Comet Explodes on Jupiter—and the Web

Note: All images were downloaded from the World Wide Web, as was most of the information. Universal Resource Locators (URLs) are cited wherever possible.

Between the 16th and 22nd of July this year, the periodic comet designated P/Shoemaker-Levy 9 crashed into Jupiter. Scientists hoped to learn about the makeup and behavior of both comets and Jupiter’s atmosphere from the size, appearance, and composition of the impact plumes.

The scientific community did not go into the event unprepared. Teams at several supercomputing centers ran simulations that predicted the outcome of the impacts. Mailing lists sprang up to facilitate the free flow of information. Scientists all over the world programmed their satellites and spacecraft to monitor the event.

But what about the rest of us? Astronomy might be the only science in which amateurs—such as David Levy, who discovered eight comets from his backyard before joining Carolyn and Eugene Shoemaker at the Mount Palomar observatory—routinely make major contributions. Amateur astronomers all over the globe recorded their observations for programs such as the Jupiter Comet Watch and the British Astronomical Association’s Jupiter Section. And possibly millions of science enthusiasts accessed the images, data, and simulations posted on the many World Wide Web sites established. Despite slow access times, server problems, and the limitations of the current infrastructure, the WWW and the Mosaic interface provided a glimpse of how to swiftly distribute graphics and other information world-wide in the future.

Visualizing the impacts

At the Massachusetts Institute of Technology’s Department of Earth, Atmospheric, and Planetary Sciences, Joseph Harrington, Raymond LeBeau, Kari Backes, and Timothy Dowling studied the jovian atmosphere. According to their simulations, each fragment hit the planet’s atmosphere, it would cause waves to propagate outward from the impact site, much like the ripples that spread when you drop a pebble into a pond. They reported their predictions in the April 7 issue of Nature, posting the images to http://www-erl.mit.edu/flolab/csl9press/csl9j.html.

The MIT team generated its model in about 300 hours on 128 nodes of a 512-node nCube 2 parallel processor. A Sun Sparstation 2 served as a front end for the nCube, using AVS software modules as an interface. A DECstation 5000/240 PGX recorded the entire animation directly to videotape, rendering one frame for each four minutes of model time. Harrington estimated that instead of having to save a terabyte of model data, saving only a backup frame every 24 hours of the model time cut storage needs to about 4 Gbytes.

Harrington, Dowling, and MIT’s Heidi Hammel went to NASA’s Space Telescope Science Institute (STScI) to observe the Hubble images as they came in. “There is definitely a wave,” Harrington reported, citing the Hubble Space Telescope image of impact G. “We are currently arguing among ourselves about what kind of wave it is. It has the speed of an inertia-gravity wave, but is quite compact and well defined, like a sound wave.”

Message from the editor

To increase the applications focus of IEEE Computer Graphics and Applications, starting with this issue I am joining the Applications department as editor. Over the years the consistent feedback from our readership, including the recent CG&A reader survey, expressed a strong desire for more practical content and real-world applications. The goal of this department is to bring the CG&A readership examples of interesting or unique applications of computer graphics techniques and technology to different problem domains.

These articles will not be refereed; rather, acceptance will be determined solely by the department editor. Here are the criteria I will apply. First, the contribution should be unique in some way, ideally applying a graphics technique or technology for the first time to a given problem area. Second, the submission must say more than “here’s what we did.” The key is to contain some result. Finally, though we expect to talk about equipment and products by name and welcome “applications notes” from product manufacturers as a basis for articles, an article must function as more than an advertisement for a given product.

Articles will be from 1-3 pages, including images, photos, and artwork. They may contain a few (3 or so) references and should tell readers how they can follow up. Given space limitations, authors should expect that articles will be edited or rewritten by our staff as necessary. Most importantly, if you know of an interesting application our staff should investigate and report on, or if you want to write such an article yourself, please contact me at potel@taligent.com. Let’s make the “...and Applications” part of our title a reality!

—Mike Potel
While MIT studied Jupiter, Mordecai-Mark Mac Low of the University of Chicago and Kevin Zahnle of NASA Ames Research Center modeled the comet's behavior. Using Zeus, an astrophysical gas dynamics program written by Mike Norman et al. at NCSA, Mac Low and Zahnle ran simulations through the Cray C90 at the Pittsburgh Supercomputing Center. (Go to http://pscinfo.psc.edu/research/user~research/mac_low/mac_low.html.)

The images of the actual impacts bore out their predictions. The simulation called for the comet to explode on hitting the troposphere, producing a huge fireball that would blow back hundreds of miles through the stratosphere. When the first images of impact A came in, the fireball was large enough for Hubble to see around the limb of Jupiter before the actual impact site rotated into view. And according to the evidence from the Hubble telescope, the strongest waves spreading from impact site G were propagating in the stratosphere, with weaker waves spreading in the upper clouds, which indicates that the fragment exploded above the clouds (Science, July 29, 1994).

Handling the overload

While the comet impact was the big story, the event's impact on the fledgling "information superhighway" also made big news. An informal poll of comet sites revealed an estimate of 3,382,466 Internet accesses since July 15, 1994. Demand was so heavy that NASA's Jet Propulsion Laboratory set up a mirror site at the lab. The JPL sites alone received more than 2 million visits.

While JPL's two servers—http://newproducts.jpl.nasa.gov/sl9/sl9.html and http://navigator.jpl.nasa.gov/sl9/sl9.html—had little trouble handling the high demand, other sites were not so lucky. The first incarnation of the NASA National Space Science Data Center (NSSDC) broke down under the pressure on July 19, the third day of comet impacts. Within three hours, according to systems programmer Syed S. Towheed, the NSSDC had brought an alternate server on line at http://marvel.stsci.edu/EPA/Comet.html. He speculated that the high ratio of image files to text files downloaded (3 to 1 in number of files, 4 to 1 in number of bytes) might have contributed to the server problems at NSSDC.

The primary server at STScI also suffered critical server overload. Scott Mace, a systems developer at Neosoft who reported 745 accesses at his STScI mirror site at http://pluto.neosoft.com/, saw the effects. "For a while, STScI was so slow because of everyone hitting it that my mirroring software timed out," Mace said.

The three NASA sites accounted for about 2,970,000 accesses. However, other servers experienced heavy traffic as well. "During the frenzy, my server saw 10,000 accesses a day," said Greg Bothun of the University of Oregon. The Oregon site, http://zebu.uoregon.edu/comet.html, features links to Kitt Peak and Pine Mountain Observatories, as well as selected images from Hubble and Earth-bound observatories.

Planning for the future net

The server problems and general slowdown on the Internet raised some serious questions about how the proposed National Information Infrastructure, based on the existing Internet, will be able to function. According to MIT's Harrington, what we've learned about the NII is that "a relatively small percentage of the population . . . can totally hose the net looking for just one type of information on a recreational basis. . . . The 'information superhighway' will be a big, ugly mess at current levels of planning."

Towheed agreed about the need for planning, but sounded more optimistic. In his paper prepared for the 2nd International WWW Conference in October (see http://nssdc.gsfc.nasa.gov/misc/www~conf/towheed.html), he called the experience a success, despite the server problems: "Through the Shoemaker-Levy 9 collision event, NASA has demonstrated the 'real-world' use of this new technology [WWW] as an immensely powerful and cost-effective tool for. . . the massive transfer of data to a wide user base."

Some scientists were even more excited about the Web possibilities than Towheed. "The SL-9 event contributed in a major way to putting the Internet/Web/Mosaic indelibly into the minds of astronomers and the interested public," said Finn Murtagh of the European Southern Observatory. "In July [astronomical data sharing] was very open—very democratic—and the Web made this possible."