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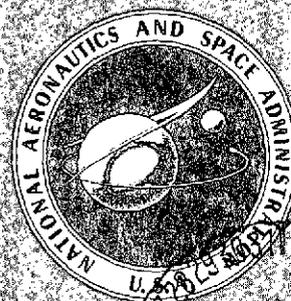
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DATA COLLECTION SYSTEM

Earth Resources Technology Satellite-1

A workshop held at
Wallops Flight Center
Wallops Island, Virginia
May 30-31, 1973



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DATA COLLECTION SYSTEM

Earth Resources Technology

Satellite-1

The proceedings of a workshop held at NASA Wallops
Flight Center, Wallops Island, Virginia, May 30-31, 1973

Edited by

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U.S. Army Corps of Engineers
and
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Prepared at Wallops Flight Center



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PREFACE

The purpose of the Earth Resources Technology Satellite (ERTS-1), launched on 23 July 1972, is to assess its capabilities for better management of our earth's resources by: (1) providing imagery of the earth's surface using remote sensing equipment and (2) providing communications capability for testing the feasibility of a nationwide or global real time data collection system.

Significant results obtained for ERTS-1 were reported at a symposium held on 5-9 March 1973. The data collection portion of the experiment also reported significant findings, but several other satellite programs were underway or planned, and therefore, it was decided to hold a separate workshop to discuss and better understand the pertinent features of each program.

This Workshop was held at NASA Wallops Station, May 30 & 31, 1973. Numerous papers were presented concerning results to date on the overall data collection system including sensors, interface hardware, power supplies, environmental enclosures, data transmission, processing and distribution, maintenance and integration in resources management systems. Other technical presentations were given for other satellite systems that can or will be used for data collection including GOES, NIMBUS, DAP and TRANSIT systems.

The technical papers established the usefulness of satellite data collection systems and emphasized the need for an operational system. During the Workshop Dr. Vincent Salomonson summarized the technical presentations. He was followed by presentations of policy by government agency heads working with data collection for their individual needs. The final summary address was given by Dr. Paul Bock who set forth five overall recommendations for consideration. These recommendations won the overwhelming approval of those present and are listed at the end of these proceedings; however, they do not necessarily reflect the official position of the agencies represented at the Workshop.

I am satisfied that this Workshop has achieved the goals it set forth; namely the exchange of ideas and possible elimination of duplication.

We may not have generated all the answers, but we now have:

1. A better understanding of the overall ERTS, DCS program.
2. An insight on various types of DCS experiments being carried out under this program.
3. Based on results to date, an enthusiastic feeling from the investigators that space relayed data is a major way of the future.

In addition, this Workshop has made it possible to establish better lines of communication between investigators and potential users.

The Chairman wishes to acknowledge the assistance of Mr. Krieger, Director of Wallops Station, and his staff for their participation and hospitality which greatly enhanced the Workshop. Earle Painter, NASA, and Richard Paulson, USGS, helped greatly in organizing the agenda and speakers for the Workshop. Special thanks to Vincent Salomonson, NASA and Paul Bock, University of Connecticut for their excellent summary addresses; to the authors whose well prepared technical papers provided the attendees with the latest

results of satellite relayed data systems, and to Mathews of NASA, DeNoyer of Department of Interior, Kutsandreas, Environmental Protection Agency, Flanders of NOAA and Jarman of the Corps of Engineers for their presentations on their respective agency policies on data collection. The Chairman also wishes to thank those whose special efforts helped make this publication possible.

SAUL COOPER
New England Division
Corps of Engineers
Workshop Chairman

CONTENTS

Welcoming Remarks - Robert L. Krieger, Director 1
NASA Wallops Station

Introductory Comments - Saul Cooper (Chairman) 3
Chief, Water Control Branch
U.S. Army Corps of Engineers
New England Division

TECHNICAL PRESENTATIONS

The Use of Earth Resources Technology Satellite for Relaying Hydrologic Data in the Delaware River Basin
Richard W. Paulson 5 ✓

Data Retransmission from Water Survey of Canada Gauging Station Using the ERTS Data Collection System
Robert A. Halliday 17 ✓

Mobile Data Buoy System
Rex A. Morton 21 ✓

Monitoring the Changing Hydrologic Regime of the Florida Everglades Through ERTS-1 DCS
Edward H. Cordes 29 ~~29~~

Performance of ERTS-1 DCS in a Prototype Volcano Surveillance System
Peter Ward 31 ✓

Use of ERTS-1 DCS in the Management and Control of Water Resources Systems
Joseph W. Finegan 45 ✓

ERTS-1 DCS Technical Support Provided by Wallops Station
Roger R. Smith 53 ✓

USDI DCS TECHNICAL SUPPORT
Duane M. Preble 57 ✓

Auxiliary DCP Data Acquisition System
Robert V. Snyder 65 ✓

DCS Tracking System
Robert Kee 71 ~~71~~

Space Data Relay Systems
Charles E. Cote 73 ✓

Operational Satellite Data Relay Systems
Jack H. Puerner 81 ~~81~~

ERTS-1 Data Collection System - Status and Performance
J. Earle Painter 83 ✓

A Summary of ERTS-1 Data Collection System Applications
Vincent V. Salomonson 97 ✓

AGENCY PRESENTATIONS

USDI Requirements and Programs
John M. DeNoyer 101 ✓

U. S. Army Corps of Engineers Requirements and Programs
John Jarman 105 ✓

NOAA Requirements and Programs
Allen F. Flanders 107 ✓

EPA Data Collection Programs and Requirements
John D. Koutsandreas 115 ✓

NASA Requirements and Programs
Charles W. Mathews 121 ✓

Summary Address
Paul Bock 123

Recommendations
Paul Bock 125

Appendix - List of Attendees 127

WELCOMING REMARKS

Robert L. Krieger, Director
NASA Wallops Station

We at Wallops are primarily concerned with operating a launch range; managing about a third of the national sounding rocket programs; running a research airport; and a deep involvement in applications projects.

Wallops is very interested in the applications area of remote sensing. Initially, we were more interested in doing remote sensing from aircraft rather than satellite partly because the satellite was not yet operational, and partly because satellite operations did not fall within Wallops' primary mission. Several years ago, we did have a conference here on remote sensing problems in the Chesapeake Bay area; and we also have an SR& T Program to do things in the Chesapeake Bay area.

We became interested in the DCS aspects of ERTS which, for some of the people we work with, is actually more useful than the imagery. So we did propose an experiment for ERTS. We did want to support other experimenters working in the Chesapeake Bay area both with aircraft flights and DCS efforts. This effort expanded to trying to support all who were working with DCS to the limits of our capabilities.

We have established a repair depot where we can refurbish and repair DCS's. We would like eventually to establish a DCS "lending library" here. We would like to accumulate a few DCS's so that when someone wants to measure something, we can loan them a suitable system. We would like to give field support to far more people than we are doing at the moment. (We have been in the DCS business for a year or so now.) Many of the people we are working with are beginning to use DCS at a pretty good pace and, of course, ERTS contributes much as far as NASA is concerned.

Many of the people we have been talking to are thinking of installing fairly substantial systems and need to know what is going to be the follow-up to ERTS. What is the operational system that we can look forward to?

Most of all, since we do have a very intensive but small effort in the DCS area, it is a real pleasure to welcome you to Wallops. I hope this will be a very productive meeting.

INTRODUCTORY COMMENTS

Saul Cooper
U.S. Army Corps of Engineers

I would like to give you some background as to how the ERTS-1 Workshop came to be. You will recall the ERTS Symposium in March 1973 when several hundred papers were presented on significant results obtained from ERTS-1. Most of these papers covered various aspects of the imagery portion of the study but not too much time was devoted to the Data Collection System. I talked to people from NASA responsible for the data collection portion of ERTS and others with large DCS experiments, and it was the consensus that a DCS meeting would be worthwhile to exchange ideas and possibly eliminate duplications of effort. Mr. Robert Krieger, Director at Wallops Station, offered his facilities for this meeting.

Just how did we get to where we are today in the field of data collection systems technology? Back in 1966, NASA contracted a study on the probable usefulness of satellites for practical earth-oriented applications with the National Academy of Sciences. Thirteen panels were organized to cover the various disciplines. I would like to summarize some of the objectives which were reported by several of these panels in 1969.

Four hydrologic objectives amenable to current space technology (1969) are:

1. Basic studies of the hydrologic cycle and large scale hydrological systems.
2. Snow and ice mapping.
3. Surveys of coastal hydrologic features and large inland lakes.
4. Real-time communications of ground-based hydrologic data.

Another objective was: Space technology applied to hydrology should be evaluated in the interest of the users taking into consideration the following:

1. The transfer of data from ground stations or sensors to users.
2. The impact of economic, social and political factors on water resource development and the need for hydrologic data.
3. The administrative structures to coordinate and integrate all space programs regarding these types of applications.
4. NASA and other appropriate agencies should develop a capability for acquiring data in an operational mode on or before 1975.

In the compilation of papers prepared for the thirteenth meeting (1972) of the panel on sciences and technology for the U. S. House of Representatives, several articles were concerned with space relayed data. The near term goals of ERTS included:

1. Collection of data from remote, fixed stations having river gauges, fathometers and other instruments.

2. Advance ground computerization techniques enabling the data to be quickly processed, interpreted and applied.
3. For improved water resources management systems, the development of low-cost, ground-based, remote sensing platforms. These will provide corollary data on water or snow depth, flow rates, sedimentation and pollutant concentrations which will, when integrated with spacecraft data, provide information for modeling, planning and predicting. Interrogation of these platforms by spacecraft will simplify the correlation of ground-based and orbital data.
4. Spaceborne and ground-based remote sensing, communications, computational and data dissemination elements must be integrated for improved real time operation of water resource management systems, if we are to realize the full benefits of space observations.

We are now approaching the end of the first year of the successful launch of ERTS-1. Although final reports are not completed and some even have yet another year to go, many significant results concerning DCS are available and will be discussed at this Workshop. Some may suggest that we are ready for an operational system now. If this is so, then it is up to us to suggest the best possible approach to achieve this goal. At the Workshop are representatives of several agencies committed to data collection who will present their policies on this subject. Any suggestions or recommendations arising out of the Workshop should be in concert with these policies.

We have attempted to provide a well rounded agenda. Papers and discussions cover overall system performance and include:

1. Data collection platform sensors
2. Interfacing hardware
3. Power supplies
4. Environmental enclosures
5. Data transmission, processing, and distribution
6. Maintenance
7. Integration in resources management systems

THE USE OF EARTH RESOURCES TECHNOLOGY SATELLITE FOR RELAYING
HYDROLOGIC DATA IN THE DELAWARE RIVER BASIN ^{1, 2}

Richard W. Paulson

U.S. Geological Survey

The U.S. Geological Survey, in cooperation with the National Aeronautics and Space Administration (NASA), the Earth Resources Observation Systems Office of the Department of the Interior, and the Delaware River Basin Commission, is conducting an experiment to test the feasibility of relaying hydrologic data operationally from water-resources stations in the Delaware River basin, using the Earth Resources Technology Satellite. The twenty stations in the basin, which include stream-gaging stations, water-quality monitors, and observation wells, are instrumented with small battery-operated radio transmitters called Data Collection Platforms (DCP). The DCP's transmit data to the satellite several times a day when the satellite's polar-orbital-track passes near the eastern part of the United States. Upon reception of a DCP message, the satellite immediately transmits the data to a NASA receiving site at Goldstone, California, or the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. The data are routed to the Geological Survey's Current Record Center in Pennsylvania, through the GSFC, for processing and distribution to user agencies. The experiment will help to define whether the satellite relay of earth-resources data is a viable alternative to conventional landline telemetry.

Introduction

In July 1972, NASA launched the Earth Resources Technology Satellite (ERTS-1), the first satellite dedicated to testing systems of earth resources data acquisition. The satellite is being used by several hundred American and foreign investigators to test improved methods for remotely monitoring earth resources from space. This paper is a report on research being conducted by the U.S. Geological Survey on the water resources in the Delaware River basin. The research is being conducted by the U.S. Geological Survey in cooperation with NASA, the Earth Resources Observation Systems (EROS) Program of the Department of the Interior, and the Delaware River Basin Commission (DRBC).

The ERTS Observatory

The ERTS observatory, shown in Figure 1, weighs approximately 900 kgs (2,000 pounds) and orbits the earth at an altitude of about 900 km (500 nautical miles). The satellite carries three systems that are being tested by investigators for experimental earth-resources monitoring. Two of the systems, the Return Beam Vidicon (RBV) and the Multi-spectral Scanner (MSS), provide repetitive imagery, in several spectral bands, of the earth's surface. The third system, the Data Collection System (DCS), relays telemetered data from ground-based radios called Data Collection Platforms (DCP), to NASA ground-communication sites.

The observatory revolves about the earth in a polar orbit 14 times daily. This orbit periodically carries the vehicle from the vicinity of the north pole down over the daylight side of the earth, crossing the equator at an angle of 99° , to the vicinity of the south pole, then up over the dark side of the earth to the north polar region. The relationship of the ERTS-orbital plane to the centers of the earth and the sun remains

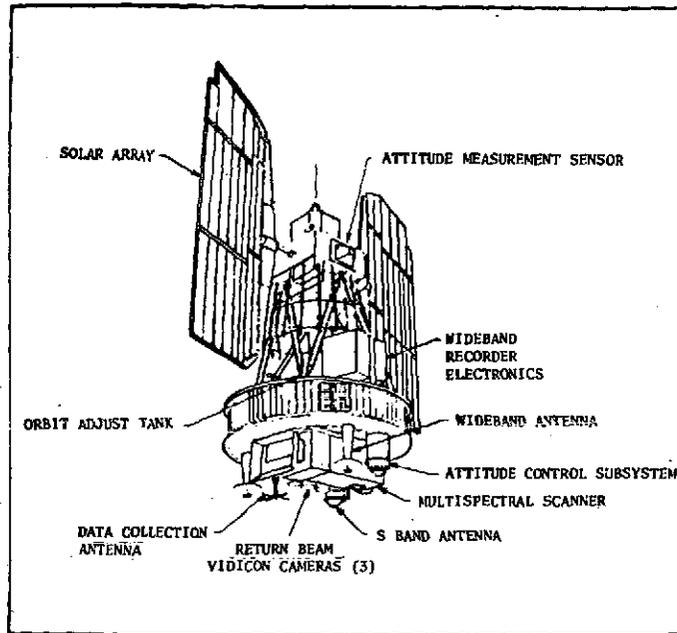


Figure 1. Earth resources technology satellite

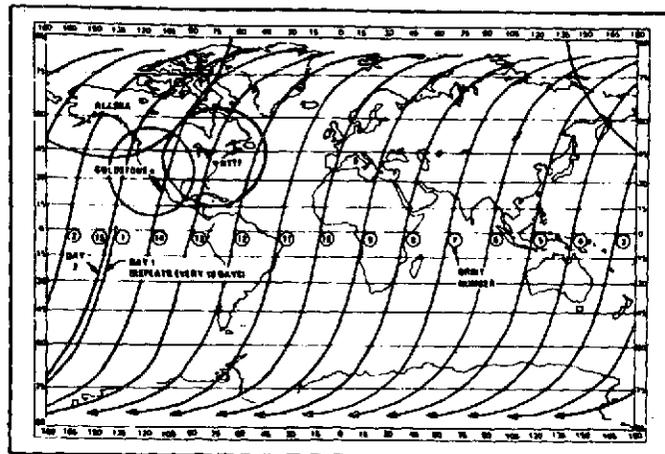


Figure 2. Daylight orbital transits of ERTS observatory for typical day

constant while the earth rotates beneath the observatory. When ERTS makes a north-to-south transit of the daylight side of the earth, the observatory crosses the equator at about 9:40 a.m. local time. When the next daylight transit is made, about 103 minutes later, the earth has rotated beneath the orbital plane of the observatory and the equator is crossed again at a point about 2900 km (1,900 miles) to the west of the previous equatorial crossing point. The 14 daylight orbital tracks over the daylight side of the earth are shown schematically in Figure 2.

The imaging systems are configured to allow the satellite, on any given day, to image a 185 km (100 nautical mile)-wide swath of the earth on each of the 14 daylight passes. The 14 daily imaging swaths are spaced about 2900 km (1,900 miles) apart at the equator, and become less with increasing latitude. Imaging swaths on a subsequent day are displaced to the west, and slightly overlap the swaths of the previous day. The overlap is about 14 percent at the equator and increases with latitude. During 18 consecutive days the swaths completely cover the earth, with the exception of extreme polar areas, and allow almost any location of the earth to be imaged, barring obscuration by clouds. On the 19th day the imaging cycle begins again.

There are two important differences between the frequency at which data are gathered from the earth's surface by the imaging systems, the RBV and the MSS, and the frequency of data gathering by the DCS. The first difference is that the imaging systems gather information on a 185 km (100-nautical-mile)-wide swath, while the DCS can receive data from a swath that is in excess of 4,000 km (2,500 statute miles) wide. Since the orbital tracks are only about 2900 km (1,900 miles) apart at the equator, the DCS frequently gathers data from DCP's on two, and occasionally three, successive orbits, thus covering a time span of up to almost five hours. Figure 3 is a sketch of two ERTS orbital tracks over North America and the instantaneous fields of view of the imaging and DCS. Characteristically, in the latitudes of the United States, these data-relay transits occur between 8:00 a.m. and 12 noon local time. The second difference between the imaging systems and the DCS is that, while both systems can provide data from the daylight side of the earth, the DCS can also provide data from the dark side of the earth. Since every north-to-south daylight imaging pass must be matched by a subsequent south-to-north pass of the earth's dark side, there is an additional semidiurnal opportunity to collect DCP telemetered data. This opportunity characteristically occurs on two or three orbits between 8:00 p.m. and 12 midnight. The net result is that the imaging systems can image a scene on the earth's surface, simultaneously in four spectral bands, once every 18 days, and the DCS can receive point-collected data nominally from two orbits between 8:00 a.m. and 12 noon and two orbits between 8:00 p.m. and 12 midnight local time.

All of the ERTS systems have provided data that contain useful information for remotely monitoring the earth's surface from space. The imaging systems are being found to have a great potential for monitoring a wide range of phenomena in the earth sciences. This potential is being reported on by others in this session.

The research described in this paper is oriented primarily to testing the DCS as a means of gathering water-resources data from widely scattered remote locations in a river basin and to reducing data turnaround time.

Data Collection System

The DCS consists of field operating DCP, relay equipment on the ERTS observatory, NASA ground communication sites, and the NASA ground data handling system. The DCP and ground data handling system are the most visible elements of the system to the user.

The DCP is a small, battery-operated radio that broadcasts 64 bits of earth resources data and station identification. In the Delaware River basin experiment, stream stage, ground-water stage, or water-quality data are encoded in the 64 bit data message.

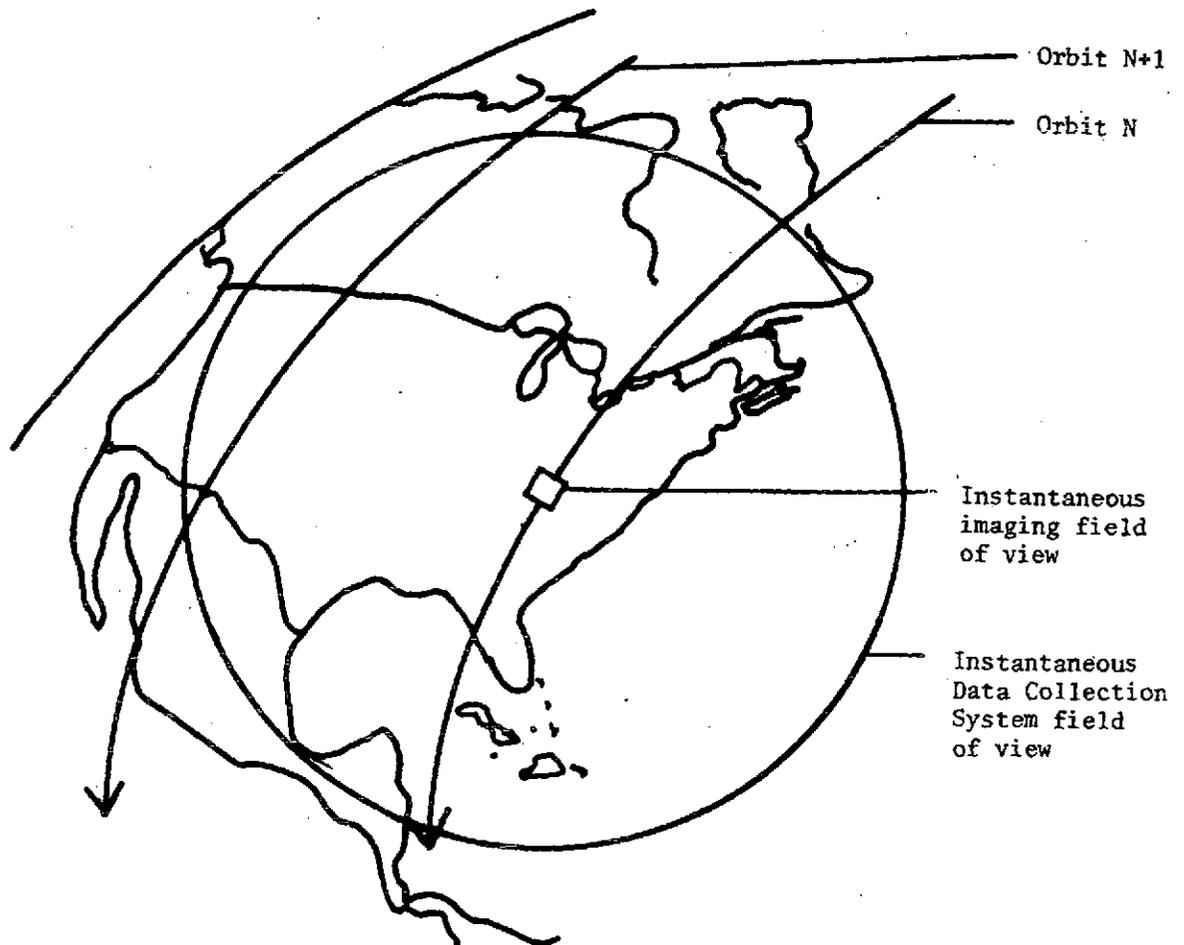


Figure 3. Sketch of two orbital transits over North America showing instantaneous fields of view of imaging and data collection system

The DCP is designed to communicate earth-resources data with ERTS during relatively short periods of radio transmission, known colloquially as data bursts, spaced at three-minute intervals. The DCP uses a crossed dipole antenna, which includes a 117 cm (46 inch) diameter aluminum ground plane. A drawing of a DCP and antenna is shown in Figure 4.

The antenna radiates the data burst almost uniformly throughout a 140° inverted cone of space directly above the ground plane. During an ERTS transit, the DCP can be within radio range--that is, the observatory lies within the inverted cone--in excess of 10 minutes, and thus there can be several opportunities for the data to be received by the observatory. There is a 170° inverted cone of space above each NASA ground communication site, within which the observatory also must be able to communicate with the site. Data bursts can be successfully relayed whenever both a DCP and one of the NASA ground communication sites at the Goddard Space Flight Center, Greenbelt, Maryland, or Goldstone, California are mutually visible from the satellite. This is shown schematically in Figure 5.

It is highly improbable, but possible, for two DCP's operating at the same frequency, and both within the ERTS visibility cone, to emit data bursts at the exact same time. If this were to occur, the DCS radio receiver on ERTS would be unable to distinguish the messages and would reject both. This would prevent data from either DCP being relayed. By design, the data burst timers on the DCP's have a small differential time range in their operating characteristics. Some timers cause data to be transmitted slightly more frequently than once every 180 seconds, others slightly less frequently. Since there is a slight variation in the timers from DCP to DCP, the probability of a second interference, approximately 180 seconds later, is vanishingly small.

Additionally, individual DCP's broadcast at frequencies within a 10 kHz band centered about the frequency of 401.55 MHz. The spacecraft receiver can discriminate between simultaneously transmitted messages from different DCP's if there is a frequency difference of 20 kHz between the transmissions. Because of the range in the timers and the range in the radio frequencies of the DCP's, the ERTS-DCS system design assures about a 95 percent probability that at least one successful data relay is made from any one (or every) DCP every 12 hours. This specification is being exceeded by the DCP's actually operating.

Thus, simply stated in review, DCP's transmit data once every three minutes around the clock. Four or five times a day the ERTS observatory passes within radio range of the DCP, and relays the data to NASA ground communications sites if they also are in radio view.

After the data are acquired by NASA, time of message reception is added to each message, and the data are telemetered by NASA communication systems to the NASA Ground Data Handling System at the Goddard Space Flight Center. ERTS-DCS users receive their data by landline teletype within a few minutes after reception or either on punch cards or magnetic tape by mail within a few days of the relay of the data. The former mode of data transmission is discussed in some detail below.

Delaware River Basin Research

The Data Collection System is being tested by several ERTS experimentors in a wide range of earth resources applications that includes hydrology, geology, forestry and agriculture. This paper describes one of several hydrology experimental tests of the DCS that is being conducted by the U.S. Geological Survey.

Twenty DCP's are being installed and interfaced with water-resources stations in the Delaware River basin. The location of the stations are shown in Figure 6. These stations, which include stream-gaging stations, ground-water observation wells and water-quality

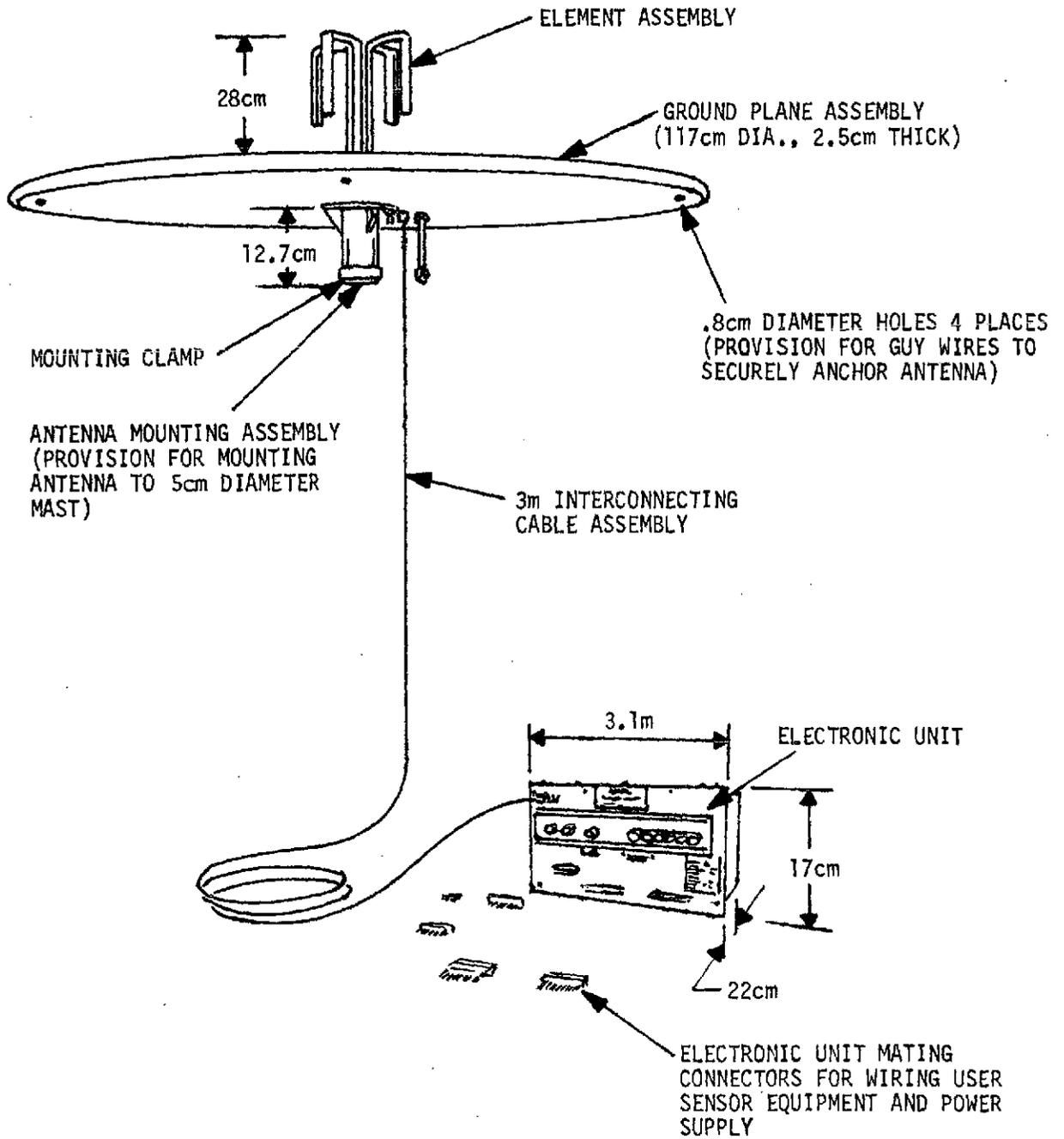


Figure 4. Data collection platform and antenna

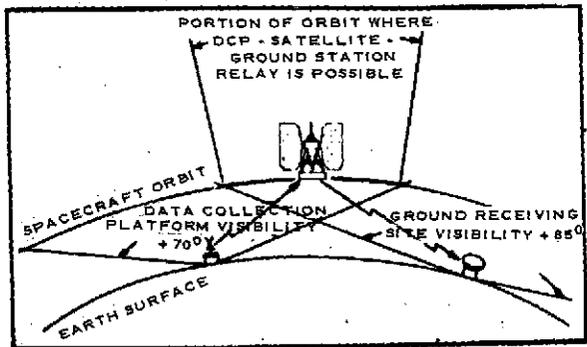


Figure 5. Geometry of Mutual Visibility of a data collection platform and a ground communication site from ERTS

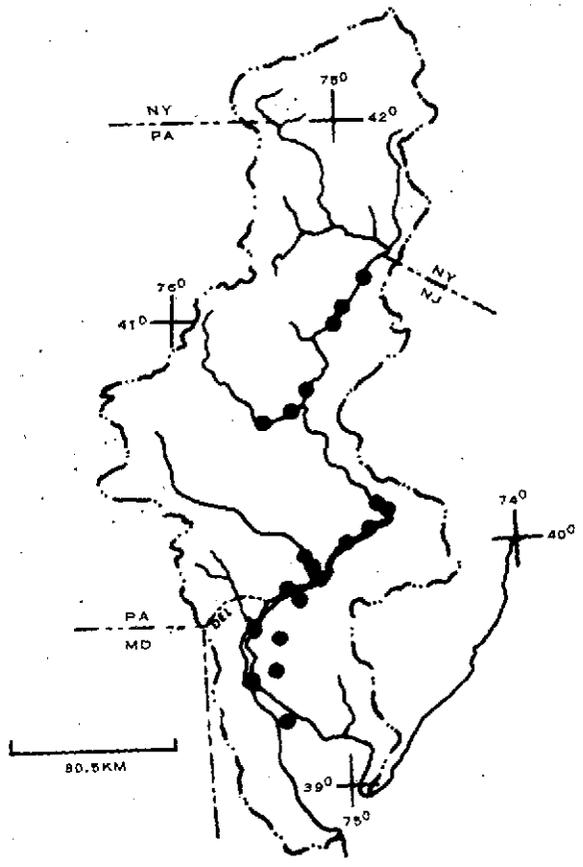


Figure 6. Location of ERTS DCP's in the Delaware River Basin

monitors, are a subset of a larger number of field instruments operated by the Geological Survey in the almost 3400 Sq. km (13,000 square mile) basin. These instruments are operated in cooperation with several local, state and other federal agencies. The ERTS experiment is being conducted by the Pennsylvania District of the Survey in cooperation with the Delaware River Basin Commission. Members of the staff of the DRBC guided the selection of the twenty stations being instrumented for the experiment. The DRBC was created by the Delaware River Basin Compact, whose signatory parties are the United States of America and the States of New York, New Jersey, Pennsylvania and Delaware and is responsible for the management and conservation of water resources in the basin.

One of the prime objectives of the Delaware River Basin data relay experiment is to determine whether standard operational U.S. Geological Survey water-resources instrumentation can be interfaced successfully with the Data Collection System, and the data made to flow operationally to data users. The Delaware River Basin experiment is a test of the compatibility of ERTS-DCS with Geological Survey computer facilities as well as with field instrumentation. There has been a great deal of progress in meeting that objective. The DCP's have been successfully interfaced with ground-water observation wells and stream-gauging stations and, with somewhat more difficulty, water-quality monitors. There has also been good success in processing the data and providing it to user agencies, such as the DRBC, in near real time.

The processing scheme being used for the Delaware River Basin DCS data is intended to simulate an operational system within the constraints of an experimental test. Daily processing of Delaware River Basin ERTS-DCS data is being done from the Pennsylvania District office in Harrisburg, Pennsylvania, using remote terminal access to the Geological Survey's computer in Washington, D.C.

The Delaware River Basin experiment is one of a few ERTS-DCS experiments that receive their data over teletype in near-real time from the Goddard Space Flight Center. A typical message received after an ERTS data-relay pass lists all of the data transmissions received from Delaware River Basin DCP's sorted by DCP identification number. This message is normally received within 30 minutes of the end of a data-relay pass.

The daily processing routine for these data normally begins around midday when data from the previous 24-hour period are entered into the computer. Since ERTS makes two or three relay transits between 8:00 A.M. and 12:00 m., the data entered into the processing system may be collected as recently as an hour or two before the processing begins. Some of the data may be as old as 24 hours. The turnaround time for the processing is nominally within the range of 10 minutes to two hours.

The processed data are partitioned into two sets. The first set is used by Survey data processing and field maintenance personnel to monitor the performance of the DCP's and the field instruments. The data are formatted to provide ease of surveying the status of the instrumentation. The second set of data is formatted into a daily water-resources summary, which is returned from the computer on a low speed ASR-33 teletypewriter terminal. The summary provides, on a station basis, a synopsis of the data received in a format suitable for water-resources management decisions.

Figure 7 is an example of a daily summary of water resources in the Delaware River Basin, prepared by computer from ERTS-DCS data. The summary normally is released on a daily basis to water-resources agencies in the basin.

The DCS can provide data at least twice daily throughout the ERTS 18-day cycle and can provide ground truth for image interpretation during imaging passes. The ERTS-MSS image in Figure 8, taken in the 0.8 to 1.1-micron region of the spectrum, contains good definition between land and water. Philadelphia and the Delaware River estuary are well defined in the lower center of the image. The DCS provided, in near-real time, the status of streamflow from five key locations in the basin at the same time the image was taken

EROS-NASA
USGS DELAWARE RIVER BASIN DATA COLLECTION SYSTEM EXPERIMENT
WATER RESOURCES SUMMARY
MARCH 16, 1973

Water Quality Stations

<u>Time</u>	<u>S.C.</u> <u>UMMS</u>	<u>D.O.</u> <u>MG/L</u>	<u>Temp.</u> <u>F/C</u>	<u>PH</u>
<u>Delaware River at Reedy Island</u>				
13:01:00EST, March 15, 1973	4800	9.5	46/ 8.0	6.9
19:30:37EST, March 15, 1973	4960	9.4	46/ 8.0	6.9
21:10:53EST, March 15, 1973	6800	9.9	45/ 7.0	6.9
22:53:49EST, March 15, 1973	8400	10.2	45/ 7.0	7.0
22:59:51EST, March 15, 1973	5640	9.6	46/ 8.0	7.0
9:41:50EST, March 16, 1973	8080	10.0	46/ 8.0	7.0
<u>Delaware River at Chester</u>				
19:32:33EST, March 15, 1973	332	5.2	55/13.0	6.5
19:38:50EST, March 15, 1973	332	5.1	55/13.0	6.5
21:10:18EST, March 15, 1973	336	5.0	54/12.0	6.5
22:54:48EST, March 15, 1973	336	5.0	54/12.0	6.5
9:39:38EST, March 16, 1973	556	4.8	54/12.0	6.5
<u>Delaware River At Pier 11, Phila.</u>				
21:13:12EST, March 15, 1973	205	12.6	47/ 8.5	6.9
9:42:31EST, March 16, 1973	199	13.1	43/ 6.0	6.9
<u>Delaware River At Bristol</u>				
19:33:00EST, March 15, 1973	164	10.4	48/ 9.0	7.0
21: 8:44EST, March 15, 1973	165	10.5	48/ 9.0	7.2
9:41:40EST, March 16, 1973	165	10.4	48/ 9.0	7.0

Surface Water Stations

<u>Time</u>	<u>Gauge Height</u> <u>Meters</u>	<u>Discharge</u> <u>CFS</u>
<u>Delaware River At Montague</u>		
19:32:04EST, March 15, 1973	2.37	9030
21:10:17EST, March 15, 1973	2.37	9100
21:17:03EST, March 15, 1973	2.37	9130
22:51:49EST, March 15, 1973	2.40	9420
9:42:11EST, March 16, 1973	2.41	9480
9:48:58EST, March 16, 1973	2.41	9510
<u>Delaware River At Trenton</u>		
21:12:14EST, March 15, 1973	3.17	14500
9:44:00EST, March 16, 1973	3.16	14200
<u>Lehigh River At Bethlehem</u>		
21:15:12EST, March 15, 1973	1.08	1960
9:43:11EST, March 16, 1973	1.12	2140
<u>Schuylkill River At Phila.</u>		
19:32:11EST, March 15, 1973	1.94	2270
21:10:10EST, March 15, 1973	1.94	2310
22:54:37EST, March 15, 1973	1.94	2310
9:42:00EST, March 16, 1973	1.95	2450

Ground Water Stations

<u>Time</u>	<u>Well Depth</u> <u>Meters</u>
<u>Salem City Number 1</u>	
19:31:49EST, March 15, 1973	7.12
21:11:10EST, March 15, 1973	7.12
22:54:04EST, March 15, 1973	7.11
23: 0:08EST, March 15, 1973	7.11
9:43:47EST, March 16, 1973	7.12
<u>Penns Grove Number 24</u>	
13: 1:28EST, March 15, 1973	5.92
19:33:25EST, March 15, 1973	5.92
21:14:29EST, March 15, 1973	5.92
21:17:39EST, March 15, 1973	5.93
22:52:54EST, March 15, 1973	5.94
9:39:03EST, March 16, 1973	
<u>Shell Chem. Co. Number 5</u>	
19:32:16EST, March 15, 1973	11.16
21: 8:55EST, March 15, 1973	11.11
22:56:19EST, March 15, 1973	11.04
9:41:17EST, March 16, 1973	11.00

EROS-NASA
USGS SUSQUEHANNA RIVER BASIN DATA COLLECTION SYSTEM EXPERIMENT
WATER RESOURCES SUMMARY
MARCH 16, 1973

<u>Time</u>	<u>Surface Water Stations</u> <u>Gauge Height</u> <u>Meters</u>	<u>Discharge</u> <u>CFS</u>
<u>Juniata River At Newport, PA.</u>		
19:31:20EST, March 15, 1973	1.64	5860
21:10:05EST, March 15, 1973	1.64	5860
22:55:01EST, March 15, 1973	1.63	5830
9:42:15EST, March 16, 1973	1.65	5980
<u>W. Br. Susquehanna At Lewisburg, PA</u>		
19:31:22EST, March 15, 1973	2.01	19700
21: 9:58EST, March 15, 1973	2.13	21700
22:54:53EST, March 15, 1973	2.16	22300
9:42:08EST, March 16, 1973	2.59	30300

These data were relayed by the ERTS observatory and are provisional. The symbols -- indicate data were suspect and were deleted. This summary was prepared by the Special Projects Section in Harrisburg using remote terminal access to the Geological Surveys 360/65 computer in Washington, DC. Call 717-782-3420 for further information.

End of Summary

Figure 7
DAILY WATER-RESOURCES SUMMARY OF CONDITIONS
IN DELAWARE RIVER BASIN COMPILED FROM ERTS DATA COLLECTION PLATFORM DATA

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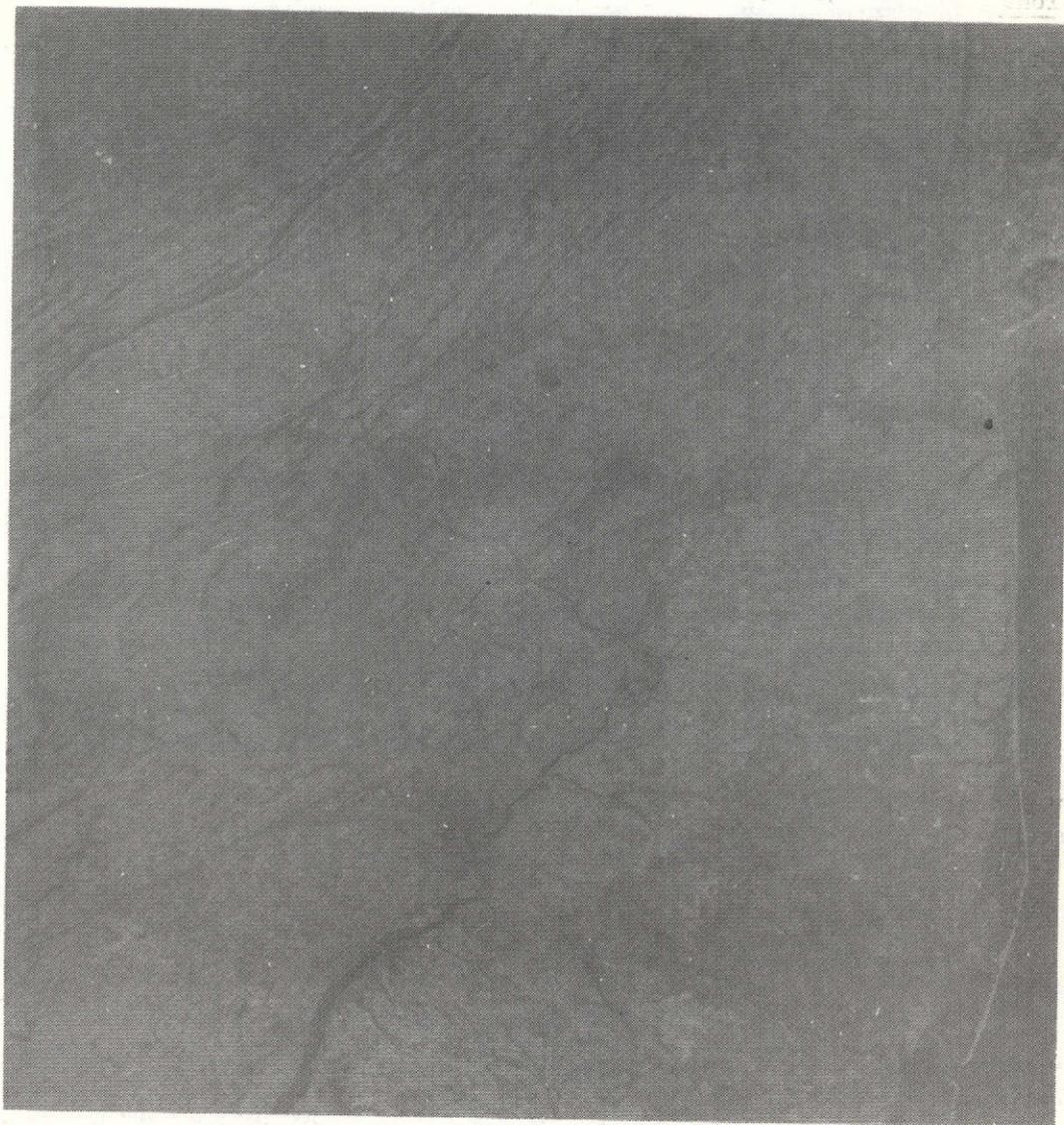


Figure 8. An ERTS-MSS image of much of New Jersey and Eastern Pennsylvania, including most of the Delaware River Basin.

(30 seconds after 10:10 a.m., January 26, 1973). At approximately the same time, the stream gauge heights shown in Table 1 were picked up by the ERTS DCS. These data, plus ground-water levels in major aquifers and water-quality data from several major streams, provide information on the broad-scale hydrologic conditions in a large part of the image.

Conclusions

The earth resources data acquisition systems on ERTS are providing data from the earth's surface that have great potential for resources management. The Data Collection System is providing water-resources data several times a day from widely scattered locations in the Delaware River Basin. Within the constraints of an experimental test, the data are being processed and released to water-resources agencies in near-real time.

The results of the ERTS investigation described in this paper and the results of other ERTS investigations have shown that there is a potential application for satellite borne systems for earth resources data acquisition. It is becoming clear that the solutions to many of our natural resource problems can be found faster and more efficiently with the help of data acquisition systems such as those on the ERTS observatory.

Under operational conditions, low cost battery-operated DCP's could provide the Geological Survey with data from a large number of field instruments. These data could be used by the Geological Survey to monitor the operational status of field instrumentation and could be used by cooperating agencies to monitor a wide range of earth-resources conditions. Under operational conditions, the data flow could be in real time. The delay from time of data acquisition by ERTS to the time of data availability to data users could be reduced to seconds, rather than the present lag time of a few hours.

Acknowledgements

The Delaware River Basin ERTS-data relay project described in this report is sponsored by NASA, and the EROS Program, and is being conducted in cooperation with the staff of the DRBC. The author acknowledges the excellent cooperation provided by these agencies. In particular, the excellent cooperation provided by J. Earle Painter and members of the ERTS NASA Data Processing Facility at the Goddard Space Flight Center is acknowledged. Illustrations 1, 2 and 5 in this report were extracted from NASA Document No. 71SD4249, ERTS Data Users Handbook.

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1. Publication authorized by the Director, U. S. Geological Survey.
 2. The Journal of the American Waterworks Association has kindly given the author a release from copyright to include this paper in these proceedings.

TABLE 1. ERTS-DCS STREAMFLOW DATA COLLECTED AT ABOUT THE SAME TIME THE IMAGE IN FIGURE 8 WAS TAKEN BY ERTS

	Time of Transmission on Jan. 26, 1973 HOUR:MINUTE:SECOND	Gauge height, in Meters	Streamflow, in CMS
Delaware River at Montague, N.J.	10:14:58	2.30	237.3
Delaware River at Tocks Island, N.J.	10:15:10	2.27	254.3
Lehigh River at Bethlehem, Pa.	10:14:28	1.25	78.7
Delaware River at Trenton, N.J.	10:14:18	3.29	484.3
Schuylkill River at Philadelphia, Pa.	10:15:20	2.02	102.5

DATA RETRANSMISSION FROM WATER SURVEY OF CANADA
GAUGING STATIONS USING THE ERTS DATA COLLECTION SYSTEM

Robert A. Halliday

Department of the Environment, Ottawa, Canada

The Water Survey of Canada is an organization engaged in collecting hydrometric and other related data in Canada. Water level data are obtained at 2400 sites and at about 2000 of these sites, the data are used in conjunction with river discharge measurements to produce daily streamflow records. Suspended sediment data are collected at 150 of these sites and water quality sampling is conducted at 300 sites. In addition, the Water Survey operates 140 tide gauging stations along Canada's coastlines and in the Great Lakes - St. Lawrence River system.

There is a steadily increasing demand by data users for near real time data from Water Survey gauging stations. The data are used for reservoir operation and flow or flood forecasting. In addition, if near real time data were available, the data could be used by Water Survey personnel to monitor the performance of the sensors installed at a gauging station. This would result in decreased loss of record and would enable personnel to time their visits to the site to coincide with the most appropriate water levels.

If water levels were obtainable once or twice daily, this would be adequate for all of the uses mentioned above with the exception of flood forecasting. In that case, it would be desirable to receive hourly data during critical streamflow conditions.

In partial fulfillment of these requirements, about 70 Telemarks are installed at gauging stations. These permit the station to be interrogated by telephone. Also radio telemetering systems are installed at two gauging stations. At other locations, arrangements are made with local residents to read a gauge, then telephone or mail the reading to a Water Survey office. In other cases, gauging stations are hundreds of miles from populated areas and are visited only four or five times a year. Costs of obtaining real time data from these sites by conventional means would be prohibitive.

It was felt therefore, that there was a real need to investigate the possibilities of the data collection system carried by ERTS-1. Nine sites were selected for installation of Data Collection Platforms (DCPs) with the objective of obtaining one near real time water level reading a day from each site. Also the dependability, costs and other aspects of the system could be studied and decisions made with respect to the feasibility of operating a much larger network of DCPs.

DCPs have been installed at nine sites in western and northern Canada. These are shown in Figure 1. In addition, a tenth DCP, operating by Dr. J. Kruus, another Canadian principal investigator, was installed at a Water Survey gauging station in Ottawa. This DCP has been used for testing of sensors and the Ottawa antenna was used for checking the performance of the other DCPs prior to shipping to the field location.

Three different power supplies have been used with the DCPs. These are, two No. 564 Eveready re-chargeable alkaline batteries, two heavy duty lead-acid car batteries and two lead-acid snowmobile batteries. No problems have been encountered with the power supplies.

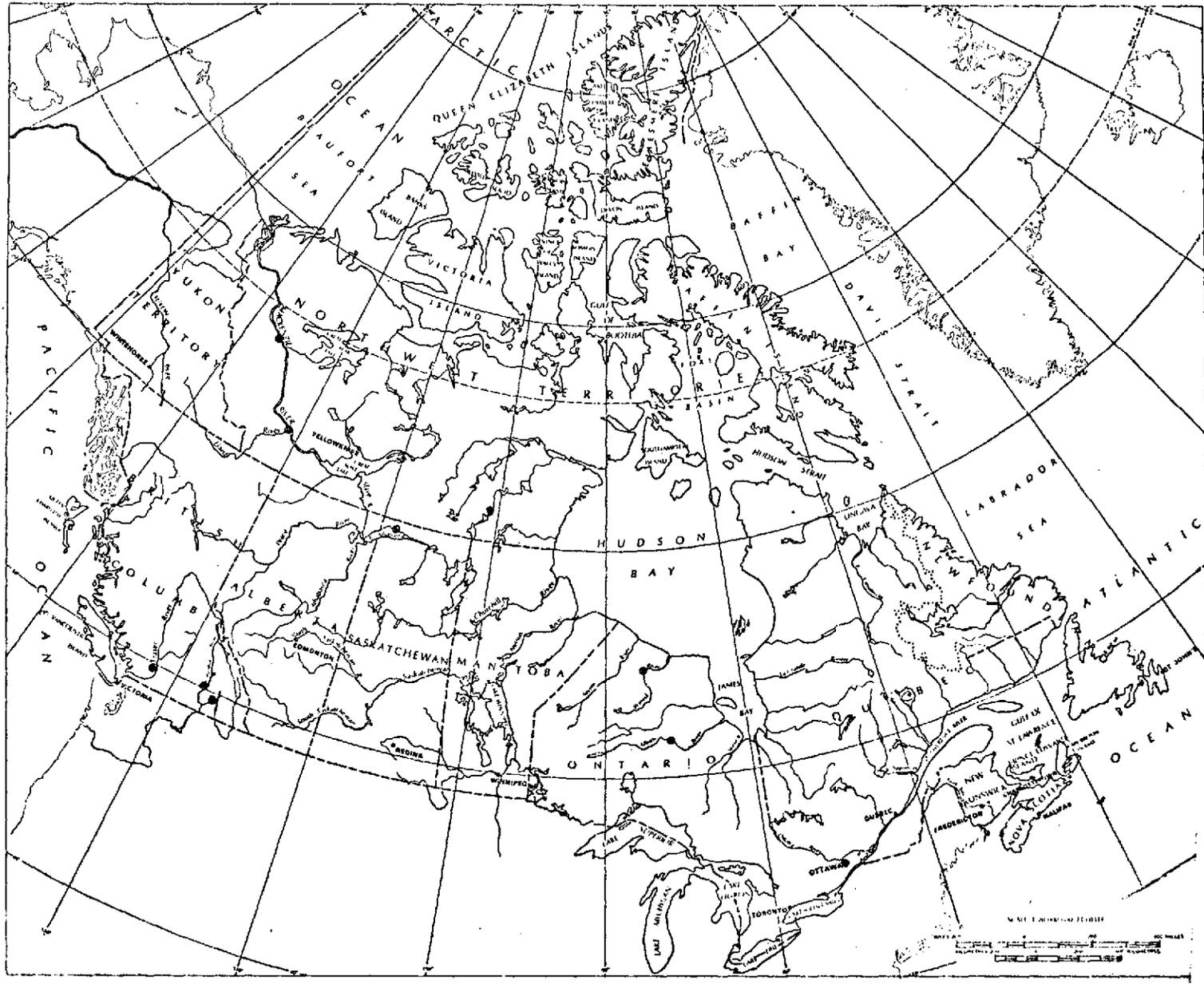


Figure 1. Data Collection Platforms at Water Survey of Canada Stations

Most of the DCPs are installed in regions where severe winter temperatures in the order of -50°C can occur. Some of the DCPs were heated to protect them from these temperatures. The method of heating consisted of constructing an insulated compartment of plywood and styrofoam around the instrumentation. This enclosure was heated using a catalytic propane heater having a 630 kJ (600 Btu) orifice. One 45.36 kg (100 lb.) tank of propane is sufficient to last three to four months.

All of the DCPs are transmitting water level data in words one and two. Water level is sensed by either a float or a water stage servo-manometer which senses head above an orifice fixed in the stream bed. The water level is recorded on a Leupold & Stevens Type A-71 analogue recorder and is also encoded in BCD format by a Leupold & Stevens Memomark II which updates every 15 minutes. No interface is needed between the Memomark II and the DCP.

The only other data now being transmitted is that from an ice-out indicator. If the time of river ice break-up were known, this would enable field crews to fly into a site on float equipped aircraft and obtain a discharge measurement soon after break-up. One method of indicating break-up consists of imbedding a 4-1/2 volt battery in the river ice and connecting the wires from the battery to an analogue input on the DCP. When the ice goes out, the wires break, thus dropping the voltage level to zero.

Another indicator was made up using the same idea except that one bit in a parallel digital word was used. In this case, a friction type plug was fixed at the shoreline and one side of the plug shorted so that when the ice surface was intact, the input was zero. When the ice moved out, a line attached to one side of the plug pulled it apart, thus causing the DCP to transmit a one.

Since the DCPs have considerable excess capacity, it was decided to investigate the possibility of transmitting additional parameters. Those under active consideration include precipitation, river velocity, ice thickness, temperatures, battery voltage check and recorder operation.

Two Fisher-Porter parallel digital interfaces of the type designed by Mr. D. Preble of the Gulf Coast Hydrosience Center have been purchased for interfacing with the Fisher-Porter precipitation gauge used in Canada. Installation of these is expected shortly.

An electromagnetic velocity sensor having a voltage output of zero to five volts corresponding linearly to a velocity of zero to 3m (10 ft.) per second has been purchased for installation in one stream. Data from the meter will be used to assist in computing streamflow under backwater conditions.

The water stage servomanometer can be used to sense ice thickness, however to transmit this information, an additional Memomark II is needed to store the data. Data would be used in streamflow computations and possibly as an indication of when ice thickness may be sufficient to permit landing of aircraft on a river.

Air temperature is a useful parameter when determining melt rates for flood forecasting. Thermocouple temperature probes having an analogue output will be installed at some of the DCP sites. Another probe could be used to transmit water temperature or temperature inside a heated instrument compartment.

A battery voltage sensor has been developed by Dr. Kruus, which can be used to check the power supply to the DCP. The sensor is turned on by the data gate at the time of transmission so that the sensor does not draw much power. The output occupies one analogue channel.

In order to check on the operation of the chart drive mechanism of the A-71 water stage recorder, it has been proposed that a cam and a switch in the chart drive be installed that would cause one of the parallel digital bits to alternate from a one to a zero as long as the mechanism continued to operate.

At present, data is received at the Canada Centre for Remote Sensing (CCRS) in Ottawa by teletype on a real time basis from the nine Water Survey of Canada DCPs and five other DCPs operated by other Canadian investigators. The data are then stored in the CCRS computer where they are translated into engineering units. Any user in Canada can interrogate this computer by teletype to obtain data. Normally, the user experiences a two-to twelve-hour lag time in receiving data in this way; however, during critical streamflow periods, the data can be received on virtually a real time basis if CCRS is notified in advance.

The number of transmissions received each day from the gauging stations varies from a maximum of 26 to 12 and a minimum of 10 to 3, depending on the location. The locations in the mountainous parts of western Canada that are well treed produced noticeably fewer transmissions. Quality checks of data have indicated that the data are good.

None of the nine DCPs have failed once they have been successfully activated. One DCP did not transmit when it was tested in Ottawa prior to installation in the field and was returned to the factory at Daytona Beach for repairs. All other apparent failures have been attributed to either sensor or encoder malfunctions. At present, one DCP is transmitting incorrect parallel digital data, but the site will not be accessible until June.

An ice out indicator that was installed in a DCP on the Mackenzie River did transmit information indicating that the ice had gone out on May 10, 1973. It was later determined that the ice moved out on May 13, 1973, although a shore lead opened up on the tenth. The River is about 3.2 km (two miles) wide at the point where the sensor was installed. The experiment was considered a success since it was apparent that the sensor operated as intended but that its location was not representative of the entire River. The ice on the other rivers where these indicators have been installed has not moved out yet.

The experience with the ERTS data collection system up to now has been excellent. The DCP appears to be a rugged, reliable piece of equipment. The ones installed at Water Survey sites have withstood temperatures less than -40°C and the antennas have withstood wind speeds of over 80 kph (50 mph) and snow loads of 0.6m (2 ft).

The concept of satellite retransmission of data from remote areas has been amply demonstrated. It has been shown that it is possible to obtain data at least twice daily from anywhere in Canada (with the possible exception of some of the arctic islands) on a near real time basis at reasonable cost. A need does exist for more frequent data from some sites for flood forecasting. This need could be met by a geostationary satellite or by several polar orbiting satellites having an ERTS data collection system.

MOBILE DATA BUOY SYSTEM

Rex A. Morton

NASA Marshall Space Flight Center

The Mobile Data Buoy System was conceived to serve the users requirement for obtaining water quality parameters from two separate watershed systems. In view of the cost constraints of the ERTS program it was obvious that the network of 10 sampling stations required could not be of the fixed installation type; therefore, it was decided to go to a system of battery powered buoys of a size that could be used in one watershed system for a period of time and then moved to another by use of a relatively small 6.7 m (22 foot) boat.

The basic idea of the water quality measurement program was to establish the water quality pattern of change from the headwaters of the watersheds to and through the Mobile Bay. This would allow the investigator to develop a good picture of the state's major water resources and the pressures from pollution that are being imposed.

As the Mobile Bay is a salt-water body and subjected to a more severe weather environment, a buoy design, different from that of the fresh-water rivers, was dictated. The fresh-water buoy (Figure 1) is a two piece container, approximately 76 cm (30 inches) diameter and 46 cm (18 inches) high with a 1.1m (3 1/2 foot) extension tube, all fabricated from 1 cm (3/16 inch) stainless steel, and has a separation plane of the V-band and flange type. The dome shape for the upper portion of the container is not required for pressure but is a means of helping deflect bullets fired by vandals. The cylindrical portion of the container is far enough below the surface that there is no danger from bullets.

The buoy is stationed on site by driving a 4.9 cm (2 inches) diameter pipe piling and attaching a 1 cm (3/8 inch) cable between clamps as shown at "E" in Figure 1. Since the pipe is in sections put together with standard pipe couplings, a piece of plastic water pipe is installed over the total length to prevent the slide guide "D" from hanging up on the couplings as the water level changes.

To accommodate various types of stream beds, hard or soft, the pipe piling is in sections of 3.1, 1.5, and 0.75 meters to permit a final installation with an antenna height above normal water of approximately 3.1 m (10 feet). Additionally, if the stream bed is hard and the piling can be driven only 1/2 to 1 meter deep, plans were included for stabilizing anchor pilings and cable to be installed in the 120° sectors around the main piling. Installation and servicing is planned around a currently available boat, a 6.7 m (22 feet) Thunderbird hull with outboard engines. A 454 kg. (1,000 lbs) capability crane was installed in the boat as shown in Figure 1. As the crane is not tall enough to lift the entire buoy assembly over the boat gunnel, the Sonde tube is removable with a quick release pin. This feature of disconnecting the tube also allows the buoy to be set in place on a work stand in the boat at a reasonable work height for servicing the interior components of the system.

Figure 1, view D, also shows two quick release pins for attaching and detaching the buoy for installation and subsequent servicing.

The complete buoy with support tube, Sonde and interior components weighs approximately

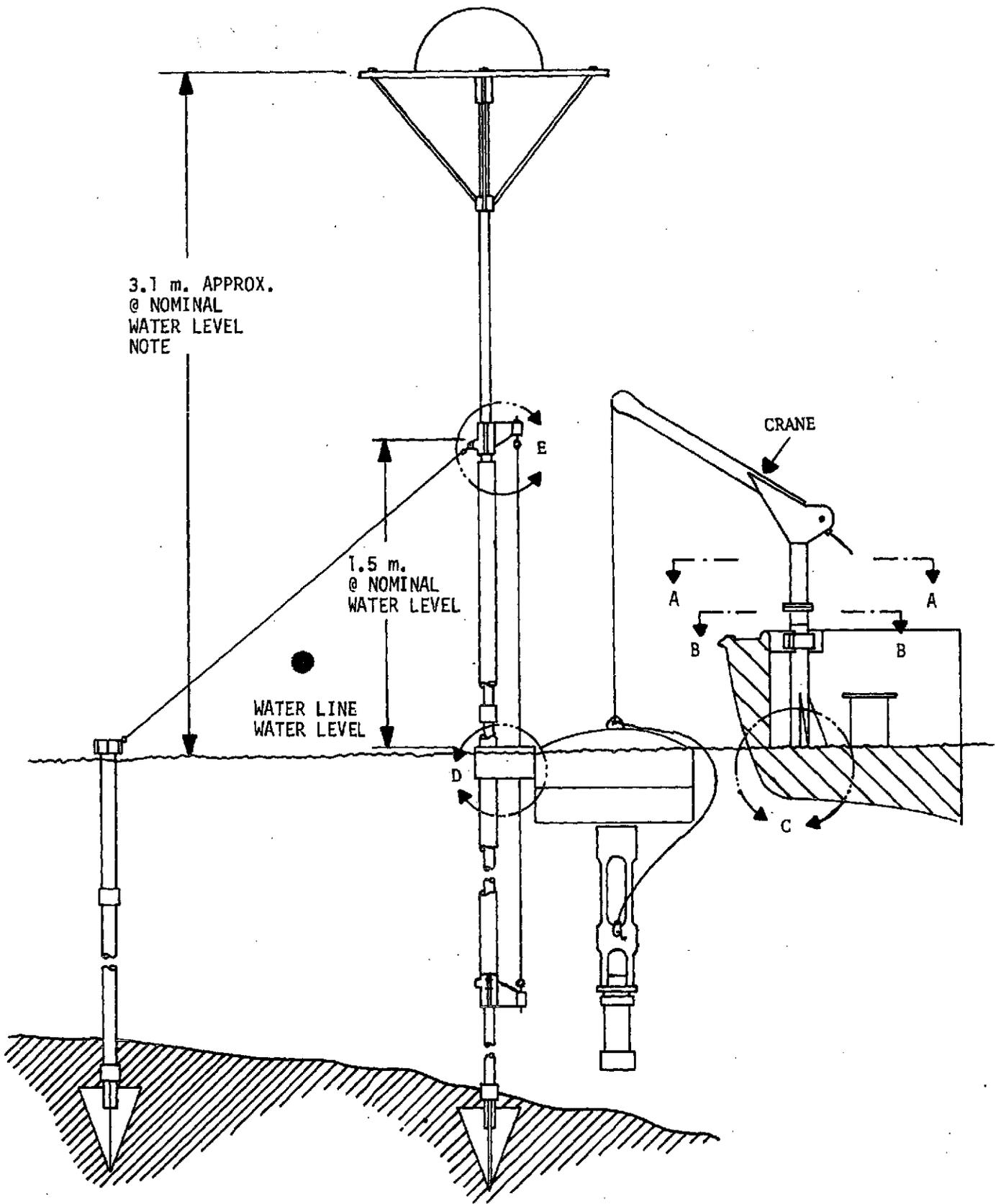


Figure 1. Earth resources buoy water application

170 kg (380 lbs) and, excluding the interior components and antenna, costs approximately \$1500 each for materials and requires 560 manhours each for fabrication.

The operational components of the buoy system, shown in Figure 2, consist of the data collection platform and antenna system provided by the ERTS program and a commercial water quality analyzer with sensors for temperature, dissolved oxygen, Ph and specific conductivity, manufactured by HYDROLAB of Austin Texas, a programmable timer fabricated in-house, and surplus ni-cad batteries for power. The programmable timer is a unique feature incorporated for the purpose of conserving battery power when the satellite is not in view. The timer was designed so that a plug-in programmer could be connected to the timer and set the timer internally for any turn-on delay from five minutes 30 seconds up to 17 hours after the reset switch is thrown. Once the timer turns on after the delay period, it then cycles the buoy sensing and transmitting systems on for three hours and off for nine hours. This allows ample time for warm up and stabilization of the sensor system prior to the earliest time of a pass and remains on long enough to cover the latest time of a pass. This timing cycle allows approximately 27 days of operation between battery changes.

The sensor system consists of a surface unit that contains the read-out meter, power and electronics to drive and read-out the sensors that are mounted on the Sonde unit. The Sonde unit contains a pre-amplifier for the sensors, the sensors probes and a circulator motor.

The sensor input to the read-out meter as normally manufactured was a 0.5 volt signal. The vendor was required to modify the surface unit internally to give a 0 - 5. volt output signal which could be input directly to the DCP analog connector without an interfacing electronics system. The tests that we have conducted show the end to end system accuracy to be within one hundredth of a volt, this is, from the sensor end immersed in a known solution to the octal number read-out at the GSFC control center. In addition to the four water quality parameters, battery voltage is read out on two spare DCP channels in order to monitor battery conditions.

Maintenance and logistics factors are largely unknown at this time but present plans provide for changing the dissolved oxygen sensor membranes and electrolyte every seven days and batteries every 27 days. If vandals do not prove to be too much of a problem, little trouble is expected with the five fresh-water buoys as they are in somewhat protected waters.

As stated earlier, measurement requirements for the salt-water buoys for Mobile Bay were different and a much different environmental immunity was required.

Where the fresh-water buoys data read-out period of once every 12 hours is adequate to provide the necessary data, the bay data requirements were for a read-out at least once each hour in order to track the tidal movement effects, circulation pattern changes and other factors that have a period of less than 12 hours. The salt-water buoy shown in Figure 3 is the result of altering the core fresh-water unit to meet the bay environmental requirements. The center containment vessel is the same as the fresh-water unit except it has "ears" welded on to attach to the stabilizing flotation ring and legs to mount the antenna directly to the buoy dome. This buoy is designed to survive 3m (10 foot) waves. It is to be noted that the Sonde is to make measurements at approximately the 3cm (one foot) depth as opposed to the 1.5m (5 foot) depth of the fresh-water unit. This is to try to establish a correlation between ERTS-1 imagery and the in situ measurements of circulation patterns.

Measurements to be made with the Bay Unit are temperature, dissolved oxygen, Ph, water velocity and direction. As the Bay requirements were to read-out at least hourly, it was necessary to put together a ground station system that would accept the 38 millisecond data transmissions recording it for later read-out into a computer for data reduction.

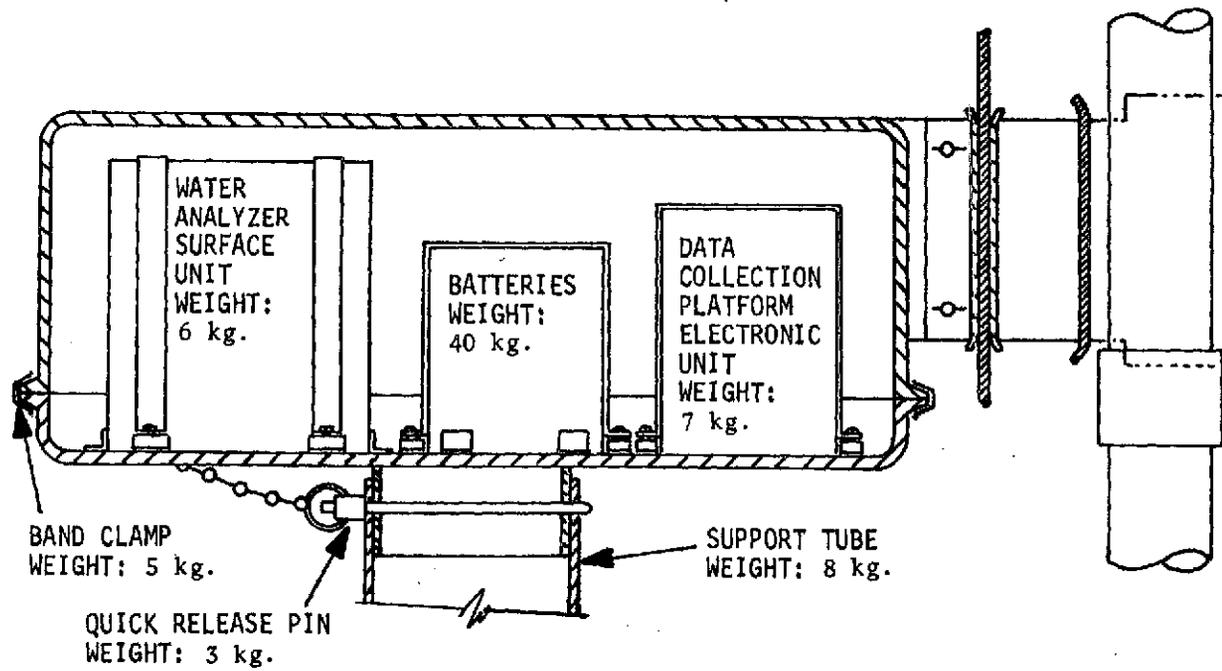


Figure 2. Buoy cross section

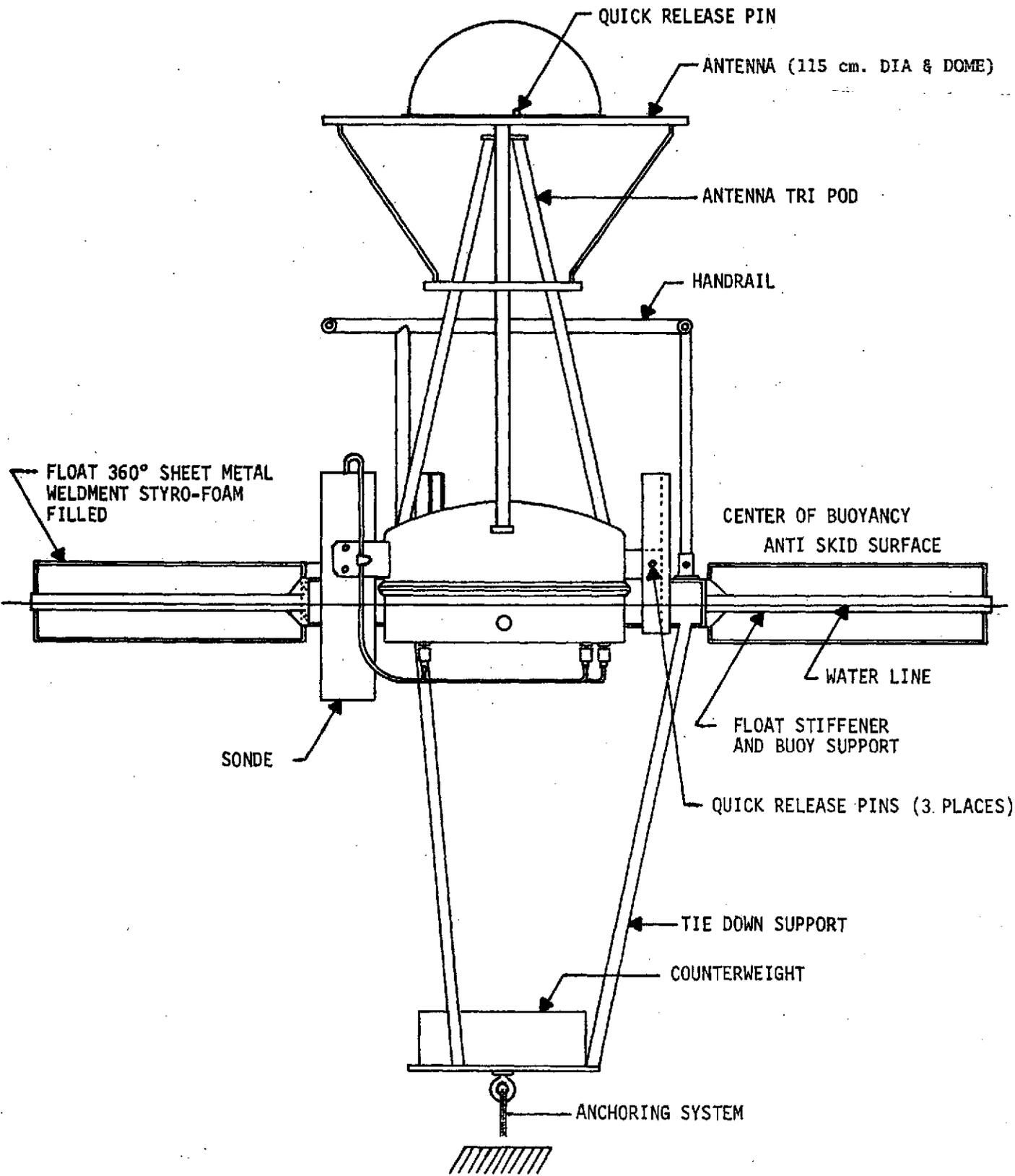


Figure 3. Salt water application earth resources buoy

It was almost mandatory to have a quick look capability in order to assess the system performance daily at the Dauphin Island laboratory which is the site of the receiving station. A ground station system has been designed and fabricated and is in the check out process. This station has the configuration shown in Figure 4.

This equipment functions as a receiving and data processing station for information transmitted from remotely located data buoys. The system presently contains the necessary circuitry to handle two buoys, with space provided and allowance made so that the electronics associated with two additional buoys could be added later if that should be required.

Data is received over an RF link which at the ground station consists of both antenna and RF receiver. The station then performs two major functions. The data is either processed, decoded and displayed on strip charts or the raw data (before decoding) is recorded on magnetic tape for shipment to more sophisticated processing facilities.

The data after it is received from the RF link, first has the bi-phase coding removed, then this information is sent over two parallel paths to either A. the convolutional decoder or B. the storage circuitry for the tape recorder.

Path A consists of a suboptimal convolutional decoder, which removes the convolution coding, and places the resulting data in a shift register. Once this operation is completed, buoy selection circuits steer the data to a holding register corresponding to that buoy. The data corresponding to each channel is then supplied to a digital to analog (D/A) converter the output of which drives a channel on the strip chart recorder.

In path B the data coming from the bi-phase decoder is placed in a shift register and a start signal is sent to the tape recorder. Once the tape recorder is up to speed, the information is shifted out of the shift register through a bi-phase encoder and recorded on the magnetic tape along with the local time of day when the data arrived. After the register is empty a stop signal turns off the tape recorder.

The station also contains a self test and calibrate system along with an alarm system to indicate that data is no longer being received.

At this point in deployment of this mobile system of buoys, it is too early to put a quantitative value on the system, however it appears less expensive than known fixed installations as to first cost. It has a basic advantage in that it can be moved, at very little expense, to alternate sites where it is desired to obtain water quality data. It is to be noted this buoy system which covers a 80 Km (50 mile) stretch of the Black Warrior River and then skips down 483 Km (300 miles) to Mobile Bay for the next measurements would not be feasible unless there is a satellite to collect and relay the data.

EDITORS NOTE:

Mr. Morton has informed us that since the Workshop was held, the buoy program has been highly successful in providing accurate data especially the Mobile Bay salt water buoys and its attendant shore receiving station. That buoy design was altered slightly to use external lead-acid batteries mounted on the flotation ring for powering the measuring instruments and an internal gel-cell battery for the transmitter. The lead-acid batteries are conventional 90 Ampere-hour batteries that will power the instruments for up to 30 days continuously and the gel-cell is good for 9 months. Since emplacing the salt water buoys in late September 1973 they have been recording very accurate data with no calibration of the instrumentation. The accuracy has been checked by using independent instruments at each buoy location. If any further details are required contact Mr. Morton at the address indicated in the Proceeding Appendix.

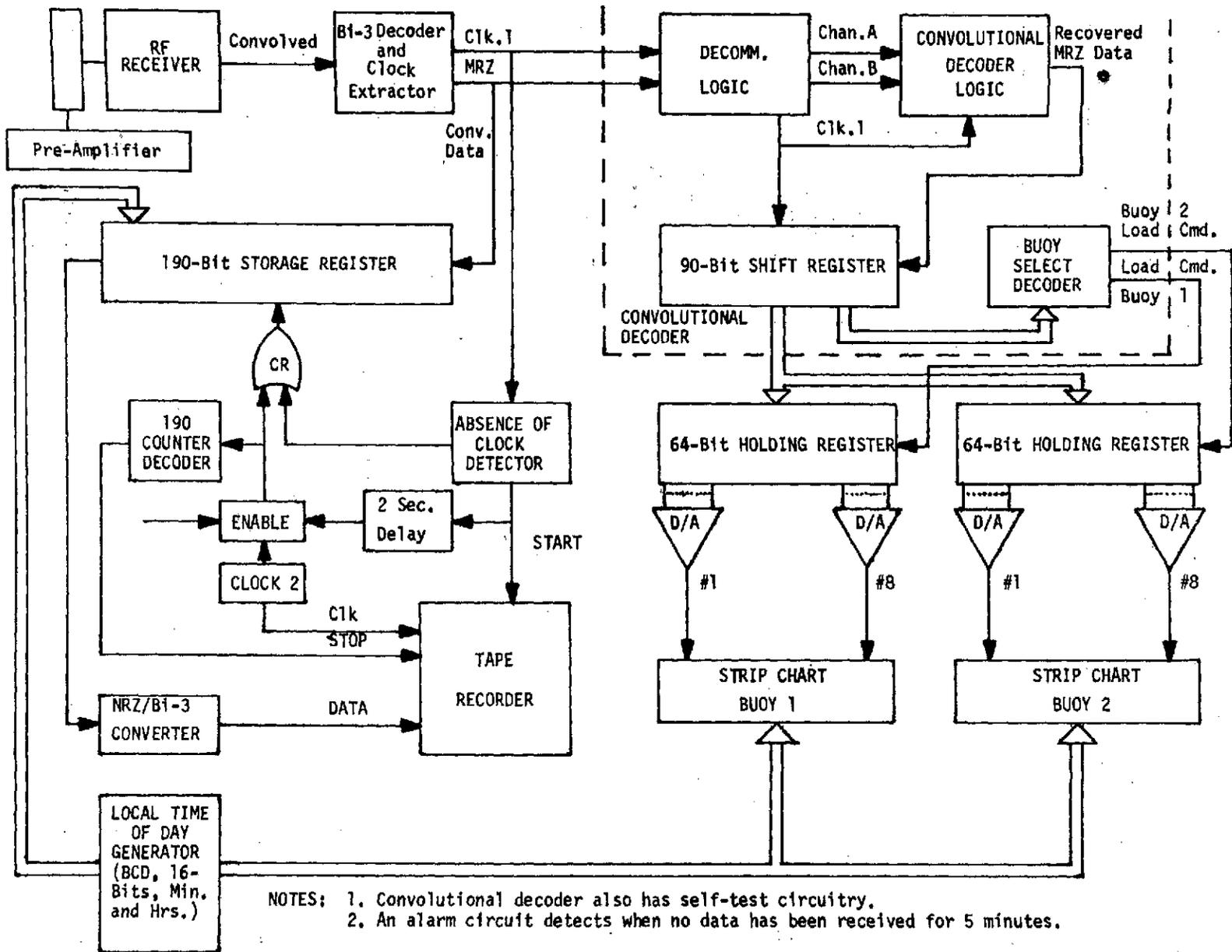


Figure 4. Ground station

MONITORING THE CHANGING HYDROLOGIC REGIME OF THE
FLORIDA EVERGLADES THROUGH ERTS-1 DCS

Edward H. Cordes

United States Department of Interior

U. S. Geological Survey

PAPER NOT AVAILABLE AT TIME OF PUBLICATION

PERFORMANCE OF THE ERTS-1 DCS IN A PROTOTYPE
VOLCANO SURVEILLANCE SYSTEM

Peter L. Ward

National Center for Earthquake Research (NCER)
U.S. Geological Survey

During the past 10 months, we have installed a prototype volcano surveillance system on 15 volcanoes in four states and four countries. I would like to review briefly today the need for this system, the techniques we used, the method of implementation, the major problems, the results and the future that we see for such a system.

Need

There are over 500 historically active volcanoes around the world, but only a few of these are active at any one time. Some volcanoes may steam profusely and appear very active for hundreds of years, but never explode violently. Others that appear dormant may suddenly erupt. Thus, there is a need for monitoring volcanoes to determine the level of activity. So far, there have been very few volcano observatories developed around the world because of the high cost of maintaining a staff in the field. Typically, if there is an eruption that draws attention to an area, an observatory may be built and then five or ten or even 50 years later the scientists may be left studying an inactive volcano. Thus, there is a clear need for finding a relatively inexpensive system that can be put on large numbers of volcanoes with the data collected rapidly in one central location for a small group of specialists to analyze.

Technique

Two parameters have been best proven to gauge the level of activity of volcanoes: Earthquake activity and ground tilt. NCER therefore set out to develop sensors to measure these two different phenomena.

The typical seismograph for recording earthquakes collects data at the rate of about 20 million digital bits in a 12-hour period. This data rate is clearly orders of magnitude too large for the ERTS system. If a satellite system were to be built around this high data rate for each station, the surveillance system would most likely be too expensive to be practical. Thus, it is necessary to compress the data. Typically only small parts of these data are of real interest and the seismologist selects the most interesting data. NCER has been developing in California a computer system that can analyze these data from 100 stations and select the important information. This is a rather expensive system; however, it is quite sophisticated and although not proven, it is extremely promising.

The fact that seismic activity increases by orders of magnitude before and during eruptions makes it easier to design a sensor for use on volcanoes. Thus NCER set out to develop earthquake counters that could count events and send the information into the ERTS data collection system. To select events, which may reasonably be expected to be earthquakes, we first full-wave rectify the 5-to-20-cycle-per-second signal from the seismometer. For an event to be counted, the rectified signal must have 10 peaks above a given threshold in 1.2 seconds and there must have been no peak above the threshold for the previous 15

seconds. Four different thresholds are used to attain a wide dynamic range. The requirement that there be no peak above the threshold for the previous 15 seconds effectively turns the counter off in times of high background noise due, for example, to cultural noise, wind or perhaps even to harmonic tremor from vibration of the ground caused by moving magma. The amount of time that the system is turned off or that any one level is turned off is counted on separate counters. These data are shifted from a storage register serially into the DCP and transmitted. A parity bit is included within the 64 bits, and thus far there have been only three or four cases where there is a parity bit error but there is no error flag on the data coming through the ERTS system. This suggests that some errors occur in the transmission system. In addition, since earthquake counters are somewhat suspect to most seismologists, standard seismometers were installed at most of the sites where there are DCP's, or else the DCP's and event counters were installed at sites where there are standard seismometers, so that in this initial experiment it can be determined whether the event counters are working as planned.

The second type of instrument used is a tilt meter. The data rate of tilt meters is quite low; a few readings per day are more than adequate for most volcanic studies. The problem has been in developing the proper instrument and techniques of implantation. Very few tilt meters that have the required sensitivity and that can be easily deployed have been developed for use on volcanoes. A considerable research and development program has been carried out at the National Center for Earthquake Research over the past few years studying tilt meters. One built by North American Rockwell that uses a precisely manufactured level-bubble was chosen. The bubble is mounted in a tube 5 Cm (2 inches) in diameter and 1.2 meters (4 feet) long and can be placed in a shallow borehole. The instrument is sensitive to about 1 micro-radian of tilt, which is adequate for use on volcanoes. The tilt meter electronics attach directly to the analog input of the DCP. It is planned to develop a method for multiplexing these readings similar to the system discussed by Duane Preble today. It would be desirable to have more than an 8-bit resolution and to obtain readings over shorter periods of time for certain studies. It would also be desirable to be able to alternate transmissions between the event counter and the tilt meter so that one DCP can be used to send information from both sensors and thus transmit twice the bit rate. In most locations enough messages are received per day to allow alternate transmissions.

The data collection system does seem to provide sufficient data return, short of providing a complete voice link through the satellite, and does allow very low-cost ground stations.

Implementation

The map in Figure 1 shows the locations of the test sites in the study; two in Alaska, three in Washington state, one in California, one in Hawaii, one in Iceland, one in El Salvador, five in Guatemala and four in Nicaragua. The data are transmitted to Goddard and then sent by teletype to Menlo Park, California. Installed at these sites were six tilt meters, 23 event counters and 11 standard seismic stations. The station-to-receiver range from which reliable reception is obtained is 4200 kilometers from Hawaii to Goldstone and 4500 kilometers from Iceland to Goddard. Data from these sites are being transmitted at 90-second intervals and the reception seems quite adequate.

Figure 2 shows the outside case of the event counter, the box in which the transmitter is placed, and the batteries, which are adequate for a year's operation. The event counter operates at a total power consumption of about one ampere-hour a year (a tenth to a twentieth of a transmitter's power consumption). These batteries are more than sufficient to operate in a deep snow environment and fairly hot tropical environment. The sealed cases contain dessicant both for the transmitter and the event counter just as added safety considering the large expense of field work to replace a defective instrument. Experiments are underway with another type of power source using 5 volt air cell batteries and an inverter. It is known that this system operates but there is a need to develop the best inverter for the purpose. The advantage of this system is that the air cells

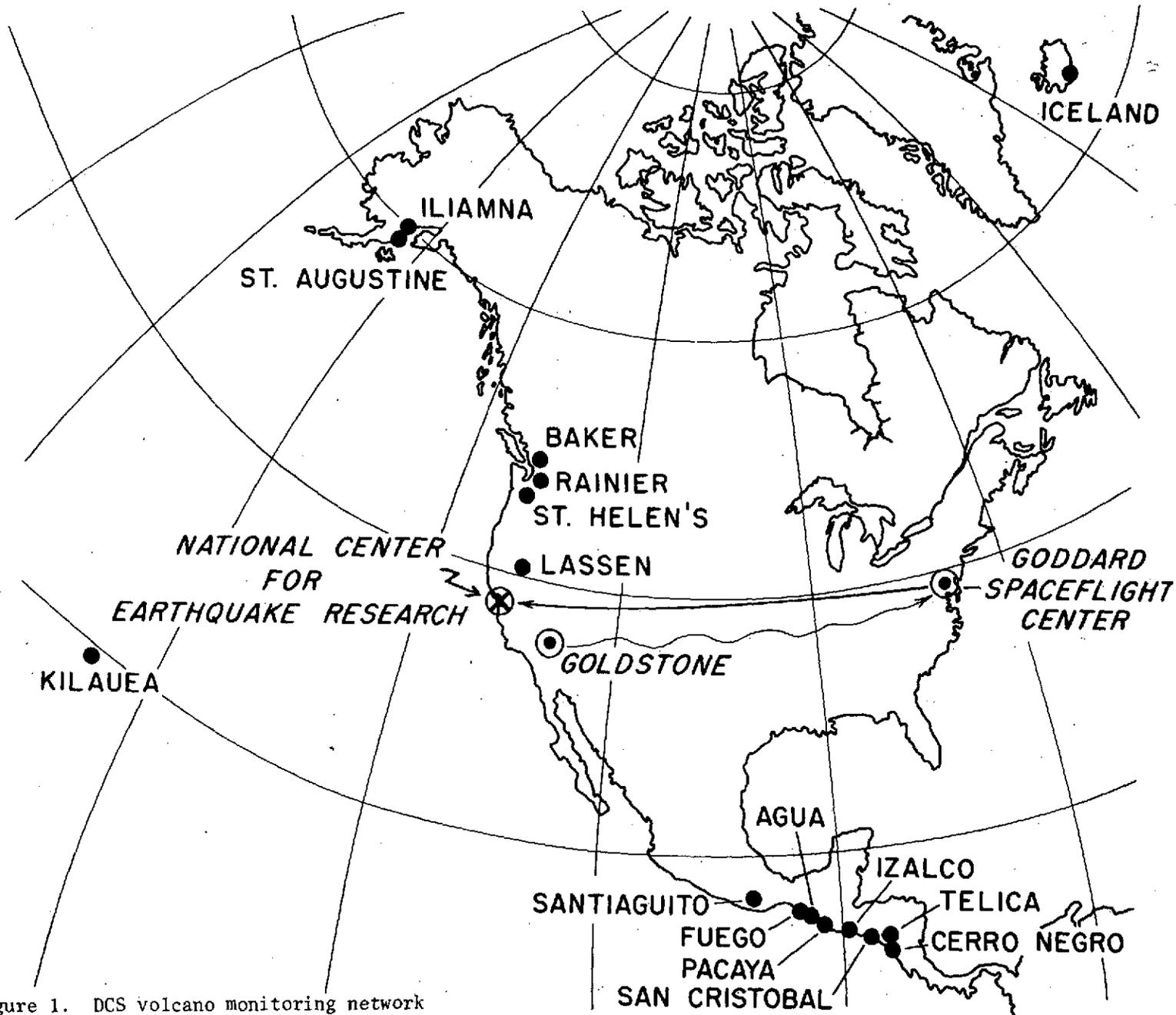


Figure 1. DCS volcano monitoring network



Figure 2. Equipment used in DSC installations
(from left, DCP electronics, event counter, 1 year battery)

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have a shelf life of three years and a capacity of 1000 ampere hours. Thus within a very large safety factor they can power the system for three years.

Figure 3 shows the control panel of the event counter. The sensor, a magnet and coil, generates a voltage that is a function of the velocity of the ground. The counters contain a considerable amount of logic in two analog and six digital circuit boards. There is also a small printer with a cassette of paper tape. Each printed character is a matrix of dots that represent a 10-bit binary word. Printing eight characters once every six hours, this spool of paper tape will last for about two years.

Figure 4 shows a typical installation on Mt. Baker in Washington state. The antenna is covered with a plexiglass dome to protect it from snow loading and vandalism. Some domes are painted for camouflage and for ecological reasons. The batteries and instrumentation are all in the partially buried box at the base of the antenna. The box is about 35.6 Cm (14 inches) high.

In Central America, security is much more of a problem. A concrete base was constructed at most sites to hold the heavy duty steel boxes. The antenna wires go up the inside of the antenna mast. In order to decrease vandalism, all of the guide wires are fastened with crimp connectors. The stations are placed in remote areas on private land.

Figure 5 shows the tilt meter as packaged for our use. The level-bubble is at the base of this pipe. The pipe is used to give some stability, some long base by which to measure the tilt and to decrease the effect of small tilts from freezing and thawing, etc. The tilt meters are borehole type that must be implanted a few feet below the ground surface. Figure 6 shows a drill, which is used in the construction industry, that can be bolted to the rock and then used to drill a 10.2 Cm (4 inch) hole at least 127 Cm (50 inches) deep. The drill operates on power from an electric generator. In many other locations, the hole can be dug in soil with an ordinary post-hole digger.

Figure 7 shows a typical standard seismometer site with the steel box with battery and equipment in it for servicing for one year's time.

Figure 8 shows the installation of a standard seismometer and event counter on Izalco in El Salvador.

Problems

Since installations are operating in several foreign countries, there are many logistic problems, but the following will concentrate on the instrumentation problems.

It is felt that in rugged environments perhaps the weakest element of the equipment provided with the DCP is the antenna. First of all, the ground plane is too large by several inches to be shipped on many airplanes. Only freighters and certain large airplanes can carry boxes of this size. As a result, problems have been encountered in shipping the equipment. Secondly, the elements are not rugged. Several of the antennas were crushed by snow loading (Figure 9). Thirdly, the connector in the ground plane is a very poor design and has caused considerable headaches because there is no mechanical fastening for the central pin and the pin can be pulled out inadvertently. It is felt that considerable effort should go into finding alternative antennas - either making a smaller ground plane or perhaps even using a different radiating system. The NCER is most interested in hearing from anybody who is working on or testing such antennas.

Experience has revealed that the test set is quite inadequate in the serial mode. Typically, it shows that the platform is in error even though the platform works correctly. Part of this problem has been traced back to the power supply for the platform. Although the platform will work adequately on a certain battery configuration, it cannot be tested by the test set on that same battery configuration. Furthermore, there is no way to read

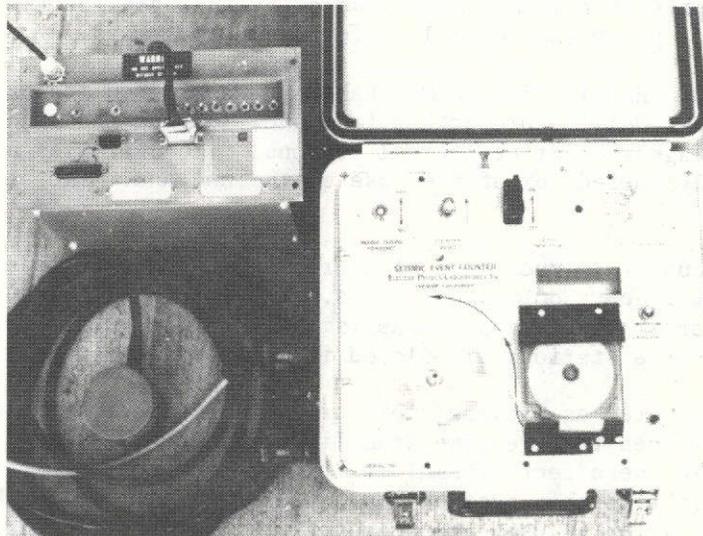


Figure 3. Close-up view of equipment-
DCP electronics (upper left) and event counter



Figure 4. Typical installation of seismic
event counter antenna, transmitter,
batteries and steel box containing
event counter are visible

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OF POOR QUALITY

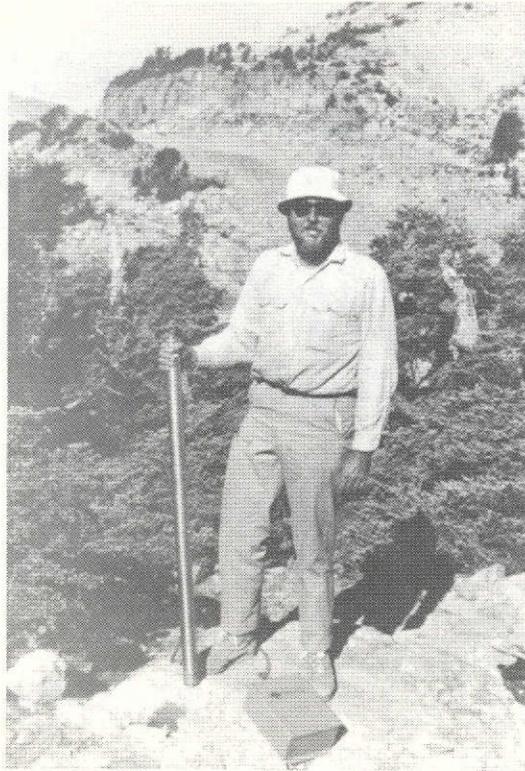


Figure 5. Tiltmeter and associated electronics



Figure 6. Drill used to drill hole in rock for tiltmeter

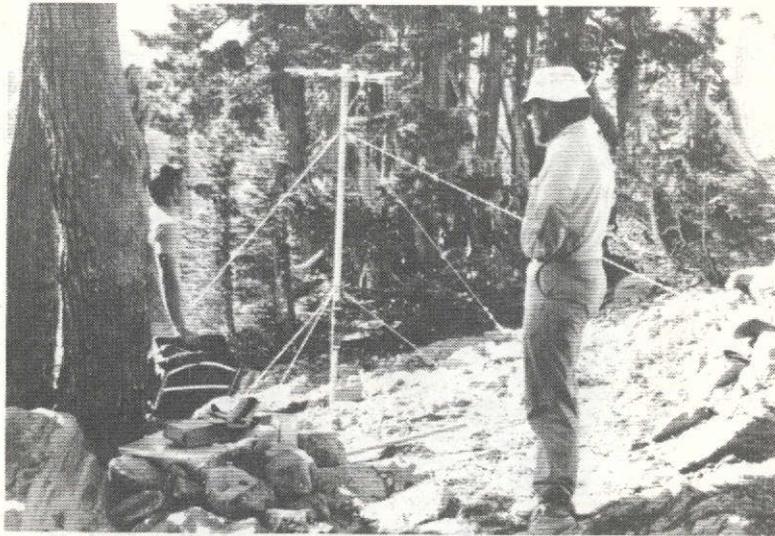


Figure 7. Typical installation of standard seismograph station used in the study



Figure 8. Installation of standard seismometer and event counter on Izalco volcano in El Salvador

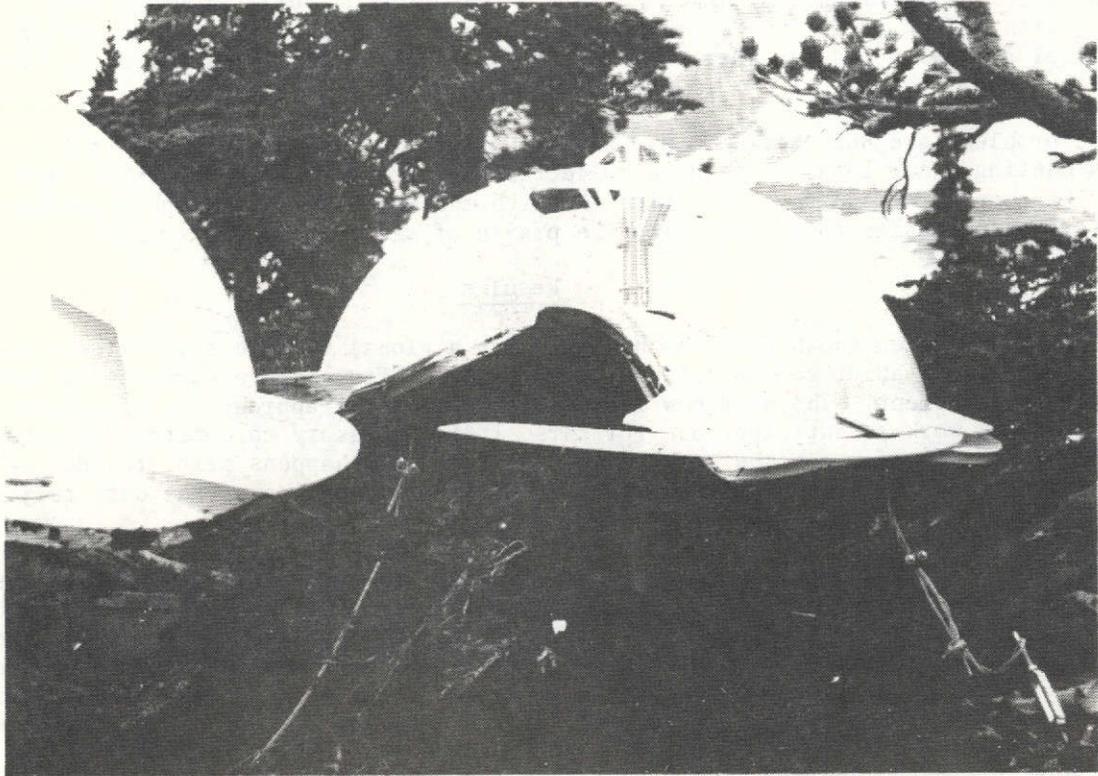


Figure 9. Antennas on Mt. Lassen destroyed by ice and snow

serial data on the test set if the data are input from the sensor. It would also be useful if the test set could test the antenna, since considerable problems have been encountered with the antenna primarily because of the connector. A number of unexplained DCP programmer failures have occurred for which it has not yet been possible to isolate any design problem.

It is recommended that different types of DCP design should be examined. In applications such as this experiment where only the serial digital mode is used, the design could be considerably simpler and cheaper. Perhaps a DCP could be built around a serial digital mode, with add-on cards including all capabilities for clocking, etc. in analog or parallel digital modes in order to make a basic, less versatile system available at less cost.

These problems are not overwhelming, and are pointed out simply because of the purpose of this meeting. All in all, the data collection system has worked remarkably well considering the complexity and the short time in which the whole system was put together. The writer has no desire to detract from the praise of the system.

Results

So far, it has been shown that the hardware for a global volcano surveillance system is feasible. Inevitably, some details will be changed after more experience is accumulated with this equipment. The need now is to show whether the approach is indeed the right one and will work as anticipated. For this, it is necessary to monitor for some time the level of activity for a number of volcanoes to see what happens prior to, during and after eruptions as shown by these sensors. Careful evaluation of the data is just beginning.

Fortunately, there was an eruption of the volcano Fuego in Guatemala only 10 days after the event counter was installed. Figure 10 shows Fuego in December, a distance of about 5 km. Figure 11 shows the events per day, most of which are assumed to be earthquakes, counted on three different event counters. The solid bars are data from a counter installed 30 km away from Fuego to count regional seismic activity. Note that there is very low regional activity - on the order of a few events per day or less. The cross-hatched bars are data from a station on the volcano Agua, 15 km away from Fuego, and the open bars are data recorded 5 km away from the summit of Fuego. The station on Agua had a DCP programmer failure about a week after the transmitter began operating, but since this station was operating first, it is included here to show the quiet period before the large swarm of earthquakes on February 17. The level of seismic activity remained relatively high throughout the eruption but dropped again after the eruption.

As pointed out earlier, there are inhibit time counters that tell the time when ground noise is interfering with the counts. These counters counted essentially nothing during this eruptive period except on one day where there were over 300 events. The high peak on that day was possibly due to atmospheric disturbances but more likely was due to harmonic tremor from the volcano.

This type of result is exactly what is sought. It is important to point out that just because a swarm of earthquakes preceded the eruption, it would not have been possible to predict that there would be an eruption within the next few days or a week. But these data do show an increase of activity at that volcano.

It is thought that in the future, we will have a very high probability of observing a number of eruptions. Event counters were deployed, at least in Central America, on those volcanoes that were considered to have a high probability of erupting. Probably there are four or five likely prospects for an eruption in the next few years, if not few months, and so it is hoped that these data can be collected.



Figure 10. The summit of volcano Fuego as viewed from the event counter, tiltmeter and seismograph site on side of mountain

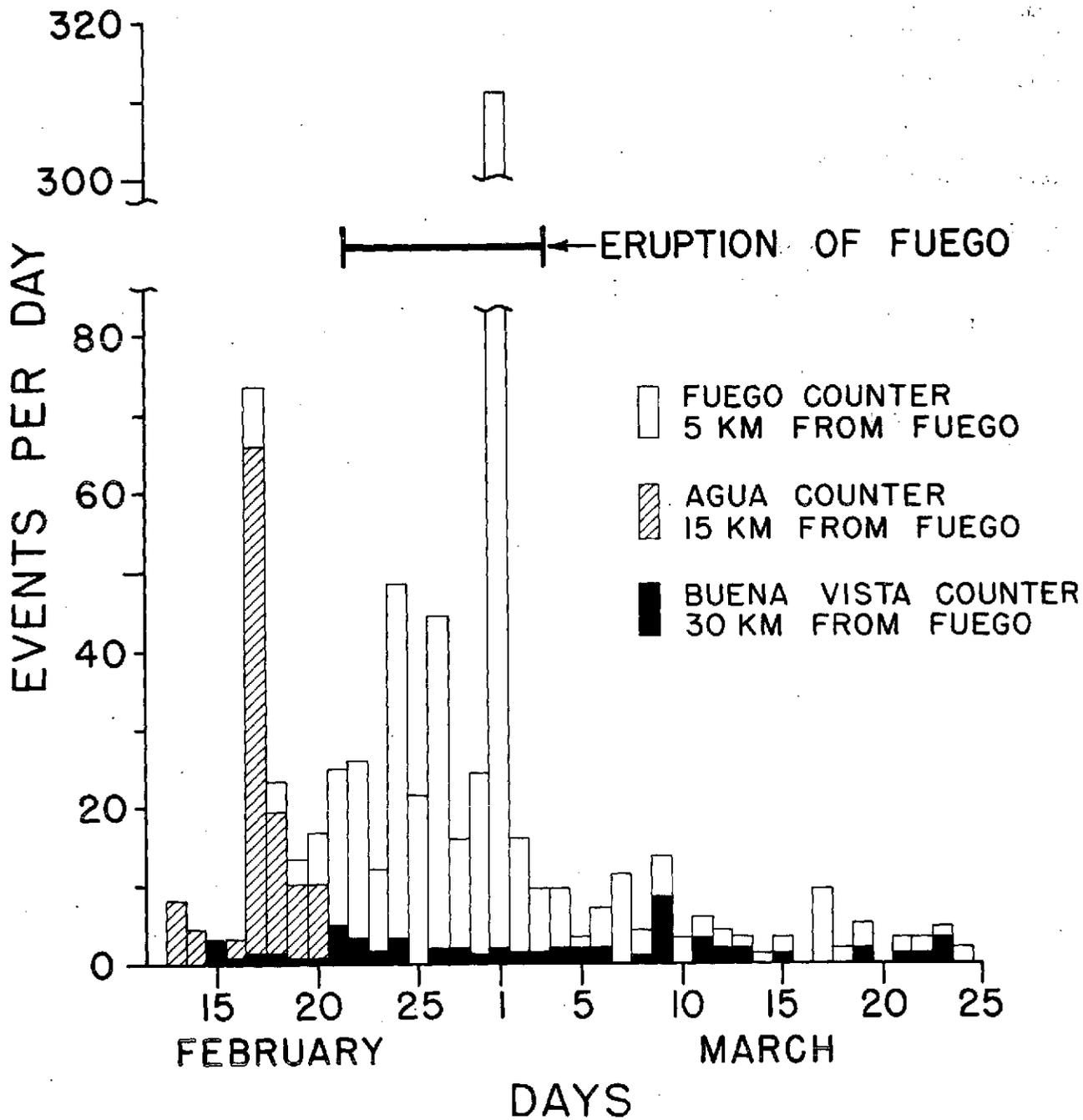


Figure 11. Events per day recorded at three sites in Guatemala for part of February and March 1973

It is foreseen that in the more distant future the possibility of putting together in one box (about the size that I showed in the field installation) the batteries and all the instrumentation and perhaps attaching the antenna to the top of the box so that this box could be carried out in the field, installed by relatively unskilled personnel, and left to operate unattended for three years. It seems possible that such a system could be put together including an event counter, transmitter and batteries in some quantity at a price of about \$5,000 each.

There has been interest shown already for a number of countries where there is considerable volcano research, suggesting the possibility that such packages could be bought by different countries to be installed on their volcanoes.

If the data collection system is shared by a large number of users, the total cost of monitoring various volcanoes could be considerably cheaper by many orders of magnitude than that of stationing local unskilled observers on each of these volcanoes. Of course, the data would be collected almost instantaneously in one place where a few specialists could analyze it rapidly.

In conclusion, if this prototype volcano surveillance system continues to operate as observed and anticipated, it should provide a considerable step forward in the surveillance of potentially dangerous volcanoes.

USE OF ERTS-1 DCS IN THE MANAGEMENT AND CONTROL
OF WATER RESOURCES SYSTEMS

Joseph W. Finegan, *Jr.*

U. S. Army Corps of Engineers
New England Division

I will briefly summarize the water resources projects the New England Division (NED) has constructed, and the communications and hydrologic data collection systems we utilize in operating our projects. I am doing this to give you a feeling of what our operational needs are and how we are accomplishing this with the present means of communications. In addition, I will review the ERTS-1 experimental hydrologic Data Collection Platform System that has been established at NED, the reasons for getting involved with the experiment, some of our initial problems associated with the data collection hardware, and a preliminary conclusion based on our operating experiences.

The New England Region includes the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut. The entire area consists of approximately 97,000 sq. km. (60,000 square miles), half of which is in the state of Maine. The limits of the NED are all of Maine, New Hampshire and Vermont to the western limits of the Connecticut River basin, Massachusetts, Connecticut to the western edge of the Housatonic River basin and Rhode Island.

Presently the Corps has constructed 35 flood control reservoirs, 36 local protection projects and four hurricane barriers (which are located along the southern coastline).

Most of the population in New England lives in the southern and central regions, and for that reason there are only several projects in the northern areas of New Hampshire and Vermont and nothing in Maine. In fact, all of our reservoirs and most of our local protection projects are located in five river basins:

Connecticut	18,000 sq. km.	(11,000 square miles)
Merrimack	8,100 sq. km.	(5,000 square miles)
Housatonic	4,300 sq. km.	(2,000 square miles)
Thames	1,600 sq. km.	(1,000 square miles)
Blackstone	800 sq. km.	(500 square miles)

Of the 35 reservoirs, there are seven that hold back floodwaters automatically, and releases are controlled by small ungated conduits. These projects control runoff from drainage areas up to 24 - 32 sq. km. (15 - 20 square miles). The remaining 28 reservoirs, having areas from approximately 40 sq. km. (25 square miles) to 1,609 km. (1,000 miles) are gated, staffed 24 hours a day, and all releases are under the direction of the Reservoir Control Center.

All reservoirs have flood control as a primary purpose. Other uses include water supply, recreation and low flow augmentation. However, none of the reservoirs are presently operated for hydroelectric power, navigation, or irrigation purposes. Basically then, flood control regulation is NED's primary concern.

In addition, two of the four hurricane barriers have navigation gate openings, and the Control Center is responsible for the closing of these gates during severe coastal storms and hurricanes to prevent damage from tidal flooding to the communities.

The New England region is subjected to floods every month of the year. The probability of a flood is greatest in the spring when the snow melt occurs and the rivers are flowing at or near bankful capacity for several weeks. Most of the minor and moderate floods occur during the spring runoff period, and can encompass the entire region rather than a single basin. During the hurricane season, various portions of the region are exposed to flooding related to the path of the hurricane. Tidal flooding is also a concern in the New England region and can occur during hurricanes and severe coastal storms.

Most of our reservoirs are regulated initially to reduce damaging stages on their respective tributaries and regulation usually is continued to afford reductions at main stem damage centers. Until the early 1960's, we did not have enough reservoirs in a single river basin to exert a large amount of control. The method of collecting data from the dams or river stations at that time was either by telephone or field observation. Although this was time-consuming and subject to telephone lines remaining open, it was considered adequate to meet the regulation needs of that time. However, in the last 10 to 15 years the Corps has constructed an additional 25 reservoirs and four hurricane barriers. Now we effectively reduce flooding on the tributaries and main stems in four of the five basins we regulate.

A comprehensive data collection network has been established in order to operate the flood control system. In the 1960's each dam and hurricane barrier was equipped with a voice radio for relaying data and receiving instructions from the Control Center. All dam-tenders are responsible for obtaining and reporting data from a group of index stations, either through telephonic river gauges, cooperative observers or visual observations. This information usually consists of precipitation reports in the basin, climatologic and hydrologic data at the dam, river stages and river conditions at strategic locations, and snow cover in the late winter and spring months.

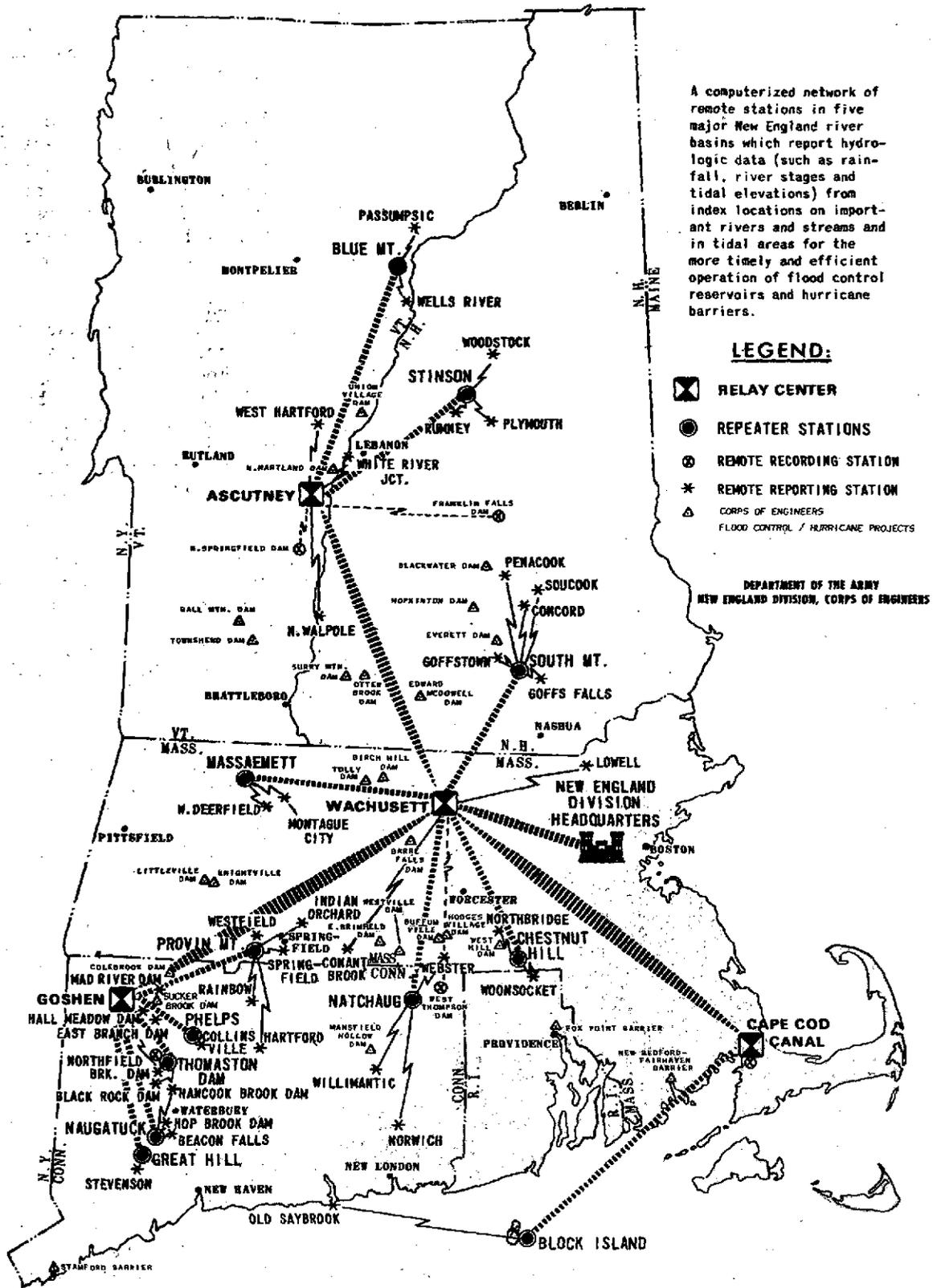
Getting reports even by radio from about 30 projects is time-consuming. Therefore, in January 1970, NED dedicated a new automatic hydrologic radio reporting system, consisting of 41 remote (unmanned) reporting stations, which report information such as river stage, reservoir level and precipitation directly into the Control Center. Two of the stations are used for the operation of hurricane barriers, and report tide elevation, wind speed, wind direction and barometric pressure.

I will review this reporting network in more detail because it is an extremely useful tool in the regulation of reservoirs, whether it be during flood periods or nonflood periods.

Figure 1 is a map showing the locations of the 41 Remote Unmanned Reporting Stations, 12 Repeater Stations and four Relay Stations.

There are four ground-based relay stations which transmit the signals from the reporting stations to the Control Center. In order to bring the radio signals from the 41 reporting stations to the relays, 12 repeater stations were built to provide a strong reliable signal.

The system reports by radio and uses batteries as its primary source of power. This eliminates many of the problems that arise during major floods and hurricanes when power and telephone lines are down and normal means of communications fail. The batteries are charged either by thermoelectric generators or AC power where available. When the outside source of power is out, the batteries have sufficient energy to operate for about three weeks without recharging.



A computerized network of remote stations in five major New England river basins which report hydrologic data (such as rainfall, river stages and tidal elevations) from important rivers and streams and in tidal areas for the more timely and efficient operation of flood control reservoirs and hurricane barriers.

LEGEND:

- ☒ RELAY CENTER
- REPEATER STATIONS
- ⊙ REMOTE RECORDING STATION
- * REMOTE REPORTING STATION
- △ CORPS OF ENGINEERS FLOOD CONTROL / HURRICANE PROJECTS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS

Figure 1. Automatic hydrologic radio reporting network

The control at the Reservoir Control Center consists of an interface between radio equipment and an IBM 1130 computer. Under computer programmed control, the reporting stations can be interrogated singly or as a group at automatically selected or various time intervals. Normally an interrogation is made every six hours, however, during flood periods, we interrogate every two or three hours. During hurricane or severe coastal storms the two coastal stations report every 15 or 30 minutes. Response time is about three seconds for a single interrogation which is considered "real time" for regulation purposes. A complete set of readings from all 41 stations is obtained (see TABLE 1.) and printed out in about four minutes. River stage data is converted to flow, and data received at the Control Center are stored in the computer for further analysis. Data from the seven ungated dams are analyzed and reservoir inflow and outflow are computed automatically. Information received on the voice radio network from the 28 manned dams are keypunched and stored in the computer for further analysis and computation of inflow.

The reporting system is capable of handling up to 100 remote stations, and each station can transmit up to four parameters. The reporting system also includes five recording stations located at strategic reservoirs. All information received at the Control Center from the system is transmitted to the recording station. This allows one dam in each river basin to have access to all available information. During emergency conditions such as communication failure with the Control Center, each strategic reservoir can interrogate certain stations in its own area without going through the Control Center.

Water quality monitoring stations are also being studied for possible inclusion in the system and studies continue to improve the functions of the data collection system.

The installation and first costs associated with this network are approximately \$750,000 which includes supporting equipment at four relay stations, all equipment at the 12 repeater stations, all supporting equipment at the 41 reporting stations, and a data control interface with the computer at the Control Center. We are now in the fourth year of a five-year maintenance and lease contract and at the end of five years NED will own the entire network. The maintenance contract is approximately \$23,000 a year, if a reliability of 91 percent or higher is maintained each month.

During the last 16 months the reliability has been above 97 percent with the exception of two months. During two months the reliability fell below 91 percent. Last year additional expenses incurred over and above the maintenance costs included \$3,000 for vandalism, lightning and ice and snow damage.

Now that you have an idea as to what our reservoir operational needs are, and a summary of NED's ground-based radio relay hydrologic reporting network, I will review the experiment that we are involved with in conjunction with the ERTS-1 satellite. The first aim of our studies is to evaluate the future usefulness of satellites, such as ERTS-1, in the day to day operation of our water resource projects. A more important long range purpose of this two-year study is to investigate the operational reliability and to review the economic feasibility of establishing and operating a satellite network on a Corps-wide basis as compared to the conventional telephone, telegraph or ground-based radio relay methods.

The ERTS-1 satellite relays data from 27 collection platforms, located all over New England, to the Reservoir Control Center in "near real time". It does this by transmitting the data by radio signal to the Goddard Space Flight Center, and about 45 minutes later the data is received in Waltham, Massachusetts on both tape and teletype via a teletype link. As the satellite circles the earth every 103 minutes, it passes directly over New England twice a day. In addition, we have been receiving data on an average of three other nearby passes, resulting in about five readings a day.

TABLE 1. - STATION READINGS

All Station Scan 25 Sep. 1972

Coastal Station	File No.	Day	Hr.	Min.	Tide	Barometer	Wind Velocity	Wind Direction
40 Block Island	180	269	8	0	-1.90 FT	30.00 In.	15 MPH	234 Degr.

Coastal Station	File No.	Day	Hr.	Min.	Tide	Barometer	Wind Velocity	Wind Direction
41 Old Saybrook	163	269	8	0	-1.30 FT	30.18 In.	10 MPH	260 Degr.

Sta. No. and Name	File No.	Day	Hr.	Min.	Disch.	CFS/SM	Stage	Rain	Inch.
98									
39 Passumpsic	176	269	8	0	259.	0.6	2.40 Ft.	7.78 In.	0.00
38 Wells River	176	269	8	0	392.	0.1	0.80 Ft.		
36 West Hartford	179	269	8	0	200.	0.3	3.00 Ft.		
35 White River Junc.	170	269	8	0	515.	0.1	3.00 Ft.		
37 N Walpole	166	269	8	0.	-0.	0.0	1.60 Ft.	NVLD	
7 West Deerfield	133	269	8	0	59.	0.1	1.50		
6 Montague City	134	269	8	1	492.	0.1	4.20 Ft.	CHRG	
15 Conant Brook Dam	174	269	8	1	2.	0.3	0.90 Ft.		
17 Indian Orchard	183	269	8	1	620.	0.9	5.00 Ft.		
18 Westfield	109	269	8	1	215.	0.4	3.30 Ft.		
16 Springfield	183	269	8	1	2400.	0.3	1.60 Ft.		
27 Mad River Dam	180	269	8	1	31.	1.7	17.70 Ft.		
24 Collinsville	182	269	8	1	592.	1.7	4.90 Ft.		
20 Rainbow	182	269	8	1	189.	0.3	1.40 Ft.		
19 Hartford	182	269	8	1	4900.	0.5	2.30 Ft.		
97									
34 Rumney	142	269	8	2	32.	0.2	2.40 Ft.	1.89 In.	0.00
33 Woodstock	32	269	8	2	120.	0.6	2.30 Ft.	6.05 In.	0.00
32 Plymouth	130	269	8	2	400.	0.6	0.20 Ft.		
10 Penacook	180	269	8	2	233.	0.3	1.70 Ft.		
3 Soucook	166	269	8	2	29.	0.4	5.10 Ft.		
11 Concord	182	269	8	2	1160.	0.5	2.80 Ft.		
8 Goffstown South Br.	166	269	8	2	12.	0.1	3.10 Ft.		
9 Goffs Falls	182	269	8	2	250.	0.1	1.40 Ft.		
14 Lowell	180	269	8	2	3971.	0.9	42.90 Ft.		
96									
28 Wall Meadow Dam	182	269	8	2	12.	0.8	1.50 Ft.		
30 East Branch Dam	181	269	8	3	-0.	0.0	-0.00 Ft.	NVLD	2.54 In.
26 Thomaston Dam	182	269	8	3	272.	2.8	4.80 Ft.		
31 Northfield Brk.Lake	183	269	8	3	7.	1.3	21.90 Ft.		
25 Black Rock Lake	182	269	8	3	22.	1.0	27.00 Ft.		
23 Hancock Brook Lake	157	269	8	3	35.	2.9	6.70 Ft.		
29 Hop Brook Lake	145	269	8	3	-0.	0.0	15.40 Ft.	NVLD	
22 Beacon Falls	182	269	8	3	245.	0.9	2.50 Ft.		
21 Stevenson	181	269	8	3	272.	0.2	1.90 Ft.		
99									
13 Northbridge	182	269	8	3	267.	1.9	3.40 Ft.		
12 Woonsocket	182	269	8	4	368.	0.9	1.80 Ft.		
2 Webster	182	269	8	4	51.	0.6	4.70 Ft.		
1 Willimantic	124	269	8	4	404.	1.0	2.80 Ft.		
4 Norwich Tailwater	183	269	8	4	15799.	12.5	25.20 Ft.		
5 Norwch HW Natchaug	183	269	8	4	944.	1.3	45.61 Ft.	10.53 In.	0.00

Sta.	C.S.M.	6.0 HR Periods							
39	1.00	34	1.00	33	1.00	30	1.00	5	1.00

TTST	STA	Daytime	NTME	Rain
94	0	2690804.	4	49 16
93	0	2690808.	4	49 16
92	0	2690811.	4	49 16

The air distance between the northernmost station at Fort Kent, Maine, which by the way had its greatest known flood in April 1973, to the most southern station at the Stamford Hurricane Barrier in Connecticut is approximately 800 Km (500 miles). Data is received from units situated along rivers in the wilderness areas as well as urban areas, at Corps reservoirs, on high mountain tops up to elevation 8,839 meters (2900 feet) MSL, and one coastal station. Parameters include river stages, precipitation, tide levels, wind speed, wind direction and water quality indices. This variety of locations was considered necessary so that the effects of environmental conditions on the DCP's and antennas could be analyzed. Pertinent data on the stations is listed in TABLE 2.

In addition to effects of climate, other aspects were given consideration. For example, during pre-flood and post-flood emergencies there are many areas where river stage data is required to assess the flood potential or keep up-to-date on the progress of a flood. The five stations in the state of Maine fall into this category. Several of the sites in New Hampshire were chosen so that we would be using all available conventional and ERTS Data Collection facilities in the Merrimack River basin to continue development work at NED on a predictive model of flood behavior within the basin. DCP's are located at the University of Connecticut and the Cold Regions Laboratory in Hanover, New Hampshire.

The first platform was installed in July 1972. Since September, and excluding the winter months of January and February, the platforms have been installed at the rate of about three per month. Today, all but four DCP's have been installed. During this period the equivalent of two-engineer man-years have been expended on all aspects of this experiment, and a technician has been working part time on the equipment installation.

Brief comments on the field equipment are as follows:

1. There have been a few equipment failures with the DCP's. We have had problems and still do, concerning the interfacing of all sensors to DCP's, but these are, in all cases, due to NED's lack of expertise with the new equipment.
2. There have been no problems with the GEL-CEL batteries which power the DCP installations. In fact, the service life of these re-chargeable batteries, which was expected to be four to six months, appears to be significantly longer.
3. There have been no problems with snow or ice on the antennas or from hunters using them as targets, and none of the antennas has been struck by lightning. However, a platform from one of the original gauges in an urban area was removed because of antenna vandalism by youngsters.
4. During cold weather the cable from the antennas to the platform becomes brittle and has to be handled carefully.
5. Once installed in a working condition, the DCP's have been operating in a reliable manner, with a minimum of service maintenance necessary.

Until a short time ago the major thrust of NED effort has been with the installation of the equipment, including the necessary trouble-shooting with the sensing equipment at the stations.

We have been collecting and filing information from the satellite, and as previously mentioned, data relay from NASA via our "near real time" link continued to be timely, with a lag of approximately 45 minutes between ERTS-1 passovers and arrival of the data on tape at the Control Center. However, the occurrence of broken or garbled teletype messages is not uncommon.

TABLE 2. - ERTS-1 DCP INFORMATION SHEET
 ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION 20 May, 1973

ID NO.	DCP NO.	TYPE*	STATION NAME	LAT	LONG	IN-STALLED
1	6201	S	ST. JOHN RIVER AT FORT KENT, MAINE	47 15	68 35	091972
2	6355	S	PENOBSCOT RIVER AT WEST ENFIELD, MAINE	45 14	68 39	092072
3	6021	S	CARABASSETT RIVER AT NORTH ANSON, MAINE	44 52	69 57	100472
4	6304	S	ANDROSCOGGIN RIVER AT AUBURN, MAINE	44 04	70 12	112772
5	6171	S	SACO RIVER AT CORNISH, MAINE	43 48	70 47	112872
6	6271	S	PEMIGEWASSET RIVER AT PLYMOUTH, N.H.	43 45	71 41	112272
7	6106	S	MERRIMACK RIVER AT GOFFS FALLS, N.H.	42 57	71 28	032773
8		S	SOUHEGAN RIVER AT MERRIMACK, N.H.	42 51	71 31	
9	6356	S	CHARLES R. AT CHARLES R. VILLAGE, MASS.	42 15	71 15	071772
10	6207	S	TOWN BROOK AT QUINCY, MASS.	42 15	71 00	090872
11	6010	S	PAWTUXET RIVER AT CRANSTON, R.I.	41 45	71 27	090672
12	6127	S	CONNECTICUT RIVER AT HARTFORD, CONN.	41 46	72 40	083072
41	6142	S	NORTH NASHUA RIVER AT FITCHBURG, MASS.	42 34	71 47	110672
20	6042	P	STINSON MOUNTAIN, N.H.	43 50	71 47	032273
21	6345	P	SOUTH MOUNTAIN, N.H.	42 59	71 35	120672
22	6206	P	FRANKLIN FALLS DAM, N.H.	43 28	71 40	051773
23		P	BLACKWATER DAM, N.H.	43 19	71 44	
24	6012	P	MACDOWELL DAM, N.H.	42 54	71 59	042473
25		P	MANSFIELD HOLLOW DAM, CONNECTICUT	41 46	72 11	
30	6101	C	STAMFORD BARRIER, STAMFORD, CONNECTICUT	41 02	73 32	011073
40	6254	Q	ASHUELOT RIVER AT WINCHESTER, H.H.	42 47	72 23	121272
42	6272	Q	WESTFIELD R. AT WEST SPRINGFIELD, MASS.	42 06	72 38	092872
43	6242	Q	CHICOPEE RIVER AT CHICOPEE, MASS.	42 09	72 35	121472
50	6147	T	NED HEADQUARTERS, WALTHAM, MASS.	42 24	71 13	071772
51	6325	T	COLD REGIONS LAB AT HANOVER, N.H.	VARIABLE		042373
52	6216	T	COLD REGIONS LAB AT HANOVER, N.H.	VARIABLE		120572
53	6335	T	UNIV. OF CONN. AT STORRS, CONN.	VARIABLE		
54	6063	T	U. S. GEOLOGICAL SURVEY, BOSTON, MASS.	VARIABLE		032073

* S-RIVER STAGE
 P-PRECIPIATION
 C-COASTAL (WIND DIRECTION, VELOCITY AND TIDE)
 Q-WATER QUALITY (TEMPERATURE, CONDUCTIVITY, PH AND DISSOLVED OXYGEN)
 T-TEST SET (SENSORS VARIABLE)

Analysis of the ERTS-1 DCP data is only preliminary at this time and limited in nature for two reasons:

1. NED does not have sufficient information to develop statistically significant performance results.
2. Certain aspects of data analysis procedures have been curtailed due to unexpected problems encountered with the software of a recently purchased Data General mini-computer, which is being interfaced with the 1130 computer. However, this is considered to be temporary in nature and expected to be resolved by the end of June 1973.

To date the installation and first costs associated with the ERTS Program are as follows:

1. \$85,000 - cost of equipment which includes 30 platforms, antennas and test sets.
2. Additional \$4,000 for miscellaneous items such as interfacing with sensors, batteries, cables, clamps, connectors, etc.
3. Salaries equivalent to two-man-years at an engineering GS-11 level and one-third man-year at a technician GS-7 level.

The most important aspects of the NED experiment are to determine the viability of satellite data relay in relation to existing ground relay configurations in terms of cost, timeliness and reliability, and also to investigate the feasibility of establishing and maintaining such a network on a Corps-wide basis. This experiment is quite relevant to the Corps needs because today several Corps offices in different parts of the country are constructing or planning data collection systems with ground based radio relays.

Much of the system has operated through the winter and spring runoff period and information is being used in an operational mode, especially in areas where no other data are available. Based on the status of the experiment to date, even though it is still preliminary in nature, NED confidently reports that data relay by satellite, for management of water resource systems, is both feasible and reliable.

ERTS-1 DCS TECHNICAL SUPPORT PROVIDED BY WALLOPS STATION

Roger Smith

NASA Wallops Station

Wallops' participation in the ERTS DCS Program has probably been different from that of most organizations since we have been involved in several phases of the overall effort. This resulted from the original proposal Wallops submitted in response to NASA's request for ERTS proposals back in 1970, our general interest in ERTS, and subsequent communications with Earle Painter and other individuals at Goddard. We subsequently accepted the tasks of providing ground truth to several ERTS investigators, operating a DCP repair depot here at Wallops, designing and building an airborne DCP Data Acquisition System and providing aircraft underflight support for several other investigators. Additionally, our Data Bank is generally available for use by ERTS and other investigators that have a scientific interest in data pertaining to the bay area. From our viewpoint, working with DCS gives us a chance to evaluate the system as a data collection device possibly applicable to our ongoing Earth Resources Program in the Chesapeake Bay Area as well as provide useful data and services to other ERTS investigators.

I would like to briefly discuss two of the areas of technical support that Wallops is providing for the ERTS Program.

Ground-Truth Stations

We are currently in the process of collecting ground-truth data from several locations in the bay area for several ERTS investigators whose primary experiments relate to the interpretation of ERTS scanner data. The data we are gathering is received via the ERTS/DCS and includes measurements of such parameters as water temperature, dissolved oxygen, PH, transmissivity, current speed, current direction, conductivity, wind speed, wind direction, wave height and several others. The locations and quantity of stations are subject to change as the requirements for ground truth to support the experiments change but we expect to eventually have about eight stations in this area.

During the time the stations have been deployed in the field, no major problems unique to the DCS have been noted but we have had the usual problems with corrosion, marine growth and fouling normally found in a saltwater environment. The sensors themselves, primarily due to the environment, have presented the most problems. It seems there are several parameters, such as dissolved oxygen, transmissivity, and probably others, for which there are no marine-type sensors on the market that are designed for long-term in situ operation in salt water. We have found that calibration has been lost between the eighteen-day cycles for scanner coverage because of an accumulation of mud and/or slime on this type sensor. Another problem we have found, and not a surprising one, is that a DCP installed in anything but an airtight enclosure in close proximity to salt water will start to corrode in less than three weeks. The switches and connectors will probably be the first source of trouble since they are not sealed with a conformal coating like that used on the circuit cards. The antennas seem to survive fairly well without additional protection in the salt air environment. We have resolved these problems by using airtight enclosures for the DCP's and other electronics, stainless steel or plastic hardware wherever possible and with frequent servicing and cleaning of the sensors.

The only area noted in our activities where the DCS has fallen short of the investigators requirements is in the measurement of stream height where a particular investigator has expressed a desire for data taken at more frequent intervals than can be obtained by normal satellite coverage. A storage circuit has been discussed that would remedy this problem. If this circuit is developed, and our requirement still exists, we will build or procure one and provide the investigator with the more frequent data that was requested. We have found that, in some cases, data resulting from millisecond samples taken at infrequent intervals has little value. Average values are more desirable but the infrequent data samples received through ERTS make it necessary to have any data averaging done in the sensor itself or at least prior to transmission by the DCP. It is often difficult or impossible to find off-the-shelf sensors that provide average values for such parameters as wind speed and direction and water current speed and direction.

We have found at least one firm application for DCS in our other programs. We are installing a DCP at the Tidewater Research and Continuing Education Center at Holland, Virginia, to measure several parameters required for the remote sensing in agriculture program at the Virginia Polytechnic Institute. We expect that other applications will appear once people become aware of DCS's capability and as new systems are required.

We receive data at Wallops via a teletype link with Goddard within hours of the actual sample time, reduce it to engineering units and forward it to the investigator by mail, normally within a couple of days. This could be done faster but it has proven adequate for mission requirements so far.

DCP Repair Depot

We began limited operation of the DCP Repair Depot about March of this year. In order to become fully operational as fast as possible, a supply of spare parts was immediately ordered from various vendors, including all the integrated circuits and other standard components. Special components, such as the coils in the transmitter circuit will probably have to be handmade as needed. We have an Instrument Construction Shop on the station that has this capability. We contracted with General Electric (GE), Daytona, for an experienced engineer to come to Wallops and give our technicians a week of training in theory of operation and repair of the DCP's. This turned out to be very worthwhile and has brought our technicians up to speed much faster than would have been the case without this training. We also obtained from GE, through Goddard, a piece of test equipment called the bench test equipment (BTE) which was originally used in the production and checkout of the DCP's at Daytona. This equipment has also greatly expedited the troubleshooting and repair of the circuit cards at Wallops and is well worth having.

We may have been a little slow in repairing some of the first DCP's and cards received because of the leadtime required for procurement and delivery of the necessary spare parts. All DCP's or cards received to date have been repaired and returned or the trouble has been diagnosed and repairs will be made as soon as parts are received. We can say that in no case are repairs being held up because of a lack of manpower or effort on the part of Wallops personnel. We fully expect that the average return time will be less than two weeks after we have received our full complement of spares.

We are involved in negotiations with GE to buy some spare cards to be used to replace some of those damaged beyond economical repair. We are also trying to find a source for compatible antennas for the same purpose.

Our experience indicates that the programmer card has been the main cause of DCP failures

with integrated circuits being the main failure points. Out of the first thirteen defective cards received by our repair depot, ten were programmer cards, two were analog cards and one was a transmitter card. Most of the programmer cards have had failures in the same areas of circuitry and, after discussing this with GE, we have come to the conclusion that this is caused by failure of the DCP users to tie the sensor power supply ground to the DCP power supply ground. This isn't clearly indicated in the users' manual but should be done as part of the standard installation procedure. For those who are interested in the exact cause of failure of their equipment, we maintain a log on each card or DCP repaired at Wallops and we can provide details on the repairs that were necessary to return it to a serviceable condition.

USDI DCS TECHNICAL SUPPORT
MISSISSIPPI TEST FACILITY

Duane M. Preble

U. S. Geological Survey

The objective of the technical support effort is to provide hardware and data processing support to DCS users so that application of the system may be simply and effectively implemented. Data processing support services are being handled by Dick Paulson of the U. S. Geological Survey in Harrisburg, Pennsylvania. Technical support at Mississippi Test Facility (MTF) is concerned primarily with on-site hardware.

The first objective of the DCP hardware support was to assure that standard measuring apparatus and techniques used by the USGS could be adapted to the DCS. The second objective was to try to standardize the miscellaneous variety of parameters into a standard instrument set. The third objective was to provide the necessary accessories to simplify the use and complement the capabilities of the DCP.

The first objective has largely been met. These parameters and their interface are outlined in Table 1. About 50% to 70% of USGS, WRD sites are used to measure surface water or groundwater elevation. These requirements are easily met using the Stevens ADP wired directly to the DCP parallel digital input or with the F&P ADR and a memory interface which is also wired to the DCP parallel digital input. Another standard USGS measurement situation is the line operated water quality monitor. This equipment punches a value which is proportionately equivalent to QW parameters (standard four are dissolved oxygen, conductivity, pH, and water temperature) on paper tape via a servoed F&P ADR. Interface to the DCP is accomplished by sequentially storing the values punched in the Bristol Datamaster (USGS land line telemetry equipment) flip flop memory which is wired to the DCP parallel digital input. Water quality monitors have also been interfaced by connecting the signal conditioner outputs directly to the DCP analog input. Voltage limiters (series resistor and parallel zener diode) were placed in the analog line to prevent out of specification voltages from being applied to the DCP input. A few thermal sites have been instrumented. Both platinum and thermistor type probes have been used. Probes are connected to signal conditioners which are programmed "on" only during the DCP 'Data Gate' "on" time. Output from the signal conditioners is fed to the DCP analog input. The signal conditioner case and line shields should be well grounded and kept out of the antenna field. If these precautions are not taken, the generated r-f power will affect the input voltage.

There are at least three other types of sites which require different parameters and interfaces; these are evapotranspiration, meteorological and battery operated water quality. Efforts to instrument these types of sites will be proceeding in the next few months. These sites, parameters and interfaces are outlined on the bottom half of TABLE 1. The meteorological and evapotranspiration site parameters are temperature (dry air, wet bulb and water), tipping bucket rain gauge, pressure (barometric or water stage), solar radiation and wind speed and direction. All but temperature will use digital techniques to produce an average or integrated output. Temperature will use the data gate programmed signal conditioner. A second new type of site will be the battery operated water quality site. The sensor basket must be in situ as there will be no power to drive pumps. Four basic parameters (dissolved oxygen, pH, conductivity and temperature) are

TABLE 1. - CURRENT USGS DCP INTERFACING

	PARAMETER	INTERFACE	DCP INPUT
Ground H ₂ O Level	Shaft Position Water Level	Stevens ADR with Mod. A wired direct to	parallel digital
		Fischer and Porter ADR with Memory Interface to	
Water Qual. Site	Temperature Dissolved Oxygen Ph Conductivity	USGS WQM and F&P ADR connected to Bristol Datamaster (land line telemetry). Datamaster memory wired to	parallel digital
	Temperature	Data Gate Programmed Signal Conditioner to	analog
FUTURE INTERFACE EFFORTS			
Weather	Temperature (1) Tipping Bucket Rain Gauge Pressure, Barometric or other Solar Radiation Wind Speed Wind Direction	Data Gate Prog. Sig. Cond. Integrating Counter Stored Digital Reaching Integr. Counter (Analog to Freq) Integrating Counter 4 Quadrant Averaging	analog parallel digital " " "
	Battery Powered	Temperature (2) Conductivity Ph Dissolved Oxygen (D.O.)	Stored digital reading parallel digital

presently being planned. The site will be periodically programmed "on" for about one to two minutes, readings will be taken and digitally stored, and then the system will be subsequently shut down. The digitally stored values will be connected to the DCP parallel digital input.

Many miscellaneous accessories are required to maintain program operation. MTF support has supplied cables, batteries, power supplies, lengthened antenna cables, etc. Three items currently under development or investigation include a solar power supply, small antennas and DCP memory.

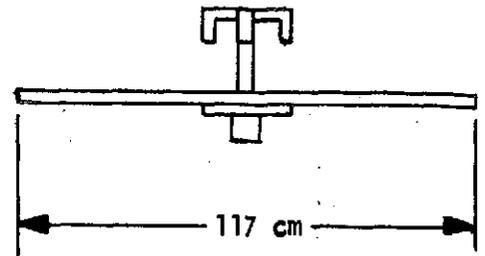
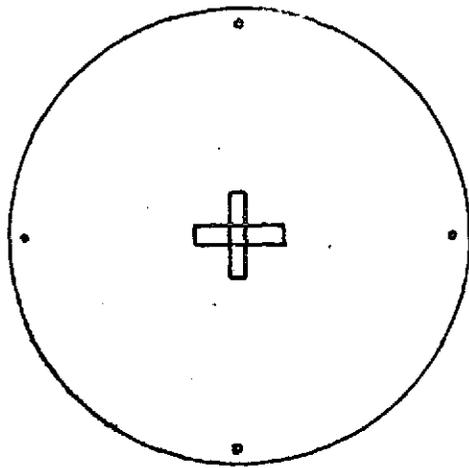
Several solar power supplies are either being installed or are being used by the Arizona USGS and Pennsylvania USGS. These units have a panel size of 15 x 51 cm (6 x 20 inches). They are equipped with a 2 amp/hr. rechargeable, sealed, lead acid battery and a regulator which floats the battery set at the recommended 2.15 volts per cell (25.8 volts for 12 cells). The battery has enough capacity to supply the DCP (on 180-second transmission interval) with 3 weeks of power without any charging. Only 20 hours of sunshine are required during that 3-week period to maintain full battery voltage (about 4% duty cycle). Units are available from Spectrolab of Sylmar, California, as Model LECA 24V1.5W, (note application) for about \$200 each.

The most awkward part of shipping or installing a DCP is the handling of its 117 cm (46 inch) antenna. Several tests have used other antennas. One test performed by Kee of NAVOCEANO confirmed that the Chu and spiral antennas both perform adequately. Figure 1 describes the results of a test performed jointly by USGS and NOAA at MTF. This test compares the Chu volute antenna with the presently used ERTS antenna. The upper half of Figure 1 shows comparative scale sketches of the two antennas. As can be seen, the Chu antenna is much smaller. Both antennas were operated with DCP's which had fixed digital inputs and were on a 90-second transmission rate. They were operated at different power levels over the period of November 27 to December 19, 1972. The number of messages possible was calculated from satellite orbital information and compared with the number of '7' level messages received. The Chu antenna was from 46% to 104% as effective as the ERTS antenna. The average figure was 78%. However, at higher power levels (6W), it appears that the Chu will perform adequately for most sites. A 10% reduction in message number may not be too great a price to pay for easing transportation and installation problems. Antennas are available from Chu Association of El Cajon, California, for about \$300 each.

A final item which is currently out on invitation to bid is a DCP memory unit. The purpose of this unit is to allow previously stored data to be transmitted as well as real time data. Most DCP sites have 3-15 messages completed per day. If a 90-second transmission rate were used, 3-15 messages per 12-hour period would be completed. The memory functions and controls are outlined in Figure 2. Twelve memory sets consisting of 64 bits each will be available. The formatted bit stream will be interrupted just prior to entry into the DCP encoder. This allows the DCP analog and digital inputs to be used to convert and format the inputs. There are four formatting controls in the memory: Write frequency, number of active memory sets, bit length of memory set, and number of bits stored per write cycle. An example of the way these controls are used might be:

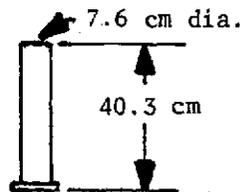
Number of memory sets used	12
Active bit length of memory	30
Number of bits stored per write cycle	30
Write frequency (Determines the number of data gate pulses between write cycles)	41
41 x 89 sec. trans. interval = 1.01 hours.	

This setting would allow 30 bits to be stored each write cycle. Each transmission would be composed of 34 bits of stored data (30 bits memory and four bits memory set I.D.) and 30 bits of real time data. Each write cycle would store data in a different memory before it started over with set one; therefore, since about a one-hour write cycle has been



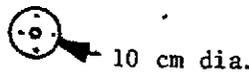
GE-ERTS DCP ANTENNA

401 MHz
CHV ANTENNA
El Cgion, Calif.



SCALE

2.540 cm (1 inch) = 50.8 cm (20 inches)



ERTS + CHU ANTENNA COMPARISON TEST USSS, NOAA 1-73									
RF POWER		GODDARD			GOLDSTONE			% CHU	
		POSSIBLE	RECEIVED	%	POSSIBLE	RECEIVED	%	% ERTS	
6.0W	CHU	81	32	39.5	92	33	35.9	92.5	Gd
	ERTS	96	41	42.7	100	38	38.0	94.5	Gs
3.0W	CHU	75	13	17.8	109	10	9.2	60.0	Gd
	ERTS	74	22	29.7	115	23	20.0	46.0	Gs
0.6W	CHU	65	18	27.7	74	5	6.8	104.5	Gd
	ERTS	68	18	26.5	79	9	11.4	60.0	Gs
0.3W	CHU	60	14	23.3	79	19	24.0	72.0	Gd
	ERTS	68	22	32.4	90	27	30.0	80.0	Gs
TOTALS	CHU	279	77	27.6	354	67	18.9	83.0	Gd
	ERTS	306	100	32.7	384	97	25.2	72.5	Gs

TEST PERIOD NOV. 27 TO DEC. 19, 1972
 COMPARES MESSAGE POSSIBLE TO 7 QUALITY MESSAGES RECEIVED

Figure 1. Antenna test performance

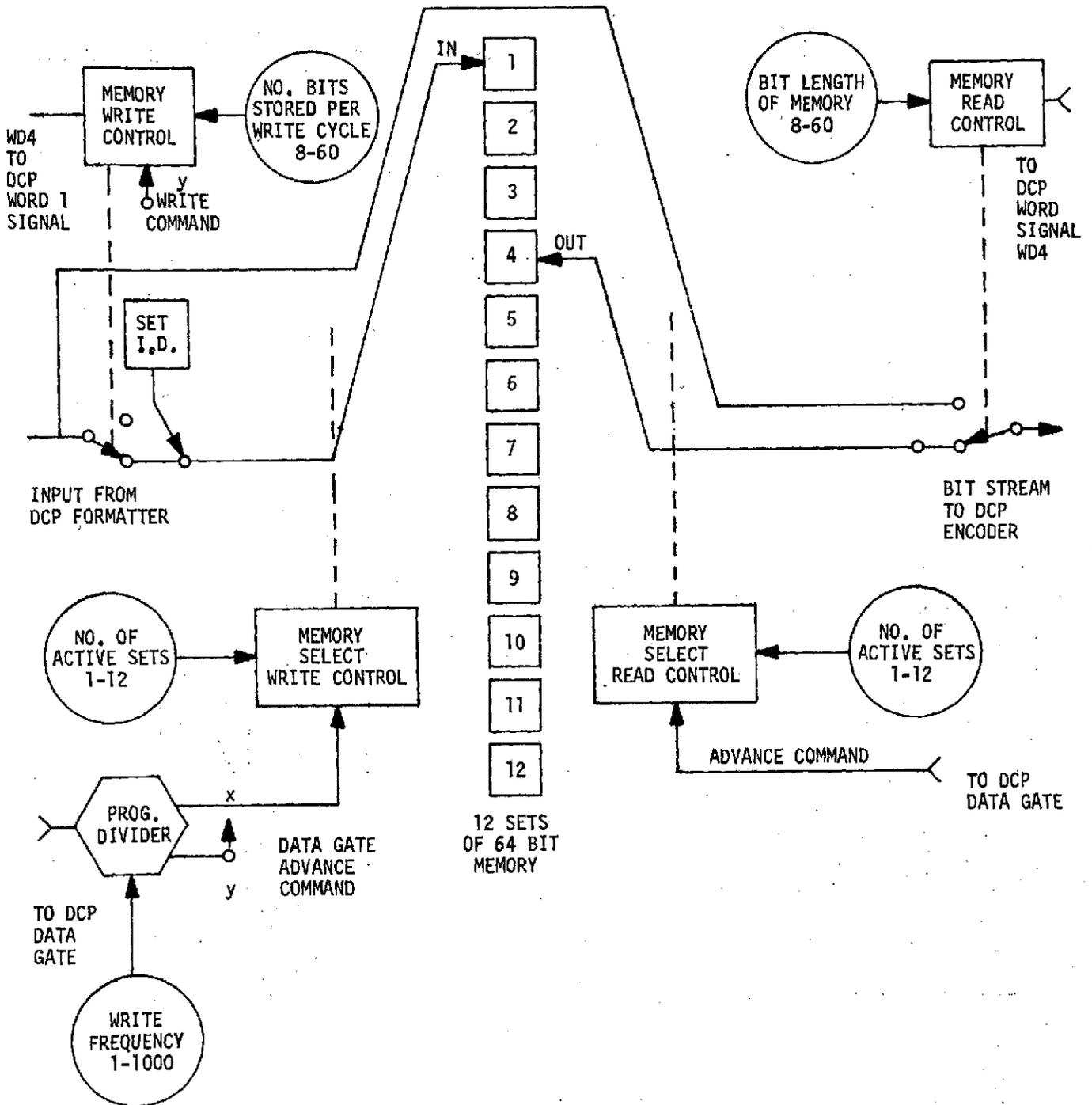


Figure 2. DCP memory accessory

chosen there would be 12 hours of data in storage. Twelve transmissions would be required to transmit all stored data; subsequent transmissions would step through all 12 memory sets and repeat. These controls were selected to provide maximum versatility for both data and site selection. TABLE 2 illustrates the improvement provided by the memory unit. Use of this memory unit should provide an interesting capability to the present data collection system.

In summary, the standard USGS sites have been interfaced and are presently operating. These sites are stream gauge, ground water level and line operated quality of water. Evapotranspiration, meteorological and battery operated quality of water sites are planned for near future DCP operation. Three accessories which are under test or development are the Chu antenna, solar power supply and add-on memory.

The DCP has proven to be relatively easy to interface with many monitors. The large antenna is awkward to install and transport. The DCS has met the original requirements well; it has and is proving that an operation, satellite-based data collection system is feasible.

It is hoped that the technical support has been and will continue to be effective in aiding in the application and expansion of the ERTS DCS.

TABLE 2.- MEMORY BIT ASSIGNMENT

STAGE

DATA REPORTED FROM DCP WITH NO MEMORY

I.D. TIME CODE
 6230 GMT
 145034055
 PST
 144 20 40 55

WORD - 8 BITS EACH

1	2	3	4	5	6	7	8
STAGE	STAGE	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK

16.24 REPRESENTS STAGE VALUE PUNCHED AT 2000

MEMORY ADDED TO DCP

I.D. TIME CODE NO. BITS
 6230 145 03 40 55
 6230 145 03 45 45
 6230 145 03 46 34
 6230 145 03 49 24

	4	15	15	15	15
I. D.	HR 2000	HR 1900	HR 1800	HR 20 STAGE	
I. D.	HR 1700	HR 1600	HR 1500	HR 20 STAGE	
I. D.	HR 1400	HR 1300	HR 1200	HR 20 STAGE	
I. D.	HR 1100	HR 1000	HR 0900	HR 20 STAGE	

AUXILIARY DCP DATA ACQUISITION SYSTEM

Robert V. Snyder

NASA Wallops Station

Introduction

My talk will hopefully acquaint you with an airborne DCP Data Acquisition System designed to augment the ERTS satellite data recovery system. The DCP's are data collection platforms located at pertinent sites. With the appropriate sensors they are able to collect, digitally encode and transmit environmental parameters to the ERTS satellite. The satellite in turn relays these transmissions to a ground station for processing. The satellite is available for such relay duty a minimum of two times in a 24-hour period. The purpose of the subject equipment is to obtain continuous DCP data during periods of unusual environmental activity--storms, floods, etc. Two circumstances contributed to the decision to design such a system; (1) Wallops Station utilizes surveillance aircraft in support of rocket launches and also in support of earth resources activities; (2) the area in which Wallops is located, the Delaware and Chesapeake Bay areas, are fertile areas for DCP usage. Therefore, by developing an airborne DCP receiving station and installing it on our aircraft we could provide more continuous DCP data from sites in the surrounding areas at relatively low cost.

Data Acquisition System Operation

The equipment consists of a 400 MHz telemetry receiver, a cassette data recorder and the black box containing the electronic circuitry necessary to process the received video and control the cassette recorder. The equipment is designed to require a minimum of attention aboard the aircraft and to provide, on a tape cassette, a high density of recorded DCP data. This data is then to be inputted via a PCM input equipment to Wallops' telemetry computer for the generation of a binary tape of desired format. The observation range of the equipment is estimated to be in excess of 160.9 km (100 miles) depending on aircraft altitude.

The electronic box, 11.32 cm (5 1/4 inches) high, rack-mounted, receives the detected video, develops the data clock, decodes the received data, determines errors, time tags the data and stores it in temporary semiconductor storage (see Figure 1). This data is formatted, including sync words, for inputting via the PCM system into Wallops' telemetry computer. When the temporary semiconductor storage is full, or a dump button is depressed, the cassette recorder is automatically started and after several seconds of data preamble, the data is dumped onto the tape and the recorder stopped. The dump process requires about 12 seconds and results in relatively high density storage on the magnetic tape and a limited semiconductor storage requirement for the system (see Figure 2).

The telemetry computer can then be programmed to provide a binary tape of the desired format for later data analysis.

System Components

The electronics consist primarily of Transistor-Transistor Logic (TTL) integrated circuits (in excess of 100 chips) and approximately 40 Metal Oxide Semiconductor (MOS) chips, which provide for semiconductor buffer and mass storage. Additional Complimentary Metal Oxide Semiconductor (CMOS) chips are presently being added to provide a battery operated time-of-day function. The semiconductor storage is 40,000 bits and provides for storage of 250 DCP data bursts along with time-of-day and other pertinent information as well as necessary

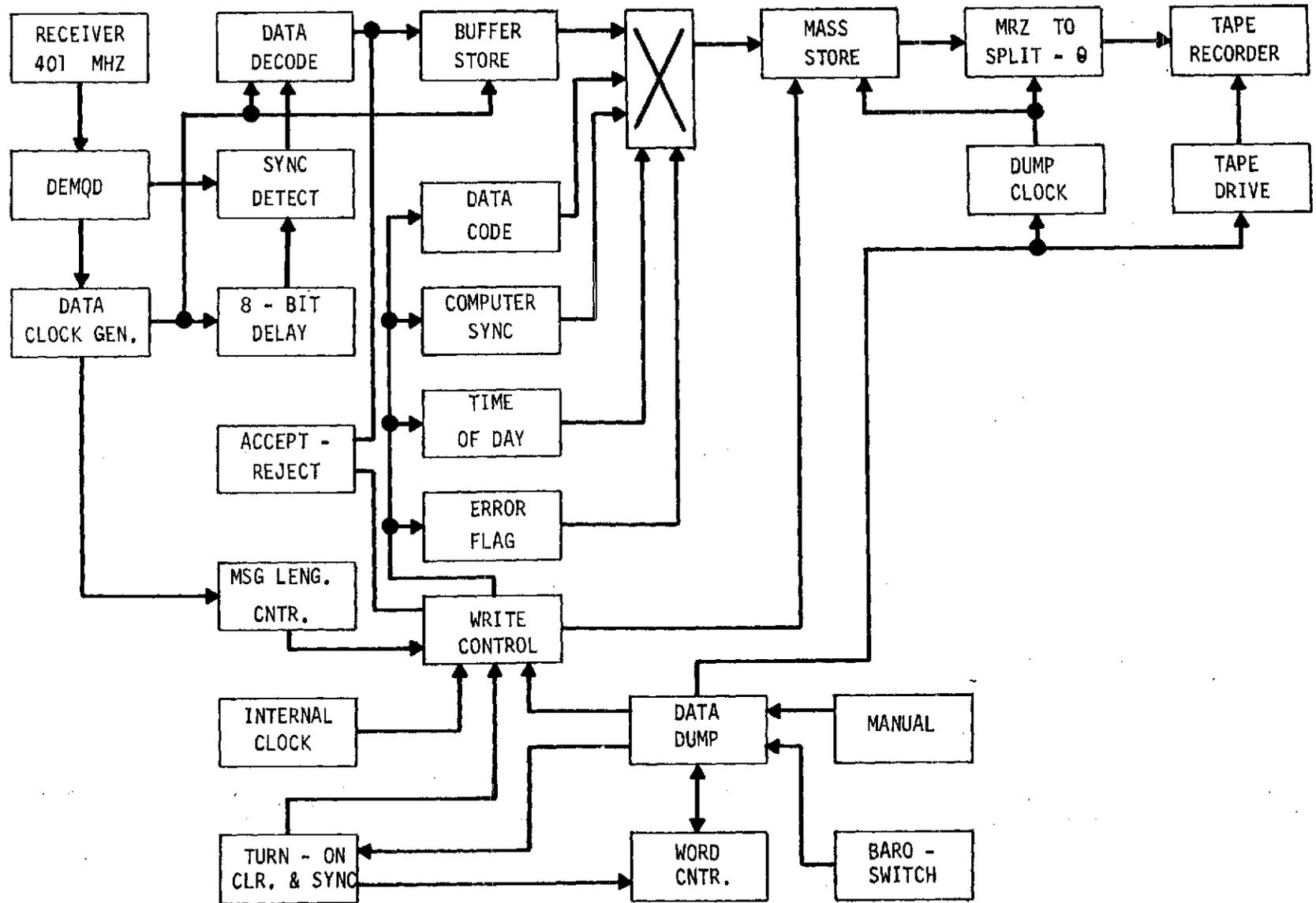
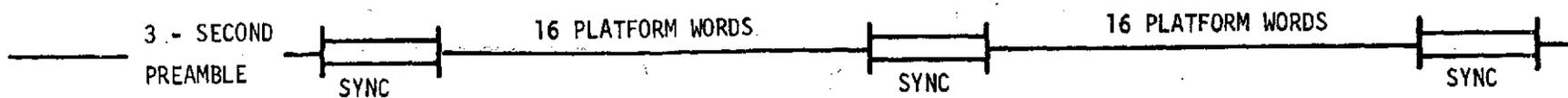


Figure 1. DCP Data acquisition system



A DUMP MAY INCLUDE FROM 0 TO 250 PLATFORM WORDS



PLATFORM WORD - 160 - BITS

Figure 2. Data dump format

computer input sync word requirements. The system organization can best be followed by referring to the block diagram.

The raw, coded, bi-phase digital data is used for the generation of a data clock. After an 8-bit delay, during which the clock period must be compatible with data rate constraints, the raw data is passed through to the sync detector. Upon receipt of a sync bit ("1") the message length counter is preset to 159 and subsequently clocked by the generated data clock to zero. This counter must be clocked to zero as one of the data acceptance criteria. As the data is clocked in, it is divided into odd and even bit streams and decoded with the inverse process by which the convolutional coding was achieved. The decoding process generates two data bit streams (dual decoder), these dual bit streams are sequentially checked for equivalence to determine the presence of errors. If an error should occur during the reception of the platform I D number, first 24 raw data bits, the data is rejected; if an error occurs during the last 136 raw data bits, the data is retained but an error flag is added to the data code word. The decoded data is clocked into the data buffer store as it is received and decoded. The write control now strobes the data, properly flagged, into the semiconductor mass storage with a 1 MHz internal clock. The write control also adds the time-of-day and other identifier bits and, when required, inserts a computer sync word into the data stream. A manually actuated data read-out circuit displays the latest received data on Light Emitting Diode (LED) front panel lights in 16-bit bytes. When the word counter achieves 250 counts (storage full), the dump circuits are automatically actuated and the stored data, preceded by a proper preamble (to permit a computer clock-lock) is converted to bi-phase and recorded on the cassette tape. The cassette is automatically started and stopped. The dump process requires approximately 12 seconds. The data dump process can also be initiated manually and the possibility of using a modified baro-switch to initiate dump is being considered. A baro-switch initiated dump would provide a data jump upon aircraft landing and insure that no data would be lost at prime power turn-off. This would permit the data acquisition system to be utilized with minimum attention, only requiring removing and inserting a cassette tape. A 30 minute cassette can store almost 20,000 DCP emissions on each side of the tape.

Alternate Potential Uses

The input, decoder and read-out portions of this equipment, approximately 45 chips, lend themselves, with minor modifications or additions, to several other potential uses.

With the addition of rf down-converter circuits and a demodulator, an abbreviated version of this equipment would make possible an operational field check of DCP's. Such a device could be used to quickly and simply make a field check of newly emplaced DCP's or those exhibiting questionable operating results. A check of radiated 400 MHz field strength could be made as well as a complete read-out of the status of the sensors. This sensor read-out would be made in the DCP's operating mode, that is, via the 400 MHz radiations. This equipment could be packaged in a small hand-held device. For such use, the TTL chips should be replaced with CMOS chips and the unit could be operated from a small self-contained battery. CMOS pin for pin replacements of the TTL chips are available for most of the presently used chips.

Another possible modification could include the addition of several asynchronous first-in-first-out (FIFO) buffer chips. This could permit direct digital printing on paper tape of received DCP data. Several buffer FIFO chips should provide adequate buffering to properly receive and print out data from a dozen DCP's. For such an application several additional chips would be required for printer control.

With suitable modification, it would be possible to read the cassette-recorded data back into the system and either print it out as above or use the manual read-out for manually recording the data.

With the addition of a phase-lock loop type FM demodulator, it may be possible, with a suitable T/M auto tracking antenna, to receive DCP relayed data directly from the ERTS satellite. In a recent field test, a 3.05 meter (10-foot) mobile tracking antenna system was utilized and the ERTS satellite was tracked. The DCP data sideband was observed using conventional T/M receivers, 100 KC IF bandwidth and no phase-locked loops. The signal-to-noise ratio (gross estimate) varied between 3 db and perhaps 6 or 7 db depending upon the satellite elevation angle. If a phase-lock loop receiver system could permit an IF bandwidth of 30 or 50 kHz to be used, then a 5 db detector threshold (phase-lock demodulator) should permit such a system (3.05 meter tracker) to be useful as a mobile ground station. Such a relatively inexpensive system would allow DCP usage in areas of the world where no ground stations presently exist.

DCS TRACKING SYSTEM

ROBERT KEE

United States Naval Oceanographic Office

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SPACE DATA RELAY SYSTEMS

Charles E. Cote

NASA Goddard Space Flight Center

Introduction

Over the past decade, earth orbiting satellites have proven invaluable in the acquisition of quantitative data related to the earth and its environs. Significant technology developments have been realized in remote sensing and in-situ or direct sensing. The latter area has been served by location and data collection systems. These systems provide a means of monitoring remote unattended sensory platforms through radio communications on a global scale. Tracking applications such as balloons or buoys positioning techniques are based on platform-to-satellite measurements of range, doppler, or through relay of ground navigation signals (e.g., Omega). In fixed site applications, multiple readings of sensors may be monitored daily or hourly from local or remote areas.

The development of location and data collection systems began in the 1960's and has continued to the present. Throughout these years, a never ending goal has been to improve techniques in the interest of user needs and applications. In addition, the application of existing concepts to new areas has been continually pursued. User participation in experimental systems has been encouraged and has proven invaluable in judging performance and determining future requirements. These requirements served to guide later technology development. Foremost among needs has been a desire for lower cost, less sophisticated platform equipment. Significant progress has been achieved in this area, and efforts will continue.

Ordered Systems

In the early 1960's meteorologists developed quasi-Lagrangian measurement techniques for constant level balloons using ground radio tracking. Under programs such as GHOST¹ (Global Horizontal Sounding Techniques) superpressure balloons became viable monitoring platforms. With the advent of satellite technology, developmental research began within NASA and CNES* on system techniques to track constant level balloons on a global scale. By 1969, NASA had developed and tested two concepts: the ATS/OPL² (Application Technology Satellite/Omega Position Location Equipment) and the Nimbus-3/IRLS³ (Interrogation, Recording and Location System). By 1971, experimental operations were underway with the Nimbus-4/IRLS⁴ and the CNES/EOLE⁵ (Derivative of Aeolus, Greek god of the winds). The designs, features and experimental results are well covered in the reference material; however, Table I lists system aspects which reflect improving technology and system designs in accordance with user needs.

TABLE I

	Platform Weight (kg)	Number of Platforms per orbit
OPL/1968	16	40
IRLS/1969	11	10
IRLS/1970	4.5	185
EOLE/1971	3.2	511

*Centre National d'Etudes Spatiales

In this tabulation, the weight of platform equipments shows a downward trend with time, while system capacity increases. Likewise, platform costs were reduced from approximately 50K to 10K per unit. As a result, considerable user interest and participation was devoted to the latter two systems by investigators from Governments and private institutions. In addition to meteorological balloon tracking, experimentation was carried out in oceanography (buoys), geology (volcano monitoring), wildlife monitoring (animal tracking) and sea/ice studies (ice island tracking).

Fundamental to each of the above systems is an ordered or regimented multiple access scheme. In operation, platform transmissions are initiated by satellite command. The sequential execution of commands enables interrogation of multiple platforms. This technique offers great versatility in platform selection and precludes mutual interference between platform transmissions. However, this is accomplished at the expense of added platform hardware. In particular, receiver and antenna diplexing equipment are required. Also, command synchronization and decoding circuitry must be incorporated. The result of all this is added weight, cost and power requirements. Consequently, emphasis within NASA turned toward system concepts compatible with minimum platform requirements and even greater capacities. The use of random access schemes in combination with Doppler-only tracking techniques emerged. Additionally, concepts compatible with reduced sophistication in ordered systems were investigated.

Random Access System

As the platform design became the nodal point of system design, random access techniques were developed for the ERTS⁶/DCS (Earth Resources Technology Satellite Data Collection System) and the Nimbus-F/TWERLE⁷ (Tropical Wind, Energy Conversion and Reference Level Experiment). The rationale was to utilize transmit only platforms controlled by unsophisticated timers operating at low duty cycles. An additional departure from previous techniques was incorporated into the ERTS design. The DCS system was not required to provide location capability; data collection from fixed sites was needed to provide ground truth for remote sensing experiments. Previously, both features were incorporated into system designs.

The technique devised for ERTS is described in detail in Reference 8. In summary, however, the system accommodates 1000 platforms simultaneously in the field of view of the spacecraft antenna. DCP (Data Collection Platform) transmissions occur in bursts at random times and at random frequencies within a 100 kHz predetection bandwidth ($f_0 = 401.55\text{MHz}$). This gives rise to the possibility of mutual interference between transmissions. This is resolved by selecting a duty cycle which provides 180 sec. between successive 30 millisecond transmissions (duty cycle - 1/6000). Each transmission contains an identifier code and eight coded sensor readings (8 bits each). Convolutional coding of Manchester data is used to improve the channel bit error rate. On the basis of these parameters, DCP's requiring 5 watt transmitters operating into moderate gain antennas (2-3 dB) were designed. In support of the ERTS-1 mission launched in July 1972, 200 DCP's were deployed by user agencies throughout the western hemisphere.

A Random Access Measurement System^{8,9} (RAMS) is under development for the Nimbus-F/TWERLE experiment beginning in June 1974. During the experiment, 400 constant level meteorological balloons will be launched from the tropics. The RAMS equipment aboard the Nimbus-F satellite will provide a means of tracking and collecting data from up to 1000 platforms per orbit; design details are contained in the reference material. In summary, the system performs satellite on-board processing of up to eight simultaneous platform transmissions. Received data is stored aboard the satellite for readout every 108 minutes (orbital period); platform locational coordinates and velocity components are determined in a central ground processing facility. The system accuracy goals are +5 km position-location, +1 meter/sec. velocity. The platforms operate at a 1/60 duty cycle and require 600 milliwatt transmitters operating into a moderate gain antenna (4-5 dB). Mutual interference is reduced by time and frequency diversity; the predetection bandwidth

is 30 KHz centered at 401.2 MHz. Each transmission contains a coded identifier followed by four sensor words (eight bits each). The entire payload of a TWERLE balloon configuration is estimated as 1 kg. The electronics portion weighs approximately 400 grams using conventional current design techniques. The low weight and size features of the TWERLE platform are compatible with numerous additional applications. Participation from investigators is anticipated in the areas of oceanography, geology and wildlife monitoring.

The departure from ordered to random access represented a major step forward in meeting user needs. Platform costs and complexity were reduced substantially while system capacities increased. However, ordered systems will remain as is done on the SMS/DCS¹⁰ (Synchronous Meteorological Satellite/Data Collection System) discussed below. For certain applications the versatility of ordered systems is required. Also, with improving designs and component technology advances, platforms can be produced at reasonable cost.

In addition to the new technology activities described above, the application of existing techniques to national needs forms an integral and vital part of NASA's data collection program. A glaring example is the GRAN¹¹ (Global Rescue Alarm Net) program currently underway within NASA, the U.S. Navy and the U.S. Coast Guard. In early 1971, representatives of the respective agencies met informally to discuss the need for a real time distress alerting and alarm reporting system due to the large number of human lives lost each year due to mishaps which pass undetected for days or weeks. Interest was expressed in applying the NASA developed OPLE technique to this problem. At that time NASA had already initiated study and development of an advanced OPLE system with SAR (Search and Rescue) as a principal need. Likewise, efforts were underway within the U.S. Navy on a similar scale. A joint effort was initiated which is continuing at present.

A major objective of experimentation with the GRAN concept is to resolve position-location ambiguities existing within the Omega System. In its current state, phase measurements made on Omega transmissions yield equally likely positions at multiple points on the earth. In fact, an ambiguity exists every 133 km (72 miles). However, through satellite assisted techniques, it appears feasible to position a victim or survivor unambiguously to an accuracy of 3.7 km (+2 n miles). Furthermore, the position computation would be derived within three minutes of the alarm transmission.

In supporting this activity, the original OPLE platform design weighing 16 kg was miniaturized into a 1 kg hand hold unit. The linearity and frequency stability specifications of the original design were retained in the interests of phase measurement precision during ambiguity studies. However, less complex designs will be tested once the ambiguity work is completed.

Operational Systems

Operational facilities are currently planned in conjunction with the SMS/GOES and Tiros-N satellite series. Both systems draw upon NASA developed technology, with SMS providing data collection through interrogated platforms and TIROS-N using random access to provide data collection and position-location. Facilities are currently planned through 1980, with initial launches scheduled in early 1974 and late 1977 respectively. In addition, an ERTS-B mission is scheduled for early 1976, and will utilize the system described for ERTS-1.

The SMS and Tiros-N satellites are being developed by NASA for the National Oceanic and Atmospheric Administration (NOAA). In operation, the SMS will have a nominal capacity of 10,000 platforms, with data rates and message length highly variable. Current plans call for sequential interrogation of all platforms every six hours. NOAA is providing data distribution through eight level teletype code in ASCII format (American Standard Code for Information Interchange).

The Tiros-N system is being developed by CNES under NASA management. Although definitive

plans and designs have not been formulated, the system is expected to have a capacity of 2,000 platforms on a global scale. Platform size, weight and power characteristics are comparable to those of the Nimbus-F/TWERLE system.

System Comparison

In TABLE 2, a launch schedule of upcoming data collection missions is shown. The systems are grouped on the basis of data collection only capability and data collection with position-location. Assuming a three to five year lifetime for the synchronous missions (SMS/GOES), and one to two years for the low altitude facilities exist through 1980. Conceptually all systems operate in an analogous manner, i.e., remote or in-situ data is collected from unmanned platforms. However, a major distinction exists between the tracking and data only systems due to their applications. TABLE 3 contains system parameters which illustrate the areas of commonality and differences for the above systems.

As shown, characteristics of the position-location systems are quite comparable. The only major difference exists in the platforms data rates (Nimbus F - 100 b/s; Tiros N - 400 b/s). This in turn accounts for the difference in platform transmitter power. In application, the Nimbus system is tailored to meteorological balloon requirements which place emphasis on minimum power and weight. The platforms are powered by solar cell only, although battery power may be employed in non-balloon applications. Tiros-N was configured more toward oceanographic buoy applications. The system data format is variable in that from four to 32 channels of sensor data are available with each transmission. Both Nimbus and Tiros systems use the Doppler effect for deriving position coordination of moving platforms. In applications where position is not required, requirements on the platform specifications may be somewhat reduced; the frequency stability and transmit duty cycle can be relaxed.

The data only systems differ in operation, complexity and coverage. This is caused primarily by the orbital characteristics of the satellites. However, differing data rates and modulation techniques have also been selected. Theoretically, both systems are compatible with random access, however, the six hour synoptic sampling period for SMS meteorological and environmental data users places stringent demands on low duty cycle timers. Since all platforms are continuously in view, increased duty cycles would result in enormous amounts of data. An ordered or regimentated scheme is therefore used in the interest of data management. The increased path loss to synchronous orbit requires additional platform radiated power. As shown in TABLE 3, increased platform antenna gain (10db) is used in the SMS system. Operation at lower power levels, however, is possible by increasing signal integration times or through use of earth coverage satellite antennas.

Summary

Significant progress has been achieved in simplifying platform concepts through random access techniques. This is particularly important in applications such as balloons where weight is critical. In applications, where weight restriction may not be a problem (e.g., ERTS), the concept lends itself to uncomplicated designs and low cost. Nevertheless, ordered systems offer inherent advantages in managing data flow (e.g., SMS) which justifies their use. With continuing improvements in technology, particularly low power receivers, ordered systems should become quite competitive with random systems for many applications. Future developments directed toward this end will be encouraged.

Additional considerations for the future must also be directed toward operational system requirements. In particular, commonality and standardization between low and synchronous orbit systems platforms is vitally needed to serve user interests. The launch schedule, through 1980, currently shows ten separate satellites carrying data collection equipment, while four different systems are used. At the present time, commonality between them does not exist. In fact, the question as to whether any system contains growth capability

TABLE 2. - DATA COLLECTION MISSION SCHEDULE

NO POSITION LOCATION	1972	1973	1974	1975	1976	1977	1978	1979	1980
ERTS 1	△								
SMS A			△						
SMS B			△						
GOES			△						
ERTS B					△				
POSITION LOCATION									
NIMBUS F			△						
TIROS N						△			
NOAA A							△		
NOAA B								△	
NOAA C									△

TABLE 3. - DATA COLLECTION SYSTEM PARAMETERS

SYSTEM CHARACTERISTICS	POSITION LOCATION		NO POSITION LOCATION	
	NIMBUS F	TIROS N	ERTS	SMS/GOES
MULTIPLE ACCESS	RANDOM	RANDOM	RANDOM	COMMANDED SELF TIMED
COVERAGE	GLOBAL	GLOBAL	2/3 OF WESTERN HEMISPHERE	EARTH DISK
PLATFORM CAPACITY	200 IN VIEW	200 IN VIEW	1,000 IN VIEW	10,000/6 HOURS
FREQUENCY (MHz)	401.2	401.65	401.55	402
PLATFORM REQUIREMENTS				
TRANSMITTER POWER	600 MILLIWATTS	3 WATTS	5 WATTS	5 WATTS
ANTENNA GAIN	2-3 dB	2-3 dB	2-3 dB	13 dB
BIT RATE (b/s)	100	400	2,500	100
WEIGHT (ELECTRONICS)	454 GRAMS (1 POUND)	560 GRAMS (1.2 POUNDS)	4.1 KILOGRAMS (9 POUNDS)	5.5 KILOGRAMS (12 POUNDS)
DATA CHANNELS	4	4-32	8	8

for the future should also be addressed. However, user interests would be well served with designs which allow platforms to operate with the various satellites, and even more importantly, on successive follow-on missions. The non-recurring costs of hardware development for each mission would be replaced by lower recurring production costs. NASA is devoting effort to this problem while also bearing in mind future growth requirements. Through continued user contact and technology improvement, effort is being devoted to the formulation of rational cost-effective approach to future location and data collection systems.

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OPERATIONAL SATELLITE DATA RELAY SYSTEMS

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PAPER NOT AVAILABLE AT TIME OF PUBLICATION

ERTS-1 DATA COLLECTION SYSTEM

STATUS AND PERFORMANCE

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System Description

The Data Collection System flown on the first Earth Resources Technology Satellite (ERTS-1) relays earth resources data from remotely located in-situ sensors to Goddard Space Flight Center (Figure 1). Data is received at Goddard at least twice each day from every sensor installation and is distributed to users (who operate the sensors and transmitters) by mail and teletype.

The system (Figure 2) consists of a data formatting and transmitting unit, called the Data Collection Platform (DCP), a receiver and a retransmitter aboard ERTS-1; and receiving, demodulating and decoding equipment located at the Goldstone, California and Goddard data acquisition stations. Data is transmitted from the data acquisition stations to the ERTS Control Center at Goddard, then to the NASA (ERTS) Data Processing Facility (NDPF) where it is processed and distributed to users.

A sample of data from each of as many as eight sensors is accepted by the DCP in either analog or digital form. The DCP converts the analog data to digital form, adds a DCP identification number, encodes the data for error control purposes, and transmits it at 401.55 MHz in an omnidirectional pattern at a nominal level of 10 watts.

When the MHz spacecraft is within range (about 3,000 km, the DCP transmission is received onboard and converted to an intermediate frequency (IF) by the on-board receiver. The IF modulates the unified S-Band transmitter as a subcarrier and is retransmitted at 2287.5 MHz, again in an omnidirectional pattern. The transmit power is nominally one watt. If the spacecraft is within range (300 km) of one of the data acquisition stations at Goldstone or Goddard at the same time it is receiving and retransmitting a DCS message, the transmission is received by the 9.14 M (30 foot) dish and Unified S-Band receiving equipment at the station. The subcarrier containing DCS data is recovered and applied to the DCS Receiver Site Equipment (RSE) unit.

The DCS/RSE demodulates, digitizes and decodes the data, assigning quality confidence bits to the messages. Also, time of reception is added to the message format and the data are transmitted via the NASA Communications System (NASCOM) to the ERTS Control Center at Goddard.

In the Control Center the DCS data are arranged on computer compatible digital tapes which are forwarded to the NDPF. NDPF screens the data for quality and produces computer listings and punched cards for distribution to users by mail. Data belonging to those users subscribing to the teletype distribution system are separated from the stream, appropriately arranged and forwarded to NASCOM for teletype transmission.

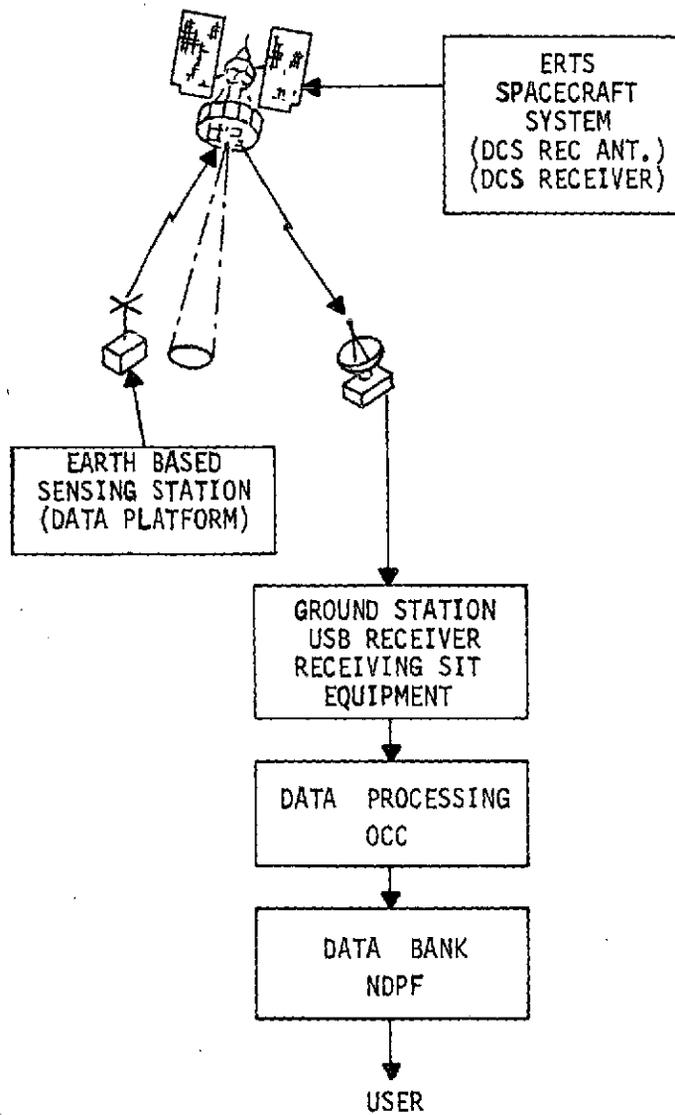


Figure 1. ERTS DCS system description

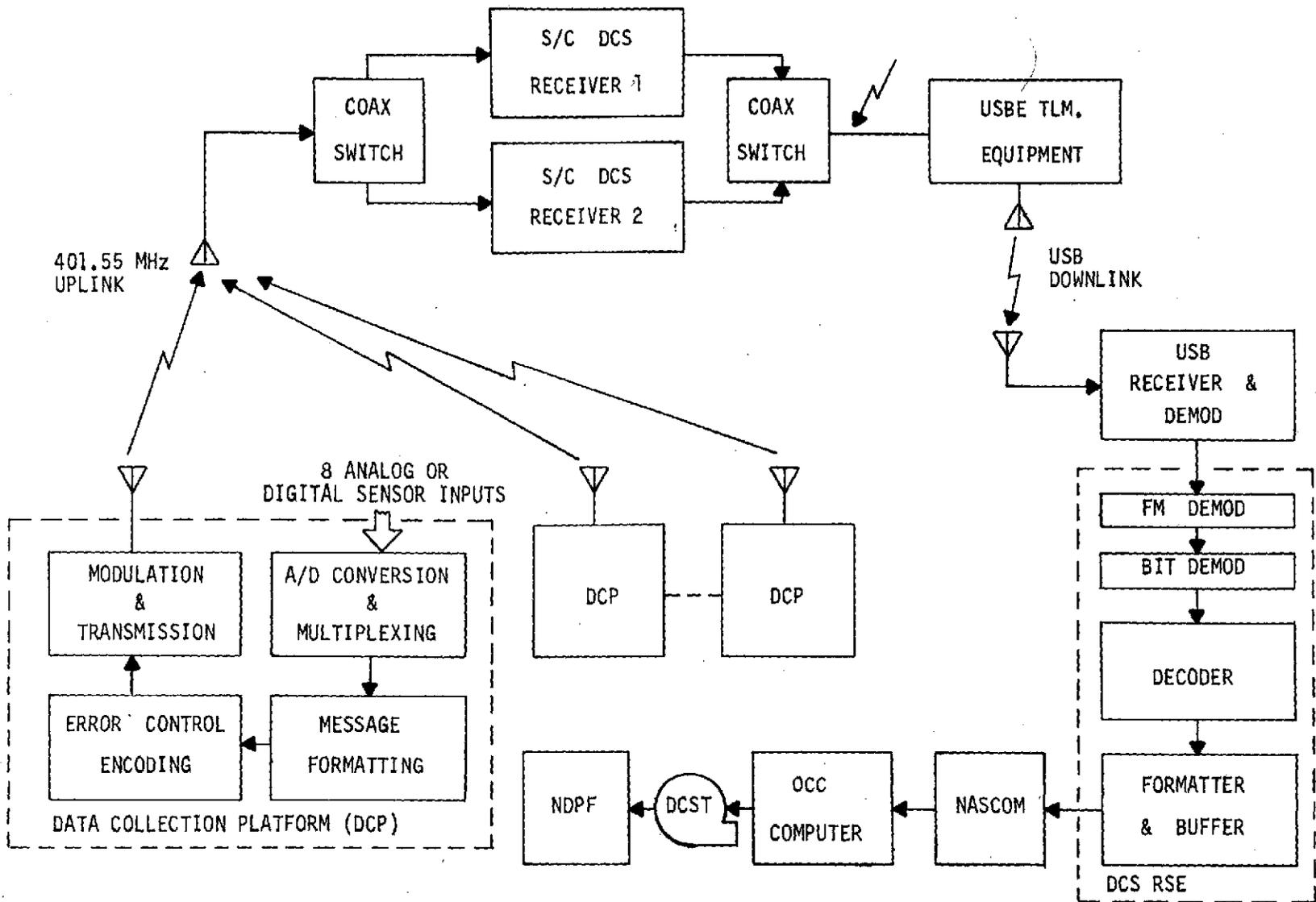


Figure 2. Data Collection System functional block diagram

TABLE 1. - ORGANIZATION USING ERTS-1 DCS

<u>ORGANIZATION</u>	<u>NO. INVESTIGATORS</u>	<u>ASSIGNED DCP'S</u>	<u>ACTIVE DCP'S</u>
FOREIGN (CANADA)	6	14	12
U.S. GEOLOGICAL SURVEY	10	106	58
BUREAU OF LAND MGMT.	1	8	3
FORESTRY SERVICE	1	3	3
CORPS OF ENGINEERS	1	30	21
NAVOCEANO	1	3	0
UNIVERSITIES	4	18	3
STATES	1	1	1
NASA	3	29	4
INDUSTRY	1	2	1
TOTALS	<u>29</u>	<u>214</u>	<u>106</u>

System Implementation

Users of the DCS were originally selected from proposals submitted in response to the ERTS-1 opportunities announcement. Additional users within the Geological Survey have been accepted where their selection resulted in no additional cost to NASA.

A total of 29 users are currently involved in the program (Table 1) representing six federal agencies, one state, one foreign country, four universities, and one industrial firm. These investigators are using the system for eight major application categories (TABLE 2). The most active organization is the U. S. Geological Survey, accounting for one-third the users and one-half the DCP'S. Hydrology is the primary application. Volcanology is second closely followed by water quality. TABLE 3 is a partial list of parameters monitored by the DCS installations.

The system was developed on contracts with the General Electric Company Space Systems Organization and Radiation, Inc. (Melbourne, Fla.). Subsequently, a production contract for 200 DCP's was let to the G.E. Apollo and Ground Systems Division in Daytona Beach, Florida. Test sets, spare modules and manuals were included in the production contract. The first units were delivered in April 1972, to Canadian users. A gap in hardware deliveries occurred in June and July due to production difficulties. Deliveries were completed in November and no future production is planned (Figure 3).

DCP deployment began shortly after launch (Figure 4). Two Users were operating units in a checkout mode at launch (23 July 1972). Deployment proceeded rapidly through the late summer and fall, slowed to a trickle during the winter months and resumed a high rate with the onset of spring weather. About 60% of the DCP's produced are currently active. It is expected that 80% to 90% of the units will eventually be deployed with 10% to 20% held in reserve or in a failed condition at any point in time.

Maintenance and Logistics Support

In addition to the 200 DCP's supplied to users, 25 field test sets, 84 spare plug-in modules and 250 technical manuals were distributed. The prime contractor, G. E., was authorized to make 15 field assistance trips and to provide advisory communications services during the deployment period. A maintenance depot was established at NASA-Wallops Station to facilitate economical repair of failed DCP's. Users can mail failed DCP's or plug-in modules to Wallops for replacement or repair. This service is expected to substantially increase the total "DCP-days" of operation available to users.

The Geological Survey maintains a support service for Survey users at their Gulf Coast Hydroscience Center, located on the NASA Mississippi Test Facility reservation. This service provides replacement of failed hardware, development of interface circuitry and general installation and maintenance services to Geological Survey DCS users.

Operations

A 125 DCP network (Figure 5) is in operation with installations extending from the MacKenzie River in the Canadian Northwest Territory to Honduras and from Iceland to Hawaii. DCP's are transmitting from locations in 22 states and five foreign countries (TABLE 4).

An individual DCP in the network is contacted during two to seven orbits per day, depending upon location (latitude and proximity to a data acquisition station). One to four messages are received during each contact period averaging 17 good messages per day.

Over 200,000 messages have been shipped to users since launch (Figure 6). The current rate is about 10,000 per week. This amounts to 80,000 data samples per week and a cumulative total of more than 1,600,000 samples (assuming all data channels are used).

TABLE 2. - USE OF ERTS-1 DCS BY APPLICATION

<u>APPLICATION</u>	<u>NO. OF USERS</u>	<u>DCP'S ASSIGNED</u>
METEOROLOGY	5	10
HYDROLOGY	20	75
WATER QUALITY	4	26
OCEANOGRAPHY	3	9
FORESTRY	1	3
AGRICULTURE	1	3
VOLCANOLOGY	2	33
ARCTIC ENVIRONMENTS	1	2

TABLE 3. - PARAMETERS MONITORED BY ERTS-1 DCS

RESERVOIR LEVEL	WIND DIRECTION
STREAM FLOW	WINDSPEED
GROUND WATER	HUMIDITY
TIDAL VARIATION	PRECIPITATION
ICE CONDITIONS	SOLAR RADIATION
SALINITY	SNOW DEPTH
DISSOLVED OXYGEN	SNOW WATER CONTENT
TURBIDITY	EVAPORATION
ACIDITY-ALKALINITY	SOIL MOISTURE
BIOLOGICAL CONTENT	EARTH TILT
WATER TEMPERATURE	TREMOR EVENTS
AIR TEMPERATURE	EARTH TEMPERATURES

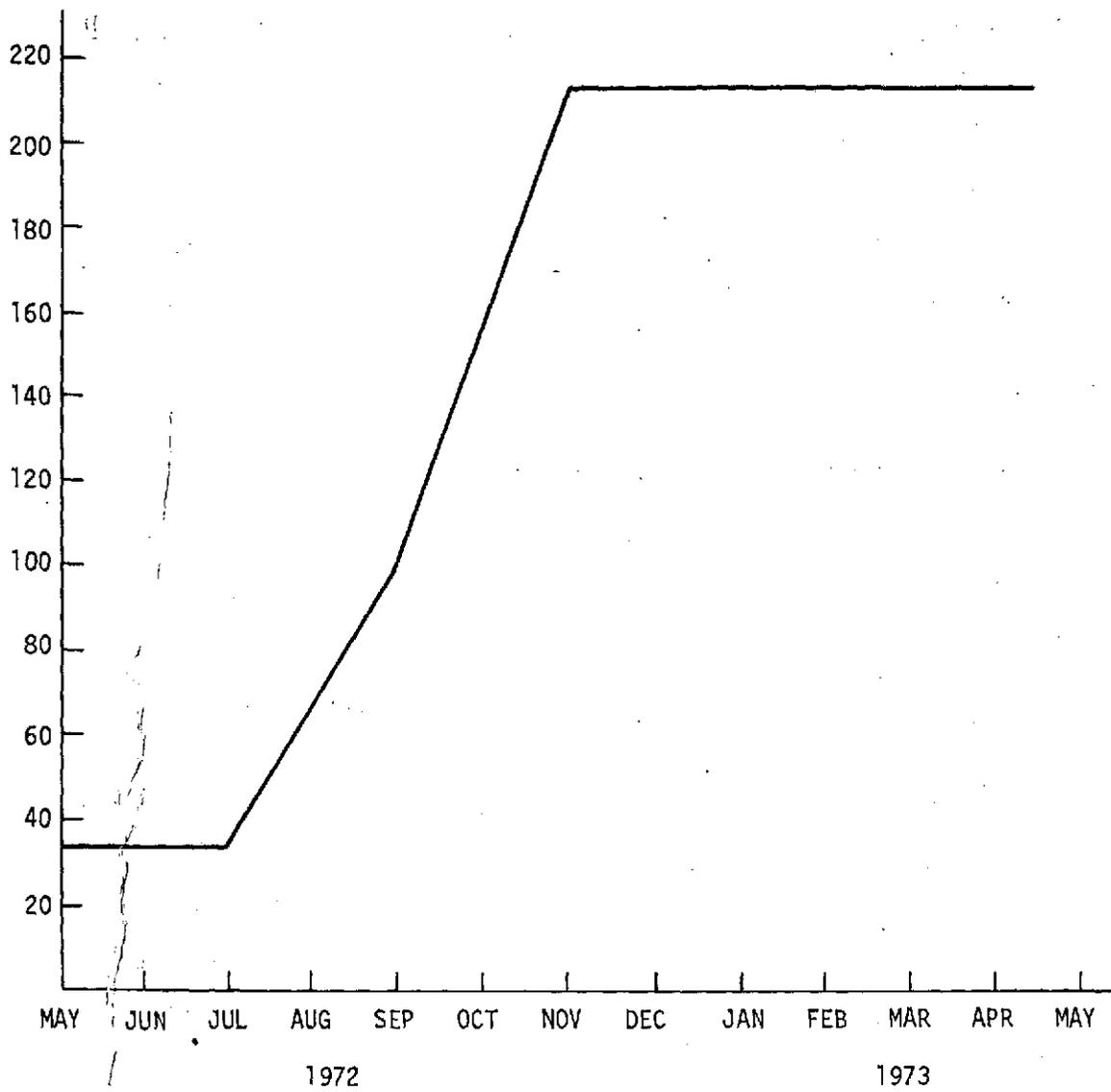


Figure 3 ERTS-1 DCP shipment to users

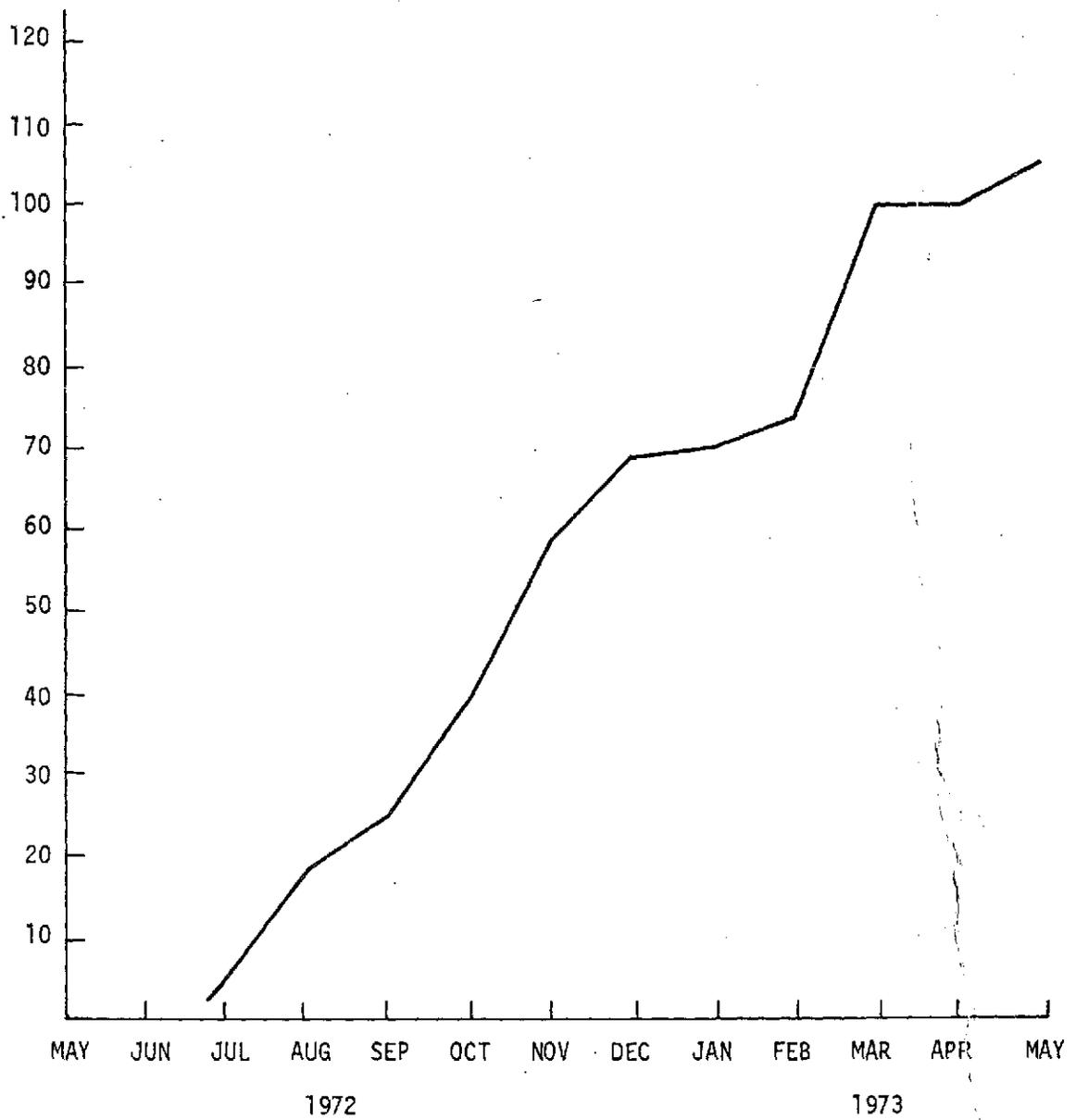


Figure 4. ERTS-1 DCP activation

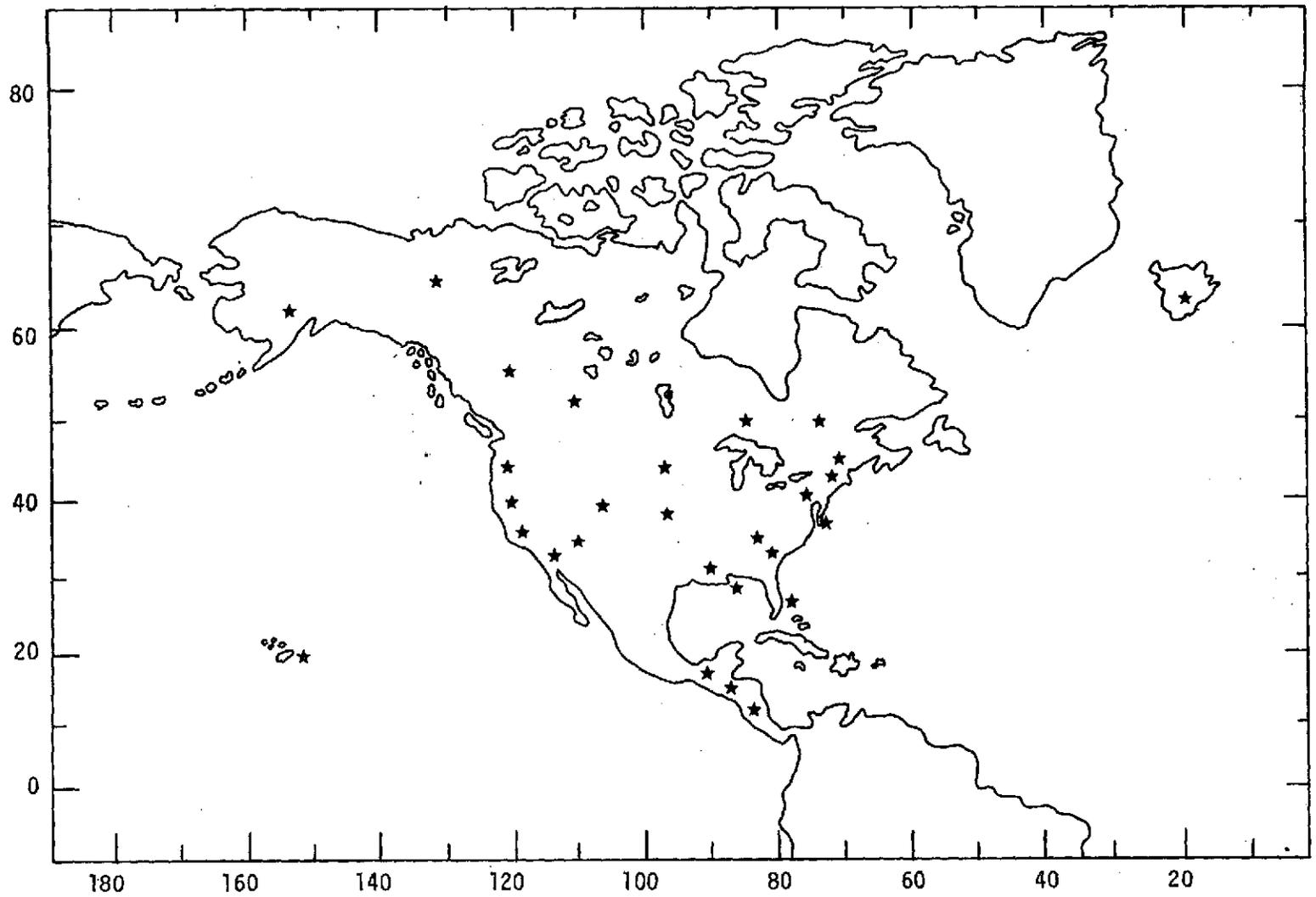


Figure 5. ERTS-1 DCP network

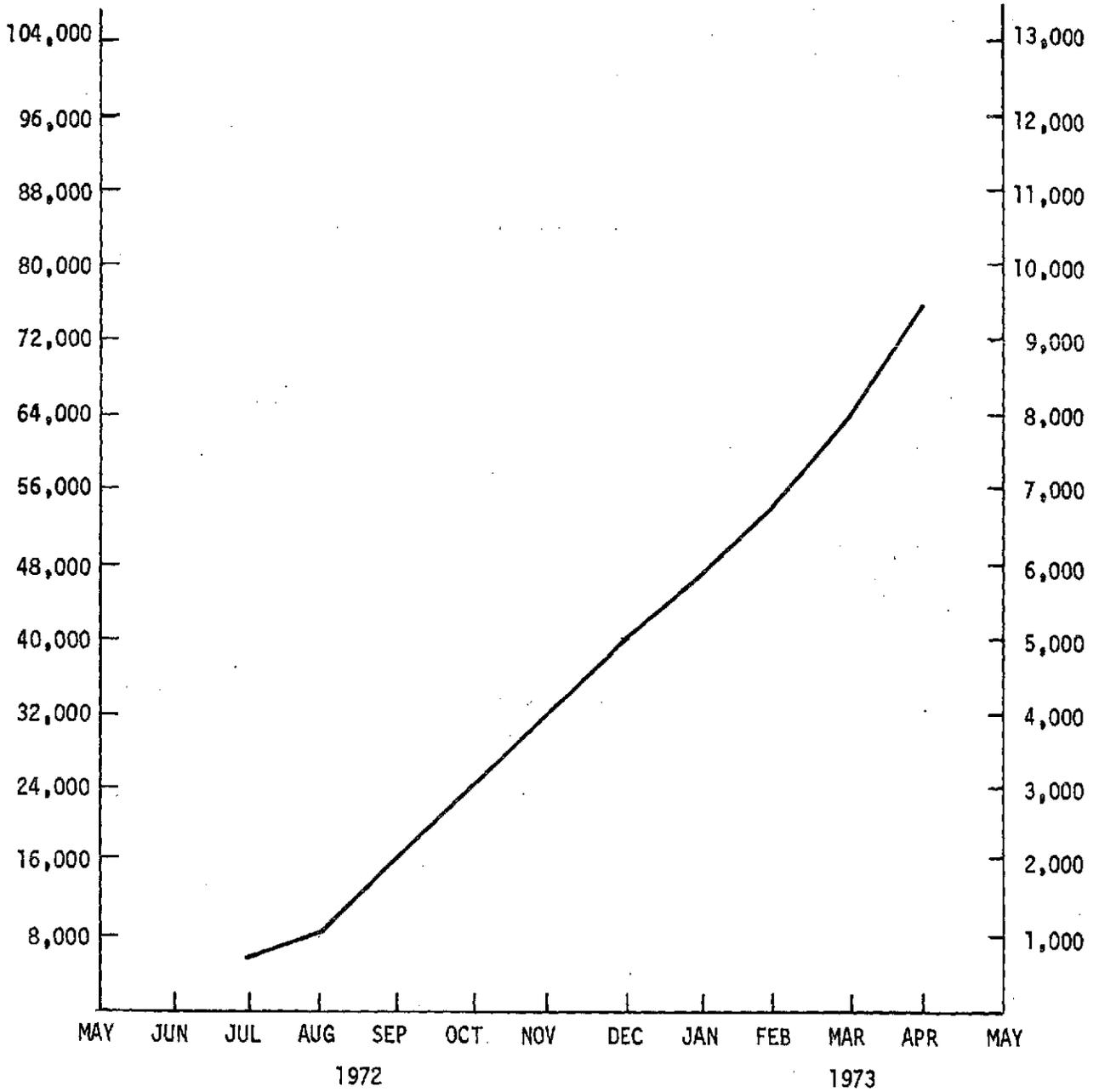


Figure 6. Weekly ERTS-1 DCS data delivery

TABLE 4. - GENERAL LOCATION OF ERTS-1 DCP'S

22 States

ALABAMA
ALASKA
ARIZONA
CALIFORNIA
CONNECTICUT
DELAWARE
FLORIDA
HAWAII
KANSAS
LOUISIANA
MARYLAND

MASSACHUSETTS
MICHIGAN
MISSISSIPPI
NEW HAMPSHIRE
OHIO
OREGON
PENNSYLVANIA
TENNESSEE
VERMONT
VIRGINIA
WASHINGTON

5 Foreign Countries

CANADA
EL SALVADOR
GUATEMALA
ICELAND
NICARAGUA

The system exhibits a high degree of immunity to interference resulting, primarily, from the error control coding technique used and transmission redundancy. Three periods of high level, in-band interference were experienced to date. In the worst case, about 40% of transmissions were discarded as unreliable. These were redundant transmissions and it was still possible to deliver the specified two or more transmissions per day from each DCP. Users reported no errors in the data distributed during periods of interference.

Most users found mail delivery of data to be too slow. A teletype distribution service was established to serve major users. The teletype service currently includes 10 users and about 90 DCP's, and delivers data within 30 to 45 minutes of the time it is transmitted from the DCP site.

Results

The following average figures summarize system performance:

Messages per day per DCP	17
Message error rate	10^{-6} (EST)
Data delivery time	
Mail	8 days
Teletype	30 minutes
DCP failure rate	2% per month

User Evaluation of DCS

A mail survey of DCS users (TABLE 5) revealed that the data transmission link quality and DCP hardware design are adequate for their needs by an overwhelming margin. The survey results and many direct contacts leave no doubt that the system is easy to use, accurate and reliable.

One performance parameter, however, did not receive a passing grade: frequency of data sampling. About half the users consider twice per day sampling (the ERTS-1 system rate) adequate. Those who do not fall into two groups:

Data delivery once or twice per day is adequate, but hourly sampling is required.

Data delivery on demand is required.

Several ERTS-1 experimenters are designing on-site data storage equipment which will permit hourly readings to be acquired and transmitted at an accelerated rate when the satellite is in view. This technique has no technical disadvantages except to increase the system load from each DCP, resulting in a decreased number of DCP's the system can handle. It increases installation cost, of course.

For those who need data on demand, synchronous satellites, ground networks, and airplace relays are necessary. Unfortunately, ground networks and airplanes are at a disadvantage during severe storms and other disaster conditions.

TABLE 5. - RESULTS OF USER SURVEY

USERS QUERIED - 26

REPLIES - 18

SYSTEM ADEQUACY:

<u>PARAMETER</u>	<u>ADEQUATE</u>	<u>INADEQUATE</u>
- SENSOR INTERFACE	18	0
- NO. OF CHANNELS	14	4
- DATA ACCURACY	17	1
- ERROR RATE	18	0
- DATA DELIVERY		
- MAIL	5	13
- TELETYPE	18	0
DCP RELIABILITY	17	1

- OVERALL ADEQUACY FOR OPERATIONAL NEEDS:

ADEQUATE - 10

INADEQUATE - 8

- REASONS GIVEN FOR OPERATIONAL INADEQUACY:

- NEED DATA STORAGE FOR MORE FREQUENT SAMPLING
- NEED 3-6 HOURS BETWEEN CONTACTS
- NEED DATA ON DEMAND 2% OF TIME
- NEED REAL TIME DATA

Synchronous satellites can deliver data on demand if they use commandable DCP's and their operation is properly planned. They are disadvantaged by the high cost of attaining world coverage (three satellites required) and inability to acquire polar data. DCP installations are considerably more costly at present for synchronous satellite systems, though this may be temporary. It should be recognized that any "pipeline system" is limited in providing on-demand service by the number of "pipes" available and the number of users needing service at a given time.

Conclusions

The ERTS-1 Data Collection System is nearing full activation and use. Experience to date indicates the design is adequate for operational use for 50% of the users and, with minor modifications, could meet the requirements of 75%. Some users will have to augment the system by other data collection techniques to meet their operational requirements.

A SUMMARY OF ERTS-1 DATA COLLECTION SYSTEM APPLICATIONS

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Introduction

The technical presentations that have been made at this Data Collection System (DCS) Workshop have brought to everyone's attention that some very fine progress has been made in the application of the ERTS-1 DCS. It is a pleasant task to summarize these technical presentations in that they generally indicate that space technology has again been successful in expediting the gathering of data leading to better management and understanding of our environment. In the summary that follows, the geographic and discipline areas where the DCS has been employed will be reviewed first. Then some of the implementation, maintenance and data processing facets that were discussed most frequently during the course of the workshop will be reviewed. Finally, what is believed to be the consensus of the group will be presented regarding the desirability of the overall system as presently constituted, how it might be improved and the importance of continuing and extending this capability in forthcoming months and years.

Area of Application

Geographically, applications were made over nearly the entire area where direct readout could be accomplished using the data acquisition stations in the ERTS-1 system. The extreme areas included Iceland, the Canadian Arctic, Alaska, Hawaii and Central America. In the discipline sense the majority of applications were in the water resources area with other applications being formally and informally reported in meteorology, oceanography, volcano surveillance and forestry.

R. Paulson of the Department of the Interior reported that considerable success has been achieved in applying the DCS to water resources monitoring activities in the Delaware and Susquehanna River basins. The collected data are being utilized by the Delaware River Basin Commission and the Susquehanna River Basin Commission. At the present time over 20 data collection platforms are gathering water quality, stage and ground water observation well information. This information is being processed and disseminated to the water management agencies on a daily basis. This rate of data retrieval and dissemination is at least one order of magnitude faster than has been provided using conventional approaches. This capability often gives these agencies that much more time to react to adverse conditions involving water quantity and water quality.

J. Finegan reported that the New England Division of the Corps of Engineers is evaluating 27 data collection platforms so as to ascertain the applicability of this approach for the monitoring of 35 reservoirs and several hurricane barriers coming under their responsibility. To date, they have found the ERTS-1 system to be reliable and capable of providing timely information under adverse conditions in a cost-effective manner. In a specific instance occurring in Maine, a data collection platform recently provided essential and unique information in near real time during a record flood on the St. Johns River.

R. Halliday noted that nine platforms have been deployed over a wide range of conditions in Canada including heavily forested and mountainous regions involving considerable snowfall and temperatures as low as -40°C . In all cases the DCS has provided data in a matter

of hours from locations where 5-6 data gathering visits per year were considered normal.

The DCS has been evaluated for monitoring environmental conditions associated with the increasingly important management of: (a) water volume necessary to preserve plant and animal life in Central and South Florida, (b) estuary dynamics associated with dredging in Tampa Bay and nuclear power plant thermal pollution in Biscayne Bay, (c) salt water intrusion and waste disposal into aquifers, (d) urban storm runoff discharging into dead-end canals, and (e) agricultural runoff with high nutrient content going into marshy areas where wildlife environment can be affected. E. Cordes noted that the data from the DCS are being acquired and relayed in periods of less than one hour to a wide variety of water resources management agencies. The general conclusion to date has been that this is a very attractive way to proceed in the gathering of data.

Other results utilizing the DCS which were noted during the course of the workshop included the use of a transportable buoy arrangement for monitoring purposes in fresh and salt water environments in Alabama. The DCS is also monitoring meteorological conditions in the mountains of Colorado, and ocean currents off the east coast of the United States. All of these applications indicated that the DCS is very useful for the monitoring and managing of water and atmospheric parameters.

In a different discipline area, namely volcanology, the DCS has been employed to gather earthquake activity and tilt meter data in the vicinity of volcanoes found throughout the ERTS-1 direct readout area. This area of accomplishment was a large step forward insofar as observational capability is concerned for this research area. In one very notable instance involving volcanic activity in Guatemala this observational approach was proven to be a reliable monitor of relevant parameters preceding and during an actual volcanic eruption.

Implementation

Installation and maintenance of the data collection platforms, as is true with nearly all new systems, was not accomplished without difficulty. On the whole, however, it has gone well enough so that everyone involved seemed to agree that it is a system which is amenable to installation in a variety of physical situations and the installation is accomplished with an ease commensurate with eventual use in an operational system. These circumstances were certainly facilitated by the competence and the dedication of the General Electric personnel responsible for building the system and NASA personnel at Goddard Space Flight Center including, in particular, the DCS Engineer, J. Earle Painter. Wallops Station personnel represented by Roger Smith and the U. S. Department of Interior personnel at the Mississippi Test Facility represented by Duane Preble also have made invaluable contributions.

It was generally reported that the DCS would operate not only in exposed situations but also in wooden and concrete enclosures. With reference to operation in exposed situations, the DCS performed well in environments ranging from the cold of the Canadian Arctic to the heat of Central America. The DCS operated properly in corrosive environments such as those found on the ocean or in near-shore salt water conditions. In fact, for this last instance, it was noted that more research is needed on sensors that would be self cleaning or durable enough to provide information over periods compatible with DCS durability and reliability.

The factor which seemed to limit data receipt frequency most consistently was a limited horizon encountered when the data collection platform was placed in a depression associated with mountainous conditions or large variations in relief. Deep melting snow over the transmitting antenna was reported to markedly inhibit data transmission and the possibility of heavy timber decreasing data transmission effectiveness was also noted. None of these conditions seemed insurmountable, however, and in the vast majority of situations, the specified minimum number of two transmissions per day were obtained.

On the average, 3-5 transmissions per pass and 17 per day have been received.

Vandalism was a very common problem, but the investigators' ingenuity came to bear here in that camouflaging, reconfiguration, and encasement of the instrumentation were accomplished to hide, limit accessibility, or resist penetration by bullets from rifles and pistols.

Several miscellaneous aspects of the data collections platform maintenance and operation were discussed. The programming circuitry or cards were found by some investigators to be the source of occasional problems, but repairs at the NASA Wallops repair depot and/or the Mississippi Test Facility were readily accomplished. The antenna of the data collection platform was felt to be cumbersome and one of the most difficult portions of the DCS to ship and install. A collapsible antenna design is being considered and smaller spiral antennas have been examined and found to be very nearly as satisfactory as the present DCS antenna. Power supplies in the form of batteries were uniformly found to be adequate. However, some experimentation with solar power supplies has been conducted in Arizona and Pennsylvania. Applicable units are available for approximately two hundred dollars that can maintain the data collection platforms over extended periods with as little as 20 hours of sunshine in a three week period.

An aspect where research is continuing concerns the collection and transmission of data taken more often than twice each day. Systems recording data from other time periods for transmission when the satellite comes overhead are under investigation. Presently, it seems feasible to record hourly data over a twelve hour period and transmit this information effectively when the satellite is within view. Another means of gathering data from the platforms more frequently was described by Mr. Snyder of NASA Wallops wherein airborne equipment has been constructed that will receive data from platforms as far away as 129 km (80 miles) at any given time and record the information on a cassette tape.

The processing and dissemination of data received from the ERTS-1 DCS has been accomplished in an adequate manner at Goddard Space Flight Center and relayed to users using telephone and teletype facilities. If problems do occur in this process, most of them seem attributable to the telephone lines. The opinion was frequently expressed that a direct readout or downlink to the user capability would be desirable so as to alleviate dependence on land based telephone or communications facilities. Additional data processing, checking and reformatting of data is done in some instances. For example, a water resources summary of data collection platform data in the Delaware River Basin is accomplished daily and sent to the Delaware River Basin Commission and other agencies with responsibilities in the basin area.

Overall Status, Other Possibilities and Future Implementation

It is clear from the presentations and the discussions held on a formal and informal basis that there is considerable agreement as to the success of the satellite data collection concept represented most recently and dramatically for earth resources, particularly water resources, by the ERTS-1 system. Because there has been such success in the form of reliable, time-tested and relevant data being delivered in near real-time to water resource management agencies, there is considerable desire to have this capability continued. This capability could be improved or take somewhat different forms relative to the ERTS-1 system as indicated by the C. Cote of NASA Goddard and J. Puerner of NOAA. It is interesting to note that a survey of ERTS-1 DCS users reported by E. Painter of NASA Goddard indicated that a considerable number of those investigators found the ERTS-1 system satisfactory as it is. However, if one were to construct recommendations from the group attending this workshop, they would probably take the form of the comments that follow.

- (a) An operational system or continuing support and maintenance of the present system is highly desirable. This suggested action seems particularly important so as to continue and improve the capability, experience and enthusiasm developed.

as a result of the ERTS-1 efforts.

(b) A direct readout capability for the user would be desirable so that he could shorten the time it takes for information to get to him, check out received data and process his own data in a way best suited to his needs, and eliminate dependence on ground-based communications networks.

(c) A satellite system is desirable wherein the data can be provided to more facilities. A geosynchronous satellite or a system of 2-3 polar orbiting satellites would be appropriate. Data is needed generally on 2-3 hour intervals.

(d) Other factors to consider that would be improvements include data storage capability on the polar orbiting satellites for global coverage and different data collection platform units or capabilities tailored to organizational mission responsibilities and needs.

The presentors and attendees appear to agree that if an operational system were brought to fruition it will prove beneficial in (a) increasing the ability of the resource management and research agencies to monitor specific phenomena and make predictions or decisions that are more accurate or have a higher confidence level, and (b) conserving and making more effective use of existing and projected manpower levels. As a quantitative measure of the extent to which the DCS could be extended and utilized, it was estimated that some 40,000 gauges and monitoring stations in the U.S. could have data collected and relayed via satellite.

From the work reported here and the ease with which the concept has been grasped and accepted by a wide spectrum of users, it would seem that if an agency or agencies were to consider taking the necessary steps to bring this type of operational capability into being, they are virtually assured of having their investment of time, money and energy returned manifold.

USDI REQUIREMENTS AND PROGRAMS

John M. DeNoyer

United States Geological Survey

I have heard many people express surprise during the past day and a half at the rate at which these experimental data are being put to operational use. I think that that is the consequence of "doing research for a purpose," and I am personally glad to see it.

Quite a few speakers have pointed out, including a few from my own agency, the manpower savings that can be obtained through the use of data collection systems in connection with the present monitoring program. I think that they are absolutely right. There is a large manpower savings, and it goes way beyond the people that just go out and maintain the conventional stations and collect the records. Once these records are collected, they have to be modified in format to be put into a data base. We keep all of our water data in a digital data bank in Washington. It all has to be prepared. This is a lot more manpower than just for field work and there are also time delays in making the data available.

With a data collection system such as we have been experimenting with on ERTS, we get the data much faster and can cut out a lot of these intermediate steps. The manpower savings are great. The timeliness is also very important because the ability to make these data available earlier can effect management decisions that can produce large benefits.

We have two kinds of factors. One is the direct dollar saving in terms of manpower and another is being able to use the information to obtain additional benefits. In addition, it has been necessary to consider logistics in any system where we have to service a station on a regular basis. Power lines, roads, and land line communications are major logistic factors.

With a capability like the ERTS data collection system, you can immediately begin to design the monitoring system to fit the data needs rather than be constrained by the logistic considerations. So, I would see a capability of this type making it possible to develop a much improved monitoring system as well as provide for a more efficient and timely system.

With water data, we are showing that a job that has been done for many years can be done better and more efficiently. There are other measurement programs that the DCP's make possible that were too difficult or expensive to attempt. Experiments like Pete Ward's have demonstrated this. It is now feasible to monitor tilt and seismic event counts on a world-wide basis.

There are more of these. The water content and condition of snow in mountains is a very difficult set of measurements to make. The ways of doing it in the past have been with aerial photography and with snow traverses. These surveys are difficult and sampling is often inadequate. The reports I have received from the DCP's that are just being installed in the San Juan Mountains are very optimistic in terms of the ability to really know what is going on in that snow field in terms of thickness, water content and the extent that can be measured from the imagery. Putting all of these together with

meteorological data provides data needed for predicting total water available and rates and times of discharge. This is important for flood control, but water is also a resource and proper management is needed for hydroelectric power, irrigation, recreation and wild-life. In the reservoir systems such as the Bonneville Power Administration, water management is a very tricky job. They have got quite a few things to consider there; how much water is there going to be, when is it going to arrive, how much power are they going to generate, how much do they draw down the reservoirs for flood control, and water for irrigation. They also have to consider recreation. I have heard them refer to getting a river out of line, and there are problems of getting it back in line.

The data collection system is a real credit to those who worked on it. Some comments were made concerning the complication of the input to the DCP. I really consider the input characteristics a simplification because ordinary people have been able to pick the thing up and attach instruments to it with a minimum of difficulty and have the system work under field conditions. The simplicity of getting data into the black box has been a major factor in terms of the general acceptance and ease of installation and operation that has been reported on here.

The capability has been demonstrated and the problem we now face is how do we best get on with the business.

The presentation on SMS/GOES was excellent. This data collection system should be running a year from now, and I personally plan to invest some in the platforms and start using them. This can do a lot for the immediate problem of insuring continuity of data collection capability.

I have discussed my position on data collection platforms with Chuck Mathews quite a few times, and I have always told him my position which I will repeat to you. I don't really care what satellite data collection systems are on, the more important concern is to standardize the ground system so that agencies can afford to invest in and deploy the platforms. There are also quite a few research systems reported on that will cover the time span for the immediate future. I don't know how these can be used operationally if the ground systems change into another generation that is incompatible with the last. So, I think that there is a need to settle down, take something that works, something that is simple, something that really functions like an ERTS DCS and start implementing programs to get these measurements.

The ERTS is an experimental satellite. However, Earl Painter pointed out this morning, that the DCS system looks like it should have a long life way beyond the rest of the spacecraft payload. My own feelings are that it would probably pay to invest in ERTS type platforms for operational use providing that we can get assurance that the satellite will be kept operating for DCP use. We need to make the most out of the capability that we have.

I have heard many suggestions of other ways to link DCS designs on other satellites or it might be possible to do this with a dedicated launch if necessary. These would certainly have to be studied rather hard, but I would certainly like to see these looked at to see what can be done because the repeat time problem has to be solved some way either in the data collection platform itself, or with more frequent satellite passes. I think that both approaches need to be looked at. I don't know which is the best way to go. I think the answer concerning the best way to go would become quite clear once this is looked at with a real hard analysis.

One of the original concepts of the data collection system was to collect ground truth for the imagery. This has not really turned out to be a primary use for the data collection system as it has been used up to now.

Ground truth data collection platform requirements can be met in several ways. They can be met by a polar orbiting satellite with imaging and data collection capabilities such as ERTS. They can also be met with data collection systems that can be interrogated at the right time.

The original intent of the ERTS DCP will be increasing with time as people go digging deeper into the imagery and the interpretation. It wasn't a wrong idea; it is just one that takes a lot more work and is not required to skim the most obvious information from the imagery.

To summarize my own feelings on data collection platforms, we have got a good thing that works; it works very well. It meets an extremely large number of needs. We need to get on with more truly operational applications.

U. S. ARMY CORPS OF ENGINEERS REQUIREMENTS AND PROGRAMS

John Jarman

U. S. Army Corps of Engineers

In my comments today, I hope to be able to convey to you the reason for the Corps' enthusiastic support of the space data collection systems.

The Civil Works program of the Corps of Engineers has as its basic mission the full and efficient development, utilization and conservation of the water resources of the Nation in the interest of advancing the national economy and enhancing the welfare of the people. That is a rather concise statement but it covers a wide spectrum of activities. Protecting lives and property from flood waters has been a primary responsibility of the Corps since 1936. Since that time we have constructed close to 700 projects including about 400 reservoirs. We also collect and compile data used in developing non-structural flood damage prevention measures. Through Fiscal Year 1972 we have issued over 700 floodplain information reports, over 50 flood hazard reports and, in a typical year, respond to several thousand requests for flood hazard information. In addition to preventing damages with its flood control projects, the Corps plays a major role in emergency flood fighting and other types of disaster relief.

The mission statement also covers other responsibilities. The Corps protects and preserves navigable waterways by maintaining adequate depth through dredging and flow regulation and by regulation construction in or along navigable waterways. Corps reservoirs provide over 7 1/2 billion liters (3 1/2 billion gallons) of water a day for municipal and industrial use. Over 100 cities or towns obtain some or all of their water from Corps projects. Corps lakes provide more than 45,052 km (28,000 miles) of shoreline and four million acres of water surface for recreation use and in terms of recreation days, the Corps has the largest recreation program in the Federal Government. Another important element in the Corps program is the generation of hydroelectric power. Corps projects produce about 25% of the hydropower produced in the United States.

You will recall that all of these activities relate to the utilization and conservation of water resources. You can easily see that the critical factor in managing this diverse program is timely and accurate data. Data has been collected for years and we feel that we have been relatively successful in performing our mission. What has changed? Why do we need new methods? In answer to these questions, I would like to raise several points. First, rapid industrial and urban expansion for the burgeoning population have increased the need for effective flood control and water supply and the demand for power, transportation and recreation. As these needs and demands increase, the competition for the controlling resource, water, increases. If water is released from a reservoir to provide flood control storage for anticipated run-off, that water may be unavailable for power generation or water supply. Second, our data collection activities have generally been designed for general coverage, basic studies, and hydrologic engineering. These data were useful in the planning and design of projects but the data sampling requirements for project operation and river forecasting have been limited by the practical considerations of time, economics and data handling capability. And, finally, many of the tools presently available to the water resource manager have become available only in the past few years. So, the Corps is accelerating its efforts in the direction of optimized river basin control. We are developing more efficient project operating procedures to explicitly recognize all project purposes and to recognize the trade-offs between purposes. We are developing

comprehensive models for simulating basin run-off, reservoir conditions and the interaction between natural and man-made features in order to treat a river basin as a total system. We are studying automatic data collection networks to provide timely hydrologic data. To develop true river basin control, we will need to know water input elements, river and reservoir conditions, meteorological elements and conditions affecting runoff such as land-use and ground water conditions. I don't mean to imply that we can state standard requirements. Each river basin possesses individual characteristics which will dictate the types of data, location and density of sample points, and the time constraints. However, there is a need for a national system of hydrometeorological systems. It is reasonable to assume that within the next 20 years cooperative units will be established to serve forecasting and project operations groups in every major river basin area. I believe that these units will be dependent upon reliable satellite data collection systems.

NOAA REQUIREMENTS AND PROGRAMS

Allen F. Flanders

National Oceanic and Atmospheric Administration

The National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce have cooperated in developing a Geostationary Operational Environmental Satellite (GOES). NASA is developing the prototype spacecraft in its Synchronous Meteorological Satellite (SMS) program in response to requirements for data and performance coordinated and established by NOAA. The launch, by NASA, of the prototype satellite SMS is planned for January 1974.

The first spacecraft, SMS A, will be placed in earth synchronous orbit 22,000 miles above the equator near 100° West longitude. From that position it will:

- a. Provide near-continuous day and night imaging of the earth's surface and its cloud cover.
- b. Rebroadcast that imagery in a "slowed-down" mode for simplified direct readout by regional user stations.
- c. Monitor the space environment in terms of energetic particles, X-ray and the geomagnetic field.
- c. Broadcast environmental service products, which may include charts, advisories and warnings to remote locations.
- e. Collect and relay data sensed by a variety of widely dispersed in-situ platforms such as river and rain gauges, seismometers, tide gauges, buoys, ships and automatic weather stations.

This paper will consider only the service programs in NOAA that contemplate using the GOES Data Collection System (DCS). The GOES DCS will be operated by the National Environmental Satellite Service (NESS) of NOAA as an integral part of the national operational environmental satellite program. This plan is concerned with that part of the GOES program connected with collection and relay of data from remote locations.

The basic elements of the DCS are the remotely located Data Collection Platforms (DCP), the GOES spacecraft and the Command and Data Acquisition (CDA) station. The GOES spacecraft, with its continuous data collection and relay capability, has been designed to accommodate 10,000 or more individual observing platforms within each six-hour period. Each platform will radio its sensor data to the spacecraft either in an interrogated or self-timed mode of operation, using frequencies in the lower UHF band. The data will be transmitted in digital form at a rate of 100 bits per second. The power output of a typical platform will be five watts. It is expected that reliable communication between the satellite and the platform can be maintained at "look angles" of 7 1/2 degrees or higher. The data received at the satellite will be transponded at S-band frequencies and recorded at the NESS CDA station located at Wallops Station, Virginia. The data will then be relayed to the NESS data analysis and computer processing facility at Suitland, Maryland where minimal processing, necessary to determine the status of the responding radio set, will take place. The raw data will then be forwarded by schedule or on demand

to the user (e.g., data phone, teletypewriter). Costs for this service will be borne by the user.

An interface is required between the DCPRS (Data Collection Platform Radio Set) and the sensors. One such interface, the National Weather Service DARDC (Device for Automatic Remote Data Collection), has been successfully demonstrated with the DCPRS. The DARDC is a solid-state electronics package which interfaces with one to four sensors and communications systems. It is battery powered with the capability of operating unattended up to six months.

The TIROS-N Data Collection System, in our planning schedule for launch in 1976, has the advantage of polar coverage and the ability to locate platforms as well as collect data from them. Since the TIROS-N Data Collection System is in the early planning stage and the GOES is scheduled for launch in January 1974, near-term planning will be keyed to GOES.

NOAA policy related to the use of the GOES DCS has been established and users will be required to negotiate a Memorandum of Agreement with NESS regarding participation. A copy of the policy statement is outlined in the appendix to this report.

NOAA SERVICE PROGRAM AREAS

Hydrological Data Collection

The river and flood forecast and warning service of the National Weather Service depends on meteorological data and a vast hydrologic reporting network exceeding 5,000 stations. Reports are collected daily or on a criteria basis during periods of heavy rainfall and/or high flow in the rivers. Less than 15 percent of the hydrologic network is telemetered. Although most of the observations are recorded automatically on site, an observer must telephone the report to a data collection center for relay to one of the 12 National Weather Service River Forecast Centers.

In 1967-1969, an experiment in river and rainfall data collection via NASA's ATS-1 satellite was conducted. The technical and operational feasibility of data collection from river and rainfall sites via satellite was proved in the test. In conjunction with the launch of GOES, a prototype network of 18 stations will be operating in the Columbia Basin of the Pacific northwest. This system could form the basis for a national data collection system to serve the nation's real time water resources agencies. During the next decade, it is anticipated that the hydrologic data collection network will double in size to satisfy river and flood forecast service needs placed upon the National Weather Service. It is estimated that this network will comprise some 3,500 GOES hydrologic data collection platforms.

Interrogation and self-timed DCP's are contemplated as each having a place in satisfying the data collection needs of the NWS flood forecasting service. The interrogation type platform is considered the most necessary to meet emergency flood events. Generally, the forecast model being implemented at the River Forecast Centers requires data every six hours from key river and most precipitation stations. During a flood threat the data collection frequency would need to be increased from once every six hours to once every three hours at many of these sites to define the rainfall regime and the condition of the streams. In situations where flash flooding is a threat, interrogations at one or two hourly intervals will be required.

The self-timed DCP's could be used on the slower rising rivers where data collection frequency can be predetermined not to change. These DCP's can also be used on flash flood alarms which would be set to trigger the transmitter upon the water level reaching a specific height.

Meteorological (land and shipboard) Data Collection

The weather and marine service programs of the National Weather Service currently plan to use GOES to collect data from remote weather stations and ships at sea where other means of data collection are not available. The land locations will be Remote Automatic Observing Stations (RAMOS) equipped to report wind, pressure, temperature, dew-point and precipitation. The RAMOS stations will be erected on a tower 6.1 meters (20 feet) high and can easily accommodate the DCPRS and its antenna. The satellite interrogated RAMOS field units will be deployed mainly in Alaska and the Pacific area west of Hawaii.

In 1974 the National Weather Service plans to conduct a data collection test via GOES aboard the NOAA ship, David Starr Jordan. The ship will be in the eastern Pacific (south of 30°N and east of 140°W) during the test period. About four DCP's are scheduled for RAMOS locations in Alaska.

Basic shipboard hardware will be a Data Collection Platform Radio Set (DCPRS), a Keyboard Cathode Ray Tube (KCRT) data input interface, and an omnidirectional antenna (still to be decided upon). The test may be expanded by installing a Remote Automatic Meteorological Observing System (RAMOS) aboard ship. Under this arrangement the observations would be a mix of automatic and manual entries. The purpose of the test is to evaluate the durability and performance of the DCP system aboard ship and if successful extend it to other NOAA and merchant ships in the U.S. cooperative ship program.

Typically, the data from the stations and ships will be required at the National Meteorological Center (NMC) in Suitland, Maryland. Observations from RAMOS land stations will be needed at NMC and by the Weather Service Office with forecast and warning responsibility within 500 miles of the station. Observations will be necessary on a frequency of at least six hourly intervals cycling to every three hours during storm periods and possibly hourly during severe weather events.

Oceanographic Data Collection

Two specific areas will be discussed in this section. One will cover data buoys and the second the TSUNAMI Warning Service.

Data Buoys

Moored and drifting data buoys are available for marine observations. Each has special characteristics which offer different capabilities for marine observations.

Moored data buoys can provide those operational data that are especially hard to acquire in areas outside of shipping lanes or away from fixed coastal facilities. The available measurements will include surface weather parameters (i.e., wind velocity, pressure, temperature, and dewpoint); oceanographic surface measurements of sea state, temperature, and salinity; and subsurface measurements of temperature, salinity and current velocity.

Drifting data buoys, besides providing integrated current velocity data, can measure surface wind velocity, air temperature and pressure, sea surface temperature and sea state. Recent tests by the National Marine Fisheries Service of NOAA have shown that drifting buoys may also have an application in detection and surveillance of ocean fisheries population.

Data buoys systems developed to date for test and evaluation purposes have been the 12.2 meters (40 foot) discus (monster) buoys. To reduce the cost of special applications, minimum capability buoys are also being developed. Two such general classes of buoys are being planned to meet operational and research requirements:

--Operationally simple data buoys with the capability for measuring a few basic parameters such as air and near surface water temperatures, wind speed and direction and atmospheric pressure.

--Medium capability buoys which will increase the number of measurements that can be taken, and with the flexibility to accept a variety of special-purpose sensors. They will be especially suited for observations of the lower atmosphere, air-sea interface, and subsurface ocean.

Plans for environmental data buoy applications include use in support of operational monitoring, prediction and assessment services and large scientific research programs.

The present identifiable operational requirements for oceanic data are associated with meteorological uses for warnings and forecasts. The National Weather Service has reviewed requirements for data from marine areas and has determined 24 preferred locations for buoys along the east and west coasts and in the Gulf of Mexico and Alaska so that warning and forecast services can be improved. The Weather Service need is for three-hourly data reports along coastal areas and hourly reports from selected buoys along the Atlantic Coast and in the Gulf of Mexico during occurrences of hurricanes and other severe weather conditions.

A number of larger scientific research programs presently underway have also indicated needs for data buoys such as the International Decade of Ocean Exploration (IDOE 1970-1980) Global Atmospheric Research Program (GARP). GARP is an international cooperative research effort aimed at increasing our understanding of the general circulation of the atmosphere. The sea surface temperature and its changes in relation to the atmosphere and ocean circulation is one factor that determines the statistical properties of the general circulation. Buoys are a convenient, and in some regions, the only means of monitoring the thermal and dynamic structure of the upper ocean layer which determines sea surface temperatures.

Tsunami Warning Service

The Tsunami Warning System (TWS) plans to use the GOES interrogation data collection system. Figures 1 and 2 are the proposed and current network of tide and seismic stations. The GOES system will provide data collection service to network stations in the eastern and central Pacific; stations in the western Pacific are beyond the range of GOES. Data collection service for these locations may be possible from the planned Japanese GMS (Geostationary Meteorological Satellite). In FY-75 it is planned to initiate the program with the procurement of four seismology platforms and four tide gauge platforms all having digital storage capability. Interrogations would be on an unscheduled basis except for a daily test message to check system operations.

The TWS requires one readout of the storage register from each seismometer immediately after each major earthquake. Data from tide gauges may be necessary for up to 30 hours after a major earthquake. Storage registers would be interrogated every 10 to 15 minutes. A reading would be placed in storage every 30 seconds and the register would have enough capacity to store 15 to 20 minutes worth of data.

Possible data "blackouts" presented by outage problems as well as satellite eclipse could be a serious threat to emergency data demands. To alleviate the problem, changes in platform design and CDA configuration are being considered.

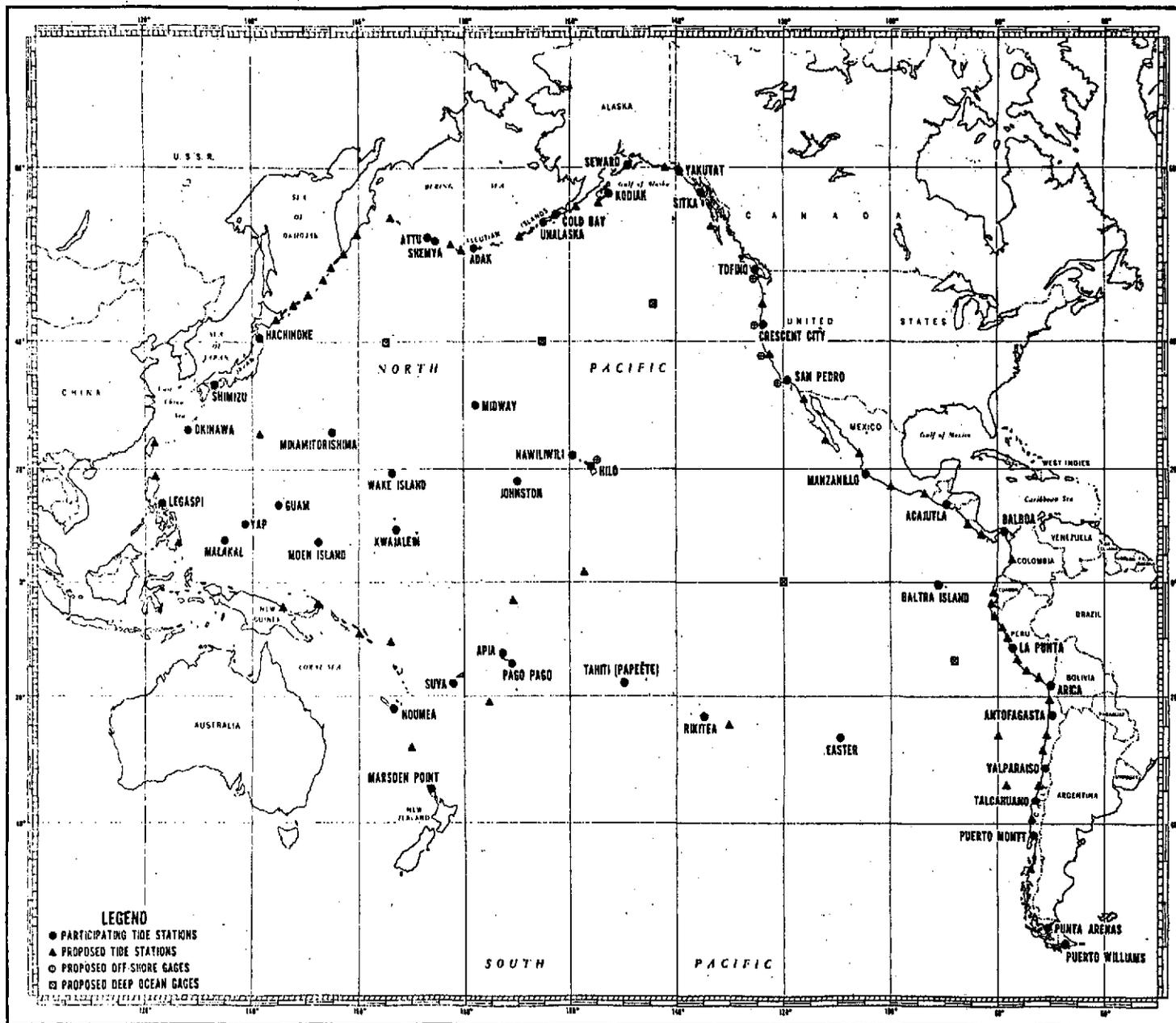


Figure 1. Participating and proposed tide stations in the Pacific Tsunami Warning System

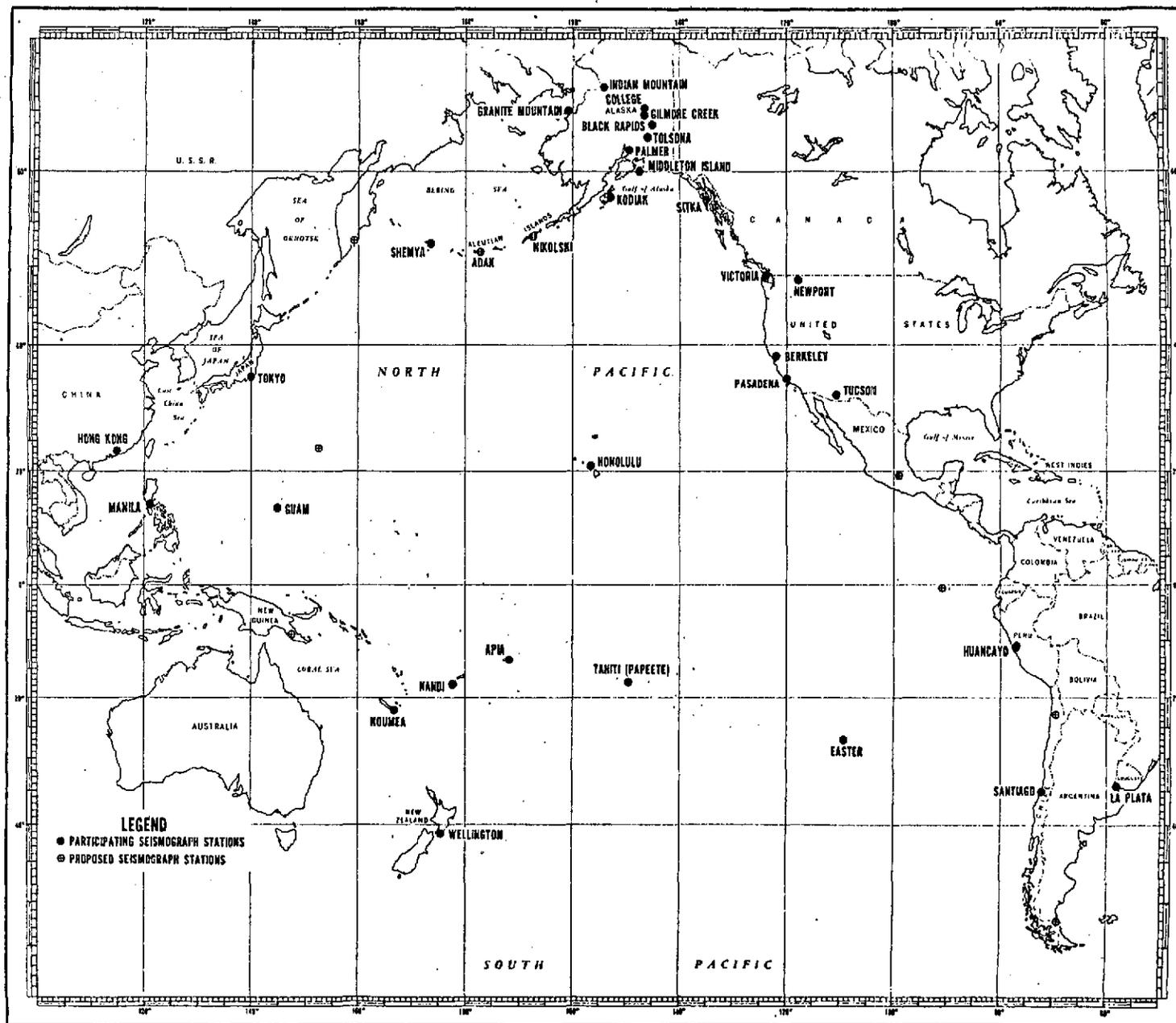


Figure 2. Participating and proposed seismograph stations in the Pacific Tsunami Warning System

SUMMARY

The following table depicts the short-term goals for reaching a minimum level of operation as soon after the launch of GOES in January 1974 as can be reasonably attained. This planned implementation of DCP's for NOAA service program areas is naturally dependent upon funding allocated to the agency. The GOES DCS is viewed as a means for significantly resolving environmental data collection problems particularly those in remote locations and the inability of obtaining essential observations on demand, day or night.

FY	72	73	74	75	76	77	78
Hydrological Service							
River/Rainfall Stations	24 ⁽¹⁾	39 ⁽²⁾	100	90	180	180	270
Meteorological Service							
Land Stations	--	5	0	20	20	20	20
Ships at Sea	--	--	0	10	10	10	10
National Environmental Satellite Service							
Test and Evaluation Projects	26 ⁽³⁾	--	--	--	--	--	--
Oceanographic Service							
Buoy Project	*(4)	--	--	*(5)			
Tsunami Program							
Seismology Stations	--	--	0	4	5	5	5
Tide Gauges	--	--	0	4	15	15	15

NOTES:

- (1) Includes order by Corps of Engineers
- (2) Includes order by USGS and SCS
- (3) Includes order by FAA and Navy
- (4) 11 Buoys undergoing test and evaluation
- (5) Operational funding for buoys scheduled to start--planning not complete.

ACKNOWLEDGEMENT

This material was extracted from published and unpublished manuscripts with the assistance of NOAA staff members Jim Moore, Jack Puerner, Bob Schoner, Jim Jones and Mark Spaeth. Their assistance is acknowledged with thanks.

APPENDIX

FEDERAL REGISTER, VOL. 37, NO. 200--Saturday, October 14, 1972

TITLE 15 - COMMERCE AND FOREIGN TRADE

Chapter IX--National Oceanic and Atmospheric Administration, U.S. Department of Commerce

Subchapter A--General Regulations

Part 911--The U.S. Geostationary Operational Environmental Satellite Data Collection System

Availability of System

911.1 General.

(a) With the advent of the United States of America Geostationary Operational Environmental Satellite, operated and controlled by the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce, a satellite environmental data collection capability will become available to meet national requirements.

(b) The environmental data collection system includes the NOAA Command and Data Acquisition (CDA) Station (Wallops, Va.) and the spacecraft which collects information from radio equipped environmental sensor platforms, and conforms to applicable standards and regulations established by NOAA and the International Telecommunications Union (ITU).

(c) The use of the data collection system of the operational environmental satellites operated and controlled by NOAA will be limited to the collection of the environmental

data in accordance with applicable ITU regulations concerning use of the allocated frequency bands. Environmental data are defined as observations and measurements of the physical, chemical or biological properties of the oceans, rivers, lakes, solid earth and atmosphere (including space).

(d) Users of the environmental data collection system - Government agencies, academic institutions, industry - will be responsible for the costs of the environmental sensors and platform, the radio equipment required to provide the communications link between the environmental sensor platform and the satellite, and any unique equipment/communications required to receive the data at the user's facility.

(e) Design characteristics of the environmental data collection system on the spacecraft require that users conform to technical standards established by NOAA. A use agreement will contain, but will not be limited to, statements as to (1) the period of time the agreement is valid and procedures for canceling it, (2) conformance with ITU agreements and regulations, (3) required equipment standards, (4) standards of operation, (5) frequencies, (7) data formats, (8) data delivery systems and schedules, and (9) user-borne costs.

(5 U.S.C. 552)

Additional information may be obtained by writing to the National Oceanic and Atmospheric Administration, National Environmental Satellite Service, Washington, D.C. 20233.

Robert M. White
Administrator.

September 25, 1972
(FR Doc.72-17441 Filed 10-13-72;8:45 am)

EPA REQUIREMENTS AND PROGRAMS

John D. Koutsandreas

Environmental Protection Agency

Introduction

The movement of pollutants horizontally and vertically through the environment knows no political boundaries. As a result, the monitoring of our Nation's environmental quality must be a cooperative effort involving all levels of government. The objectives of Environmental Protection Agency (EPA) environmental monitoring are to characterize existing environmental conditions, identify trends, evaluate compliance with standards and assess the interchange of pollutants among air, water and land.

EPA's research and monitoring objectives are divided into short-term and long-term activities. Short-term research activities are aimed at providing the measurement capabilities required to meet regulatory deadlines. By and large, specific measurements must be readily adaptable to state, local and private laboratories. Most instrumentation must be relatively inexpensive, accurate and easy to operate and maintain. We expect some NASA-developed technology such as the data collection systems to be adaptable and some ongoing research to provide information applicable to our programs.

Our long-range activities are those which now are not required for immediate regulatory requirements but which relate to long-range needs. For instance, where we presently stress methods for monitoring individual pollutants, we recognize the need for multi-pollutant systems. In this regard, we again would expect some NASA-generated technology to be adaptable.

Research and Monitoring

Research and monitoring are vital to environmental improvement. Our philosophy in EPA, since we are so strongly mission-oriented, is that all of our work in research and monitoring is done with anticipation for use in problem solving. In closely coordinated research programs, EPA strives to develop a synthesis of knowledge from the engineering, biological, physical and social sciences which can be interpreted in terms of total human and environmental needs.

The effective control of variables which determines environmental quality requires the use of reliable and timely information such as can be provided by aerial surveillance. Thus, one key to effective environmental quality management lies in the ability to monitor environmental characteristics and provide timely interpretation of the data obtained. Such data are essential throughout the pollution abatement effort -- from initially identifying the problem to finally providing direct evidence in enforcement actions. The ERTS-Data Collection System (DCS) and similar data relays could help immensely in this area.

Monitoring the Environment

The Environmental Protection Agency monitoring activities are carried out in two fundamental ways:

(1) A series of networks located in urban and non-urban areas throughout the Nation; and

(2) Special projects where information is not provided by the networks.

In large measure, the success of an environmental pollution control program rests upon the reliability and timeliness of the data provided by monitoring activities. Assessments of environmental quality, whether they be within one or among several environmental media, require data collection and analysis. When such assessments are made in support of an enforcement action, the data used must be legally defensible.

The acquisition of legally defensible data requires EPA-wide use of a set of standardized measurement and calibration procedures, an inter-laboratory quality control program, a laboratory performance certification program and a standardized laboratory record-keeping procedure. These serve not only to ensure data uniformity and reliability, but also to document the quality of the data produced.

ERTS-DCS Program Objective

The prime objective of the proposed ERTS-DCS system is to allow EPA the capability to evaluate, through demonstrable hardware, the effectiveness of automated data collection techniques. The total effectiveness of any system is dependent upon many factors which include equipment cost, installation, maintainability, logistic support, growth potential, flexibility and failure rate.

This can best be accomplished by installing the system at an operational CAMP station to insure that valid data is being obtained and processed. Consequently, it is imperative that the equipment interface must not compromise the validity of the sensor data nor should the experimental system effect the present operations of the CAMP station. Since both the system which is presently in use and the automatic system would be in operation in parallel, conformation and comparison are readily obtained.

In addition to the prime objective many sub-objectives can be evaluated.

Define sensor interface.

Evaluate satellite system (ERTS).

Evaluate data format both for reporting and record keeping.

Define remote automatic collection problems.

Provide real time data.

Provide capability of running redundant or special projects without effect to present manpower requirements.

Provide experimental information for system data requirements.

In order to meet the prime objective, it is necessary to first develop an operational scenario for the CAMP station. This would include, at a minimum, the following:

Routine reporting

Critical episodes

Record keeping

Special testing

Validation of data

With eventual expansion to include:

Remote location data gathering

Non permanent or transportable sensors

Special projects

System Description

The prime functions of the regional or local environmental control agencies (CAMP station) are to provide valid air pollution information both on a real time or hourly basis during critical pollution episodes and on a daily basis for statistical evaluation and record keeping of the total pollution environment. At a minimum, this requires keeping track of the data from such sensors as carbon monoxide, oxidants, nitrogen dioxide, nitrogen oxide, total hydrocarbons, methane and sulfur dioxide air pollution analysers. During critical pollution episodes, local sites are to report into regional offices on an hourly basis on the pollution index from as many as five prime sensors. This requires reducing and averaging the stripchart recording from each sensor and depending on the duration of the episode, recalibration of the equipment. For the record keeping function, the CAMP station is required to calibrate and provide hourly averages from as many as eight sensors. In either case, the present instrumentation located at the CAMP stations provide continuous analog data on stripchart recorders which require manual reduction from each sensor.

During the critical episodes, this reduced data is telephoned into a regional office both for information and action. Otherwise, the information is tabulated and telephoned to EPA's Durham, North Carolina facility. No provisions are presently provided for remote sensing or for an unattended facility to satisfy the total requirements of the local pollution control facility.

The proposed DCS experiment will have the capability of providing real time data on an hourly basis as well as allowing the capability of collection remote sensing data having both hourly and daily automatic reduction information available to be relayed to EPA's Durham facility.

Proposed System

The fundamental concept of the automated monitoring system is to design the equipment around an inexpensive programmable computer (or desk calculator). By this means, a flexibility of operation is achieved which allows for a large variety of peripheral input/output devices, not possible with a special purpose equipment. Major changes in the formatting, reporting, and collection of data can therefore be made with no affect on the system hardware.

The computer will simultaneously compute the hourly average of all sensor inputs, the peak sensor output during the previous hour, and an exponentially weighted running average available at any time on demand from the master station.

It could transmit over telephone line, to a typewriter, or via an r-f transmitter to the ERTS, whose times of passage could be stored in the computer.

Potentially serious pollutant readings could be flagged and produce special output, and servicing requirements of the sensors could be reported to on-site personnel.

In addition, the basic components of the system can also be used for down time maintenance and servicing. The A/D converter, for instance, is a digital voltmeter, the computer accepts manual data for routine calculations, and the typewriter can be used to print any message desired.

The proposed system will be configured to allow the user to evaluate the use of a satellite network and a real time data presentation. This system is shown in Figure 1.

An alert for episode or equipment malfunction can be conveniently programmed based on either instantaneous or 60 minute time values. The computer can calculate longer time averages, update and provide alarms based on compound averages for several pollutants.

Two means of data display are included in this system, teletype and ERTS, to obtain record keeping data from the sensors. The Data Collection Platform (DCP) accepts sensor input data from the computer. It should be pointed out that in simple remote applications, the DCP could be fed directly from the A/D converter.

The antenna is fairly insensitive to location and can be conveniently mounted on the CAMP station or on the firehouse located adjacent to the CAMP site at the Washington location.

The DCP collects, encodes and transmits ground sensor data to the ERTS satellite. The DCP gathers sensor data from collocated sensors and uses an 8-bit word to describe each sensor sample. The message is encoded and then transmitted. The whole operation is repeated every 180 seconds depending on the period of contact between the DCP and the ERTS spacecraft or on command from the computer.

The sensor inputs to the DCP are processed and formatted by the DCS into computer sensible forms for dissemination to the user when requested. All the data is uncalibrated; that is, the data bits are sent to the user without conversion to engineering units. The recorded data is made available to the user on magnetic tapes, punched cards or computer listings.

EPA has conducted a DCP experiment at our NERC/Cincinnati center. At this center, progress is being made in developing automated contact sensors for the detection of water pollution. A sensor system has been developed which has led to a program utilizing sensors in tandem with a satellite data relay system link to the NASA Nimbus satellite. The project provides for the automatic sensing, recording and transmittal of five to eight water quality parameters from the Greater Miami River to the satellite, where the data is in turn transmitted via the NASA/Lewis Research Center to NERC/Cincinnati for near time analysis. Such programs are intended to demonstrate the real time capability of data relay systems and the potentials of geo-stationary satellites.

Future EPA data relay applications are shown below:

- Monitor sewage waste plant effluents

- Sanitary landfills

- Ocean dumping

- National eutrophication survey

EPA Data Collection System

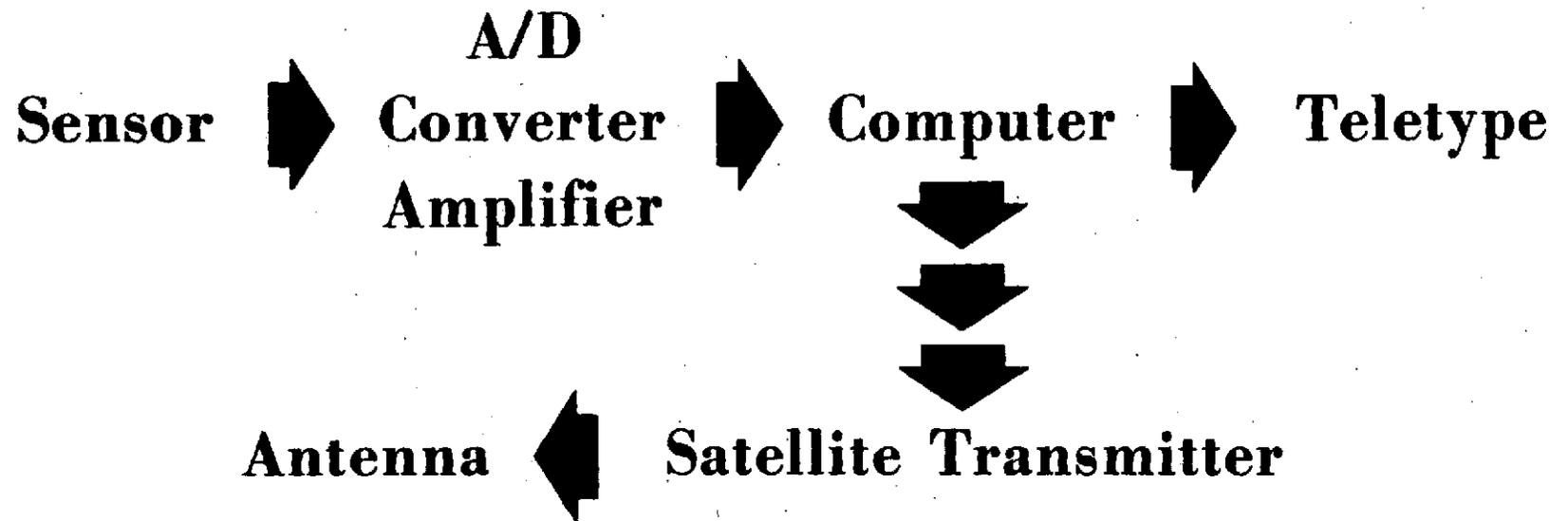


Figure 1.

Automated In Situ Sensors

NASA's capability to monitor the health and conditions of the astronauts during lunar flight is commendable. It could be equally challenging to convert this technology to monitoring the health and vigor of a lake, river basin, or urban atmosphere. The data relay systems currently available in the ERTS and similar satellites could provide near real time environmental data to our regions, States and cities through utilization of the DCP.

However, the present sensors which are suitable for continuous monitoring of chemical, biological and physical properties require standardization and frequent cleaning. This results in a serious limitation to their use in remote locations where it may be necessary to service an instrument weekly or semi-weekly.

The instrumentation capability of NASA could be invaluable towards the development and demonstration of in situ sensors integral with the DCP for monitoring specific environmental parameters for months without requiring servicing. Remote monitoring with such systems would provide timely data for control and abatement of pollution by establishing baseline data and identifying environmental trends.

NASA REQUIREMENTS AND PROGRAMS

Charles W. Mathews

National Aeronautics and Space Administration

I was quite impressed with the extent of the activity and beneficial uses of the ERTS Data Collection System (DCS) that has been described during the two days of this workshop. It is clear that the dedication and enthusiasm which you people have shown here has had much to do with the success of the DCS. I am additionally impressed by the wide variety of applications to which this system has been put, especially the early operational uses that have developed. It comes out loud and clear that the users want an operational DCS and that you are ready to apply it in such a fashion. Although there are some problems that remain to be solved, these are clearly within the state-of-the-technology and should in no way represent a bottleneck to the initiation of such an operational system.

I would like to address myself to a few of your requirements which have found their way into the recommendation of this workshop. Before I do, however, I would remind the attendees that in any recommendations that are finally offered, it is important that you remain aware of the proper level of detail that would be needed to do the job. By that I mean what are the minimum requirements for the job. A realistic approach to this would go a long way toward eliciting a sympathetic response to the recommendations.

It is clearly the desire of this group that continuity of capability be provided by the continued operation of ERTS-1 for DCS purposes, even after the imaging sensors have ceased to function. Further, it is clear to me that you want a DCS capability to be included in ERTS-B. I am in sympathy with the desirability of such an action and will bring it to the attention of the Interagency Coordination Committee on Earth Resources Survey Programs (ICCERSP). I feel they will agree with such a recommendation and would expect that it will be favorably treated in their annual report now in preparation.

A second recommendation of this workshop is that the ICCERSP undertake to study the potential for further development of DCS that will lead to the initiation of an operational system to meet national and international requirements. I will bring this matter to the attention of the ICCERSP. If this committee does not consider such an effort appropriate under its Charter, I will see to it that such an effort is mounted elsewhere.

I do ask that we all keep in mind that NASA is basically an R&D agency and, although a beneficial result of these meetings will be that the requirements will be identified, these must be placed in perspective with other agency requirements and programs. The outcome of meetings such as these will help all agencies by providing information that will support continued or expanded development of associated technology. Hopefully it will lead to the marriage of technologies, for example the marriage of DCS data with ERTS imagery to enhance the value of both. In fact, I'm a bit disappointed that this has not already happened to a greater extent.

I congratulate all of you for an aggressive approach to the development and use of a technology that will be of benefit to this nation and the whole world as well. I encourage you to continue this approach until it comes to fruition, for I am confident that it will come about soon.

SUMMARY ADDRESS

Paul Bock

University of Connecticut

After listening to the presentations and informal discussions, I can report tremendous encouragement, optimism, and truly two-way communication between the speaker and his audience.

Dr. Salomonson has done an excellent job summarizing the technical presentations. I shall only attempt a general summary and, in addition, to presenting for consideration four recommendations which appear to be reasonable extensions of our workshop deliberations.

I shall attempt to summarize the presentations using the "non-technical" words of the speakers themselves in describing their own experiments and experiences. I think the enthusiasm and the optimism of the speakers have come through -- at least to me -- especially in their ad-libbed, unprepared, extemporaneous remarks that highlighted a particular technical point or were made in answer to questions from the floor.

Here are some of the speakers' words as I got them in my notes:

"ERTS-DCS works well, is useful in a wide variety of environments"
"DCS specs have been met and exceeded"
"phenomenal successes with DCP's"
"no failures, one suspect case"
"Canada is using DCP's on an operational basis"
"remarkable piece of instrumentation"
"after ERTS, let's hope there is some DCS system available"
"ERTS DCS is feasible and reliable"
"no unique DCS problems"
"system has worked remarkably well"
"most unreliable part of this whole damn thing (ERTS-DCS) is the land line"
"system like this can be designed to satisfy the operational needs of 75% of the users needs, . . . cheap"
"We've got a good thing here. It works extremely well"

Not all comments were rosy. Some questions were raised concerning future developments in engineering designs of ERTS-DCS and alternative DCS systems.

Suggestions for improvement of ERTS-DCS:

- (1) Develop the means for obtaining hourly readings by redesign of memory-storage.
- (2) Improve antenna design (size, ground plane).
- (3) Test set is inadequate in serial mode.
- (4) Redesign DCP for operational use in severe marine environment.
- (5) Provide direct down-link to a regional user center(s).

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- (6) Re-evaluate NASA procedures for throwing out "bad" data (which may not be "bad" from user point-of-view).
- (7) Consider alternative DCSs: GOES/SMS, Nimbus F, TIROS. Why four DCSs?

Someone has asked, "Why are earth data so important? Don't we have enough gauges? More than enough?" I'll try to cite three examples in hydrology which indicate the importance of timely hydrologic information.

- (1) There are some 250,000 hydrologic gauges of all kinds throughout the world: precip. 100,00+, stream 100,000+, snow 25,000+, evap. 4,000+, sedimentation 3,000+, quality 4,000+. In spite of all these gauges, hydrologists want to install even more. But, what is required is more systematic hydrologic information which can be extrapolated spatically and temporally. ERTS imagery plus DCS capabilities provide the start toward the necessary integration of multiple point-data which are maldistributed. ERTS data ultimately may lead to improved observational network design, which in fact for many situations would likely lead to a reduction of the number of in-situ gauges.
- (2) U. S. urban flood damages amount to one billion dollars annually. (The recent Agnes and Mississippi floods will increase this average annual damage figure.) There are only 50 rainfall-runoff networks in all the cities of the U. S. A drastic need for urban hydrologic data exists to guide urban storm design. Drainage development costs are now estimated at some \$1,000 per acre. The engineering design method most used in storm drainage is now 84 years old, developed when rain was measured in tin cans and stream flow was measured using pairs of whitewashed sticks placed in the flow. There is no question that improved hydrologic data could provide better design and save costs in storm drains, gutters, culverts, water openings, etc.
- (3) The annual expenditure for construction and maintenance of highway culverts and small bridges in the U.S. is estimated at \$500 million annually. This is not an insignificant cost. In the U.S. there are less than 500 watersheds sufficiently gauged to develop design criteria to reduce the \$500 million highway drainage cost (for small structures). Insufficient hydrologic data translates to inefficient hydrologic design which extracts a recurring penalty in increased costs in construction, maintenance, and operational efficiencies.

RECOMMENDATIONS

The following recommendations, presented by Paul Bock during his Summary Address, were indorsed by the Workshop participants:

- (1) Recommend that NASA maintain the ERTS-DCS capability, even after useful life of sensors and recorders have expired and continue such capability up to ERTS-B.
- (2) Recommend that ICCERSP create an ad hoc interagency DCS panel to coordinate study and development of DCS leading to (a) early deployment of data collection systems to meet agency missions and (b) to consider the international aspects of DCS and to report findings and recommendations to ICCERSP. (This recommendation follows 1968 NAS Woods Hole recommendation for an operational DCS capability by 1975 and is supported by highly successful accumulated experience of ERTS-DCS users.) (c) Study the overall technical feasibility of piggy backing civilian DCS packages onto unclassified military polar orbiting satellites.
- (3) Recommend publication of proceedings of this Workshop on ERTS-1 Data Collection.
- (4) Recommend to undertake to consolidate the overall experience of DCP users by preparation of a "Manual of Experience" which would describe the operational aspects of DCP's environmental problems and solutions; e.g., sites: snow, marine, heat, wind urban, equipment: batteries, antenna testing procedures, etc., lists of P.I. names, addresses, telephone numbers, type of problem. (For the benefit of present and future community of DCS users.)

APPENDIX

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