Status Report on Landsat

as a

Source of Cartographic Data

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BACKGROUND

This report is based primarily on the performance of Landsat-1* and -2, but it also covers the expected performance of Landsat-C and others that might follow.

Landsat-1, launched July 23, 1972, circles the Earth in a near-polar orbit at an altitude of about 919 km. The payload includes two sets of remote sensing instruments which image a 185 km strip of the Earth beneath the satellite. In 18 days the entire Earth, except for 8° circles at the two poles, may be covered. This results in a system of nominal scenes which can be imaged every 18 days. Each Landsat image covers 185 by 185 km. The remote sensor principally used is the Multispectral Scanner (MSS), a scanning radiometer which discretely and continuously records the response from 79-m squares of the Earth's surface in four spectral bands: band 4, 0.5 to 0.6 μm; band 5, 0.6 to 0.7 μm; band 6, 0.7 to 0.8 μm; and band 7, 0.8 to 1.1 μm. The second set of sensors are the Return Beam Vidicons (RBV), which record discrete 185-km squares of the Earth like a television camera. The three RBV bands are band 1, 0.475 to 0.575 μm; band 2, 0.580 to 0.680 μm; and band 3, 0.698 to 0.830 μm. The RBV's have had very limited use on Landsat-1 and -2.

Landsat data are either stored on tape in the satellite or transmitted in near real time. In both cases, the data are transmitted in the S-waveband frequencies of 2220.5 and 2265.5 MHz. Receiving stations are located in the United States (3), Canada (1), Brazil (1), and Italy (1)--others are under construction. Landsat-2, a carbon copy of Landsat-1, was launched on January 22, 1975. The two satellites cover the same Earth scene 9 days apart. Except for both tape recorders on Landsat-1 and one of the two on Landsat-2, both satellites are still operating properly (June 1976).

STATUS OF LANDSAT-C and -D

As of June 1976 the third Landsat satellite (C) is under construction and scheduled for launch in September 1977. It differs from Landsat-1 and -2 in the following respects:

- The three multispectral RBV's of Landsat-1 and -2 have been replaced by a pair of single-band (0.505 to 0.750 μm) RBV's of twice the focal length. Together they will cover the same swath width as the MSS but at about twice the resolution. Four RBV images will cover one MSS image.

- The MSS will remain as is except that a thermal waveband of 10.4 to 12.6 μm will record with a resolution 3 times coarser (237 m element) than in the visible and near-infrared wavebands.

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* In Jan 1975, NASA renamed ERTS "Landsat"--thus Landsat-1 (ERTS-1), Landsat-2 (ERTS-2), and Landsat-C (ERTS-C).

During the spring of 1976, NASA developed possible parameters for a Landsat followon which are considerably different from those of Landsat-1, -2, and -C. The question of whether this Landsat would be experimental or operational has also been raised but not resolved. At least 3 or 4 years is required between the definition and launch of a satellite; thus there is an urgent need to define and approve another Landsat if the program is to maintain continuity.

CARTOGRAPHIC CHARACTERISTICS OF LANDSAT-1, -2, and C

1. Coverage and long life. In one year cloud-free coverage of the United States was obtained by one satellite (Landsat-1). Landsat-1, -2, and -C promise to provide systematic coverage of the Earth for 10 years. Landsat also provides seasonal coverage of selected areas.

2. Orthogonality. The 185-km sweep of the current MSS represents an angular coverage of only 11.52°. Due to this nearly vertical view, relief displacements are minimal and the images, without resorting to a stereoscopic model, are well suited to small-scale planimetric mapping and revision.

3. Geometric fidelity. The relative positional accuracy of Landsat imagery meets or approaches that required by U.S. National Map Accuracy Standards (NMAS)* for 1:500,000-scale maps (1:250,000 scale under ideal conditions). By decreasing the equivalent instantaneous field of view from 79 m (Landsat-1 and -2) to 40 m (Landsat-C), map accuracy can be somewhat improved.

4. Multispectral records. The MSS bands 5 (red) and 7 (infrared) have proved most useful for recording land features and land-water boundaries. Under optimum conditions band 4 (green) provides for water penetration of more than 20 m and thus can assist in the charting of shallow seas. Band 4, when enchanced and combined with bands 5 and 7 in analog or digital form, provides for differentiation between dormant and growing vegetation. Near-infrared band 7 has also proved capable of better thin-cloud and haze penetration than bands in the visible spectrum. The thermal band of Landsat-C will enhance thematic mapping by differentiating areas of various temperatures under both day and nighttime conditions.

5. Radiometric sensitivity. The MSS records 64 radiometric levels for each of the 4 wavebands. Bands 4 and 5 can also be given a 3X gain setting that strengthens the signals from areas of low light response. These capabilities enable Landsat to image scenes of very low light, such as the polar regions at near-zero Sun elevation.

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* similar to those established by other countries

Although high-gain settings enhance the subtle signatures from underwater features, they have had only limited use because many land areas are saturated (equivalent to overexposed) by the 3X gain setting. Landsat can under optimum conditions also record light flux at night from such sources as large gas flares.

6. Suitability for automation. MSS coverage can be fitted to a Space Oblique Mercator projection with a distortion generally less than 1:10,000 (ref. 4). Repetitive coverage of the same nominal scenes and electronic transmission and generation of images of cartographic quality provide a basis for automating the production of small-scale cartographic products.

(References 1, 2, and 3 provide additional technical data on Landsat and its cartographic applications.)

RESULTS

1. Prototype image maps of various areas of the world have been produced in a wide variety of scales and forms. Within the United States they range from 1:250,000 scale for selected areas to about 1:5,000,000 scale for the conterminous United States. When properly referenced to ground control, the maps generally meet NMAS at 1:500,000 scale and under ideal conditions, at 1:250,000 scale. USGS has prepared image maps (mosaics) of sizable States (Florida, Georgia) by a film-montage technique that preserves image quality far better than the conventional paper-print assembly. (References 5, 6, and 7 provide additional data on the maps produced.) Landsat image maps of areas outside the United States have been produced by both government and private industry--again in a wide variety of scales and forms. They include areas of heretofore unmapped parts of Antarctica, South America, and Africa.

2. Map and chart revision to some extent has been based on Landsat data. For areas in the United States other source material of higher resolution is generally available, but even so, certain features on aeronautical charts and small-scale line maps have been revised with Landsat imagery. Recently the Defense Mapping Agency Hydrographic Center, which prepares nautical charts for civil as well as military use, found that Landsat coverage is potentially valuable for nautical chart revision. In one area "Notices to Mariners" are being prepared and charts are being revised based on the Landsat recording of uncharted shoals and errors in the positions of previously charted reefs and shoals. Canada has made significant, but limited, use of Landsat imagery in revising and repositioning selected features on maps and charts as large as 1:50,000 scale (ref. 8). Other countries throughout the world are selectively applying Landsat data to map and chart revision.

3. Thematic maps in many forms have been derived from Landsat data. USGS has demonstrated (ref. 9) that open water, vegetation (infrared reflective), and snow and ice can be autographically isolated from Landsat imagery. The National Oceanographic and Atmospheric Administration has applied the technique to preparation of an open-water plate for an aeronautical chart at 1:500,000 scale (ref.10). Agencies throughout the world have produced numerous other thematic extractions based on both computer processing and human interpretation of Landsat (and other) data. Most of the thematic maps lack precision, but some approach map-accuracy standards and lend themselves to quantitative analysis and positional reference. The thematic mapping of changes that requires precise register of temporal records (ref. 11) is one of the more demanding tasks accomplished with Landsat data.

CONCLUSIONS

Landsat-1 and -2 have demonstrated that continuous sensing of the Earth's surface from space is both feasible and useful. Landsat is providing data in both digital and analog form that are of economic and social value to the world. It has introduced the parameter of time into mapping since temporal and seasonal phenomena can be mapped. Due to its orthogonality Landsat mapping is basically a 2- rather than a 3-dimensional problem and thus promises to become an automated planimetric mapping system at the smaller scales. However, Landsat has two definite limitations:

1. Its resolution precludes the recording of many cultural features.
2. Its orthographic characteristics mean that it cannot be applied to topographic (3-dimensional) mapping.

Thus Landsat must be supplemented by other space and aircraft systems, probably of the film-camera type, to meet the most comprehensive mapping needs.

Landsat, to date, has been an experimental program. Current data acquisition, processing, and dissemination procedures are not designed to meet operational needs. Moreover, the program does not have a defined future, and thus many who might apply it are loath to invest in personnel and facilities until the program has been defined. Landsat covers all of the Earth except the two 8° circles centered at the Poles. Thus it is global and must be evaluated and defined in its worldwide applications. The cartographic capabilities of Landsat are important not only for mapmaking but for all those Earth science disciplines that find Landsat signatures and their distribution valuable.

RECOMMENDATIONS

Landsat should be converted from an experimental to an operational program as soon as possible. Therefore the next Landsat to be defined should be designated operational, and Landsat processing and distribution facilities should, in the interim, meet operational needs. The parameters of Landsat-1 and -2 have proved their worth and should be the basis for the operational satellite. Further experimentation in remote sensing of the Earth from space is obviously needed, but in a separate program.

The problems of funding and managing such a program are obviously complex and beyond the scope of this paper. Landsat's economic viability and overall value to mankind deserve operational testing, and just as worldwide communications via satellite have developed into a successful operation so now must remote sensing of the Earth. Photogrammetrists, cartographers, geographers, as well as many others will play key roles in that undertaking.

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