SATELLITE (ERTS-A) NETWORK OF GROUND DATA

SENSORS: A USER-ORIENTED EXPERIMENT 1/

by

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ABSTRACT

The first Earth Resources Technology Satellite, which will supply data for the EROS Program, is scheduled for launch in early 1972. Included among the experiments to be conducted with the satellite is the relay of ground-sensor data (primarily related to streamflow and water-quality) in a near "real-time" mode.

The goals of the experiment are to 1) provide "ground truth" to aid in interpretation of the imagery obtained from on-board sensors, and 2) test the feasibility of using "real-time" data from satellite relay as an aid in river basin management. This paper will present the preliminary network of hydrologic sensors and the relationship of that network to the design goals.

1/ Publication authorized by Director, U. S. Geological Survey

2/ U. S. Geological Survey, St. Louis, Missouri
INTRODUCTION

The first Earth Resources Technology Satellite (ERTS-A) is scheduled for launch in early 1972 as part of the Earth Resources Observation Satellite (EROS) program of the Department of the Interior. ERTS-A will be a polar-orbiting, sun-synchronous satellite with an orbit time of about 104 minutes. Although the primary output of the satellite will be earth imagery in the visible and solar-infrared parts of the electromagnetic spectrum, included among the experiments to be conducted is the relay of ground-sensor data to the satellite and thence to a central data acquisition station or stations.

The transmitted data will include measurements of parameters related to the fields of hydrology, meteorology, and geology, as well as parameters useful in the operation of the satellite itself. The last category could include sensors indicative of illumination levels with which evaluations regarding acquisition of satisfactory images could be made. This paper will present the currently envisioned network of stations and the rationale which governs the design of that network.

RELAY CAPABILITIES

Because there have been many papers presented regarding ERTS-A in various outlets (Fischer, 1968, NAS, 1969, Pecora, 1967, Robinove, 1967, U.S. Geol. Surv., 1969), it is important here to separate the capabilities of the satellite to obtain imagery from the capabilities to relay ground-sensor data in
order to avoid any confusion which might result. Table 1 lists briefly both capabilities, while Table 2 shows pertinent platform characteristics.

One cannot treat the data relay without consideration of the imagery but it is important that confusion be avoided about the frequency of acquisition of each. The most important point regarding this frequency is that imagery of a particular area can be obtained once every 18 days but that data from the ground sensors can be obtained twice daily. The remainder of Table 1 shows that the major purpose of the data relayed is for correlation with and interpretation of the imagery.

DESIGN GOALS

Ground data will be acquired twice daily (table 1) to partially fulfill each of the two primary goals of the data relay experiment. The first goal is that the ground data be available concurrently with the imagery obtained by the satellite in order to provide an aid in interpretation of that imagery. In other words, it is desirable to correlate ground truth with the imagery to arrive at a better interpretation of what single images or changes in repetitive images are portraying. The second goal is to test the feasibility of using "real-time" data relayed by the satellite as an aid in resource and river basin management. The second goal can be stretched with a little imagination to form the basis for determining the practicality and economics of an earth-resource data communications satellite.
Interpretation Aid

The goal regarding correlation of ground truth with imagery implies two ways in which the ground data can be used. One is the use of ground data to interpret a single image or concurrent set of images. Such a use requires data which is directly relatable to information portrayed in the image. Table 3 lists parameters being considered for relay. However, because of the region of the spectrum which will be sensed by ERDS-A, the only parameters which may have direct relation to a single image or set of images are: stream and reservoir levels for drainage features and inundated areas; wind speed and direction for cloud formations; turbidity for tonal differences in water; and solar radiation for effect on reflectance from all features. It is anticipated that ERDS-B will include a thermal infrared sensor which will bring water, air, and soil temperatures into the category of being directly relatable to individual images.

The other, and perhaps more important, use of the ground data for aid in interpretation relates to the differences in successive images. For example, knowing that a precipitation gage reads one inch for one image and four inches for a later image would probably not be of much value for either image. However, the knowledge of the time distribution of the three inches which occurred between the two images may be of value in interpretation of tonal differences related to changes in soil moisture between images. For this type of use, then, the parameters of importance might include: stream and reservoir levels for change in area of inundation with change
in flow regime; precipitation for the reasons in the foregoing example; water temperature, dissolved oxygen, pH, and solar radiation as they affect or are affected by the photosynthesis process and change in water vegetation; and most of the remaining meteorological parameters for their effect on the total reflective return in successive images.

Management Potential

The orbital characteristics of ERTS-A result in a ground track which advances 25.7 degrees of longitude west per orbit at the equator and 1.5 degrees longitude west per "day" (14 orbits = 1456 minutes). In other words, orbit 2 would be 25.7 degrees west of orbit 1, and orbit 15 would be 1.5 degrees west of orbit 1. This, in conjunction with; 1) acquisition sites at Fairbanks, Alaska, Corpus Christi, Texas, and Greenbelt, Maryland; 2) logistical problems of handling the data after acquisition and; 3) financial considerations, tend to limit the number of ground stations which can be used in a "real-time" mode for this experiment.

Because perishability of management purpose data is usually expressed in hours, the experimental use of real-time hydrologic data will probably be confined to one locality or basin in close proximity to an acquisition site. One basin has been tentatively chosen in which to carry out the real-time part of the experiment. It is the Delaware River basin network of stations where a major management use of data is in the location of the salinity front as it affects local water supply decisions. Another basin being considered is the
Ohio River basin network of stations where, again, a major management use of data is largely related to water quality as it affects supply and disposal decisions. Instrumentation of all or part of either of these basins would provide a good test of the satellite capability to relay real-time data.

The feasibility of relaying hydrologic data through a satellite to central locations has already been established with the ATS-1 satellite (Flanders and others, 1969). Therefore, the thrust of this experiment is that of utilizing a transmit-only platform of simple design and, therefore, low initial cost. Table 1 shows that ERTS-A will provide only one data transmission per 12 hour period. However, successful transmissions with this system will point the way toward an economically instrumented ground network reporting to geo-synchronous satellites which will afford continuous data collection. The success of this part of the experiment will depend not only upon how well the system itself works, but also on how well the data can be used in existing real-time systems. Again, the Delaware River basin system will provide a test of this.

Geologic sensors also provide a real-time test for relayed data. Successful twice daily transmission of tilt measurements and the occurrence of seismic events will provide data needed for research in earthquake dynamics as well as for judging the effectiveness of a more widespread network of such sensors.
Another purpose which the relayed data will fulfill is that of a key to image requests by users. By supplying ground data along with the catalogs of imagery available, the user will be able to make a more judicious choice as to which imagery he desires to analyze rigorously. For example, if an investigator desires to analyze imagery indicative of dry hydrologic conditions, he would merely have to refer to the relayed ground data to see if the concurrent imagery fits his criteria. The same would hold true for wet hydrologic conditions. Alternatively, standing requests could be made for imagery to be supplied when hydrologic conditions are favorable as indicated by particular ground stations. While this is not a major goal of the network, it will be useful nonetheless.

GROUND SENSOR NETWORK

Ideally, it would be desirable to have some ground sensor information within each 100 mile square image viewed by the satellite. However, this is an experiment and a number of obvious constraints would not allow instrumentation of such a large network. Therefore, in order to satisfy as many uses as possible, a basic network of ground sensors which measure stream gage height and quality parameters has been chosen based on the Geological Survey's Office of Water Data Coordination (OWDC) Level 1 Accounting Network. Figure 1 shows the location of all continuous recording stations in that network which are located on streams having a drainage area larger than 8,000 square miles. These stations comprise the basic areal coverage network.
Because the resolution of the imagery obtained from the
satellite will be about 200 feet, the 3,000 square mile criterion
is intended to assure visual recognition of the streams. Streams
of this size should have enough width so that water can be recognized
rather than just a line on the image.

Most of the water quality stations in the Level 1 Accounting
Network are not continuous recording stations. Instead, they are
sampled on a daily, weekly, monthly, or even seasonal basis, depend-
ing upon the magnitude of quality problems. The continuous recording
criterion is intended to assure that there are sensors in existence
to which transmitters can be attached.

In the case of stream gage height sensors, there is little
problem obtaining an areally extensive network. However, with
water quality monitors it is a case of take-what-you-can-get. At
the present time within the Department of the Interior, an areally
extensive network of numerous water quality sensors subject to the
foregoing criteria does not exist. However, both the Federal
Water Pollution Control Administration and the Geological Survey,
are actively engaged in implementing a much larger network. It
is planned to include in the network new sites fitting relay network
criteria as they are instrumented. An areally extensive network of
water quality sensors is a very real possibility by the launch time
of the satellite. In the meantime, efforts will be made to interest
State and local agencies as co-investigators in this part of the
experiment.

The sites shown on Figure 1 represent only about two-thirds of
the 250 total stations planned for this network. The remaining sites
will be composed of sensors relaying parameters related to research activities and specific user needs for relayed data. Such activities as atmospheric research by the U. S. Bureau of Reclamation in Colorado, earthquake research in the west, and phreatophyte research in Arizona by the U. S. Geological Survey are included. Some interchange of sites will, of course, occur prior to the launch of ERTS-A.

SUMMARY AND CONCLUSIONS

The intent of providing ground sensor data concurrently with and in the interim of successive image sets from the ERTS-A satellite is to improve the qualitative, semi-quantitative and quantitative interpretations of that imagery. A network of a relatively small number of stations with maximum areal application to provide that data has been designed and sites have been selected. Important to that network are hydrologic sensors as they relate to visual interpretation of imagery and management of water resources. A localized network of sensors to test real-time applications of satellite relayed data will have water quality sensors as a basic ingredient.
REFERENCES CITED


Pecora, W. T., 1967, Surveying the earth's resources from space, Surv. and Mapping Jour., v. 27, no. 4, p. 639-643.


Table 1 -- Comparison of Relay and Imagery Capabilities

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Images</th>
<th>Data Platforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collected</td>
<td>Repetitive once every 18 days</td>
<td>Twice daily</td>
</tr>
<tr>
<td>7 images:</td>
<td></td>
<td>1000 ground locations (maximum)</td>
</tr>
<tr>
<td>Television:</td>
<td></td>
<td>8 sensors per location (Analogue)</td>
</tr>
<tr>
<td>1</td>
<td>475-575</td>
<td>4 sensors per location (Digital)</td>
</tr>
<tr>
<td>2</td>
<td>580-680</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>690-830</td>
<td></td>
</tr>
<tr>
<td>Point Scanner:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>500-600</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>600-700</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>700-800</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>800-1100</td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>Black and white images</td>
<td>Data lists</td>
</tr>
<tr>
<td>Color composite images</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 miles square; 1:800,000 scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td>Interpretation related to discipline</td>
<td>Interpretation aid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Management purposes</td>
</tr>
</tbody>
</table>
Table 2 -- Data Platform Characteristics

Acquisition by satellite -- Once per 12 hour period (up to 3 satellite passes within range per 12 hours)

Transmission -- 0.1 second burst every 120 seconds

Message Content -- 64 bits parameter data
  8 bits per sensor (analog)
  16 bits per sensor (digital)
  11 bits identification
  5 bits synchronization
  80 bits total length

Power Supply -- Battery pack (6 months operation)
  Commercial line
  Solar panel

Space Occupied -- 330 cubic inches

Table 3 -- Parameters Considered for Relay

<table>
<thead>
<tr>
<th>Hydrologic Parameters</th>
<th>Meteorologic Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream level</td>
<td>Air temperature</td>
</tr>
<tr>
<td>Reservoir level</td>
<td>Precipitation</td>
</tr>
<tr>
<td>Ground-water level</td>
<td>Wind speed</td>
</tr>
<tr>
<td>Water temperature</td>
<td>Wind direction</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>Total wind</td>
</tr>
<tr>
<td>pH</td>
<td>Solar radiation</td>
</tr>
<tr>
<td>Specific conductance</td>
<td>Dew point temperature</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Rime ice</td>
</tr>
<tr>
<td>Chloride</td>
<td>Snow moisture</td>
</tr>
<tr>
<td>Oxidation-reduction potential</td>
<td></td>
</tr>
</tbody>
</table>

Geologic Parameters

Seismic events
Tiltmeter
Soil temperature
Figure 1.-Map of conterminous United States showing principal geographic units used by OWDC and sites being considered for ERTS-A data relay.