The following series of typical tests are considered: static load, modal survey, sine vibration, acoustic noise, random vibration, shock and electromagnetic compatibility.

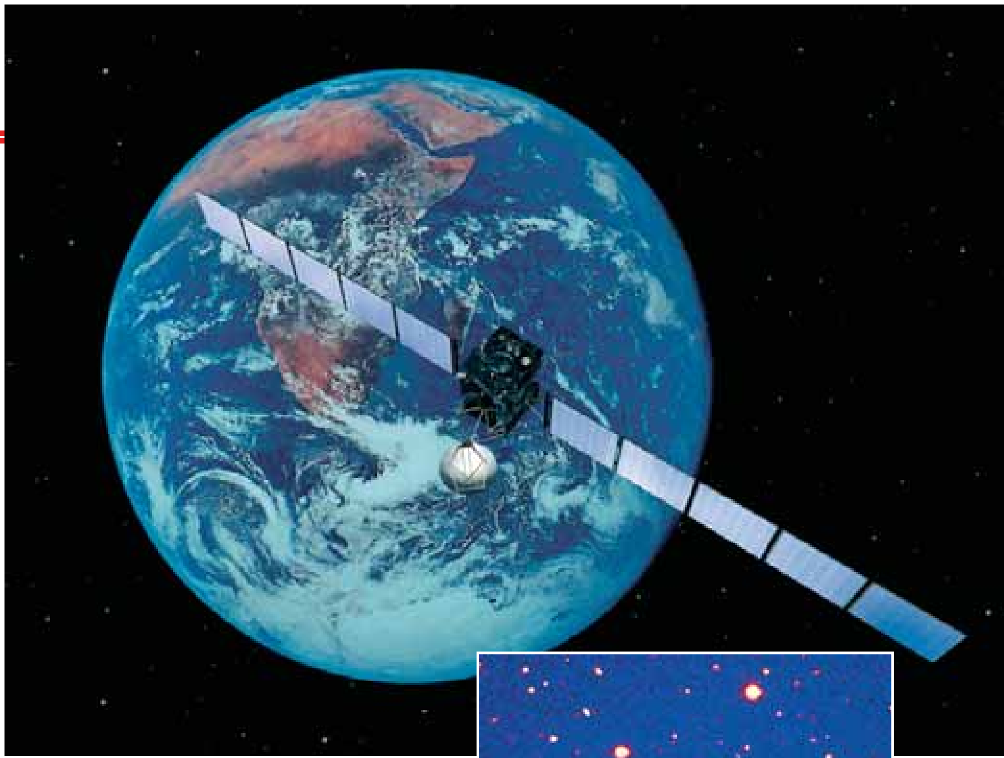
Note that the architecture of the format of ISO/CD 19933 is in line with the overall guidelines of ISO/CD 17566, *General test documentation*, with the objective of generating a self-contained document. This latter document specifies the format of presentation of spacecraft test plan, test specification, procedure and report. These topics are combined in ISO/CD 19933 to form the comprehensive and compact launch environmental test report requested by launch vehicle service providers.

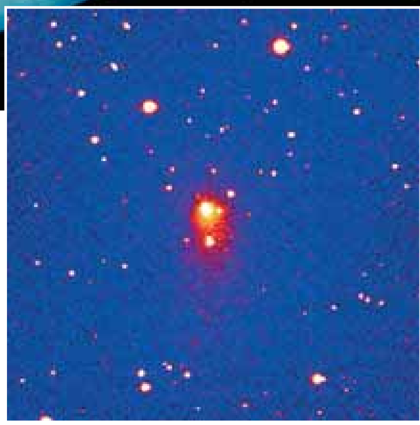
## The benefits of standard formats

ISO meetings remind us permanently that the scientific language is universal. Despite their various technical cultures and backgrounds, launch vehicle and spacecraft experts from Brazil, China, Europe, Japan, Russia and the USA have always come to a consensus on the many technical subjects that are discussed at length during the working group meetings. The group first raises the issues of common concepts and similar methods and then examines specificities from individual entities, in order to decide to what extent they can be integrated in future standards. This technique enables standard formats to be adopted on a worldwide basis as they are published.

As a result, spacecraft operators and manufacturers have a very efficient way of exchanging technical information with launch vehicle service providers. With only one standard document, spacecraft operators can address launch requests to several launch agencies at the same time, whereas with a unique standard format, spacecraft manufacturers are in a position to control technical interfaces with the various launch service providers they are working with.

Obviously this process results in a substantial reduction of workload and associated cost for everyone, and also minimizes the risk of errors, omissions and misunderstandings. ■





(Top) *ESA's Rosetta spacecraft.* (Insert) Deep impact from Rosetta. © Courtesy of NASA

# International collaboration makes a deep impact in space

*by Dr. John D. Kelley, NASA Headquarters Program Executive for Communications and Data Standards in the Office of Space Operations*

On July 4th of this year, space enthusiasts around the world scanned televisions, computer monitors and the sky hoping to catch a glimpse of NASA's Deep Impact, the kind of action-packed event in space that most of us here on Earth have only seen in a movie theatre. But as onlookers awaited a sign that the mission's Volkswagen Beetle-sized impactor had indeed met its target comet, they, along with ISO and the Consultative Committee for Space Data Systems (CCSDS), were making a bit of history themselves.

Individuals on the ground, a fleet of space telescopes, and dozens of ground observatories located worldwide made Deep Impact one of the world's largest astronomical observation campaigns ever. Observers with communications enhanced by ISO-CCSDS standards included the Deep Impact spacecraft, space telescopes Hubble, Chandra, Spitzer, and SWAS, NASA's Deep Space Network (DSN), and even the European Space Agency's own comet chaser Rosetta. The use of CCSDS-developed standards on these missions, and on others recording the event, also made Deep Impact the most standardized, CCSDS-intensive event in space to date.

CCSDS was established in 1982 by ten of the world's most influential space agencies as a multi-national forum focused on the discussion of common space communications issues. A pathfinder in international collaboration in space since its inception, CCSDS quickly grew into a global organization dedicated to the development of space data communications solutions.

As international cooperation in space has grown over the years, so has the need for international standardization. To meet this need, subcommittee SC 13, *Space data and information transfer*


*systems*, of ISO's technical committee ISO/TC 20, *Aircraft and space vehicles*, was formed to address the standardization of data/information systems associated with space instruments, vehicles and supporting ground facilities.

CCSDS has maintained a close working relationship with ISO through TC 20 / SC 13. The value of this relationship is measured in part by the success of multi-mission, multi-agency space events like the one focused on NASA's Deep Impact mission, and the influence of the relationship evidenced by the increasing number of CCSDS-compatible products developed by the commercial space industry. But perhaps the most important indicator of the success of this relationship thus far is the steady rise in acceptance of ISO-CCSDS standards by mission planners worldwide.

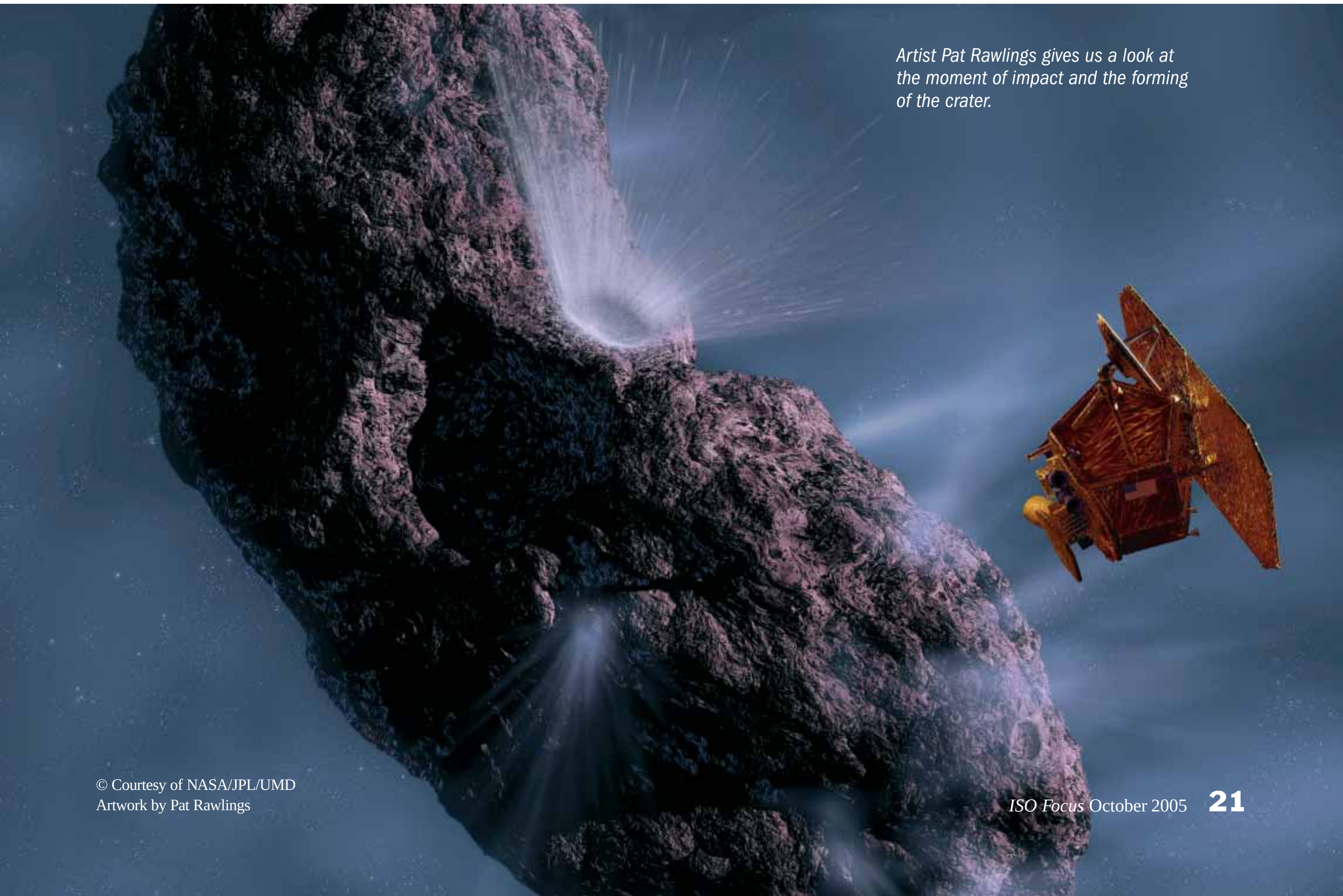
To date mission planners on more than 300 national and multinational missions to space have chosen to fly using these standards, including NASA's Deep Impact mission, ESA's Rosetta mission, and every spacecraft associated with the exploration of Mars. CCSDS has produced more than thirty ISO standards, with another sixteen currently under review.

This ongoing cooperative relationship between ISO and CCSDS provides a valuable mechanism that ensures information sharing on space communications technologies continues to occur on a global scale. This month, ISO/TC 20/SC 13 and the CCSDS Management Council will convene their bi-annual meetings in Washington, D.C. on the heels of a historic summer in space for both NASA and the world.

While countless onlookers hoped to witness Deep Impact, the history-making event with the Hollywood name, only a privileged few saw the bright flash of light that also appeared on the screens of the control room at NASA's Jet Propulsion Laboratory in Pasadena, California at 5:52:24 Universal Time. The European Space Agency's comet chaser Rosetta was one of those with a front row seat in space.

**"CCSDS has produced more than thirty ISO standards, with another sixteen currently under review."**

To help alleviate the concern that flying debris from the collision might put at risk valuable data collected by the Deep Impact spacecraft, many of the world's space agencies collaborated on a network of both space and ground-based observatories to record the Deep Impact event. Enabled by some of the same ISO-CCSDS standards, key observer Rosetta and the Deep Impact spacecraft were able to send data back to Earth in near-real time during the event. But it was Rosetta with its powerful remote-sensing instruments that was best able to monitor the target comet continuously over an extended period of time, providing researchers with some of the pre-impact and follow-up observations essential to a successful scientific out-

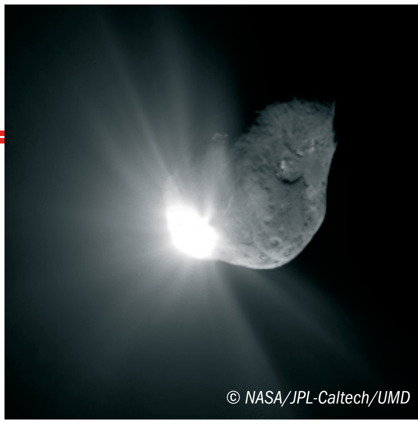


*Artist Pat Rawlings gives us a look at the moment of impact and the forming of the crater.*

come for the Deep Impact mission.

Currently on its own 7.1 billion kilometre journey to Comet 67P/Churyumov-Gerasimenko, Rosetta is one of ESA's most demanding missions in terms of ground station requirements. During critical mission phases, Rosetta uses the data communications services of NASA's Deep Space Network (DSN), the largest and most sensitive scientific telecommunications system in the world. DSN stations use ISO-accepted CCSDS Space Link Extension (SLE) services to facilitate interoperability for both NASA user facilities and international customers alike. They also require that spacecraft they support, like Rosetta, use the same standards for both forward and return data traffic.

In the past, tracking, telemetry and command cross-support between ESA and NASA meant installing and operating user equipment on the provider side, which was time consuming




*This image shows the initial ejecta that resulted when NASA's Deep Impact probe collided with comet Tempel 1 at 10:52 p.m. Pacific time, July 3 (1:52 a.m. Eastern time, July 4) .*

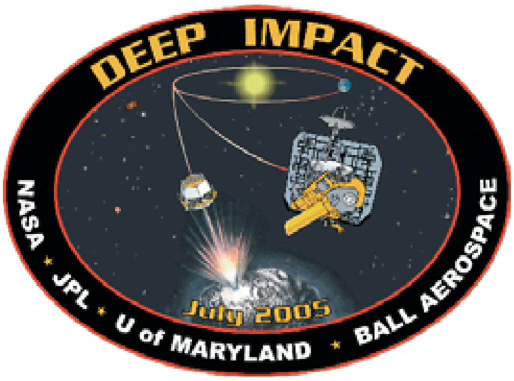
and costly. SLE services extend existing CCSDS-developed ISO standards for space links to include the exchange of spacecraft data between ground elements, and offer cost savings potential through the use of common equipment at ground stations as well as a standard user interface.

International partners collaborating through CCSDS first looked at the development of SLE services in the early 1990s. As development of the recommendation matured in the mid-1990s, a groundbreaking decision was made by the ESA INTEGRAL mission to adopt SLE for cross-support from NASA's DSN stations, which accelerated SLE-related activities within CCSDS to completion.

Eventually, NASA's CONTOUR mission, developed by the Johns Hopkins University Applied Physics Laboratory, would be the first mission to launch using SLE services in July 2002. But since that first pioneering step towards the use of CCSDS SLE by the INTEGRAL mission, SLE has become the predominant international standard supporting interoperability between mission user facilities and ground station facilities owned and managed by different organizations.

By facilitating cross-support between missions and agencies, SLE is a truly international standard in both development and use. It has allowed NASA's DSN to play an important role in the success of ESA's Rosetta mission, and in turn, has allowed ESA's Rosetta mission to play an important role in the success of NASA's Deep Impact.

The July 4th impact certainly marked a high point in a seven-year engineering and navigation effort put forth by NASA's Deep Impact team, but much of the scientific story may still lie in the gigabytes of data sent back by Rosetta and other observers. In particular, an analysis of data sent back from the Deep Impact spacecraft may reveal what lies beneath the surface of the comet and perhaps even shed light on the origins of the Solar System. To minimize the risk of losing this valuable data and to ensure a reliable bidirectional flow of data occurred, the Deep Impact mission chose to use one of CCSDS' newest internationally accepted standards, the CCSDS File Delivery Protocol (CFDP).




*The Deep Impact icon shows the partnership among the University of Maryland, Jet Propulsion Laboratory and Ball Aerospace & Technologies Corp.* © NASA

The world's leading space communications experts working within CCSDS collaborated at bi-annual working group sessions, similar to those that took place last month in Atlanta, Georgia (USA), to first standardize CFDP. They defined the protocol according to space file transfer requirements articulated by CCSDS participating space agencies, including those of NASA, the European Space Agency (ESA), the British National Space Centre (BNSC), the Centre National d'Etudes Spatiales (CNES) and the Japan Aerospace Exploration Agency (JAXA).

The first US mission to commit to this technology was the NASA / Johns Hopkins University Applied Physics Laboratory MESSENGER mission to the planet Mercury, but Deep Impact was the first NASA JPL mission to use CFDP for data transfer from ground to spacecraft (uplink) and from spacecraft to ground (downlink).

## About the author

**Dr. John D. Kelley** is the NASA Headquarters Program Executive for Communications and Data Standards in the Office of Space Operations. With decades of leadership experience in the development of information systems and operations programmes for scientific data, communications and engineering, Dr. Kelley serves in dual roles within the CCSDS as both the Chair of its Management Council and as its Secretariat. In addition, Dr. Kelley is the Secretariat of ISO TC 20 / SC 13. As the NASA and United States representative for Data and Information Standards, he heads a delegation focused on space communications standards that enhance interoperability, reduce costs and promote the use of shared space applications. Dr. Kelley holds a PhD in Public Administration, a Masters of Public Administration and a Masters of Science from the University of Southern California, as well as a Bachelors of Science from the U.S. Naval Academy.


The decision to use CFDP paid off. During Deep Impact's cruise phase, CFDP uplinked thousands of files to the spacecraft, including new flight software loads, commands and tables. CFDP also successfully downlinked well over a hundred thousand files during this time.

During the encounter phase, CFDP downlinked approximately 10 206 files from the Deep Impact spacecraft, or about 2.4 Gigabytes of data and images. Files were uplinked in "reliable" mode, which ensured a complete and accurate file transfer. Files were downlinked from both spacecraft in "unreliable" mode to save bandwidth due to the large volume.

CFDP enabled the bidirectional flow of this important data between Deep Impact spacecraft and Earth using powerful forward error correction coding that minimizes data loss in communication across deep space. CFDP also supports optional "acknowledged" modes of operation during which data loss is automatically detected and a retransmission of the lost data is automatically requested. This design allows CFDP to function reliably despite the long data propagation delays and frequent, lengthy interruptions in connectivity experienced in deep space by missions like Deep Impact.

**"Through its partnership with ISO, CCSDS will move forward in supporting the efforts of NASA, ESA, and other space agencies."**

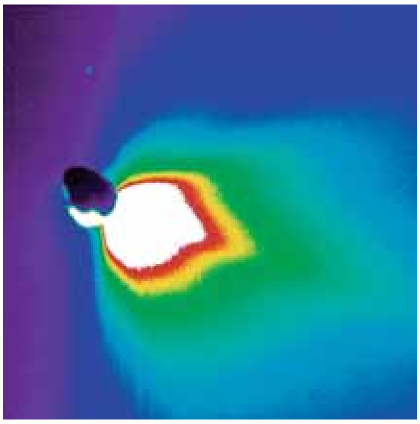
While NASA JPL's CFDP team worked closely with the flight software team to ensure that CFDP performed correctly, CFDP was also integrated into NASA JPL's multi-mission ground system for use by future missions. Incorporating an internationally-accepted standard file transfer protocol, like CFDP, into NASA JPL's multi-mission ground system provides missions with a way to get data, like large image files for example, faster and more reliably than by having to develop their own software in order to create products from the telemetry stream, as required in the past.

With space programmes around the world facing budget cuts and resource allocation, CFDP, like SLE discussed previously, also benefits missions by providing cost savings potential. CFDP allows an instrument to record an observation in a file and transmit the file to earth without having to consider whether or not physical transmission is possible at that time. Sequestering outbound data management and transmission planning functions within CFDP can simplify flight and ground software, which reduces mission costs – an important benefit to today's lower cost missions.

Nevertheless, the most striking benefit remains CFDP's ability to maintain high data transfer reliability even across interplanetary distances which makes it critical to successful communications on deep space missions like Deep Impact, and will make it highly applicable to future lunar exploration missions and missions to Mars.

*This artist's animation depicts one of the most widely accepted theories pertaining to the origin of comets.*

*© NASA/JPL-Caltech*



*Comet Tempel's silhouette – This false-colour image shows comet Tempel 1 about 50 minutes after Deep Impact's probe smashed into its surface.*

*© NASA/JPL-Caltech/UMD*

The CCSDS became a pioneer in international cooperation in space by providing an environment that fosters collaboration and information-sharing between the world's space agencies. Now a model of international collaboration, CCSDS participation includes space communications experts from 32 space agencies and 28 countries, all committed to developing the best engineered space communications recommendations in the world.


*The Deep Impact poster.* *© NASA*

Through its partnership with ISO, CCSDS will move forward in supporting the efforts of NASA, ESA, and other space agencies in using joint communications assets for future missions through the continued development of new protocols that advance both commercial and governmental interoperability in space. New possibilities for cooperation will continue to emerge as delegates to both TC 20/SC 13 and the CCSDS Management Council remain committed to growing strong relations between their respective national space agencies and those of other delegates. ■