SNOTEL: AN OPERATIONAL DATA ACQUISITION SYSTEM 632-77

USING METEOR BURST TECHNOLOGY 1/

By

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Introduction

The U.S. Soil Conservation Service is presently developing a data collection, transmission and processing system, designated SNOTEL. The SNOTEL system will eventually collect snow and other hydrometeorological data from some 500 remote data sites, transmit the data to a central computer where it is stored and validated, and provider the data in near-real-time to a variety of cooperating users. The system uses the reflection of very high frequency (VHF) signals by ionized meteor

System Requirements

In general, the architecture of a data collection and transmission system is influenced by five major factors: Types of data to be collected, geographic coverage, system responsiveness, characteristics of the users, and data processing requirements. The SNOTEL requirements are characterized by an advancing state of the art in sensors, coverage of a vast geographical area, system responsiveness requirements which will vary according to circumstances, users with a variety of regional interests and technical backgrounds, and decentralized and nonstandardized data processing facilities.

The types of data collected by SNOTEL will change as the sensor state of the art advances. The sensor technologies, as applied to snow and other hydrometeorological data, are far from stabilized. Therefore, it is a continuing requirement that SNOTEL be responsive to changes in sensor characteristics, and even to changes in the types of physical parameters which are collected. For this reason, the SNOTEL design approach strives to separate sensors from the other system components to the greatest extent possible. Quantitatively, the system must accommodate up to sixteen of any mix of analog and digital sensors. Although it is recognized that some digital sensors will pose special interfacing problems, the modular design will accommodate unforeseen sensor requirements with a minimum of retro-fitting.

The SNOTEL system is required to provide coverage to a large geographical area. It will serve the data collection needs of ten western states. The approximate system coverage is depicted in Figure 1. The data site locations extend from northwestern Washington to western New Mexico, a distance of some 1900 kilometers. The area ultimately covered by SNOTEL is estimated at over 2,000,000 square kilometers. In addition to the large area coverage, the SNOTEL system must also provide flexibility of coverage. That is, the data site locations should not be constrained by communication system considerations, as they might be in the case of land-lines or some other rigid system. The system must accommodate data site population growth without requiring any re-design of the system.

The need for system responsiveness is a factor which weighs heavily in any system design. In the synthesis of data collection systems, response time alone will typically narrow the field to just a few alternative designs, and SNOTEL is no exception. The SNOTEL service requirements include the ability to sample selected sites, on demand, with a response time of about one hour. To complicate matters, the quickest response times are

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essential only for a limited portion of the season, and only for a small and unpredictable subset of the relatively vast total population of some 500 sites. Therefore, a system with a preset periodic sampling rate, which offers the needed responsiveness for the proper sites at the proper times, would necessarily be collecting superfluous data most of the time from most of the sites. Because of this inherent "overkill" associated with a self-timed or periodic system, the SNOTEL requirements clearly dictate some form of interrogation capability.

The SNOTEL system must also provide access to a variety of types of users. Areas of expertise and depth of computer and communication knowledge vary significantly, even within the relatively homogeneous snow survey community of SCS. In cases where the users' technical backgrounds are similar, their forecasting and reporting methods may nevertheless differ. The mere presence of a common-user data collection system does not permit the forcing of standards and procedures upon a group of users with individual requirements. The need for adaptability to user requirements has influenced the SNOTEL design approach, having given rise to a separate user access and control component. This component is the interface between the users and the rest of the system. It can be modified as new users are added, or as experienced users refine their requirements.

Data processing facilities are often not as easily shared among users as the data itself. Each Government, commercial, and educational establishment has its own data processing organization(s) and facilities. As the population of SNOTEL's cooperating users expands, and as their experience with the system grows, the direct linking of SNOTEL with users' computer facilities will become increasingly desirable. This inevitable trend has influenced the SNOTEL architecture. On one hand, the SNOTEL system does not include significant data processing software, other than what is necessary to move, store, validate, and provide access to the data in a reliable fashion. On the other hand, the user access component of the system has been designed to interchange data with computer systems as easily as with people. Therefore, as user population growth adds requirements for direct SNOTEL-to-computer interchange, these requirements can be met with minimum impact on the user access component, and with no impact on the transmission component of the system.

In addition to the five major factors discussed above, the SNOTEL design has been influenced by several other constraints. The remote site equipment is required to operate continuously for up to one year without attention. This specifically implies a power system which is self-sustaining for one year. The entire transmission component is required to operate without human attention, other than periodic maintenance. Also, the system is required to be as immune as possible to single-element failures. The general reliability considerations need to account for the known severity of the environmental conditions associated with snow-related data sites. These and other factors have all influenced the SNOTEL design as it has evolved to date.

System Architecture

As implied in the above discussion, the SNOTEL system is designed around a modular or "building block" approach. The intent of this approach is to isolate, and thereby minimize, the impact of changes in the users' requirements, as well as to afford the users some latitude in their operation of the system.

A study of various users and their data collection and processing requirements resulted in a system architecture of three major components: Sensors, transmission, and user access. The relationships among these components are depicted in Figure 2.

This approach accounts for the fact that the sensor types and characteristics and system access requirements are largely user-oriented and relatively flexible, whereas the data transmission process is virtually transparent to the users and relatively rigid in its design.

Sensor Component

From the standpoint of system design, sensor characteristics are the hardest to plan for. The rapid evolution and relative lack of standardization of sensors have rendered the sensor interface problem a difficult one. The initial phase of SNOTEL includes 160 remote stations with a standard mix of four sensors, all of which have analog outputs.

Figure 1. APPROXIMATE SYSTEM COVERAGE

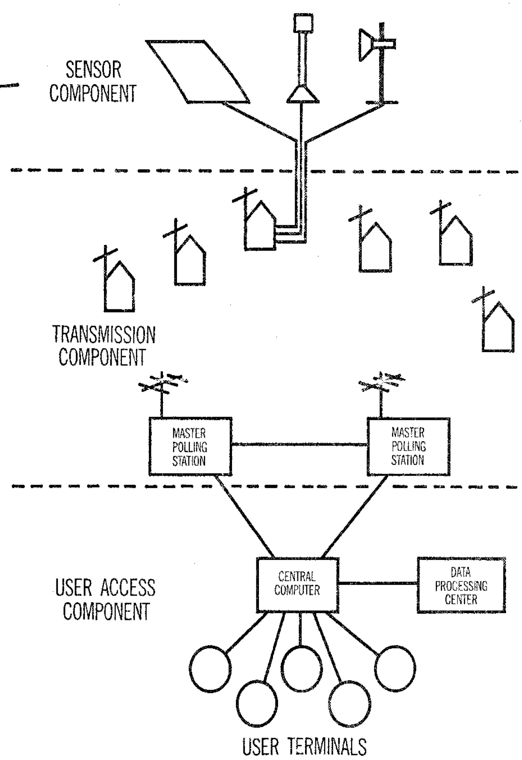

Figure 2. SYSTEM ARCHITECTURE

The four parameters are temperature, snowpack water equivalent, precipitation, and remote station power system battery voltage. This relatively simple standard mix of sensors will facilitate the evaluation of the system in its first season of operation. Later, the system will accommodate additional sensors and sensor types, both analog and digital.

At the SNOTEL remote station, the sensor interface barrier strip is the boundary between the sensor component and the transmission component. Each additional sensor does require the addition of some sensor interface electronics; however, the modular remote station design permits these changes in the field, using vendor-supplied parts and simple modification procedures. Special interfacing problems, typical of some sophisticated digital sensors, will be handled on a case-by-case basis.

Transmission Component

The transmission component is the backbone of the SNOTEL system, and the most costly element within it. The SNOTEL system uses the meteor burst telemetry technique to gather data from the remote stations. This technique is based upon the use of a master polling station, which is capable of emitting a remote station probe in the lower VHF frequency range (in this case, 40.530 MHz). This frequency allows the exploitation of ionized meteor trails, billions of which occur every day in the upper reaches of the earth's atmosphere (80 - 120 km altitude). Such ionized trails reflect or re-radiate the master station probe back to the surface of the earth. These naturally occurring reflective media can establish usable communication paths at distances up to 2000 kilometers.

When a suitable probe is reflected by a meteor trail to a remote station's receiving equipment, the remote station is activated and transmits its data over the reciprocal path. The reciprocity of the path is assured in most instances, because the return frequency (in this case, 41.530 MHz) is selected sufficiently close to the probe frequency.

The occurrence of a meteor trail in the right geometric orientation, and of sufficient duration to allow a particular remote station to read its probe and transmit its data, is a random event. In the worst of natural circumstances, the successful polling of a particular site can be expected to occur several times per hour, assuming the remote station is probed continuously.

The meteor burst telemetry technique has many features which make it uniquely responsive to SNOTEL requirements. The long range paths which it creates will allow coverage of the vast area populated by SNOTEL data sites. Also, the use of meteor trails for reflection creates, for each data site, an unlimited number of potential paths for transmission. This minimizes and in most cases eliminates blockage problems due to terrain obstacles. Meteor burst also affords great flexibility from the standpoint of expanding the data site population. The addition of a site requires only the installation of the remote station equipment and the updating of computer tables in the master polling station. No hardware changes of any kind are required.

Another facet of the meteor burst technique is that it allows complete control over which stations are probed at which times. This control is affected by governing the scheduling and content of the master station probes.

The meteor burst transmission system consists of two master polling stations plus the remote stations. The purpose behind dual master stations is two-fold. First, the overall reliability of the system is enhanced. The system will collect data from all data sites, although significantly less efficiently, during an outage of either master station. The second purpose of two master stations is to provide better-quality paths for communications. In cases where a data site location is disadvantageous relative to one master station, then the other master station, or a combination of both master stations, will yield the desired performance.

The master stations can poll any remote station or group of remote stations on command. In addition, the system will automatically perform system-wide polling once per day in the absence of any other instructions. Each master station can also store up to three days worth of data on-line, a back-up feature which will be used if land-line outages prevent the forwarding of data. The master stations are completely computer-controlled and commanded over leased telephone circuits; they are designed for unattended operation.

The two master stations are located in Boise, Idaho, and Ogden, Utah. The general locations were determined by the transmission subsystem contractor, based on the required area of coverage. Within these general areas, the selection of the specific sites was based primarily on (1) the availability of enough land to accommodate four forty-foot guyed antenna towers, (2) the availability of utility connections, (3) the absence of detrimental electromagnetic noise, and (4) the absence of terrain obstacles higher than three degrees above the horizon. The last consideration, an inherent necessity for a meteor burst system satisfying SNOTEL requirements; can rule out many superficially attractive candidate locations.

The remote stations contain all necessary equipment to detect, interpret and respond to master station probes, plus analog-to-digital conversion, sensor interfacing and data buffering electronics for sampling the sensors.

Each remote station has a unique address for probing purposes, so that the master stations may probe selectively. In that way, interference among remote stations can be minimized.

The remote stations are powered by batteries which are charged by solar panels. The power system is designed to be self-sustaining for at least one year.

The remote station uses a folded dipole antenna oriented for optimum communication with one or both master stations.

User Access Component

The user access component is designed (1) to provide SNOTEL users with access to the system and control over polling, (2) to isolate users from the complexities of radio-frequency data communications, (3) to interface SNOTEL with users' data processing facilities, and (4) to perform routine functions associated with the operation and management of the SNOTEL system.

User access is provided through a real-time computer facility to be located at the Water Supply Forecasting Unit in Portland, Oregon. The computer is a Hewlett-Packard 9640A multiprogramming system operating under the RTE-II real-time executive software. The system includes five million bytes of disc storage and two magnetic tape drives for storing data. It also includes a line printer for printing reports. Two computer terminals are used as control consoles for the computer and for the transmission system. The peripheral equipment also includes an asynchronous multiplexor for interfacing with data communication circuits.

The central computer commands the two master stations and receives data from them over leased telephone circuits operating asynchronously at 1200 bits per second. In addition to initiating probes and receiving data, the central computer uses these circuits for assigning or re-assigning remote stations to one or both master stations for polling responsibility, updating the master station clocks and transferring polling responsibility in the event of master station failure.

The users access SNOTEL by means of remote terminals located in their offices. The initial set of user terminals will consist of one in each of nine SCS Snow Survey Units. Each of these nine terminals includes a keyboard and cathode-ray tube for input and output, as well as a thermal printer for permanent copy.

The user terminals access the SNOTEL system via dial-up telephone circuits operating asynchronously at 1200 bits per second. Once connected to the central computer, the user can log himself onto the system, using identification codes which control access, and issue requests to the computer.

The user may request on-line data in various combinations. In that case, the transmission system is not involved. The user may also request the polling of a site (within his jurisdiction) for new data. In that case, the appropriate master station(s) is commanded by the central computer to probe the site. If the user does not wish to remain on-line while awaiting the response, he may terminate the call, and the requested data will be provided when he again logs on.

The user may also schedule the periodic polling of a site or group of sites, if he does not wish to issue repeated requests, provided he is authorized to poll those sites. In that case, the central computer maintains an internal schedule of all required automatic commanding of the master stations.

The central computer performs certain routine functions associated with the operation of the system. Received sensor data is converted into engineering units, and preliminary validation checks are made on the data. The data is also logged in, formatted and stored in an on-line data base. The central computer can also interchange data with users' data processing systems. Presently, the software is configured to communicate with the UNIVAC 1140 at the Department of Agriculture Computer Center at Fort Collins, Colorado. This link, a dial-up link operating synchronously at 2000 bits per second, will initially be used for archiving data at Fort Collins.

Project Status

Work is presently in progress to establish the 160-remote-station system for initial operational evaluation. The sensors, transducers, equipment shelters, antenna masts and other supporting equipment have been installed at the 160 remote locations.

The central computer software is completed and has been tested. In anticipation of the transmission system acceptance test, an automatic test driver is being developed for the central computer. These efforts are being performed by Systems Consultants, Inc., at their Emeryville facilities, under contract to SCS.

The contract for the transmission system was awarded to Western Union Telegraph Company in May 1976. The master stations have been fabricated and are undergoing installation and checkout. The remote stations are being fabricated, and the first units off the production line are being installed and checked out. After the 160 remote stations are installed, the formal acceptance testing of the transmission system will commence.

System Performance

The overall SNOTEL system performance will obviously depend most heavily upon the performance of the transmission component. The meteor burst system is required to satisfy quantitative performance criteria in two areas: Scheduled system-wide polling, and on-demand polling of selected sites.

The requirement for system-wide polling calls for polling and obtaining data from all remotes within one hour. To allow for the random nature of meteor trails, two percent of the responses can fall outside this one-hour window. For on-demand polling, the requirement calls for receiving the data within one-half hour. To account further for the random nature of meteor trails, the system-wide time limit must be met 95 percent of the time, and the on-demand limit must be met 90 percent of the time.

Preliminary tests conducted by Western Union, using SNOTEL production prototype equipment, indicate that the system will perform better than the performance criteria for SNOTEL, even during February, the worst month for exploiting meteor trails.

Summary

The implementation of the SNOTEL system will bring together several of the recent advances in sensor technology, communications engineering, and data processing, to provide a broad community of users with timely and reliable access to remotely acquired data. The system will also be a demonstration of a new communication technique, data transmission by meteor burst, which has been made possible only by the last few years' developments in digital electronics. Meteor burst will likely be responsive in several other data acquisition applications, especially where near-real-time data access requirements are combined with low data rates, and data is to be collected from isolated sites scattered over a large area.