Meteor Burst Remote Monitoring System Deployment at US DOE Hanford Site – 9375

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ABSTRACT

This paper details the efforts associated with the design and installation of a Meteor Burst system at the 200-BP-1 Prototype Barrier located at the U.S. Department of Energy (DOE) Hanford site. The existing monitoring data collection and transmission system at the 200-BP-1 location is cellular phone-based. This system required manual data retrieval and was faced with costly upgrades due to ongoing changes in cellular phone technology. The Meteor Burst system on the other hand offers automated transmission of large amounts of monitoring data with minimal infrastructure and easy real-time access to data by facility personnel via user-friendly web pages.

Under this project, a meteor burst data collection and transmission system was successfully designed and installed. This system collects and transmits data from 4 water balance monitoring stations and 13 time-domain reflectometry probes located atop the 200-BP-1 Prototype Barrier. The field system employs several dataloggers plus meteor burst components and 900-megahertz radios.

In addition to the field design and installation, system programming was performed to successfully interface the components of the field system and to facilitate communication with the Internet server. Lastly, user-friendly web pages were developed to facilitate real-time access to data.

INTRODUCTION

This paper details the actions associated with the design and installation of a meteor burst data collection and transmission system at the U.S. Department of Energy (DOE) Hanford 200-BP-1 Prototype Barrier site. The project, known as Meteor Burst Remote Monitoring System Installation at Hanford, was conducted from May 2007 through September 2008.

The operational life of many remediation systems exceeds the life of the occupied facilities; therefore, environmental monitoring systems that can be accessed from remote locations are going to be necessary in the future. Such systems must incorporate multiple sensors (some state-of-the-art), telemetry systems that allow remote access to the data from the sensors, and data management and display capabilities.

Remote monitoring systems typically rely on earth-based telemetry systems (i.e., point-to-point radios, cellular antennas, phone lines, etc). These systems also often depend on line-of-sight or hardwiring between the transmitter and receiver; consequently, multiple transmitting relaying stations may be required. An alternate approach is the use of satellite telemetry systems, which are commercially available but not widely used.

Meteor burst technology is an alternative to standard, man-made satellite data transmission and has several advantages. The first advantage is that there is a two-way communication between the ground station and the remote site, which greatly reduces the chance of data loss. Secondly, data can consist of short messages (i.e., sensor data), coded messages of up to several hundred characters, text messages of a few words, or long messages transmitted in successive "bursts." The data "burst" feature makes it possible for multiple links to share a common frequency. A third advantage is that the Meteor Burst system does not require equipment to be placed in orbit. Operation costs can therefore be reduced because expensive satellite time rental can be avoided. In addition, the monitoring systems that MSE Technology Applications, Inc. (MSE) designs are typically independent of site infrastructure. Finally, meteor burst data transmission is not susceptible to many natural and man-made atmospheric disturbances (e.g., aurora borealis and fouling due to nuclear explosions), which often render other satellite systems inoperable.

Micrometeors passing through the Earth's upper atmosphere (80- to 120-kilometer (km) region) disintegrate, leaving behind trails of ionized particles. In the 1950s, it was discovered that the ionized trails, which are typically tens of kilometers long, were capable of reflecting radio waves transmitted from the Earth's surface. Radio signals could be reflected over distances of up to 2,000 km (1,200 miles) between a transmitter and receiver (Fig. 1 is provided courtesy of MeteorComm Wireless Communications).

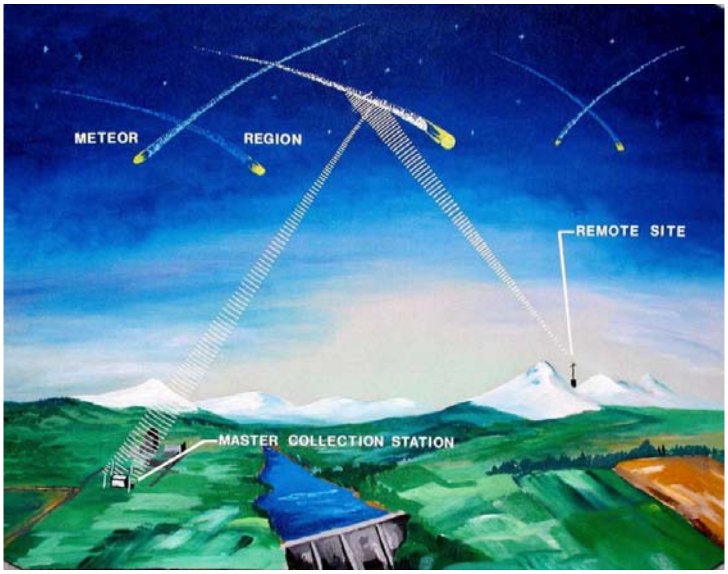

Fig. 1. Meteor burst uses ionized particles in the atmosphere to reflect signals from a field station to a stationary receiver.

To help promote the installation and use of remote monitoring systems at DOE facilities for long-term environmental monitoring, MSE developed a Meteor Burst Remote Monitoring System that provides the DOE with an improved, cost-effective tool to aid in data collection of performance and long-term monitoring information. Without sacrificing data integrity, MSE has developed an expanded system to handle multiple inputs and data sources.

Transmission time can vary since the ionized particles rapidly diffuse into the air, losing the ability to reflect radio waves. Most meteor trails last less than 1 second; however, a large meteor may create an ionized trail capable of reflecting radio waves for up to several minutes.

To take advantage of this technology, MSE has incorporated the meteor burst technology into remote environmental monitoring systems. With the meteor burst technology, data from an assortment of sensors can be stored at the site on a datalogger. The datalogger is then connected to the meteor burst radio, allowing for remote transmission of the data.

INSTALLATION SITE

The project site is located in the 200 East Area of the DOE Hanford site in Washington State. The 200-BP-1 Surface Barrier physically overlies the 216-B-57 Crib. The 216-B-57 Crib received storage condensate waste from the 241-BY Tank Farm between February 1968 and June 1973. An in-tank solidification (ITS) process created waste by heating, collecting, and condensing the evaporants within the 241-BY Tank Farm and discharging the waste underground within the 216-B-57 Crib. Crib construction includes a 12-inch corrugated and perforated steel pipe that runs the length of the 200-foot (ft)-long and 15-ft-wide crib within a gravel infiltration bed. In-tank solidification waste was discharged to the perforated pipe then infiltrated through the gravel and into the natural soils [1]. Potential contaminants of concern within the 216-B-57 Crib include cesium-137, strontium-90, plutonium-238⁄239, technicium-99, radium-226, cobalt-60, and total uranium. Nonradioactive contaminants include cadmium, nickel, and polychlorinated biphenyls (PCB) [1]. The majority of these constituents have low mobility and low concentrations⁄short half-lives and are not expected to significantly impact the aquifer. The contaminants with the highest concentrations are cesium-137 and strontium-90; both of these contaminants are bound or sorbed very strongly to the soil particles. The majority of contaminants are located at a depth of 15 to 30 ft below the ground surface. The depth of groundwater is approximately 230 ft below the ground surface.

The prototype barrier was constructed in 1994 to evaluate surface barrier constructability, construction costs, and physical and hydrologic performance of the barrier at field scale. The purpose of the barrier is to prevent surface water from percolating into the vadose zone and spreading underground contamination [2]. Since 1998, monitoring of the barrier has focused on four primary actions: water balance monitoring; barrier stability monitoring; a vegetation survey; and an animal intrusion survey.

The design and installation of the Meteor Burst system focused on the collection of water balance monitoring data. This focus was to address priorities given by Andy Ward, Ph.D., Senior Research Scientist IV of Pacific Northwest National Laboratory (PNNL) for this project. Parameters associated with the water balance aspects of the barrier that are monitored at the site include soil moisture, precipitation, temperatures of heat dissipation units (HDU), and soil temperatures. To monitor the water balance components in the top, 2-meter layer of the barrier, the surface is fitted with 14 water balance monitoring stations each of which is fitted with a precipitation meter. In addition, the soil moisture is measured at each of the monitoring stations by the use of neutron hydroprobe and time-domain reflectometry (TDR). Under the data retrieval and transmission system that historically existed at the site, data was transmitted to controllers via hardwire methods. From the controllers, the data was sent to a remote receiving station using cellular technology. The data was manually retrieved from the remote receiving station.

PROJECT GOALS

The overall goals associated with the Meteor Burst Remote Monitoring System Installation at Hanford project can be summarized as follows:

- Design an economical and efficient remote monitoring system that relies on meteor burst technology and has the ability to gather large amounts of data, process the data as necessary, and transmit the data over long distances;
- The system must be able to operate from a remote field location without electrical or phone line infrastructure;
- The data must be readily accessible to the user; and
- Install the system at the Hanford 200-BP-1 Prototype Barrier.

FIELD SYSTEM DESIGN

Site monitoring requires extensive data acquisition, processing, and storage. Conventional methods of conducting these activities may be hindered in those areas where site infrastructure (e.g., electrical power lines and telephone lines) does not exist or is removed. To that end, MSE identified meteor burst transmission as a technology to meet the needs associated with site monitoring where minimal infrastructure is required.

Before designing a system to gather, process, and transmit the monitoring data at the 200-BP-1 Prototype Barrier, the existing system needed to be analyzed to determine the types and amounts of interfacing that would be required between the existing and new systems.

During this project, MSE did not provide any new primary sensors for the acquisition of the monitoring data. All design and installation activities connected with the project were associated with modifications to equipment located at a number of data collection sites around the 200-BP-1 barrier. These data collection sites collect, store, and transmit data to receiving entities from which the retrieval of data can be accomplished. The monitoring system associated with the 200-BP-1 barrier includes five data collection sites that are designated as S201, S202, S203, S204, and S205. Each of these sites contains specific pieces of equipment and has a specific function within the monitoring system. S201 is located near the center of the barrier and contains several pieces of equipment, which include a CR10 controller manufactured by Campbell Scientific, Inc. (CSI); a 420-megahertz (MHz) HT50 radio manufactured by Motorola; a RF95 transceiver; and a data transmission system based on cellular phone technology. All the TDR sensors are hardwired to this site via an underground conduit using coaxial cable. At the time of the project, this data collection site was working well. However, the cellular phone technology used in this data collection site required an update because the phone service technology was frequently being changed, forcing costly and inconvenient modifications. Also, one of the cellular towers used to transmit the data was scheduled to be removed during Hanford site-wide renovations, posing yet another costly modification. S202 is located to the north of the barrier near a series of dosing siphons. This site contains a CSI CR10 controller and a data transmission system based on cellular phone technology. S203 is located on the southern third of the barrier. At the time of the project, S203 contained a CSI CR7 controller that was not operable, a 700X control module, a 720 input/output (I/O) module, three 723T analog input cards w/RTD, a 724-pulse counter card, and a 725 excitation card. The HDU array, precipitation meters, and three remote I/O modules are hardwired to this site. Four remote equipment locations are also associated with S203. Each of these facilities contain a CSI 720 I/O module, and a CSI CR7 controller. Remote location #4 is an exception to this as its system malfunctioned and was replaced by a CSI CR10X controller. S204 is located off the barrier to the east on the rip-rap slope section. At the time of the project, S204 contained a CSI CR10 controller. The final data collection site (S205) is located to the northwest of the barrier. S205 contains a CSI CR10 controller and an old chart recorder/datalogger. This site primarily logs rain events and measures surface runoff.

The Meteor Burst system uses a transmitter and a receiver. The master collection system continuously transmits a carrier signal to detect a suitable ionized trail to an active remote site. Once the trail is detected, information is transmitted at high speed to and from the remote station during the life of the trail. Information is stored at each end, creating a two-way communication system.

To incorporate the Meteor Burst system into the existing monitoring system at the 200-BP-1 barrier, a number of modifications to that system had to be designed, which are described below.

The main central data collection location for the Meteor Burst system was designated to be the location of the #3 remote I/O module that is associated with data collection site S203. An instrument enclosure was mounted on a tripod at this location to house the MCC545B meteor burst radio and supporting hardware.

In addition, the existing CSI CR7 controller at remote location #3 was functioning and was incorporated into the design. This CR7 controller receives data from the 14 water balance monitoring stations by means of hard wires. By using the existing CR7 in the design, all the hardwiring remained intact for the top of the barrier. A CSI CR1000 controller and a 900-MHz RF401 radio were added to the #3 remote location. Information is sent to the new CR1000 from the existing CR7 using serial communications with a print streamline command.

Data is received at the #3 remote location from the equipment located at the #4 remote I/O module facility. At the #4 remote location, the existing CSI CR10X controller was replaced with a CSI CR1000. In addition, a 900-MHz RF401 radio was added to this location.

The instrumentation design kept data collection site S201 as the central receiving location for the already hardwired TDR sensors. However, the existing CR10X controller was replaced with a CR1000, and the existing radio was replaced with one that specifically communicates between the new CR1000 controller and the new RF401/CR1000 radio and controller located at the #3 remote location.

All the data received at the new CR1000 located at remote location #3 is stored in tables in the CR1000. All of the data received is brought serially from the CR1000 to the MCC545B meteor burst radio and transmitted over the Meteor Burst system to the Internet web site in a comma-separated format. Hanford then brings this data into its web page, where it can be monitored by facility personnel.

MSE was responsible for purchasing the following equipment for the project:

- three CR1000 controllers;
- three 900-MHz RF401 radios;
- one MCC545B meteor burst radio;
- solar power equipment; and
- supporting equipment including antennas, panels, and mountings.

In addition to the other design efforts, programming was required to develop the interface for the CR7-to-CR1000 communications, all the acquired CR1000s, and the MCC545B radio script.

INSTALLATION

The initial prototype system was tested at the Mike Mansfield Advanced Technology Center in Butte, Montana, in 2007 using a substitute CR7 to mimic the remote location #3 CR7 and the CR1000 that would be installed at remote location #3. After successful testing, the system was installed at Hanford. Fig. 2 shows remote location #3.

First, the equipment was installed at remote location #3. However, after installation, the CR7-to-CR1000 communication at remote location #3 did not perform as expected. After significant troubleshooting, it was found that the control module of the Hanford CR7s PROM chips was different from that of the test CR7 instrument. A new cable was designed to interface between the CR7 and the CR1000, and the communication was successful.

At the S201 location, the CR10X was replaced with a CR1000 and 900-MHz radio. Testing proved the TDR controller/radio communicated with the equipment located at remote location #3. However, the data from the TDR was incomplete. PNNL indicated that the TDRs had been malfunctioning for a short period, and that PNNL personnel would follow up with repair.

Fig. 2. Remote location #3.

At remote location #4, the CR10X was removed and replaced with a CR1000 and 900-MHz radio. The communication between the two locations was restored, and the data was successfully transferred. Fig. 3 shows remote location #4.

Fig. 3. Remote location #4.

WEB PAGE DISPLAY

The data were successfully transmitted over the meteor burst radio and placed on a file transfer protocol (FTP) site in a comma-separated format. MSE designed a web page that brought the data from the FTP site and displayed it in a user-friendly format. The user may view temperature data, HDU data, precipitation data, or TDR data for selected date.

Examples of the temperature windows are shown below (Figs. 4, 5, 6). Each temperature window shows the temperature grid data for one location. By choosing the location at the bottom of the temperature window, this view may be displayed for any one of the 24 locations. In addition, temperature data can be viewed as a table, a graph, or bar chart.

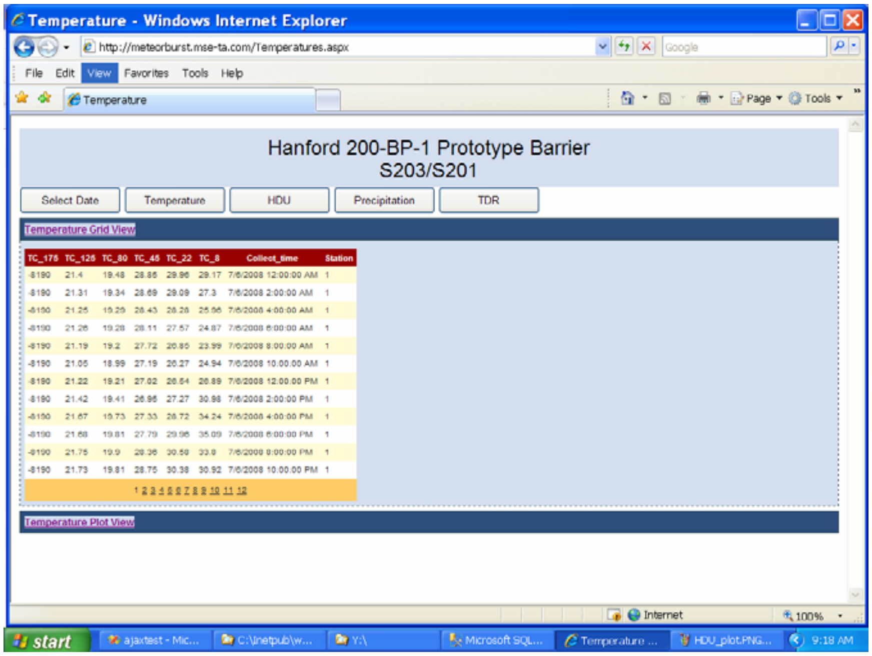

Fig. 4. Temperature data in tabular format.

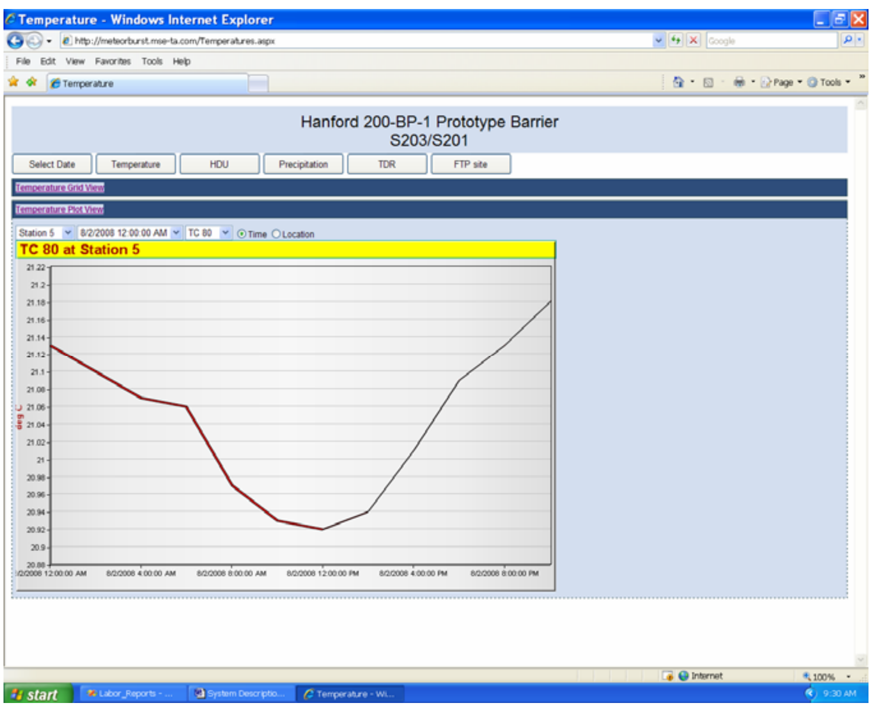

Fig. 5. Temperature data in graphic format.

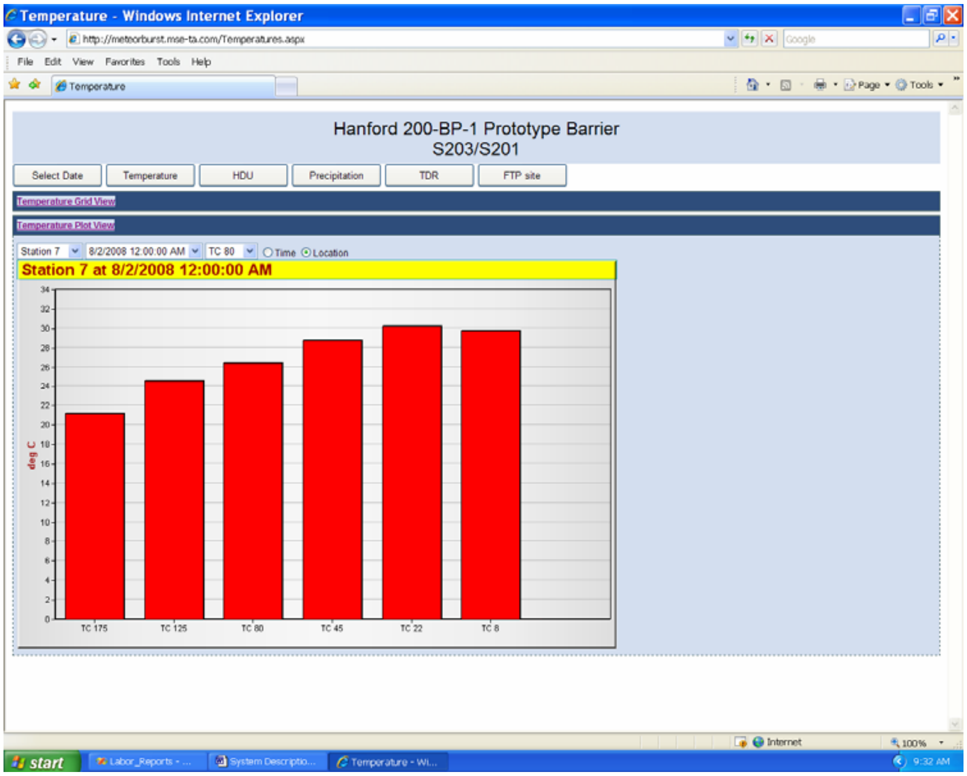

Fig. 6. Temperature data in bar chart format.

CONCLUSIONS AND RECOMMENDATIONS

The design and field installation of the meteor burst equipment at the Hanford 200-BP-1 site was successful. In addition, the data were able to be loaded into user-friendly, Internet-based web pages. This application is an excellent example of using meteor burst technology to transmit large amounts of remote data for viewing on a user-friendly web page.

REFERENCES

1. U.S. DEPARTMENT OF ENERGY, RICHLAND FIELD OFFICE, "Treatability Test Plan for the 200-BP-1 Prototype Surface Barrier" (1993).

2. WARD A., LINK, S., STRICKLAND, C., DRAPER, K., AND CLAYTON R., "200-BP-1 Prototype Hanford Barrier Annual Monitoring Report for Fiscal Years 2005 through 2007" (2007).

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