing Tempel 1.

Our Hawaii teachers and students are also fortunate to have access to the Faulkes Telescope located on Haleakala, Maui. The Deep Impact mission is providing a perfect resource for students to conduct scientific investigations supporting the STSP. An educator from Iceland and another from England attend the Maui workshop to learn about Deep Impact and comets. Teachers from both the countries participate via a polycommunication video system. After the initial four workshops on each island, follow up sessions will be done via polycommunication system that the Institute for Astronomy has on three islands. The goal for formal education is having students enter comet projects in the 2006 science fairs.

3.3.4. *Convening Organizations for Outreach*

A year before launch, the E/PO team convened groups participating in the mission, including those from observatories, universities, outreach and institutional press officers. Personnel from science centers located close to mission activity, including Denver Museum of Science, Maryland Science Center, The Bishop Museum, Honolulu and Onizuka Science Center, Hilo, HI, are participants in developing programs for launch and encounter. The important role of Earth orbiting observatories, Hubble Space Telescope, Spitzer and Chandra and ground-based observatories provide a number of active and enthusiastic partners to engage in public outreach. Broker facilitators join in this planning for launch and encounter public outreach events.

3.4. The Small Telescope Science Program

The Small Telescope Science Program (STSP) was established in early 2000 to provide baseline information about comet Tempel 1 and to complement scientific data acquired at large, professional telescopes. The STSP is a network of advanced amateur, student, and professional astronomers who use telescopes, often <1.0 m in diameter, equipped with charged-coupled devices (CCDs) to make continuous, scientifically meaningful observations of comet 9P/Tempel 1. This effort will continue for several months after encounter in July 2005. See http://deepimapact.umd.edu/stsp.

Since 1999, the science team has conducted a vigorous program of ground-based observations of Tempel 1 (see Meech *et al.*, this volume) to characterize the nucleus and dust environment of the comet in terms of volatile outgassing, dust coma development and production rates, dust tail and trail development, and jet activity and outbursts. These characteristics vary as the comet moves along its orbit. However, observers at large telescopes have limited access to telescope time, and the baseline observations have gaps in temporal coverage. Advanced amateurs with access to small telescopes and private observatories can perform valuable, long-term and continuous monitoring of Tempel 1 to fill the gaps in the temporal coverage of the comet. Often the smaller telescopes used by these observers are fast, have large fields of view and are well suited for measuring the magnitude of the comet from which dust production can be measured. It is also important to look for evidence of jet activity as the comet approaches perihelion.

The STSP is the brainchild of Gary Emerson, an avid amateur astronomer and an engineer at Ball Aerospace and Technologies, the project's aerospace partner. After discussions with several team members and E/PO manager Lucy McFadden in 1999, the program was developed as a professional-amateur collaboration for the mission. The STSP was launched in early 2000, about 4 months after Tempel 1 passed perihelion. In 2000, the network of over 40 STSP observers delivered over 700 broadband VRI and over 300 unfiltered CCD images from observers in 12 countries, spanning 6 continents. The data were analyzed and a subset of the broadband, Red (R) filter images were used to calculate dust production (McLaughlin, 2001). Results supplemented data taken at large telescopes (McLaughlin *et al.*, 2003).

The program was in hibernation from 2001 through 2003, as the comet receded to aphelion. During the interim participants observed comet targets for NASA's Deep Space 1 and Stardust missions as well as several comets for dust tail and solar magnetic field interactions. The program re-launched in late 2004 when Tempel 1 returned to the inner solar system and became favorable for observing. The 2004–2005 observing campaign straddles Deep Impact's encounter with comet Tempel 1 on July 4, 2005. The program seeks the following types of observations:

- Broadband-RI CCD images and photometry for the duration of the campaign.
- Broadband-VRI CCD images from March 2005 through August 2005 to search for jet activity.

  During the 1983 apparition, Tempel 1 appeared to have at least two jets during the months before perihelion (see Lisse *et al.*, this volume). This needs verification in 2005. The impact is expected to make a new active area on the nucleus and may cause new jets or outbursts days or weeks later and evidence of any new activity needs to be documented.
- Broadband-VR and unfiltered images, in wide format, to look for interactions of the dust tail with the solar magnetic field.
- Any narrowband photometry and spectroscopy that STSP observers provide will be accepted; these types of data are within the capabilities of some advanced amateur astronomers.

Advanced amateur and student astronomers with access to small telescopes have the necessary equipment, experience, and skills to acquire scientifically meaningful data in support of the Deep Impact Mission.

3.5. AMATEUR OBSERVER'S PROGRAM

The Amateur Observer Program (AOP) is aimed at the more casual observer who may be hearing about the mission and the opportunities to observe comet 9P/Tempel

1 later rather than sooner. The material on the web site, http://deepimpact.umd.edu/amateur is setup so that even the non-astronomer and new-comers to the field of astronomical observing can go out and observe. While all of the basics of observing cannot be taught via the world wide web alone, the goal is to convey enough so that a new comer can observe Tempel 1. Information that guides visitors through the observing process including some simple observing activities related to the project (tracking the comet on charts), and information "teasing" them into more advanced concepts are presented on the web site. Charts for finding the comet at different latitudes are also provided. AOP is designed to get people to observe and enjoy the event using the naked eye, binoculars or a small, portable telescope. The opportunity exists to present descriptions and images (sketches, film and digital pictures) on the web site. No specific equipment is needed since participants can attend events hosted by clubs and space places where telescopes are available.

While the web has become one of the easiest ways to disseminate materials, team members go to the amateurs giving presentations at astronomy club meetings and star parties (regional gatherings under dark skies). Early presentations concentrated on describing the mission and the role that amateurs could play. Later presentations focus on what the amateurs should look for just before, during and after the encounter.

4. Outreach Products

Products for outreach include a fact sheet describing the mission, a poster with educational activities on the back, paper models of the spacecraft, artwork depicting the comet and spacecraft (Figure 2), a digital animation, and a planetarium show. Their availability on the web and for distribution at launch and encounter in hard copy to organizations that serve the public contributes to successful outreach.

4.1. Planetarium show

The planetarium show was designed to provide the following information about the comets:

- They date to the beginning of the Solar System and contain pristine material.
- Parts of a comet.
- What we know about them.
- What we do not know about them.
- Where comets fit in the solar system.
- Some historical perspective on comets.

It touches on the following topics related to impacts, comets, and their effect on Earth.

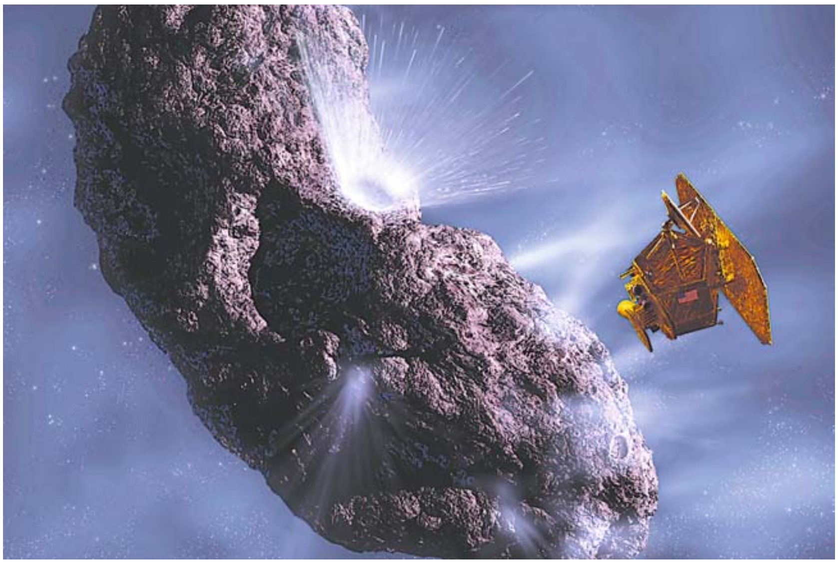

Figure 2. Pat Rawling's rendition of comet Tempel 1 after impact.

- The K-T boundary impact.
- Impact effects elsewhere in the Solar System.
- The Solar System's dynamical nature; not a "calm" and unchanging place as a casual look might suggest.

The show describes the Deep Impact mission's scenario and shows the spacecraft being built at Ball Aerospace in Boulder, CO. Interviews with project scientists, engineers and managers are included. Emphasis was given to the process of science, including the fact that there is a wide range of predictions about what will happen on impact. The show emphasizes that the outcome of the experiment is not known, and that different scientists have different ideas about the outcome.

An effort is made to convey some awe with respect to comets, that they are beautiful and that they can display a range of presentations depending on their activity and geometry with respect to the observer. In providing an historical context, the point is made that in the distant past, with little knowledge about the nature of comets, they were thought to portend ill fates or victory in history. In sharing the passion that scientists have about comets, the show's objective is to inspire the audience to see a comet for themselves.

The Deep Impact E/PO team provided scientific oversight and visuals for the show. Ball Aerospace and Technologies Corp also provided visuals of the spacecraft under construction and interviews with project engineers. Fiske Planetarium staff wrote and produced the show that was distributed on CD-rom through the International Planetarium Society's monthly publication to approximately 800 member-planetaria world-wide in August 2004.

5. Developing the Web Site

The web site is the major communication channel to achieve the goals of the E/PO program. A planned effort was made to form a "community" of Deep Impact followers vested in the mission during our encounter in July 2005. The web site houses all Deep Impact products and activities as well as posts updates about the mission. Certain areas of a NASA web site are given: a place for educators and students to go to find formal education activities, *Education*. There is also a place where young people can go to have fun with the mission and where some informal activities are, *Discovery Zone*. There are places for learning the basic facts about the mission, *Mission*, *Science*, *Technology*, and there is a place to which the Press can go, *Press*. Images and animations of the spacecraft being built, experiments run in support of the mission, and of major mission milestones are posted in the *Gallery*. In developing the site, the team started with basic information and, over time, added new material to encourage people to return for updates. The writing style is intended to be friendly and casual and the team has been given compliments for its success in that regard. A section called "*Your Community*" was added a year before encounter. This section and additions to team biographies highlight the work of individuals who have become involved with the mission in some way. Examples are:

- Up Close and Personal – interviews with project members.
- Your Community – teachers, speakers, community organization leaders who have found a unique way to involve themselves with Deep Impact through research or special projects.
- Deep News newsletter – a monthly newsletter written by the outreach team with special features, games and articles.

In approaching launch and encounter, there is a building focus on extending the original mission to the many others who are making a "Deep Impact" with their participation and contributions to the project.

6. Evaluation and Review

Two types of evaluations were carried out, review and an evaluation study. A core planning team was convened early in the mission. Products were reviewed by science team members and by members of their intended audiences. Educational materials were reviewed by NASA's review panels. An independent evaluation was initiated in the final year of the project.

6.1. Core Planning Team

The Deep Impact mission convened a 2-day Core Planning Team (CPT) retreat in the design phase (Phase A/B) to review and discuss the E/PO team's plans.

Representatives from proposed audiences including teachers, museums, planetaria and media organizations were invited. Further evaluation was carried out in classrooms and at teachers' workshops where the intent of the material and how it is communicated could be reviewed and revised.

6.2. Evaluation Study

An evaluation study is carried out in the last year of the program with the purpose of evaluating the extent to which target audiences access and use the Deep Impact materials and examining the experiences of teachers and students using them. An independent sub-contract was issued to carry out this study. The evaluation design and its implementation span the course of 12 months during 2005. Two activities, Designing Craters and Modeling Comets for Mission Success will be evaluated in-depth during this project period, whereas the two other activities, Collaborative Decision Making and High Power Activity, will ensue with an exploratory evaluation of their visibility and reach to target audiences before pursuing a more in-depth inquiry as to their use in classrooms. Evaluations of Observing the Impact (Section 2.3.2) and the Amateur Observer Program (Section 3.5) as used in informal science settings will be conducted. The evaluation will be conducted in two phases. Phase One will focus on product dissemination and reach, and will include the development of appropriate methodologies for further examination of quality, utility, and impact in Phase Two.

The evaluation will address the following questions:

1. To what extent do target audiences access the Deep Impact education materials?
2. What are effective dissemination mechanisms for the Deep Impact materials?
3. How do teachers/facilitators use the materials in their education settings?
4. What are teacher/facilitator and student perceptions of and experiences with using the materials?

Study participants will include teachers who have previously used the Deep Impact materials or who will use them as part of the case study during the spring of 2005. The evaluation of the "Eyes on the Skies" and the Amateur Observer program will include educators and students in informal settings, such as astronomy clubs or summer camps. It is intended that participant recruitment efforts will identify three teachers/facilitators for each of the modules to be evaluated. As an incentive for participation, teachers/facilitators will receive the materials for free as well as a stipend of $50 for their time and contributions to the evaluation. Participant confidentiality and anonymity and will adhere to district processes and requirements for human subjects review.

A combination of quantitative and qualitative methods is included in the design to allow for a full understanding of the nature and extent of use of the Deep Impact materials. The evaluator will collect descriptive, implementation, and outcome data throughout the project period. Descriptive information characterizes the nature of the sample involved in the study and includes

- student and teacher demographic information,
- student attendance records, and
- document review.

Product implementation and monitoring measures the use of the Deep Impact materials in the classroom and documents any local history events that occur over the course of the study. Data collection methods to assess implementation include

- site visits for observations and interviews with teachers and students, and
- teacher implementation logs.

Evaluators will conduct site visits to a sample of sites. Evaluators will conduct interviews and observations with teachers/facilitators in order to identify any implementation issues and challenges and to gain in-depth information about implementation, instruction, teacher/facilitator perceptions of student engagement and learning, and student behaviors and perceptions of the materials. Teachers in formal education settings will complete an online implementation log that captures their personal, day-to-day experiences using the materials.

Outcome data reveals how teachers/facilitators and students have been impacted by education materials. Evaluators will inquire about the availability of existing school- or district-level student performance data in science, and will incorporate these data into the final analyses, if feasible. Teacher/facilitator and student outcome data will be based on self-report feedback through

- a teacher/facilitator survey, and
- a student interest survey.

The results of this evaluation will be published in a refereed journal upon its completion.

7. Conclusion

The Deep Impact E/PO program has grown out of a plan, a schedule and a budget that have been in place since the proposal-writing phase of the project. Materials specific to the Deep Impact project take the form of short informative material, audio-visual products, educational modules for the classroom and informal education venues. The breadth of the program is leveraged through partnerships with organizations that reach audiences including under represented and under served minority cultures, school children in urban and rural areas, and teachers and science center staff across the country. With enthusiasm generated by the project scientists, engineers and educators, the E/PO program and the project itself stands poised to meet its objectives of sharing the excitement of space science discoveries with the public, enhancing STEM education in the United States, and inspiring the next generation of scientists and engineers.

Appendix I. National Science Standards Alignment: Collaborative Decision Making

National Science Standards Addressed

- Grades 5–8
  - Science as inquiry
    - Abilities necessary to do scientific inquiry
      - Identify questions that can be answered through scientific investigations
      - Recognize and analyze alternative explanations and predictions
      - Use appropriate tools and techniques to gather, analyze and interpret data
      - Understandings about scientific inquiry
      - Develop descriptions, explanations, predictions, and models using evidence
      - Think critically and logically to make the relationships between evidence and explanations
      - Communicate scientific procedures and explanations
      - Use mathematics in all aspects of scientific inquiry
  - Science and technology
    - Understandings about science and technology
  - Science in personal and social perspectives
    - Science and technology in society
    - Risks and benefits
  - History and nature of science
    - Science as a human endeavor
    - Nature of science
  - Earth and space science
    - Earth in the solar system
- Grades 9–12
  - Science as inquiry

Abilities necessary to do scientific inquiry

Identify questions and concepts that guide scientific investigations

Recognize and analyze alternative explanations and predictions

Formulate and revise explanations and models using logic and evidence

Communicate and defend a scientific argument

Science and technology

Understandings about science and technology

Use technology and mathematics to improve investigations and communications

Science in personal and social perspectives

Environmental quality

Science and technology in local, national, and global challenges

History and nature of science

Science as a human endeavor

Nature of scientific knowledge

Language Arts Standards

Standard: 8 Demonstrates competence in speaking and listening as tools for learning

Level III Grades 6–8

Listening and speaking

Conveys a clear main point when speaking to others and stays on the topic being discussed

Presents simple prepared reports to the class

Uses listening and speaking strategies for different purposes

Uses strategies to enhance listening comprehension

Listens in order to understand topic, purpose, and perspective in spoken texts

Level IV Grades 9–12

Listening and speaking

Adjusts message wording and delivery to particular audiences and for particular purposes (e.g., to defend a position, to entertain, to inform, to persuade)

Makes formal presentations to the class (e.g., includes definitions for clarity: supports main ideas using anecdotes, examples, statistics, analogies, and other evidence; uses visual aids or technology)

Responds to questions and feedback about own presentations (e.g., defends ideas, expands on a topic, uses logical arguments)

Writing

Gathers and uses information for research purposes

Uses card catalogs and computer databases to locate sources for research topics

Uses a variety of resource materials to gather information for research topics

Determines the appropriateness of an information source for a research topic

Uses the general skills and strategies of the writing process

Drafting and revising: uses a variety of strategies to draft and revise written work

Life Skills Standards

Thinking and reasoning

Applies decision-making techniques

Secures factual information needed to evaluate alternatives

Predicts the consequences of selecting each alternative

Makes decisions based on the data obtained and the criteria identified

Identifies situations in the community and in one's personal life in which a decision is required

Effectively uses mental processes that are based on identifying similarities and differences

Compares different sources of information for the same topic in terms of basic similarities and differences

Principles and Standards for School Mathematics Grades 6–8, 9–12

Problem solving

Solve problems that arise in mathematics and in other contexts

Apply and adapt a variety of appropriate strategies to solve problems

Data analysis and probability

Formulate questions that can be addressed with data and collect, organize and display relevant data to answer them

Develop and evaluate inferences and predictions that are based on data

National Educational Technology Standards Grades K-12

Standard 5: Technology research tools

Students use technology to locate, evaluate, and collect information from a variety of sources

Standard 6: Technology problem-solving and decision-making tools

Students use technology resources for solving problems and making informed decisions

Students employ technology in the development of strategies for solving problems in thereal world

Grades 6–8

Standard 7

Collaborate with peers, experts, and others using telecommunications, and collaborative tools to investigate curriculum-related problems, issues, and information, and to develop solutions or products for audiences inside and outside the classroom

Standard 10

Research and evaluate the accuracy, relevance, appropriateness, comprehensiveness, and bias of electronic information sources concerning real-world problems

Appendix II. Designing Craters

National Science Education Standards Addressed

Grades 5–8

Science as inquiry

Abilities necessary to do scientific inquiry

Identify questions and concepts that guide scientific investigations

Design and conduct a scientific investigation

Communicating scientific procedures and explanations

Develop descriptions, explanations, predictions and models using evidence

Understandings about scientific inquiry

Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations

Scientific investigations sometimes result in new ideas and phenomena for study

Earth and space science

Earth's history

Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet

Physical science

Properties and changes of properties in matter

A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample

Motion and forces

The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph

Transfer of energy

Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, etc.

Energy is transferred in many ways

Grades 9–12

Science as inquiry

Abilities necessary to do scientific inquiry

Identify questions that can be answered through scientific investigation

Design and conduct scientific investigations

Communicate and defend a scientific argument

Recognize and analyze alternative explanations and models

Formulate and revise scientific explanations and models using logic and evidence

Understandings about scientific inquiry

Scientists usually inquire about how physical, living, or designed systems function

Scientists rely on technology to enhance data

Results of scientific inquiry emerge from different types of investigations and communications between scientists

Principles and Standards for School Mathematics Addressed

Grades 6–8

Data analysis and probability

Develop and evaluate inferences and predictions that are based on data

Algebra

Understand patterns, relations, and functions

Analyze change in various contexts

Use mathematical models to represent and understand quantitative Algebrarelationships

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