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STATUS AND FUTURE OF ELECTRO-OPTICAL MAPPING SYSTEMS IN SPACE

ABSTRACT

The recent progress made in the control and determination of spacecraft position, attitude, and stability greatly improve the prospects for a spaceborne digital mapping system. Today no such system exists but the technical problems have, in most part, been solved. Once the associated funding and political problems are resolved, we should see a satellite defined which will result in an operational automated mapping system by which any cloud-free area of the Earth can be mapped in a matter of days. Surely this concept warrants the serious attention of the international mapping community, as well as engineers involved in the planning of new projects. The U.S. Geological Survey has defined and is studying a new mapping satellite known as Mapsat which appears capable of 1:50,000-scale mapping with a 10-meter contour interval.

Introduction

Even since the first sputnik was launched in October 1957, the potential use of satellites for studying the Earth has been obvious. Today several countries have developed such satellites and during the 1980's this Earth will certainly be studied from space in considerable detail. This paper is limited to the electro-optical approach - as apposed to film cameras - and concentrates on a satellite system which, among other things, is capable of precise mapping of the Earth.

For nearly 8 years Landsat satellites (originally designated ERTS) have been imaging the Earth from space. The Landsat program is well documented (1, 2, 3) and has established remote sensing from space as a recognized discipline throughout the world. The latest Landsat (Landsat-3) carries cameras of 30-m resolution\* as compared to 80+ m for Landsat-1 and -2; even so, Landsat is a relatively low-resolution system and is thus limited with respect to detailed study of the Earth. Moreover, Landsat is limited to the orthographic (near-vertical) viewing of the Earth which precludes

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\*The term resolution as used herein refers to the effective resolution element which is defined as the instantaneous field-of-view of the sensor element coupled with the estimated spread function of the sensing system.

the stereoscopic mode essential to the delineation of the third (elevation) dimension of the surface. Satellites other than Landsat have recorded the Earth's thermal response (Heat Capacity Mapping Mission) and radar response (Seasat); also, innumerable photographs have been taken of the Earth from manned spacecraft.

With the exception of the very-low-resolution meteorological satellites, Landsat is the only system which can provide nearly global continuous coverage and thus has some of the characteristics of an operational system as compared to other systems, which must be classed as experiments. The acceptance and use of Landsat data clearly indicates that there is a need for a truly operational Earth-sensing system, and that this need is global and not restricted to any one country or group of countries.

A recent U.S. presidential directive assigned management responsibilities for developing an operation system to the National Oceanic and Atmospheric Administration (NOAA) which operates the U.S. meteorological satellite program. Moreover, the directive states that the first operational system will be based on Landsat technology. How long it will take for the United States to develop a truly operational system depends on many factors, but the U.S. organizational structure has now been defined. It should also be noted that several other governments and agencies including the United Nations are considering the development of operational remote-sensing systems. From all indications, an operational Earth-sensing satellite system or systems will evolve during the 1980's. Because of the high cost involved, it is hoped that such systems will evolve on an international basis -- perhaps similar organizationally to the global communications systems -- rather than each concerned country developing its own system.

Since NOAA is the U.S. agency charged with developing an operational system it may seem odd for a member of the U.S. Geological Survey to be describing a proposed system. However, the Geological Survey has played a key role in the development of remote sensing from space and will continue to make vital contribution towards an operational system. As an example the Geological Survey, after nearly 10 years of the study of Landsat and its precursors, has conceptually defined a candidate operational Earth-sensing satellite system. This system is know as Mapsat.

#### Mapsat

On October 15, 1979, the USGS issued a Request for Proposal for a feasibility study for the conceptual design of an automated mapping satellite system (Mapsat). Proposals were received during December, technical evaluation was completed during February, and award action is expected during April 1980.

Mapsat is an effort by USGS to define an operational system. It is based on Landsat and includes the following concepts:

- o Global coverage on a continuous basis.

- o Open data dissemination in reasonable time and at reasonable cost.
- o Variable resolution, swath-width, stereoscopic and multispectral capabilities.
- o Capability of 1:50,000-scale topographic mapping (image form) with a 20-m contour interval.
- o Continuity with respect to Landsat-1, -2, and -3 including the same data transmission rates (15 megabits per second).
- o Cost effectiveness.

Details relative to Mapsat are covered in other papers (4 and 5) but a few points warrant elaboration.

o Mapping geometry. The name Mapsat implies a mapping system, but this does not mean its primary function is to serve the mapmaker. Disciplines such as geology, hydrology, agriculture, geography, and engineering, to name a few, require multispectral data in accurate mappable form. Raymond Dideriksen (written commun., 1976) of the U.S. Soil Conservation Service has stated, "Until the geometric accuracy and resolution are greatly improved, we cannot consider Landsat or LFO (Landsat Follow-On) to be competitive cartographic tools when compared with either high-altitude photography or cameras such as those that were demonstrated in Skylab." Here a Department of Agriculture spokesman is calling for a space system of higher geometric fidelity and resolution, and it is hard to conceive of any other serious user to whom geometry is not important. Thus geometric precision, which is essential to the cartographer, is also the key to an operational Earth-sensing system, and the name "Mapsat" has been applied. The products envisaged from Mapsat are not limited to conventional planimetric and topographic maps but include thematic displays and digital data extractions which have been demonstrated from Landsat data or which can be derived from digital terrain data.

The high geometric fidelity of Mapsat is achieved by defining a spacecraft and sensor system having virtually no moving parts and very precise position and attitude determination. The sensor system is based on solid-state linear arrays rather than mechanical scanners such as used on Landsat. Moreover, the antennas and solar panels are defined to remain rigid during data acquisition.

o Resolution and data rates. Mapsat is designed for operation using various spectral bands at various resolutions and swath widths. Areas requiring high resolution may be so covered, but fortunately these areas are generally of limited extent. Spectral band and stereo combinations would also depend on the type of area to be covered. However, a limitation on the data transmission rate is essential. By using data compression techniques, the current data handling capacity of Landsat receiving stations (15 megabits per second) should be adequate.

o Spectral bands. The Landsat multispectral scanner (MSS) uses four basic spectral bands, not including the thermal band on Landsat-3 which failed soon after launch. Of the four MSS bands, two are in the near infrared and are largely redundant. In order to optimize data acquisition against demonstrated practical use, the two near-infrared bands have been consolidated into one for Mapsat. The three bands selected are a blue-green (0.47 to 0.57  $\mu\text{m}$ ), a green-red (0.57 to 0.70  $\mu\text{m}$ ) and a near-infrared (0.76 to 1.05  $\mu\text{m}$ ) band. A thermal band, although important, is not considered suitable for Mapsat which records reflected solar energy. The thermal emissions from the Earth surface can best be measured at pre-dawn and late evening to separate the Sun's effects. Thus a satellite other than Mapsat is needed for thermal sensing.

o Stereoscopic capability. The delineation of the Earth's surface in three dimensions is essential for many uses. Landsat fails to record the third dimension of height, but Mapsat will definitely do this with two separate base-height ratios, depending on the type of topography involved.

The value of stereoscopic sensing does not end with the production of topographic maps. The stereo mode provides for the automated production of digital elevation data, which is a relatively new and powerful tool for depicting and analyzing the Earth's terrain. With it the computer depiction of topography based on any simulated conditions of illumination is feasible, which is of high importance for geologic interpretation and related applications. Moreover, derivative products such as slope maps and critical-elevation displays can be generated by the computer.

o One-dimensional data processing. Data processing has been the Achilles heel of Earth-sensing satellite systems. In a Landsat MSS scene approximately 10,000,000 picture elements (pixels) must be processed to produce an image. This requires a large computer, complex programs, and associated high cost. Mapsat is designed to acquire a one-dimensional flow of data from each detector in the linear array. The data from each of the several thousand detectors can be processed by relatively simple computer programs in a one-dimensional mode.

Two arrays of detectors are involved during stereo imaging, but by controlling spacecraft rotational rates corresponding detectors from the two arrays follow the same ground path. This is known as the epipolar plane condition by which the data from the two arrays are correlated and result in providing elevation data as well as planimetric position. Epipolar plane scanning is already applied to conventional stereomodels by analytical plotters such as the Bendix AS-11B-X. Some ground control is needed, but with the stability and positional accuracy expected of Mapsat, such control need be but a very small fraction of that required for conventional photogrammetry. The correlated data can be processed by automated means and thus provide the basis for an automated mapping system. The proper implementation of this concept would greatly reduce data processing time and costs.

## Conclusion

Parameters for Mapsat were first published in April 1979 (4). Since then some minor modifications have developed and the upcoming feasibility study may provide other changes. However, the basic concepts have been studied in considerable detail and the following conclusions reached:

- o The orbital parameters of Landsat 1, 2, and 3 are considered optimum for an Earth-sensing satellite, and the Landsat data transmission rate of 15 megabits per second is believed adequate.
- o Solid-state linear arrays promise to simplify the problem of multispectral imaging the Earth from space.
- o The epipolar plane condition can be achieved with a properly designed Earth-sensing satellite, and this will permit the delineation of the third dimension of height using linear arrays. Moreover, this condition will permit the automated processing of stereo data into topographic information.
- o An Earth-sensing satellite can now be built with virtually no actuated parts and thus achieve an expected long life and greatly increased cost effectiveness as compared to existing systems.

Mapsat is not an approved funded system and no one can say when it will fly. However, it is the first space system designed with mapping of the Earth as one of its primary objectives. Moreover, its study indicates that the automated mapping of the Earth from space is now within the state-of-the-art.

## References

- (1) U.S. Geological Survey, 1979, Landsat data users handbook, [rev. ed.]
- (2) Short, N.M., Lowman, P.D., Freden, S.C., and Finch, W.A., 1976, Mission to Earth: Landsat views the World: NASA SP-36.
- (3) Williams, R.S., and Carter, W.D., 1976, A new window on our planet: U.S. Geol. Survey Prof. Paper 929.
- (4) Colvocoresses, A.P., 1979, Proposed parameters for Mapsat: Photogrammetric Engineering and Remote Sensing, v. 45, no.4, April 1979, p. 501-506.
- (5) Colvocoresses, A.P., 1979, Geometric considerations for an automated mapping satellite system (Mapsat), (EC-69-Landsat): U.S. Geol. Survey open-file rept. 79-914.