IITA Bulletin

Behind the Scenes at Mars Pathfinder Mission Operations

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After twenty-one years (as a former Viking Meteorology Science Team member) it's great to be back on Mars! Unless you reside on the other side of Mars, (i.e., out of touch with current events), it's obvious that Mars Pathfinder was a major technological and scientific success. The science returns have far exceeded anyone's dreams, especially when considered in the context of initially suggested goals. The earliest plan I can remember was that up to 90% success would be attributed to getting the rover off the ramp, making a couple of measurements with its Alpha-Proton-X-ray Spectrometer, taking a lot of images, acquiring some atmospheric data, and surviving a week! Strong inputs to NASA HQ from the science community helped extend these goals, while project and engineering staff worked hard to make this far more than a "Technology Demonstration" mission.

Although this was a scientifically far less complex and encompassing mission than Viking, its operation was very difficult due to the tight integration of the IMP (Imager for Mars Pathfinder) camera and the Sojourner rover operations. IMP had to acquire images to define the hazards and objects for investigation, and the rover operations team had to plan and execute the commands within one day or less during the first few sols (Martian days). Contrast this with the orderly three- to seven-sol planning schedule of Viking! During the first several sols, data were received, processed, and analyzed, decisions were made, and rover commands were relayed while the NASA Deep Space Network tracking facilities on Earth were visible from the Pathfinder site on Mars. These operations were complicated by the one-way light (transmission) time of ten minutes or greater. The science teams and staff proficiently performed these feats, and as they gained experience they were able to increase the nominal data rates to up to four times the guaranteed values and double the maximum rates.

Four workstations were generously provided for the program by Digital Equipment, three of them as powerful or far more powerful than our Web server. Data were moved by Jim Tillman from the project machine to one of the DEC Alpha machines in the same area. This machine provided his operational resources at JPL and a conduit for data to his large DEC 9000-300 server at the University of Washington (UW); it crunched the data, archived results, produced graphics, and distributed them to the server purchased for the program, as well as to mirrors. Dr. Harry Edmon and Mr. David Warren configured these workstations and developed scripts for system-to-system procedures, supported operations, and helped solve problems.

Our educational and public infrastructure, targeted for Web viewers, simultaneously supported important science activities. Extensive procedures, software, and interfaces were developed by Neal Johnson to automatically calibrate the data, display multiple plots for editing and approval, integrate them into our Web pages, and ship them to others. Automatically updating mirror sites and transferring data to Dr. Soren Larsen at the Danish National Laboratory in Roskiled, Denmark, for scientific analysis was accomplished. Neal had to modify, test, and implement procedures on the fly, even though we had previously tested procedures during Operational Readiness Tests. One consequence of cheaper, faster is that more unexpected problems will arise! With this fast transfer of data, initial spectral analysis of the temperature data was completed by Dr. Larsen in Denmark and presented to the science team less than three weeks after the beginning of the mission.

Meteorology data were acquired and converted from raw spacecraft numbers by converting the programs of Dr. Tim Schofield, Atmospheric Structures/Meteorology Science Team leader, to the S+ statistical language. The temperatures at the three levels were displayed fifty-one times per sol throughout the first week. As during the Operational Readiness Tests, the first Martian low-rate meteorological observations were extracted from the database automatically and on schedule. Later, Jim Tillman at JPL and Neal Johnson at University of Washington and at home spent considerable time adapting to some operational problems. Subsequently, the Web page was enhanced to display animated sol-by-sol frames of Pathfinder's diurnal temperature variations. The development of

the daytime, unstable, and nighttime, stable, atmospheric surface layer was graphically demonstrated by the temperature measurements at 0.25, 0.5, and 1.0 meters on the meteorology mast. Included were comparisons of the Viking Lander 1 data for the same season, sol by sol.

Jim Tillman developed background information for Mars in general, its climate (as illustrated by his 3.3 year Martian climate record) and atmospheric temperatures (including diurnal and seasonal aspects), and characteristics of great Martian dust storms. Summary Viking meteorological data for the complete Viking mission were simplified by volunteer George LeCompte and linked by Neal Johnson. Several major descriptive components were developed or extensively rewritten, and specially modified data sets were added right up to landing on July 4. These are referenced in the links below.

A component of this program was the installation of a display at the Smithsonian National Air and Space Museum (NASM). A severe reduction in staff earlier this year jeopardized this component, but the system was installed in the exhibit area less than two weeks before July 4!

July 4 began with the automated procedures working perfectly on the first downlink and immediately thereafter. The temperature data were presented graphically in several formats. We added an animated GIF displaying complete sols of data one at a time while a commentary was added to provide periodic descriptions of the mission and meteorology status.

July 4 began with UW Grayskies, RSPAC, NASM, and Florida State providing mirroring. As the volume grew, Grayskies began to falter since it was the machine referenced from the JPL Web page. (It topped out at about 55,000 requests per hour. Requests ignore graphics calls and those from our machines and correspond to ~ 110,000 hits.) Webmaster David Dubov eased the pressure by pointing to two of our sites simultaneously, and we encouraged people to use our mirror sites. (Effective redirection is an important aspect of future Web applications and extensions.) Hundreds of compliments were received, and many can be classified as rave reviews. User locations ranged from next door to Katmandu; responses from Mars have yet to be detected.

During the early part of the mission, computer resets interrupted data collection and relay to Earth. This was reported as a meteorology problem, but it was a system bug which reared its ugly head when meteorology requested long data sequences. During debugging of this problem in the JPL “test bed” system, and until the software patch was installed on Pathfinder, meteorology was shut off during daytime operations, causing some of the gaps in the first thirty sols. Once meteorology resumed operating throughout the sol, the high data rates allowed the scheduling of fast sampling once every four seconds for a complete sol. This fast sampling and the very high resolution of Pathfinder provided unique insights into Martian meteorology. As with other investigations, continued data collection and analysis continue to provide major science returns, as well as new puzzles, from this low-cost mission.

At the end of the nominal thirty-day mission, a meeting was held to evaluate the condition of Pathfinder’s battery and to decide on its future utilization. (Both the lander and rover can operate on solar power alone.) It was decided to charge the battery to its fullest capacity and carefully use it to acquire meteorology data one out of every five nights; during the other four, the lander would operate on solar power alone, relaying its data in the afternoon. At the end each transmission, the computer would be shut down and all data in the volatile RAM (Random Access Memory) would be lost: we are now in that operational mode. The positive side of the new operational mode is that on every fifth sol, meteorology observations are made continuously at four- or one-second intervals.

Testing, mirroring, and suggestions by RSPAC staff have been very valuable during this development. Extensive support was provided by the Mars Pathfinder staff and colleagues. Project Manager Tony Spear supported

and encouraged this effort, as did Dr. Cheick Diarra. David Dubov, Pathfinder Webmaster, and Dr. Robert Anderson generously assisted by linking Pathfinder pages to ours and sharing resources. Science and operational team members provided advice, support, and data. Professor Peter Smith, PI, and Dr. Justin Maki of the Pathfinder IMP team were especially helpful. The support and assistance of Dr. John T. Schofield of the Atmospheric Structure/Meteorology Team was critical to our success. Finally, the initiative and support of NASA's Information Infrastructure Technology and Applications (IITA) project, High Performance Computing and Communications (HPCC) program, Office of Aeronautics is greatly appreciated.

This summary of our July Web use is provided by Dr. Harry Edmon.

Site	Est. Inquiries	Total Hits
UW	2,235,486	9,864,775
RSPAC	61,445	236,981
NASM	67,480	257,836
FSU	7,714	33,480

"Est. Inquiries" tries to estimate the actual number of inquiries by ignoring requests for button and small graphics. Two-and-one-half days of data for UW are missing, so the actual number of inquiries is probably around 2,280,000, and hits around 10,100,000.

Data collection, display, and supporting information development are continuing and we suggest that "Live from Earth and Mars" is a success. One teacher said that parents had never seen their children as excited about science, fulfilling a goal of mine begun twenty-five years ago to share science and engineering directly with students. I hope to obtain support to continue to provide Pathfinder data throughout the mission, to continue the development of these resources and materials, and to extend "live from Mars" to other missions. Potential collaboration, discussions, and support are welcome. We will be replying to comments for the foreseeable future and sample responses will be made available. Links to new or recently modified information can be found at the URLs listed below.

Mars (NEW)
http://www-k12.atmos.washington.edu/k12/resources/mars_data-information/mars_overview.html
Mars: Atmospheric Pressure: Overview (NEW)
http://www-k12.atmos.washington.edu/k12/resources/mars_data-information/pressure_overview.html
Atmospheric Temperature: Overview (NEW)
http://www-k12.atmos.washington.edu/k12/resources/mars_data-information/mars