The GBT Watches as Phoenix Lands on Mars

The NRAO Green Bank Telescope supported the recent successful landing of the Phoenix spacecraft on Mars with direct observations of transmissions from the lander.
The NRAO VLBA array also tracked the Phoenix cruise vehicle as it approached Mars. Here we will describe the role of only the GBT.

Phoenix is the first spacecraft to land in the polar region of Mars, where it can study the polar landscape, the subsurface ice, and analyze the minerals. A previous polar mission, the Mars Polar Lander in 1999, failed due apparently to a software glitch that caused the landing rockets to shut off prematurely. Lessons learned from that mission helped make Phoenix a success. NASA placed great importance on monitoring Phoenix very intensively through multiple channels during atmospheric entry, descent, and landing (EDL).

The Phoenix lander transmits its information to one or more of the three satellites in orbit around Mars, which relay the information (at X-band) to Earth where it is received by one or more of the three Deep Space Network (DSN) 70-meter antennas. These are located in southern California, Australia, and Spain.

For the critical atmospheric entry, descent, and landing (EDL), NASA wanted to also monitor the signals directly from the spacecraft (at ~401.6 MHz). Only the 100-meter Robert C. Byrd Green Bank Telescope is sensitive enough at the required frequency band to detect Phoenix's faint signals from Mars.

If something had gone wrong during EDL, data collected by the GBT would be vital to analyze what happened. Fortunately, everything worked correctly.
The data from the GBT will be used in combination with all the other information to improve knowledge of the details of the trajectory of the spacecraft, all important in planning future missions.

GBT staff, including Gary Anderson, Frank Ghigo, Toney Minter, Roger Norrod, and Galen Watts, have been involved in preparing for the Phoenix mission since December 2007. They collaborated with radio science experts Peter Ilott, Sami Asmar, and Sue Finley from NASA's Jet Propulsion Laboratory (JPL), all of whom are veterans of many planetary exploration missions, including support of the recent Mars Rovers: Spirit and Opportunity.

The JPL scientists brought their own sensitive sampling and data recording equipment to be connected to the GBT. NRAO Electronics staff Dave Woody and Nathan Sharp helped set up and connect the JPL equipment. Computer staff Chris Clark, Wolfgang Baudler, and Gene Runion were essential in connecting their equipment to the Internet such that data displays from Green Bank could be seen at JPL headquarters.

During tests in December 2007 and March 2008, the GBT observed the signals from the Mars Rovers, which transmit at the same frequency and a similar power level as the Phoenix lander. Shortly before the tests in March, problems with the cryogenics of the GBT prime focus receiver were discovered, and hurriedly fixed, with the expert help of electronics and cryogenic technicians Jonah Bauserman, Bob Simmons, and Kenny Lehman. These tests were successful, but we noticed some interfering signals which, if they occurred during the Phoenix landing, would obliterate the data we were trying to collect.

To identify the source of this radio frequency interference (RFI), the Interference Protection Group in Green Bank (Carla Beaudet, Wes Sizemore, and Paulette Woody) swung into action. They researched and analyzed all Earth-orbiting satellites that might interfere. They monitored the Green Bank area for any possible local sources of RFI. They contacted spectrum managers at NSF, NASA, and other agencies. Ultimately they identified two Earth-orbiting satellites that would have caused serious interference. The managers of these satellites agreed to turn them off during the critical observing period. (See the related article by C. Beaudet in this Newsletter).

Opportunities for public education and outreach were arranged by NRAO Education Officer Sue Ann Heatherly. A video link was set up from Green Bank to the Clay Center, a public facility for arts and science in Charleston, WV. A few days before the landing, Peter Ilott gave a colloquium on "Listening to Mars" in our auditorium in Green Bank. This colloquium was heard and viewed at the Clay Center. For the actual landing Sunday evening, both the video link to the Clay Center and a streaming video feed to the Internet were set up in the GBT Control Room. NRAO Computing staff Chris Clark, Carolyn White, Charlie Myers, and Steve Tritapoe worked to set up and test the video/audio links.

All these preparations led up to the climax -- "EDL": the entry into the Martian atmosphere, descent, and landing between 7:00 and 8:00 pm Sunday evening May 25th. The GBT Control Room was crowded. The JPL scientists were running their recording equipment; the GBT telescope operators, Barry Sharp and Eric Knapp, were on duty; and Frank Ghigo was making sure the GBT was actually tracking Mars. Several engineers were on hand to take care of any last-minute technical problems that might happen: Bob Anderson, head of telescope operations; Gary Anderson, Roger Norrod, Steve White, receiver and microwave engineers; Joe Brandt, Mark Whitehead, Mike McCarty, software engineers. Interference sleuths Carla Beaudet and Wes Sizemore were checking for RFI. The video camera was operated by Bill Saxton, and Internet feeds were set up and monitored by Chris Clark

Our Green Bank summer students, Anthony Woody, Colin Slater, Stephanie Moats, and Marc Eimers were on hand sharing in the excitement. An electronic engineer from Cincinnati, Rick Hunter, who had designed some of the radio communication equipment on Phoenix, happened to be visiting. A local news reporter, Heather Niday, reported for the local radio station, WVMR, and the newspaper, *The Pocahontas Times*. Also present with "front row" seats was a small group from the Central Appalachian Astronomy Club.

The videocast of the happenings in the control room was transmitted to the Green Bank Science Center and also to the Clay Center in Charleston. Both auditoriums were filled to capacity. In the control room, Sue Ann Heatherly and Toney Minter acted as commentators for the remote audience, interviewing some of the scientists and engineers and answering questions.

At 7:30 pm the audience in the Control Room was asked to be quiet so that the JPL scientists could do their work without interruption. Peter Ilott was continuously on the telephone with the control center back at JPL, and he called out the events as he learned them. Sue Ann repeated the information for the remote audiences.

We could see the signal from Phoenix as received by the GBT appear at about the expected time. The entering of the atmosphere, slowing down, deploying of the parachute, and finally settling down to the ground on its rockets could be followed by the changes in the strength and Doppler shift of the signal. The signal displays from two of the JPL data recording devices were transmitted to JPL in Pasadena in real time so that the mission controllers could see the first signals from Phoenix as soon as we did in Green Bank. When the safe landing was confirmed, there was sustained applause, and everyone was thoroughly relieved.

The illustrations, Figures 1 and 2, show the EDL phases and the data plot that was being watched in the Control Room. Figure 3 shows the happy scientists after the successful landing.

I think everyone at NRAO, whether in the GBT control room or not, was pleased and proud that we could participate in the start of this new phase in the exploration of Mars.

To learn more about the Phoenix mission and the photographs and discoveries that have been made so far, visit the web site: http://phoenix.lpl.arizona.edu/

Figure 1: Montage of Phoenix EDL stages (NASA illustration).

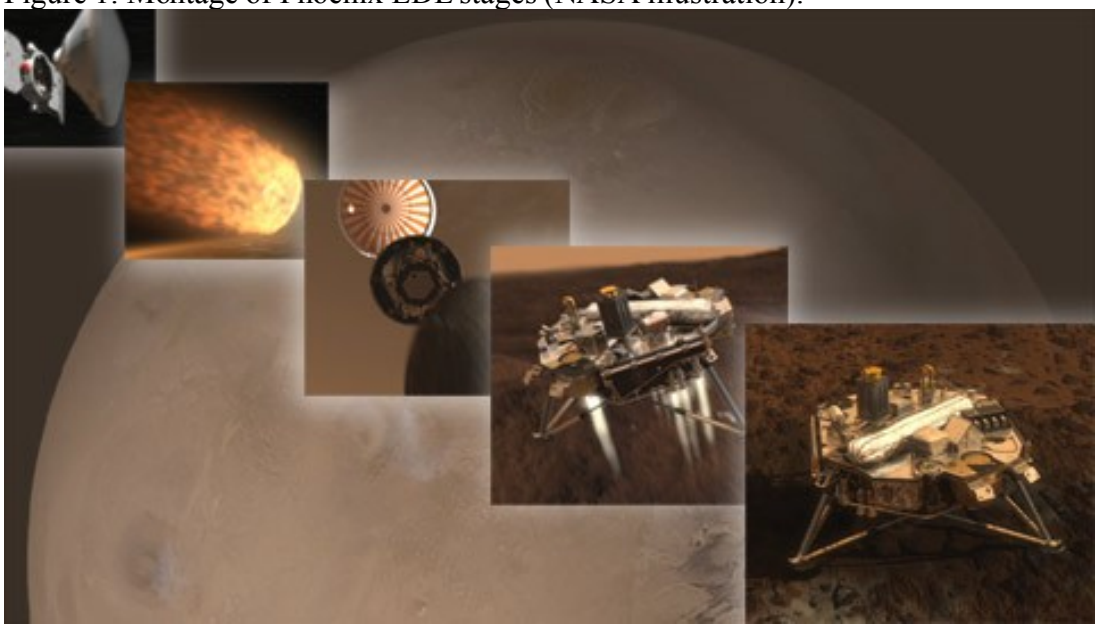
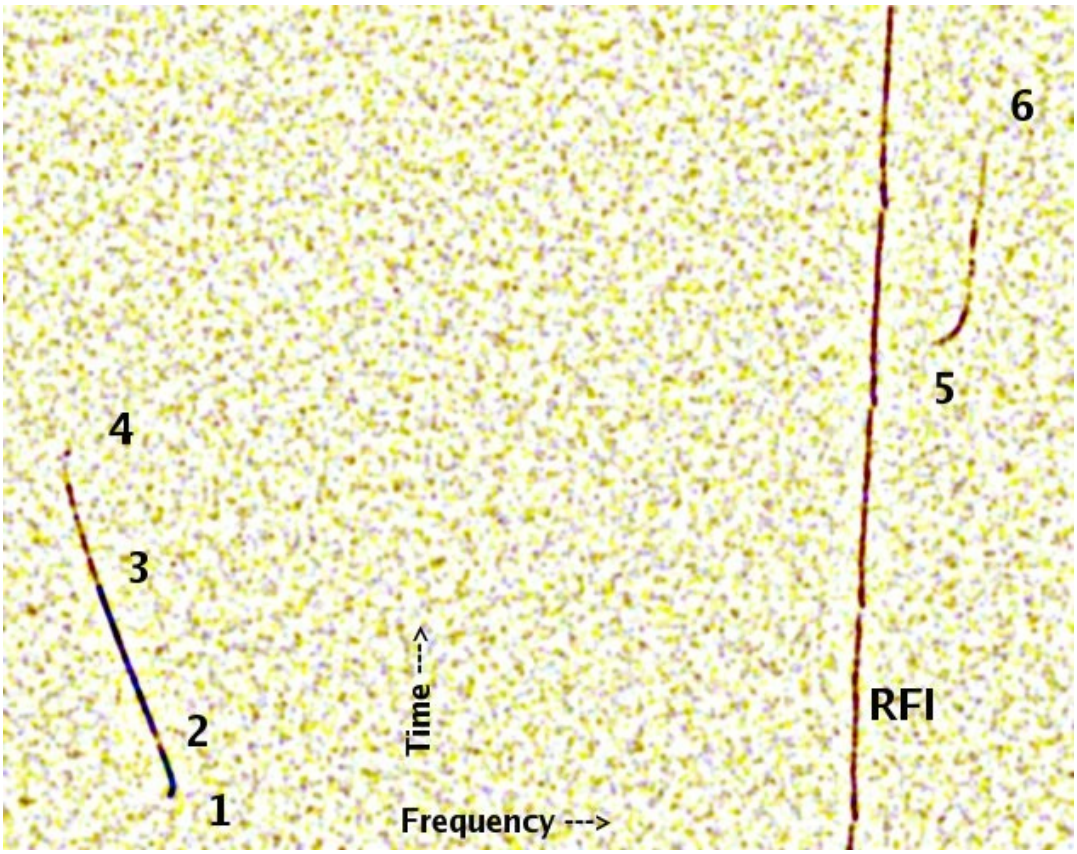


Figure 2: Phoenix signal display.



Captions for Figures 1 and 2.

Figure 1 : NASA Montage of sequence of events of EDL.

Figure 2 : Time runs from the bottom towards the top, and the signal frequency from left to right. Panels in Figure 1 correspond to changes in the signal shown in Figure 2, as follows.

Figure 2, #1: Phoenix separates from the cruise vehicle and turns on its transmitter (left panel in Figure 1).

Figure 2, #2: the signal drops out briefly during the "turn to entry" maneuver. Phoenix turns so that it is oriented correctly for falling through the atmosphere.

Figure 2, #3: we see the carrier strength drop by a factor of 4 as the signal is modulated to transmit engineering data.

Figure 2, #4: The frequency, which had been slowly decreasing due to the Doppler effect of the free fall towards Mars, turns around and increases rapidly as the friction with the atmosphere slows the spacecraft from about 20,000 MPH to 900 MPH.

The fiery braking is illustrated by the second panel in Figure 1.

Figure 2, #5: The diagram does not show the signal from "4" to "5", but it is really there in the original data. At "5" the parachute deploys, slowing Phoenix down further to about 200 MPH (third panel in Figure 1).

Figure 2, #6: The parachute has been jettisoned, and the rockets are firing to bring Phoenix down to a soft landing (4th and 5th panels in Figure 1).

Figure 3: left to right: Peter Ilott, Barry Sharp, Frank Ghigo, Sue Finley, Sami Asmar. (photo courtesy Barry Sharp)