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Applications of ISES for Geology

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Many geological investigations do not require real-time remote sensing data insofar as the scenes are not very dynamic. However, there are times when rapid data acquisition can be very appealing, such as when directing a field operation or assessing the extent of environmental damage following a natural event. Before discussing these potential applications, it would be meaningful to define what is meant by real-time data.

For the most part real-time means that the data is being sent directly to the user as soon as it is collected and put on the spacecraft local area network (LAN). However, several things could delay this. If the Information Sciences Experiment System (ISES) onboard data processing is significant, or if data must be accumulated for several minutes or even orbits, then there could be a significant delay and the term "near real-time" is perhaps more appropriate. Thus the time between data acquisition and transmission is dependent on the application.

The data requirement will depend on the sensors involved and the ground station capabilities. ISES will be able to perform such operations as calibration, registration, geometric correction, grid referencing, resampling, applying algorithms, feature extraction, and the merging of multiple sensor output products. The data transmitted could vary from a simple set of statistics for a given area to a continuous stream of raw data from several sensors. Small portable ground stations will require highly processed data and probably low data rates.

Table 1 lists a variety of occasions where real-time remote sensing capability would be beneficial. This list is not intended to be complete but should be representative of the needs in the geological sciences. A discussion of these topics follows.

Table 1. - Areas of Interest for Real-time Data Transmission

1. Remote Sensing Verification During Field Sampling Programs
2. Remote Sensing Support for Field Investigations
3. Mass Movement:
   A. Rock Slides
   B. Mud and Debris Slides or Flows
   C. Wind and Sand Storms
4. Earthquakes:
   A. Surface Destruction
   B. Fires

C. Flooding and Mud Flows

D. Tsunamis

5. Volcanics: A. Gas and Smoke Venting

B. Lava Flows

C. Lahars

D. Pyroclastic Flows

E. Major Pyroclastic and Gas Eruptions

Remote Sensing Verification

Many remote sensing programs require the collection of surface samples during the overpass of a satellite, primarily for the purpose of scene calibration. At such times it is desirable to have verification that the satellite data was satisfactory over the area of interest. This is not always apparent from the ground, so a real-time data link could reveal such parameters as percent cloud cover, average aerosol index, and condition of the satellite data. If certain conditions are not met the investigators may wish to repeat the sampling during a following satellite overpass rather than chance having to return to the field at a later date. When aircraft are used as the primary remote sensing platform, the regional view of the satellite is still a valuable asset for making decisions affecting the program activities.

Remote Sensing Support

Geological investigations that are not remote sensing oriented may still benefit from the real-time transmission of satellite data. During the preparation for the field work geologists will consult pertinent maps and remote sensing data, but once in the field it may become apparent that conditions have changed since the last data were collected. Many surface features could have changed due to erosion or deposition, or vegetation might obscure much of the geologic structure. The ability to receive satellite imagery would be an asset at such times. There is also the possibility of making new discoveries, such as the location of faults or potential ore deposits, whereby satellite data might confirm the significance of the information. In most of these cases high resolution visible or microwave imagery will be desired, but the capability to receive such data may be limited by the receiving station. Access to adequate ground facilities may be the limiting factor under these conditions.

Mass Movement

Mass movement involves the transport of some portion of the land surface, such as in creep, landslide, or slip. With the exception of rain- or snow-induced slides, most mass movements do not have precursors. The more dramatic slides can be induced by such factors as stress relief, earth tremors, surface loading, weathering, etc. Although these events can be quite extensive and life threatening, the best that can be done is to quickly assess the magnitude of the damage. Near real-time satellite data would certainly be an aid to achieving this end. In these cases, an existing facility near the incident could process the data and generate the desired end products.

Wind storms, which include hurricanes, tornadoes, and sand storms are generally associated with meteorological phenomena, but they can result in major alterations of the land's surface. The poor atmospheric conditions at such times implies the need for microwave data during the event with visible imaging data at the nearest available time. In all events that involve making estimates of surface change it will be essential to have a data base for making comparisons of scene imagery. The storage of such a data base on the satellite would probably not be feasible, except under limited conditions, and therefore the data base would have to be kept at the local ground facility.

Earthquakes

Major earthquakes are predominately confined to well known areas and zones of the earth's surface. Since most result from the build up and release of stress along extensive fault systems, there is some periodicity to their occurrence. However, with the exception of foreshocks, which are not reliable indicators, there is little or no immediate warning of an impending major earthquake. The role of remote sensing, then, as in the mass movement episodes discussed above, is primarily one of damage and impact assessment. Both day and night high resolution coverage is desired at the disaster site. Fires may also accompany a major surface disturbance in urban areas and this will require the monitoring of atmospheric conditions as well. When reservoirs, lakes, and rivers are affected there is the additional problem of flooding and resulting mud flows. This puts an additional emphasis on continuous monitoring since aftershocks are still a consideration.

When earthquakes occur on the seafloor along the continental shorelines there is the potential for the generation of a tsunami. It is not possible to predict when a life threatening tsunami will occur, even when the location and magnitude of the quake is known. An international early warning network issues predictions of arrival times of potential tsunamis at major seaports around the world as a precautionary measure. At the present time it is doubtful that real-time satellite data would be a benefit other than to monitor coastal regions for damage.

Volcanoes

Volcanic activity is basically confined to the earth's major plate boundaries, the ocean ridges, and isolated hot spots. Unlike earthquake activity, however, volcanic upheavals often display a number of warning signs that may be monitored routinely by satellite. The sighting of smoke plumes and hot spots on or near the earth's surface, and/or volcanic gases in the troposphere or stratosphere, may portend a more serious event.

Data from the thermal bands of any imaging instrument could be examined on a regular basis over the known volcanic regions of the earth and the output used to alert investigators when temperatures above a given level are found. A similar approach could be taken with the atmospheric instruments, whereby the detection of a known volcanic gas above a certain magnitude could be used to activate a more dedicated search for its source. The primary magmatic gases emitted from lavas are water vapor, hydrogen, oxygen, nitrogen, hydrogen sulfide, sulphur dioxide, sulphur trioxide, carbon dioxide, carbon monoxide, hydrochloric acid, chlorine, methane, hydrogen fluoride, argon, and helium. Only one or two of these need to be monitored on a systematic basis.

Once a volcanic event has been detected there is the need for frequent monitoring of surface and atmospheric conditions. Lava flows can be observed both day and night with thermal imagery while lahars, a more common volcanic occurrence, can be surveyed with conventional multispectral data. As a volcano becomes more active pyroclastic flows and gases become more prevalent. During a major explosive event pyroclastic material and gases can be ejected into the stratosphere and dispersed worldwide. Mapping of surface activity may be hampered by poor visibility at such times, but the aerosol plumes may be a threat to both surface and aerial transportation and will require continuous monitoring.

Eos Instruments

Many of the instruments scheduled for NPOP-1 and NPOP-2 (see Appendix A at the end of this publication for a complete list) are useful in supporting the applications discussed above. The High Resolution Imaging Spectrometer (HIRIS) and Synthetic Aperture Radar (SAR) are the two most desired instruments because of their high resolutions and all weather coverage (SAR only) but cannot be considered at this time because of their limited on-time (about 3% and 7%, respectively) and command and control problems. The microwave instruments (AMSU, AMSR, NSCAT/SCANSCAT, SWIRLS and MLS) may be very useful for monitoring snow and ice fields and specific surface and atmospheric parameters, but should not be considered as prime candidates for geologic applications. MISR, a four-band, eight-direction, pushbroom scanner could be important also, but is best utilized here as a support for the other instruments.

The major sensor requirements for the geologic area include visible-near-IR thermal imaging, surface measurements, and gas and aerosol detection and mapping. Table 2 lists eleven instruments in these three categories and shows their desired use in five primary areas of application: quicklook, field support, early warning, rapid assessment, and continuous monitoring.

Table 2. - Selected NPOP-1 and NPOP-2 Instruments and Their Areas of Application

	Quicklook	Field Support	Early Warning	Rapid Assessment	Cont Monitoring
MODIS N+T	X	X	X	X	X
ITIR			X	X	X
GLRS				X	
HIRRLS/DLS			X	X	X
SAGE III			X	X	X
MOPITT/TRACER			X	X	X
SAFIRE			X	X	X
TES			X	X	X

The MODIS instruments are the most useful because of their continuous operation and wide field of view. However, the spatial resolution is not adequate for most detailed investigations and HIRIS and SAR data will have to be requested for follow-on examinations. The Intermediate Thermal Infrared Radiometer (ITIR) has the highest resolution (15m) and will be very useful for thermal imaging.

The Geodynamics Laser Ranging System (GLRS) will be needed to establish surface elevation and horizontal distances following major upheavals. It is shown here only in the rapid assessment application because of the laser's limited lifetime. However, due to poor atmospheric conditions following some events, there may be a substantial delay in obtaining new data.

One or more of the atmospheric instruments can be used to monitor gases and aerosols for early warning detection. Because of the wide variety of gases and the different vertical and horizontal monitoring modes, perhaps all of them will be needed for continuous monitoring following a major volcanic event.

Concluding Remarks

The principal applications for onboard data processing and real-time data transmission in the geological sciences area are 1) the detection of early warning signs of potential catastrophic events and 2) the rapid assessment of impact and damage following major events. Also, the opportunity for quicklook and supporting data during field investigations should not be disregarded.

The Eos platforms are ideal for these applications because of the variety of earth sensing instruments and their differing modes of operation. Further study is required to define the role for each instrument and to assess how they can aid each other in establishing an improved output product.