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E7.6-10.348
CR-147239

Overall Evaluation of Landsat (ERTS) Follow-on Imagery for Cartographic Application (NASA No. 23960)

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1 April 1976

Progress Report 5/20/75 - 4/1/76

Prepared for
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

(E76-10348) OVERALL EVALUATION OF LANDSAT (ERTS) FOLLOW-ON IMAGERY FOR CARTOGRAPHIC APPLICATION Progress Report, 20 May 1975 - 1 Apr. 1976 (Geological Survey, Reston, Va.) 11 p HC $3.50 CSCL 08B G3/43

N76-24668

Unclas
00348

Publication authorized by the Director, U.S. Geological Survey

23960

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

Overall Evaluation of Landsat (ERTS) Follow-on Imagery for Cartographic Application

5. Report Date

April 1, 1976

6. Performing Organization Code

7. Author(s)

Alden P. Colvocoresses

8. Performing Organization Report No.

9. Performing Organization Name and Address

U.S. Geological Survey
National Center #522
Reston, Virginia 22092

10. Work Unit No.

11. Contract or Grant No.

S-543-748

12. Sponsoring Agency Name and Address

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

13. Type of Report and Period Covered

Progress Report
5/20/75 - 4/1/76

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

During this period, the cartographic applications of Landsat have accelerated worldwide. Landsat is rapidly reaching the point where it justifies definition as an operational system. Cartographic applications are manifold, and the economic viability is rapidly becoming apparent. The significant results noted during this period are too extensive to be covered in an abstract.

17. Key Words (Selected by Author(s))

image enhancement, shallow seas mapping, automated mapping

18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Not applicable	12	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

Figure 2. Technical Report Standard Title Page

Progress Report

a. Title - Overall Evaluation of Landsat (ERTS) Follow-on Imagery for Cartographic Application.

b. GSFC I.D. No. 23960

c. Problem areas

The fundamental problem of how best to process Landsat imagery for distribution in image form is discussed in the August 18, 1975, report on experiment No. 23650 (Processing of ERTS Imagery for Dissemination Purposes). Processing remains the paramount problem with this experiment as well. NASA, Goddard has been asked to process radiometrically enhanced imagery through the Electron Beam Recorder (EBR), and once this is done, the processing for cartographic purposes can be evaluated more objectively.

A second problem involves selection of optimum wavebands for follow-on Landsats. Skylab experiment S-192 (13-channel conical multispectral scanner) should have provided answers to the spectral-band problem, but processing of S-192 data provided only limited information. Other spacecraft (Landsat) and aircraft (NASA U2) experiments are being investigated to provide information lacking from the S-192 experiment.

A third problem involves the performance specifications for an operational Landsat, which is one of the experiment objectives. The problem is being addressed and a separate report--probably a formal paper--is being prepared. It will be based on the indicated requirements of cartographers throughout the world. The problem lies in separating specifications for an operational spacecraft from those for further research and experimentation.

d. Accomplishments

On several occasions NASA has been asked to turn on Landsat-1 or -2 for special purposes related to this project as follows:

1. Antarctic coverage of selected areas of the Ross Ice Shelf, McMurdo Sound, and Roosevelt Island. In most images, cloud cover prevented success in such elements of the experiment, as recording the mirror flash at McMurdo Sound and documenting the reported changes in the Ross Ice Shelf. However, the experiment demonstrated the fundamental flexibility of Landsat to cover such isolated areas on relatively short notice and promises to provide data of areas such as Roosevelt Island that were not accessible on the ground.

2. High-gain settings over the Caribbean were requested and finally used as part of the NASA/Cousteau bathymetric experiment. Analog analysis conducted by Don Ross for USGS confirmed, in general terms, the findings of Fabian Polcyn, and others, on behalf of NASA.

As a result of this experiment, USGS was able to request an optimum water-penetration band (centered at 0.5 μm) for follow-on Landsats.

3. Analysis of Defense Meteorological Satellite Program (DMSP) imagery indicated areas of relatively high nighttime response in Algeria. These are due to gas flares, and nighttime coverage of such an area was requested of Landsat-2. Coverage was obtained on January 31, 1976, and it is understood that some signals were obtained on all four MSS bands. However, records have not yet reached this office. In any case, USGS will probably recommend that this capability, if significantly different from that of DMSP, should be considered for follow-on Landsats.

An analysis of available Skylab S-192 data did lead to the conclusion that wavebands in the range from 1.5 to 2.0 μm are of high potential cartographic value. On band 11 (1.55 to 1.75 μm) cultural features, vegetation, and water bodies all showed contrast superior to that of any single band in or near the visible spectrum. A similar response seemed to carry into band 12 (2.10 to 2.35 μm) but considerable noise precluded full evaluation. My final report on Skylab EREP Experiment No. 500, covers this work in more detail. It indicates that these longer wavelengths should be seriously studied for future Earth-sensing satellites.

Since the S-192 experiment involved a conical scanner, its geometry was compared to that of the Landsat MSS line scanner. The conical scanner offers several advantages (covered in my final report to NASA on EREP Experiment No. 500) that are of cartographic and related significance and therefore warrants some consideration for follow-on Landsats. However, the solid-state linear detector arrays have great advantages from the cartographic viewpoint over both linear and conical scanners. A 1974 Westinghouse proposal to build a linear array based on the parameters of the MSS has been studied. At this time, some form of solid-state array is considered the best candidate sensor for an operational Landsat.

Progress in the cartographic processing of Landsat imagery was made during this period as follows:

1. A two-band color image map of the State of Florida was prepared and published at 1:500,000 scale. Register between the two mosaics was near perfect, and image quality and geometric accuracy were retained through use of film rather than paper mosaics. A description of this project is included in reference 3 (b). (See sec. f.)

2. Maps of the State of Arizona were published in two forms at 1:500,000 scale. One is in black and white, and the other is sepia with line data and drainage overprints.

3. The Phoenix quadrangle was published at 1:250,000 scale in sepia with culture and drainage overprints. In preparing this image map, the

published line map data were positionally inaccurate on one section and had to be corrected before being overprinted on the Landsat image base. The 1:250,000 scale is considered too large for best portrayal of Landsat imagery but was used to show how the imagery can be applied at this popular scale.

4. McMurdo Sound, Antarctica, was published at both 1:250,000 and 1:500,000 scale in black and white on an image format. Since mapping at such scales is very limited in Antarctica, the products demonstrate the cartographic value of Landsat in unmapped areas. Small-scale line maps of Antarctica (National Geographic Society) and the Arctic (American Geographical Society) have been revised in cooperation with the USGS, using Landsat data. Numerous other Landsat-based cartographic products in areas of the Antarctic, Arctic, and Alaska are in various stages of production.

5. Upper Chesapeake Bay in image format, was republished in February 1976. It incorporates the same October 1972 imagery as the previous (1974) printing of this area. The new version shows a large increase in information content and some geometric improvement due to "precision" processing. A memorandum (EC-34-Landsat) referenced as 1 (h) provides additional data on this product.

6. A sizable number of additional Landsat cartographic products, all at 1:500,000 scale and in color, were in various stages of work at the end of this reporting period. They include:

(a) A State map of Georgia, which is due for publication in May 1976.

(b) A State map of Wyoming is in the early stages of preparation, and final form and completion date have not been set.

(c) Eleven image-format maps of Florida.

(d) Various other image formats covering scattered selected areas within the conterminous United States.

A set of seven Worldwide Indexes of Landsat Coverage were published in August 1975. They indicate the extent of Landsat coverage as of July 1974, ref. 2 (f). Publication of a new edition is being considered.

A contract to define the mathematical relationship between the coordinates of the Space Oblique Mercator (SOM) projection and the figure of the Earth (lat/long) has been undertaken by DBA Systems, Inc. Results to date are promising, but an acceptable final report has not yet been received.

A contract with Mead Technology Laboratories for enhancement of definition by overlaying successive Landsat images was completed during this period.

Results indicate that resolution can be somewhat improved by the techniques employed; however, the contract was limited to specific objects, such as the Chesapeake Bay Bridge, ref. 3 (g).

The use of small mirrors to image solar reflection was continued experimentally. A contract was let to Stanford Research Institute, with William Evans as principal investigator. The final report, which is currently in draft form, ref. 3 (h), covers the scientific and technical aspects of the procedures in considerable detail.

e. Significant Results

1. The NASA/Cousteau experiment, which was in part defined and promoted by this office (EROS Cartography) as part of this experiment, produced highly significant results. It showed that under suitable conditions and with calibration data the bottom of clear tropical seas can be mapped with Landsat to a depth of 22 metres with a root-mean-square error of about 10 percent. This application required the high-gain setting of band 4 of the MSS. The experiment also confirmed that a somewhat lower waveband than band 4 (0.5 to 0.6 μm) would increase the water-penetration capability of future Landsats. As a result, the Defense Mapping Agency has requested two significant actions of NASA, as follows:

(a) High-gain setting Landsat coverage of two sizable areas in the Caribbean and one in the Indian Ocean, ref. 4 (a).

(b) The selection of an optimum waveband and gain setting for future Landsats to achieve maximum water penetration.

2. The Defense Mapping Agency indicated that the Aerospace Center has found that Landsat can be of significant use in revising small-scale aeronautical charts. However, the report covering this activity is not yet available.

3. Experiments with the processing of Landsat imagery in cartographic form clearly show that the conventional printing of Landsat imagery as now practiced by NASA/Goddard is <u>not</u> generally suitable for cartographic purposes. The experiments--illustrated by the reprinting of Upper Chesapeake Bay--indicate that the original Landsat signals must be modulated and optimized (enhanced) for the photographic and lithographic processes. Lithographic printing is aimed at serving a wide variety of users and thus should portray maximum information rather than absolute radiometry.

4. Coordination with mapmakers (and others) throughout the world indicates that there is growing support for an operational Landsat and also that the basic parameters of Landsat-1 & -2 should be retained for

the operational mode. The Department of Interior's EROS program has expressed some of these views in a recent letter to NASA, ref. 3 (d). One pertinent point inadvertently omitted from this letter is that a proposed reduction of Landsat orbital height from 918 to 700 km would reduce the coverage of any receiving station by about 25 percent. The letter covers many other technical points concerning the disadvantages of lower orbital height and other changes, such as time of imagery. No less than three important international meetings have recently examined and reported on Landsat as follows:

(a) 1975 Conference of Commonwealth Survey Officers, ref. 4 (d), where one of the three resolutions adopted noted the valuable contribution of U.S. satellite imagery and expressed hope that this form of development, assistance, and international cooperation would long continue.

(b) The Thirtieth Session of the United Nations General Assembly (Nov. 1975) adopted a resolution recognizing the Landsat program and expressing hopes for its continued development, ref. 4 (e).

(c) The First United Nations Regional Cartographic Conference for the Americas (March 1976), affirmed a resolution calling for continuation of the Landsat program. Although not indicated by the final resolutions, representatives from such nations as Brazil and Canada (as well as others) insisted that the basic parameters of Landsat must remain fixed to assure full compatibility with existing receiving stations and processing facilities, ref. 4 (f). (I served as the chairman of the remote-sensing committee, which considered such matters).

5. Recent work by the Canadian mapping agency, ref. 4 (g), indicates significant improvements in the control identification and geometric accuracy of Landsat cartographic applications. By the use of small-scale (1:60,000) aerial photographs, control has been transferred to Landsat imagery with an rms error of only 20 metres when averaged over four separate images covering the same area. Using such control and the Landsat image, offshore features (which lie outside the control block) were positioned with deviations of about 50 metres. On current 1:250,000-scale maps of Canada some offshore shoals are indicated by Landsat to be in error by as much as 2,000 metres, and others have been completely omitted. Although this Canadian work is particularly aimed at the offshore problem, the technique employed is applicable to Landsat mapping in general--particularly where small-scale aerial photographs are available on which control points can be identified.

f. Publications and Reports (References):

1. EROS Cartography memorandums as follows:

   (a) EC-27-Landsat--Landsat (ERTS) computer-generated stereopair.
   (b) EC-28-Landsat--Index to Landsat Coverage, Edition I.
   (c) EC-29-Landsat--Landsat and the scuba diver.
   (d) EC-30-Landsat--Landsat status.
   (e) EC-31-Landsat--1:250,000-scale satellite image map of Phoenix.
   (f) EC-32-Landsat--Status of Landsat image enhancement of cartographic interest.
   (g) EC-33-Landsat--NASA/Cousteau Ocean Bathymetry Experiment.
   (h) EC-34-Landsat--Reprinting of Upper Chesapeake Bay Landsat Image Map.
   (i) Unnumbered EC-Memo of November 12, 1975--Defense Meteorological Satellite Program (DMSP) light flux of North America.

2. Landsat image and index maps (published), as follows:

   (a) Florida--1:500,000 scale, color.
   (b) Arizona--1:500,000 scale, two versions, black and white, and sepia with overprint.
   (c) Phoenix--1:250,000-scale sepia with overprint.
   (d) McMurdo Sound, Antarctica--1:250,000 and 1:500,000 scales, black and white.
   (e) Upper Chesapeake Bay--1:500,000 scale, color second printing using precision processed imagery.
   (f) Index to Landsat coverage, Edition I (7 sheets).

3. Technical papers, letters, and contract reports (USGS):

   (a) Colvocoresses, A. P., 1975, Mapping and Charting from Landsat (ERTS). Presented at the First William T. Pecora Memorial Symposium, October 28-31, 1975, Sioux Falls, South Dakota.

   (b) McEwen, R. B., Schoonmaker, J. W., 1974, ERTS Color Image Maps, Photogrammetric Engineering, Vol. XLI, No. 4, April 1975.

   (c) USGS, 1975, Information sheet about Landsat gridded mosaics prepared by U. S. Geological Survey, August 1975.

   (d) Letter from Director, EROS Program of Feb. 25, 1976, to NASA Associate Administrator for Applications relative to the Landsat follow-on program.

(e) Doyle, Frederick J., 1975, Cartographic Applications of Satellite Imagery, Commonwealth Survey Officers Conference, 1975.

(f) ___________________, 1976, New Frontiers in Cartographic Science, First United Nations Regional Cartographic Conference for the Americas, March 8-19, 1976.

(g) Mead Technology Laboratories, 1975, Investigation of the enhancement of Landsat imagery by the overlay of successive images over the same scene. Final report to USGS for contract #14-08-0001-14718, August 1975.

(h) Evans, William E., 1976, Effect of Sun Angle, Atmospheric Attenuation, and Turbulence on Mirror Beacons for Landsat Image Control, Stanford Research Institute, USGS Contract No. 14-08-0001-14897 GS03. Report in draft form, March 1976.

(i) Schoonmaker, J. W., 1976, Worldwide Indexes to Landsat Coverage, Presented at ASP/ACSM Annual Meeting, Feb. 1976.

4. Pertinent non-USGS letters and reports:

(a) Letter to NASA from Defense Mapping Agency dated February 24, 1976, requesting Landsat coverage in support of nautical charting requirements.

(b) Letter from Defense Mapping Agency dated March 15, 1976, urging NASA to optimize a Landsat waveband and gain setting for hydrographic purposes.

(c) Letter to Colvocoresses from J.D. Leatherdale of Hunting Surveys Ltd., dated April 16, 1975, indicating they regard mapping from ERTS (Landsat) as a proven survey technique.

(d) Minister of Overseas Development (UK), 1975, Proceedings of the Conference of Commonwealth Survey Officers, 1975.

(e) United Nations General Assembly, Thirtieth Session, 1975, Resolution Adopted by the General Assembly, 3388 (XXX) International cooperation in the peaceful uses of outer space, November 28, 1975.

(f) United Nations Economic and Social Council, 1975, Report of the First United Nations Regional Cartographic Conference for the Americas, Panama City, March 8-19, 1976. (Report with resolutions in draft form as of April 1, 1976).

(g) Fleming, E. A., 1976, Positioning Off-shore Features with the Aid of Landsat Imagery, Dept. of Energy, Mines and Resources, Ottawa, Canada, March 1976.

g. Recommendations

The potential cartographic value of Landsat is high, and NASA should make every effort to accommodate those attempting to demonstrate cartographic applications since they are basic to most other applications.

Therefore, I recommend the following:

1. Image processing tests, as requested by USGS, should be expedited. These tests are needed to compare electron beam recorder (EBR) products with those from optical-mechanical recorders.

2. Current and expected requests to NASA by the Defense Mapping Agency should be fulfilled with high priority. Principal requests are now related to hydrographic surveys.

3. An operational Landsat, based on the parameters of Landsat-1 & -2, should be defined promptly. The definition should include:

(a) an optimum imaging system, probably of the solid-state type with no more than one band of higher resolution than obtained by Landsat-1 & -2;

(b) improved attitude control and determination in order to meet the needs for automated image mapping;

(c) relay communication facilities that will permit full and rapid dissemination of Landsat data;

(d) full compatibility with established receiving stations and processing facilities;

(e) cost data on an annual basis, to include construction and launch, operations, and data processing (this would be a prerequisite to an economic feasibility study).

An operational Landsat will meet many cartographic requirements on a worldwide basis, but it will not provide either topographic (elevation) data or cultural detail. Both are required and an operational Landsat must be supplemented by other spacecraft or aircraft programs which provide such data.

4. The nighttime use of Landsat should be further explored in an effort to monitor and map such phenomena as gas flaring and urban light flux.

h. Not applicable

i. Not applicable

j. Not applicable