George A. Rabchevsky
Rainbow Systems, Inc.
Alexandria, VA 22314

Temporal and Dynamic Observations from Satellites

Time-scale requirements are presented for repetitive observations from satellites of dynamic and catastrophic events.

Remote sensing has become accepted by most geoscientists as a useful tool, if properly applied in support of conventional ground surveys. In some instances, in fact, remote sensing technology has produced useful results without actual ground validation. This aspect of remote sensing, the sampling of terrestrial features or environmental phenomena by an airborne or satellite sensor, is especially significant when repetitive surveys are required of inaccessible or dynamic areas and in hazardous environments. Dynamic and short-lived natural events, such as floods, marine sedimentation, aquatic temperature fluctuations, forest fires, oil spills, ship movements, earthquakes, volcanic eruptions, etc., need to be detected rapidly and repeatedly for meaningful results. The launchings of the first Nimbus meteorological satellites in 1964 and then of Landsat-1 and Landsat-2 (formerly ERTS) in 1972 and 1975 respectively, the first of the ITOS-D (NOAA) series of satellites in 1970, and LAGEOS in 1976, to name a few, have provided a hitherto unavailable capability for detecting and mapping dynamic terrestrial features and environmental events on a global, repetitive, and temporal basis (Rabchevsky, 1976).

In the 17 years since the launch of the first orbiting meteorological Television and Infrared Observation Satellite (TIROS I) on April 1, 1960, over 2 million pictures of the earth have been recorded by more than 35 U.S. environmental and other earth-orbiting satellites. For example, during the ten manned orbital flights of the Gemini program, the astronauts took more than 2,400 70 mm color photographs. The coverage obtained from the Apollo VI, VII, and IX missions comprises a total of 2,100 pictures (Rabchevsky, 1971a). The Nimbus meteorological satellite series (begun in 1964) and the ESSA/NOAA environmental satellites (Rabchevsky, 1971b; Sabatini *et al.*, 1972) and now the Landsat series of spacecraft have produced and continue to generate enormous numbers of images and data on the temporal aspects of our Earth (Deutsch *et al.*, 1974; Williams and Carter, 1976; Short *et al.*, 1977; Kirdar *et al.*, 1977; etc.).

The photographic coverage of the earth's surface obtained from the Gemini and Apollo missions ranged in resolution from 9 to 60 meters. Unlike the NOAA environmental and Landsat satellite coverage, however, photography from manned spacecraft was not repetitive and was confined only to the

Abstract: *The sampling of terrestrial features or environmental phenomena by an airborne or satellite sensor is especially significant when repetitive surveys are required. Dynamic and short-lived natural events need to be detected rapidly and repeatedly for meaningful results. A series of satellites now provide a hitherto unavailable capability for detecting and mapping dynamic terrestrial features and environmental events on a global, repetitive, and temporal basis. The paper summarizes briefly some of the satellite missions and in a tabular form classifies the time-scale requirements for observing some of the dynamic events.*

Photogrammetric Engineering and Remote Sensing,
Vol. 43, No. 12, December 1977, pp. 1515-1518.

lower latitudes. On the other hand, the civilian polar-orbiting environmental satellites provide observations of nearly every point on the Earth twice every 24 hours, once during the daytime and once at night. Even more frequent coverage is provided by the geostationary operational environmental satellite, the Synchronous Meteorological Satellite/Geostationary series (SMS/GOES), placed in geosynchronous stationary orbit 36,000 kilometers above the equator. Every 30 minutes a picture is taken of environmental conditions from the equator to about 65° northern and southern latitudes in the western hemisphere. Eventually, with the launch of more satellites in the SMS/GOES series, global sub-polar coverage will be achieved from geostationary altitude.

The first Landsat satellite was launched by NASA on 23 July 1972; Landsat 2 was launched on 22 January 1975. The 18-day repeat and near-global coverage capability from Landsat (theoretically limited to tape recorder capacity on Landsat or ground receiving stations location in practice), with a maximum resolution of about 80 meters, has enabled geoscientists to observe and map some dynamic terrestrial features (coastal processes, erosion, flooding, vegetation changes, etc.) and to classify some environmental events and landforms (geologic hazards, drainage networks, lakes and swamps, etc.) on regional and temporal scales for the first time to 81° northern and southern latitudes. As of 1 December 1976, 376,045 scenes had been recorded by the Landsat series (Table 1), with additional U.S., Canadian, Brazilian, and Italian coverage being received continuously.

The multiple satellite (Landsat, NOAA, SMS/GOES, etc.) coverage, at various times, scales, resolutions, and geographic locations, has given us a unique look at the dynamic features and events of the earth on a daily, weekly, seasonal, and yearly basis. When two or more satellites are in orbit simultaneously, the capability to view each point on the earth increases. This capability has not been used extensively as yet, although it offers attractive advantages to some scientific applications. Many features would not exhibit any change even if viewed from the same angle each day, because the parameters being sensed do not change significantly during short time scales. Movements along geologic faults are an example of this type of situation. Thus, while changes of some features may be observed daily or more often, it is at times necessary to make longer temporal comparisons of imagery to determine the significance and amount of change. Table 2 summarizes some of the temporal terrestrial features, and the time scale of observations required for their detection.

The list of temporal terrestrial features and events observable from space, as summarized in Table 2, is not exhaustive, and many more may be found illustrated in the cited references. The need for repetitive observations of dynamic features is self-evident however, if we ever hope to fully understand the changes affecting our planet. Global, repetitive views of the earth from future space missions will be especially useful for a wide variety of regional inventory and planning programs. Such inventories may then be used to identify areas of change, so that acquisition of more precise informa-

TABLE 1. CUMULATIVE TOTAL OF ACQUIRED SCENES BY LANDSAT-1 AND -2 TO DECEMBER 1, 1976 (PRICE, 1976; WILLIAMS, 1977).

	Landsat 1				Landsat 2				
	MSS		RBV		MSS		RBV		
	Real Time	Taped	Real Time	Taped	Real Time	Taped	Real Time	Taped	Total
United States[1]	96,560	46,963	727	819	30,885	40,795	1,307	718	218,774
Canada[1]	45,688	—	144	—	31,455	—	36	—	77,323
Brazil[2]	33,881	—	—	—	3,443	—	326	—	37,650
Italy[2]	32,462	—	—	—	9,836	—	—	—	42,298
Total	208,591	46,963	871	819	75,619	40,795	1,669	718	376,045[3]

[1] Imagery from the 3 U.S. receiving stations (and tape-recorded data of non-U.S. areas) is available from the EROS Data Center, Sioux Falls, South Dakota 57198; imagery from the 2 Canadian stations is available from the Canada Centre for Remote Sensing, 2462 Sheffield Road, Ottawa, Ontario K1A OE4.

[2] Until recently, imagery from the receiving station in Brazil and the receiving station in Italy has not been generally available except with extreme difficulty or at excessively high cost. New NASA agreements, however, have begun to produce a change in the direction of greater available of data and lower cost.

[3] The total given does not include the MSS scenes received by the "temporary" Landsat receiving station at Rawalpindi, Pakistan, which became operational on 9 November 1976.

TABLE 2. TIME-SCALE REQUIREMENTS FOR OBSERVATION OF TEMPORAL AND DYNAMIC EVENTS AND FEATURES. MOST OF THE FEATURES LISTED HAVE BEEN OBSERVED ON SPACE IMAGERY AND SOME HAVE BEEN REPETITIVELY OBSERVED BY THE ENVIRONMENTAL AND LANDSAT SATELLITES (INCLUDING THE LANDSAT DCS DATA). SEE CITED REFERENCES FOR ILLUSTRATIONS.

	Observation Intervals[1]							
Features & Events	Continuous[2]	Every 12 Hrs	Once a Day	Once a Week	Once a Month	Seasonal	Once a Year	Periodic[3]
GEOLOGY & LAND USE								
Structural Geology Update								*
Geothermal Activity							*	
Volcanic Activity	*						*	
Seismic Disturbances	*		*					
Erosion & Deposition						*		
Glacier Ice Movement						*		
Avalanche & Landslides						*		
Coastal Changes							*	*
Urban Growth								*
Land Cover Maps								*
Thematic Maps Update								*
HYDROLOGY & AGRICULTURE								
Snowpack/fall Boundaries	*			*		*		
Inland Water Temperatures	*				*	*		
Lake Freeze & Melt	*					*		
Pollution Monitoring	*							
Playa Changes						*	*	
Sediment Transport	*				*	*		
Flooding	*					*		
Reservoir Development						*		*
Ground Water Movement						*		
Soil Moisture Distribution			*			*		
Surface Water Inventory								*
Vegetation Bloom				*		*		
Wetlands Surveys								*
Vegetation Disease Monitoring	*							
Crop/Forest Inventory						*		
OCEANOGRAPHY								
Sea Surface Temperatures	*				*			
Current Direction & Rate	*		*					
Upwellings	*							
Sea State	*							
Sedimentation			*			*		
Pack Ice Boundaries	*							
Formation of Leads	*					*		
Iceberg & Floe Migration	*					*		
MISCELLANEOUS								
Fire & Smoke Detection	*							
Dust Storms	*					*		
Jet Contrails	*							
Cloud Cover	*	*						
Economic Geography Studies						*		*

[1] Frequency of observations of many features are geography-dependent.
[2] Continuous observations, less than 12 hours, for special or catastrophic events.
[3] Every 5 years or on-as-needed basis.

tion by aircraft or ground methods can be planned.

REFERENCES

Deutsch, Morris, Frederick R. Ruggles, and George Rabchevsky, 1974, *Flood Applications of the Earth Resources Technology Satellite:* Digest of Papers, Earth Environment and Resources Conference, U.S. Environment and Resources Council, Philadelphia, Pennsylvania.

Kirdar, E., H. H. Schumann, and W. L. Worskow, 1977, *The Application of Satellite Snow Mapping Techniques for Multipurpose Reservoir System Operations in Arizona:* Proceedings of the 45th Annual Western Snow Conference, Albuquerque, New Mexico.

Price, Robert, 1976, *Personal Communication:* Goddard Space Flight Center, NASA, Greenbelt, Maryland.

Rabchevsky, George, 1971a, *Satellite Observations of Temporal Terrestrial Features:* Proceedings of a Space Congress, 'Space For Mankind's Benefit', Sponsored by NASA and the Huntsville Association of Technical Societies, Huntsville, Alabama, NASA special publication SP-313.

________ 1971b, *Hydrologic Conditions Viewed by the Nimbus Meteorological Satellites:* International Remote Sensing Workshop, Sponsored by NASA, University of Michigan, Ann Arbor, Michigan.

________ 1976, *Remote Sensing of Dynamic Terrestrial Events:* Program Abstracts, Association of Engineering Geologists, Annual Meeting, Philadelphia, Pennsylvania.

Sabatini, Romeo, R., George Rabchevsky, and John Sissala, 1972, *Nimbus Earth Resources Observations (NERO):* Allied Research Associates, Inc., Technical Report 19, NASA contract No. NAS5-10343, Goddard Space Flight Center, NASA, Greenbelt, Maryland.

Short, Nicholas, M., Paul D. Lowman, Stanley C. Freden, and William A. Finch, Jr., 1977, *Mission to Earth: Landsat Views of the World:* NASA special publication SP-360, Goddard Space Flight Center, NASA, Greenbelt, Maryland.

Williams, Richard S., Jr., 1977, *Personal Communication:* U.S. Geological Survey, EROS Program Office, Reston, Virginia.

Williams, Richard S., Jr. and William D. Carter, editors, 1976, *ERTS-1, A New Window on Our Planet:* U.S. Geological Survey Professional Paper 929, Reston, Virginia.

Notice to Contributors

1. Manuscripts should be typed, double-spaced on $8\frac{1}{2} \times 11$ or $8 \times 10\frac{1}{2}$ white bond, on *one* side only. References, footnotes, captions—everything should be double-spaced. Margins should be $1\frac{1}{2}$ inches.
2. Ordinarily *two* copies of the manuscript and two sets of illustrations should be submitted where the second set of illustrations need not be prime quality; EXCEPT that *five* copies of papers on Remote Sensing and Photointerpretation are needed, all with prime quality illustrations to facilitate the review process.
3. Each article should include an abstract, which is a *digest* of the article. An abstract should be 100 to 150 words in length.
4. Tables should be designed to fit into a width no more than five inches.
5. Illustrations should not be more than twice the final print size: *glossy* prints of photos should be submitted. Lettering should be neat, and designed for the reduction anticipated. Please include a separate list of captions.
6. Formulas should be expressed as simply as possible, keeping in mind the difficulties and limitations encountered in setting type.

Journal Staff