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SENSOR DATA RETRANSMISSION BY SATELLITE

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SENSOR DATA RETRANSMISSION BY SATELLITE

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INTRODUCTION:

The ERTS program*, because of its capacity to provide repetitive synoptic imagery of the earth's surface has resulted in increased interest in remote sensing. In addition to its RBV and MSS scanners, the ERTS spacecraft also carries a Data Collection System (DCS) that enables a user of the imagery to obtain near real time sensor data for ground truth.

The users of ERTS imagery, with few exceptions, have not used the satellite's DCS to any extent. The system was designed to handle data from 2,000 locations without degradation although only about 10% of that number were ever established. The small number of DCS users have experienced considerable success.

This paper will discuss the results of some of the ERTS DCS experiments, the SMS-GOES Data Collection System and other satellite data retransmission systems now in the planning stage. An attempt will be made to conceptualize an ideal data retransmission system.

ERTS DATA COLLECTION SYSTEM:

The ERTS spacecraft has the capability of relaying 64 bits of data from ground based sensors to receiving antennas in Goldstone, California or Greenbelt, Maryland (NTTF) whenever the satellite is in mutual view of a receiving station and a transmitting remote station. Data may be retransmitted during the southbound passes each morning and the northbound passes in the evening.

Data from the remote sites are transmitted by means of a Data Collection Platform (DCP). Sensor data are collected, encoded, and transmitted by the DCP along with a platform identification in a 38 millisecond burst approximately every three minutes. The data received by the spacecraft are then relayed in virtually the same instant to a receiving station. There is no provision for storage of data on the satellite.

The DCP will accept a data input of 8 words of 8 bits each for a total of 64 bits. The data can be in analogue, serial digital or parallel digital form. Each analogue input requires one 8 bit word having a required

* ERTS was officially changed to LANDSAT on January 13, 1975.

input voltage level of 0 to +5 volts. The serial digital input consists of one input which can be 8 to 64 bits in length in increments of 8 bits. The parallel digital input consists of up to 64 bits. The bits are sampled in 8 bit groups.

Each DCP consists of a small electronic box which assembles and transmits the data and an omnidirectional antenna. The electronic units are designed to operate in severe temperatures and high humidities. Data Collection Platforms have been manufactured by two companies. The initial supplier was General Electric while, more recently, Ball Brothers Research Corporation has manufactured platforms. Although there are many differences between the platforms, one of the most apparent is Ball Brothers use of a 14 inch square, 0.25 inch thick microstrip antenna instead of the crossed dipole element on a 46 inch diameter, 1 inch thick ground plane used by General Electric. Other antennas, notably the Chu, have also been used with the General Electric platform.

Data received at Goldstone or Greenbelt are formatted and transmitted on NASA Communication System land lines to the Ground Data Handling System at Greenbelt. The data are sorted and sent to users in computer printout or punch card format. Also, the data from Canadian platforms are sent by dedicated telephone line to the Canada Centre for Remote Sensing (CCRS) after every orbit with a delay of 30 to 40 minutes.

These data are periodically inputted to the CCRS time sharing computer system. A software data retrieval system sorts the user platforms, reformats the data into engineering units and stores individual user files on disk. The user may then access his data file using either a teletype or telex remote terminal. A typical retrieval for the Water Survey of Canada DCPs in Ontario is shown in the figure.

Fourteen DCPs were originally purchased for use in five experiments in Canada. None of the experiments was directly concerned with remote sensing although the types of data retransmitted demonstrated the suitability of the system for providing ground truth.

The Atmospheric Environment Service, Department of the Environment used a DCP to transmit precipitation, air temperature, snow pillow and wind anemometer data from a site near Toronto. The HARTS system developed for this purpose, described in Fong, 1973, was subsequently used for co-operative programs at a Water Survey of Canada gauging station in British Columbia and one in Northern Ontario.

TELETYPE RETRIEVAL OF ERTS DCS DATA FROM CCRS

S Y 000HHMM SS PID C D1 D2 D3 D4 D5 D6 D7 D8 CS

UPDATE: 8,36, 17,12,1974.

NO MESSAGES 6137

N	4	3501523	59	6137	7	43.09		0	0	377	376	0	204	6
N	4	3510304	18	6137	7	43.09		0	0	377	376	0	200	3
N	4	3501340	09	6102	7	4.6	81.94	10.4		0000FF				
N	4	3501343	34	6102	7	4.6	81.94	10.4		0000FF				*
N	4	3501522	44	6102	7	4.6	81.94	10.4		0000FF				1
N	4	3501526	09	6102	7	4.6	81.94	10.4		0000FF				1
N	4	3501529	35	6102	7	4.6	81.94	10.4		0000FF				1
G	4	3501708	40	6102	7	4.6	81.94	10.4		0000FF				1
G	4	3501712	04	6102	7	4.6	81.94	10.4		0000FF				1
P	4	3510118	41	6102	7	4.6	81.78	13.5		0000FF				2
N	4	3510122	04	6102	7	4.6	81.78	13.5		0000FF				2
N	4	3510125	28	6102	7	4.6	81.78	13.5		0000FF				2
N	4	3510300	26	6102	7	4.6	81.78	13.5		0000FF				2
N	4	3510307	13	6102	7	4.6	81.78	13.5		0000FF				2

END DCP DATA

Job 12. User [110,151] Logged off TTY4 1141 17-Dec-74
 Saved all files (b blocks)
 Runtime 1.35 Sec

NOTES

- ① RECEIVE SITE --N IS GREENBELT MD., G IS GOLDSTONE CAL.
- ② YEAR
- ③ JULIAN DATE AND RECEIVE TIME TO NEAREST SECOND.
- ④ PLATFORM ID.
- ⑤ MESSAGE QUALITY ON SCALE OF 0 TO 7
- ⑥ ACCUMULATED PRECIPITATION, INCHES
- ⑦ WATER LEVEL, FEET
- ⑧ TEMPERATURE, °F
- ⑨ UNUSED DATA WORDS
- ⑩ RECORDER OPERATION
- ⑪ BATTERY VOLTAGE
- ⑫ CHECK SUM (*INDICATES NO CHECK)

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The Glaciology Division, Water Resources Branch, Department of the Environment used a DCP to transmit water level data from a gauging station on the Rideau River in Ottawa and to test a battery voltage sensor and water velocity integrator built especially for use with the Water Survey of Canada DCPs. The DCP was also used to transmit water quality data from a site on the Presqu'isle River in New Brunswick. The data retransmitted by satellite were compared to that transmitted by a telephone system and it was found that the satellite link was far more reliable. The reliability of ERTS DCS in comparison to land line telemetry has also been noted in Cooper 1973, in Higer et al, 1973, and in Schumann, 1973.

The Lakes Division, Canada Centre for Inland Waters, Department of the Environment used a DCP to transmit air and water temperatures, relative humidity and battery voltage from an anchored buoy and from a tower in Lake Ontario. The number of messages received when the DCP was mounted on a buoy was not appreciably different than the number received when the antenna was fixed solidly.

The Tides and Water Levels Section, Marine Sciences Directorate also purchased a DCP but, until recently, have not used it. Dummy data are now being transmitted.

One DCP has been used by the Quebec Natural Resources Department to transmit water level, air temperature, and other related data from a site in northern Quebec.

Nine DCPs have been used to transmit data from Water Survey of Canada gauging stations in northern and western Canada. All DCPs transmit water level but, some transmit additional parameters such as air temperature, precipitation, water velocity, ice out indication, recorder operation status or battery voltage check. The retransmitted data have been used for a variety of purposes and platform failure rates have been low. Three platforms failed; one massive failure was attributed to some phenomenon such as lightning while the other two resulted from manufacturing defects that caused failures after two years of successful operation.

Of the US users of ERTS-DCS, Higer and his co-investigators in the US Geological Survey in Florida, have provided the best example of the use of satellite retransmission to supplement and ground truth ERTS MSS imagery. An ecological model of the Shark River Slough in Everglades National Park has been developed in order to regulate water levels in the Park. ERTS DCS is used to provide water level, water quality and meteorological data while the ERTS imagery is used for areal measurements.

While ERTS is an experimental program, its immediate future seems assured as ERTS-B is scheduled for launch in January 1975, and some investigatory work on ERTS-C is in progress. In Canada, the feasibility of receiving and demodulating DCS data at the Prince Albert station is being studied. Also, the Water Survey of Canada has purchased an additional 19 DCPs for its program. These are convertible units that can also be used with the GOES Data Collection System. A 720 bit memory will also be used experimentally.

GOES DATA COLLECTION SYSTEM:

The GOES system is the US contribution to a worldwide network of operational geostationary environmental satellites. The satellites carry a Visible and Infrared Spin Scan Radiometer (VISSR) and a Data Collection System (DCS).

The GOES system will consist of one satellite at 75° west longitude, one at 135° west longitude and an in-orbit spare. The first satellite (SMS-1) was launched in 1974 and is now at the 75° location; earlier in the year, it was placed further east for use in the GARP Atlantic Tropical Experiment (GATE). The second satellite (SMS-B) will be launched in January 1975, and GOES-A will be launched later in 1975. (The two SMS spacecraft are NASA prototypes of the GOES spacecraft.)

The GOES system is operated by the National Environmental Satellite Service (NESS) of the National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce. All data from the satellite are received at the NOAA Command and Data Acquisition station at Wallops Station, Virginia. After some processing, data are sent to Suitland, Maryland for dissemination to users. Depending on the user, NOAA lines, USGS lines or NWS lines may be used for this. The NWS system has a connection to AES in Toronto.

The users of the GOES DCS are assigned channels and time slots during which data can be transmitted. Each satellite has 150 channels and, if a 2 minute time slot every 3 hours is assigned to each user, then each satellite has a theoretical capacity of over 10,000 data collection platforms. The data rate used in the GOES system is 100 bits a second and messages will be a maximum length of 20 seconds, therefore, about 2,000 bits can be transmitted during each time slot.

There are two basic methods of operation of the GOES-DCS, that is, interrogated and self timed. The transmit sequence of the interrogated

platforms is initiated by means of a coded signal from the GOES satellite while that of the self timed unit is initiated by an accurate clock within the platform.

The interrogated platforms have been manufactured by the Magnavox Company. These are known as Data Collection Platform Radio Sets (DCPRS). The DCPRS will only handle serial inputs, therefore, a unit known as the Device for Automatic Remote Data Collection (DARDC) manufactured by LaBarge, Inc., Dorsett Electronics Division, is used to provide an interface to sensors having binary coded decimal, pulse, or analogue outputs. The DARDC unit converts these sensor outputs to an ASCII coded serial message for the DCPRS. Other interfaces such as the AES HARTS unit are also compatible with the DCPRS.

One drawback of the DCPRS from the standpoint of use under Canadian winter conditions is that it requires a $7\frac{1}{2}$ foot long helical coil antenna which must be aimed at the spacecraft with an accuracy of $\pm 5^\circ$. Also power consumption is high as the DCPRS draws 40ma in its standby receive mode. This means that a battery charging unit such as wind generator, solar panel or thermo-electric generator must be provided.

The self timed platforms have been manufactured by Ball Brothers Research and are known as Convertible Data Collection Platforms (CDCP) since they are field convertible to ERTS operation. The input to the CDCP is the same 64 bit, serial digital, parallel digital or analogue input format as ERTS, however, the CDCP converts the data to ASCII code in the GOES mode. Also, in the GOES mode, the platform can transmit the entire contents of a 720 bit memory in one message. The antenna used is an array of four microstrip patches and is 24 inches square and 0.25 inch thick.

Three Canadian users are in the process of obtaining agreements with NESS to use the GOES system. These are the Atmospheric Environment Service, the Canada Centre for Inland Waters and the Water Survey of Canada. Initial use of the system will be similar to that made of the ERTS DCS. It is expected that Canadian GOES platforms will be in use early in 1975.

OTHER DATA COLLECTION SYSTEMS:

Centre National D'Etudes Spatiales:

The Centre National D'Etudes Spatiales (CNES) of France has conducted market surveys in North America on the potential for a Franco-American data retransmission system that would be carried on a TIROS satellite

and on a satellite known as METEOSAT. Details of these systems are hard to obtain, however, it seems that the TIROS-N system would be similar to ERTS except that the possible message length would be 256 bits, the maximum number of platforms would be 6,000 and the satellite will have memory capability. The TIROS system would also have the capability to carry out a localization calculation based on the Doppler shift of the incoming message from the platform. This would be an attractive feature when sensors mounted on unanchored buoys or ice packs are used.

METEOSAT is scheduled for launch in 1976 and is the European counterpart to GOES. The satellite will probably be placed on the prime meridian so that contact even with eastern North America would be a marginal proposition since elevation angles to the satellite would be less than 10° . The data collection system aspects of METEOSAT are almost identical to those of GOES.

Other Non-Canadian Systems:

The Soviet Union and Japan are also planning to operate satellites similar to GOES/METEOSAT but these systems would definitely be inaccessible to Canada. Studies of satellite retransmission have also been carried out in the United Kingdom, Italy, and Sweden. The results of these tend to verify the conclusions reached in North American studies.

The Canadian UHF System:

During the past few years, the Department of Communications has been conducting planning studies for a low capacity, geostationary, UHF communications satellite. The satellite would have two main uses. The first is to provide voice telephone service (including facsimile and interactive data transmission at high bits rates) for communication of field parties; the second, to provide a sensor data retransmission service. The earliest operational date would be 1978.

The system would consist of two satellites in orbit and a spare that would be launched a few years after the first two. Ground control and data handling would be provided by two ground stations, one of which would be redundant. User cost analyses of the data retransmission part of the system produced attractive figures.

A study of the type of data collection platform that could be used with the satellite was conducted by RCA Victor of Canada. The study was based in part on a survey of user requirements and recommended a platform having a 288 bit serial digital capacity with parallel digital

and analogue options. The use of an activity monitor that could change the transmission interval depending on the magnitude or rate of change of a parameter was also recommended. Bristol Aerospace is now constructing a Data Processing Platform (DPP) under contract with the Water Resources Branch, Department of the Environment, that would incorporate some of the design concepts set out in the RCA study.

The plan for the UHF system is rapidly reaching a "go, no-go" situation and a go-ahead for the system could be given in 1975.

CONSIDERATIONS FOR AN IDEAL DATA RETRANSMISSION SYSTEM:

In trying to define an ideal data retransmission system, one of the first questions is that of geostationary versus orbiting satellites. Positive aspects of a geostationary system are that it permits sensor data to be relayed at any time interval that seems appropriate to the data user. Negative points include the fact that the Canadian Archipelago could not be serviced beyond 75°N (Resolute Bay) and service in the mountainous portions of the Yukon Territory and Northern British Columbia could be a problem. The data collection platforms used with a geostationary system would tend to be more costly because of higher power requirements and antenna complexity.

The main advantage of orbiting satellite systems is that the data collection platforms are relatively inexpensive and easier to deploy. Disadvantages include the inability to obtain data at all times unless large numbers of satellites are deployed and the requirement for a tracking antenna at the receive site.

There are several considerations that arise in platform design that point out the need for a modular concept. Many users, including the Water Survey of Canada would like to transmit small quantities of data from many locations. To do this economically, a "bare bones" platform having modules for various types of inputs, data storage, data analysis, etc. seems attractive. It would be preferable to convert data to ASCII or other codes at the central receive sites rather than in the DCP in order to reduce complexity and cost of the DCP. The use of a forward error correction and detection system such as that in the ERTS-DCP would be attractive as this would reduce the probability of bad data being sent to the user. A random access platform would be preferable to an accurately clocked one since this would also reduce platform costs. Platforms must be designed to function in Canadian climate with minimum protection.

A necessary part of any satellite retransmission system is an efficient ground data handling system. It is essential that data be forwarded to users with a minimum delay and as reliably as possible. A combination of a teletype facility for real time needs plus mailed computer compatible copy on a monthly basis for archival purposes would be ideal. The best method of ensuring a satisfactory data handling system would be to establish it on a national or, perhaps, an agency basis.

In summary, there is no ideal satellite data retransmission system that will meet all Canadian requirements. However, a rugged, non-sophisticated, platform capable of transmitting up to 100 bits of data on a random access basis to an operational satellite, either geostationary or orbiting, whose data processing facility is in Canada would meet most Canadian requirements. It is also apparent that until a satellite system that meets most of these requirements becomes available, Canadian data gatherers will be reluctant to make large capital investments in data collection platforms.

CONCLUSIONS:

The ERTS data collection system has been used to demonstrate the reliability and relative low cost of data retransmission by satellite from remote locations in Canada. Some experimenters in the United States have shown that the use of ERTS imagery in conjunction with ERTS data retransmission can be used to model natural phenomena.

To take full advantage of this new technology, it is essential that a data retransmission system that meets Canadian requirements be established on an operational basis. This seems likely to happen in the near future if progress continues to be made on systems now in planning or implementation stages.

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