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Overall Evaluation of Landsat (ERTS) Followon Imagery for Cartographic Application (NASA No. 23960)

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16. Abstract

During this period, the cartographic applications of Landsat continue to accelerate worldwide. Landsat has reached the point where it justifies definition as an operational system since it is now being successfully applied to the solution of a wide variety of real problems. Cartographic applications are fundamental to the other Earth science disciplines since the geometric fidelity of Landsat data is a key factor in its operational use.

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Figure 2. Technical Report Standard Title Page

July 1977

Progress Report

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

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c. Problem areas

Fundamental problems involve geometric and radiometric processing of Landsat imagery. A parallel report covering experiment No. 23950 (Processing of Landsat Imagery for Dissemination Purposes) covers some of the radiometric problems not discussed in this report.

1. Geometry presents the foremost problem even though Landsat geometry has been described as being very good. Detailed analyses of images produced at Goddard on the Electron Beam Recorder (EBR) indicate systematic geometric errors that cause an affine condition of more than 1% (scale differences with respect to direction at a given point). There is urgent need to examine Landsat geometry in detail and improve the processing. It is believed that the sensing system can produce imagery with no more than 0.1% scale change as compared with the 1% now frequently encountered. Changing to the EROS Digital Image Processing System (EDIPS) will not in itself solve the problem because EDIPS, as now defined, depends on ground control, which is available only in selected areas. However, by properly applying attitude and other geometrically related corrections, it is believed that the 0.1% condition of maximum affinity can be met by EDIPS even when ground control is not available. Nevertheless, resampling with the use of ground control is slow and costly as compared with generation of analog images from the original Landsat station tapes with the proper geometric corrections. A Department of Agriculture spokesman [Dideriksen

of SCS [ref.4(d)] has indicated that "until the geometric accuracy and resolution are greatly improved we cannot consider Landsat or Landsat Followon (LFO) to be competitive cartographic tools." Improved resolution involves an economic tradeoff, but geometric accuracy presents a problem that can be solved by designing a simple and highly stable spacecraft with precise attitude determination and controls.

2. Optimum processing has not yet been defined and remains as the second problem. Landsat images must be radiometrically enhanced to portray a maximum amount of meaningful information. Although progress has been made, optimum processing for general-purpose use has not been achieved. This problem is reported separately under experiment No. 23650.

3. Proper gain settings that will best record given Earth scenes have not been determined. The solution to this problem requires further experimentation by NASA in conjunction with users. For example, band 4 only should be tried in the high-gain mode over shallow-sea areas because band 5 saturates in 1 to 2 meters of clear water over a highly reflective bottom. Thus, the shallow-sea and adjacent land areas cannot be properly mapped when both band 4 and band 5 are in high-gain mode. Sequential normal and high gain mode could theoretically be used, but the bands from different images will then never register perfectly, and obtaining sequential coverage is difficult. High-gain band-4 data must be suppressed or eliminated in areas of saturation in order to develop a multispectral image with usable information throughout a scene that covers both land and shallow seas.

4. Future processing plans of NASA and the EROS Data Center also pose a problem for cartographic applications. Plans now call for resampled

products that have not been fully tested and compared with optimum products through the EBR. Until such tests are completed, the extent of this problem and its solution cannot be defined. Requirements now exist for unresampled data in both digital and analog form and the continued ready availability of 70 mm film products [ref. 4(f, j, o)].

5. Defining parameters of an operational Landsat presents the most critical problem. Such definition, in the opinion of the investigator, should be based on the following criteria:

- Continuity with respect to Landsat-1, -2, and -C.
- Full availability of data on a global basis.
- Economic practicality.

Unless the problem is resolved shortly and appropriate action taken, it is felt that the future of the Landsat program will be jeopardized because current NASA plans do not include a Landsat-type satellite considered suitable for operational use [ref. 4(a), 1(n)].

d. Accomplishments

1. Shallow-seas charting and mapping. In conjunction with the Defense Mapping Agency Hydrographic Center (DMAHC), the utility of Landsat for nautical charting and shallow-seas mapping was examined. Using high-gain mode imagery of the Chagos Archipelago (Indian Ocean), DMAHC was able to map extensive underwater structures to depths ranging from 10 to more than 20 meters. In the process, a new reef was found, and other reefs were significantly repositioned [ref. 4(b)]. The resulting nautical chart [ref. 2(b)(1)] is the first in which remote sensing data--other than sonar--provide the principal basis for the positioning of extensive underwater features. With respect to the newly discovered Colvocoresses Reef, DMAHC has not indicated any

depths on the new edition of their chart. This office has examined two separate Landsat records in analog form and compared the radiometric response to nearby Speakers Bank which was boat surveyed in 1837. Based on the assumptions that the survey was reasonably complete and accurate, that depth has not materially changed in the past 140 years, and that the reef and bank have similar reflective characteristics, the nominal depth of Colvocoresses Reef is estimated at 10 m. However, small elements of the reef might lie at somewhat lesser depths. A report is being prepared on this investigation and before long soundings should be available to confirm the depth of the reef. It whould be noted that if either of the first two assumptions relative to survey accuracy or the permanency of depths are not valid, the entire chart may loose its validity. The Chagos boat survey in 1837 is rather typical of the source material on which a large percentage of existing nautical charts are based. The third assumption that the reef and bank have similar reflective characteristics is a a matter of judgement. Marine geologists indicate that both are of similar (coral) structure and neither appear to have vegetation patterns that would destroy the basic coral response. The only suitable area adjacent to the 50 States that displays a highly reflective bottom through clear water is the Florida Keys, and an image map of the Keys was published [ref. 2(a)(12)]. Plans are now being made, in conjunction with DMAHC and the National Ocean Survey (NOS), to enhance imagery of the Berry Islands in the Caribbean and publish an experimental image map of the area. During June 1977, high-gain imagery of the Palau Islands area in the Pacific was requested and some imagery has been received. The Palau coverage will provide a basis for determining the values of Landsat coverage in the Trust Territory of the Pacific Islands. Cartographers in other countries, such as Canada [ref. 4(c)], Australia [ref. 4(j)], and England [ref. 4(h)], have recognized the value of Landsat imagery for shallow-seas charting and mapping and are taking definitive steps towards its operational use. Some major oil companies also plan to use Landsat as a chart complement in shallow-seas areas under exploration. For example, Amoco has asked for and obtained Landsat records in high-gain mode over portions of the South China Seas [ref. 4(e)].

2. Small-scale mapping and aeronautical charting.

(a) Within USGS, the pertinent accomplishments during the period are summarized as follows:

(1) Publication of 15 image maps (12 of parts of the United States, 2 of Antarctica, and 1 of Iceland).

(2) Initiation of image maps for the coal-rich areas of Wyoming and Montana, Chesapeake Bay under maximum ice conditions, and national park areas such as the Grand Canyon and Yellowstone. Upper Chesapeake Bay is also in the final stages of preparation as an edge-enhanced image map designed for publication at 1:250,000 scale. The Wenatchee 1:250,000-scale quadrangle is also being prepared as a prototype containing Landsat imagery to depict vegetation, open water, and relief. This project has been favorably reviewed in proof form, and publication is due by the fall of 1977.

(3) Image maps or mosaics are being prepared for portions of the following foreign countries:

Nigeria

Sudan
Yemen
Saudi Arabia
Algeria
Chile/Argentina (Santiago/Mendoza, to be published)

These projects are the result of cooperative agreements between USGS and its counterparts in the foreign country concerned.

(4) An uncontrolled mosaic of a sizable part of China and Southeast Asia was compiled for USGS to use in support of tectonic geologic studies.

(5) Initiation of various projects in Antarctica that involve Landsat image maps or map revision based on Landsat.

(b) Agencies other than USGS have recorded pertinent accomplishments during the period as follows:

(1) Defense Mapping Agency Aerospace Center (DMAAC) has used Landsat imagery in preparing aeronautical charts. Chart No. TDC L-26C (1 ed.) which covers parts of Colombia, Brazil, and Ecuador at 1:500,000, is an example [ref. 2(b)(2].

(2) DMAAC is using Landsat imagery to generate a simulation of the Earth's surface, which is particularly important for correlation with the imaging radar used with in-flight simulators. This application is currently classed as quasi-operational [ref. 4(f)].

(3) The use of Landsat imagery in the compilation of image maps and the revision of line maps throughout sizable sections of the world. The areas of most extensive use are in the lesser developed land areas, including Antarctica [ref. 2(b)].

3. Nighttime Landsat imagery. A high-gain nighttime image of Algeria has been examined by this office and by Dr. Thomas A. Croft of Stanford

Research Institute, who is under contract to USGS. The image depicts two large gas flares, which were identified by correlation to daytime Landsat imagery. It was noted that more than 2,000 nonzero responses were recorded on each band. Dr. Croft has prepared a report concerning the nighttime radiation from the Earth's surface in the visible and near-infrared portions of the spectrum. His work is based primarily on Defense Meteorological Satellite Program (DMSP) imagery, but also includes analysis of the Landsat Algerian nighttime scene. His report will be reproduced in limited quantity and should be available by late 1977 [ref. 3(h)]. As requested by the investigator, NASA has turned on Landsat in high-gain setting at night over the San Diego/Los Angeles area (Feb. 27, 1977). The results, to date, indicate city lights cannot be recorded by Landsat in its present configuration.

4. Mapping of temporal phenomena. Several temporal themes, including oil slicks [ref. 4(k)], have been recognized as being suitable for cartographic display, but because they are transient, a lithographically printed map was not considered justified. On the other hand, imagery showing the extent of maximum ice coverage in the Chesapeake Bay area is being processed into cartographic form.

e. Significant Results

1. Shallow-seas mapping and nautical charting. Landsat imagery, properly processed, can be operationally applied to the revision of nautical charts. Moreover, the imagery depicts shallow seas in a form that permits accurate planimetric image mapping of features to 20 meters of depth where the conditions of water clarity and bottom reflection

are suitable. Depth, again under suitable conditions, can be determined, with errors (rms) of only 10 to 20%, to the same 20-meter depth [ref. 4(b), (1)].

2. Aeronautical charting and Earth scene simulation. Landsat data, properly acquired and processed in image form, provides an excellent simulation of the Earth's surface, important for such applications as aeronautical charting and radar image correlation in aircraft and aircraft simulators (trainers) [ref. 4(f) & 2(b)(2)].

3. Image enhancement. Radiometric enhancement, particularly edge enhancement, a technique only marginally successful with aerial photographs, has proved to be high value when applied to Landsat data [ref. 4(p)].

4. Identification of systematic geometric errors. Landsat imagery, as produced by the NASA Data Processing Facility (NDPF) in bulk form, has systematic geometric errors that now limit cartographic application of the analog products. Reduction of these geometric errors (which is considered feasible) will greatly increase the cartographic (and other) applications of Landsat data [ref. 1(h) & 3(i)].

5. Development of HOM map projection. The Space Oblique Mercator (SOM) projection, which is optimum for Landsat-type imagery, is being rigorously developed in mathematical terms. As an interim measure, computer programs which apply segments of conventional oblique Mercator projections have been derived [ref. 1(p)]. This projection system is defined as the Hotine Oblique Mercator (HOM) and is compatible with the SOM.

6. Worldwide cartographic applications. Landsat data continue to be applied by cartographers throughout the world to an ever-increasing

extent. Landsat is now recognized as a standard small-scale mapping tool by many members of the cartographic community [ref. 4(a, c, h, j)].

7. Nighttime detection of gas flaring. Landsat nighttime data, properly acquired and processed, will record light flux such as that from large gas flares [ref. 3(h)].

8. Multispectral Linear Array (MLA) sensors. The study of solid-state linear arrays indicates that they are highly suitable for Landsat-type operations and that their use will greatly simplify both data acquisition and processing [ref. 4(m, n)]. The term MLA has been coined for this type sensor.

9. Stereographic capability. Linear arrays in a highly stable Landsat-type satellite can be applied stereographically as well as in orthographic mode and in theory provide the basis for an automated 3-dimensional mapping system [ref. 1(q)].

10. Development of an operational Landsat. The definition of proposed parameters for an operational Landsat is considered significant. Although an operational Landsat is not yet an Administration-approved program, parameters, including a sensor system based on MLA's, have been derived [ref. 1(n)].

f. Publications and Reports (References):

1. EROS Cartography memoranda as follows:

(a) EC-35-Landsat--Positioning of offshore features with the aid of Landsat imagery.
(b) EC-36-Landsat--Progress reports - Landsat followon experiments Nos. 23650 and 23960.
(c) EC-37-Landsat--Landsat enhancement on the Electron Beam Recorder (EBR).

(d) EC-38-Landsat--Landsat mapping of the polar regions.
(e) EC-39-Landsat--Solid-state linear array as a candidate Landsat imager.
(f) EC-40-Landsat--Photographic imagery and shallow seas bathymetry by remote sensing.
(g) EC-41-Landsat--Distribution of recent papers relative to Landsat cartographic application.
(h) EC-42-Landsat--Reports on scale differences and scale variation on Landsat images.
(i) EC-43-Landsat--Developments in shallow-seas mapping application of Landsat.
(j) EC-44-Landsat--Technical notes on EROS Digital Image Enhancement System (EDIES).
(k) EC-45-Landsat--Technical advantages of the 919 km orbital altitude for Landsat followon as compared to 705 km.
(l) EC-46-Landsat--Correlation of Landsat digital data to standard large-scale maps.
(m) EC-47-Landsat--Landsat receiving station status.
(n) EC-48-Landsat--Proposed parameters for an operational Landsat.
(o) EC-49-Landsat--Landsat mapping and charting of shallow seas.
(p) EC-50-Landsat--Map projection options for Landsat and the Hotine Oblique Mercator projection applied to Landsat mapping.
(q) EC-51-Landsat--Proposed investigation of Landsat stereo-mapping capability.
(r) EC-52-Landsat--Radiometric discrepancies in Landsat-2 tapes and images.

2. Landsat based cartographic products, including indexes.

(a) Published by USGS.

(1)	Vatnajökull, Iceland	1:500,000	color image map
(2)	Pensacola Bay, Fla.	1:500,000	color " "
(3)	Lake Seminole, Fla.	1:500,000	color " "
(4)	Apalachee Bay, Fla.	1:500,000	color " "
(5)	Okefenokee Swamp, Fla.	1:500,000	color " "
(6)	Gulf Hammock, Fla.	1:500,000	color " "
(7)	Lake George, Fla.	1:500,000	color " "
(8)	Charlotte Harbor, Fla.	1:500,000	color " "
(9)	Lake Okeechobee, Fla.	1:500,000	color " "
(10)	Sanibel Island, Fla.	1:500,000	color " "
(11)	The Everglades, Fla.	1:500,000	color " "
(12)	Florida Keys, Fla.	1:500,000	color " "
(13)	Georgia	1:500,000	color " "
(14)	Ellsworth Mountains, Antarctica	1:500,000	blue-tone image map
(15)	Victoria Land Coast, Antarctica	1:1,000,000	blue-tone image map

(b) Published by other than USGS.

(1) Chart No. 61610 (3 ed.) ˙hagos Archipelago. Nautical chart published by Defense Mapping Agency Hydrographic Center, August 28, 1976.

(2) Chart TPC 1-26C (1 ed). Aeronautical chart published by Defense Mapping Agency Aerospace Center covering portions of Colombia, Ecuador, and Brazil, November 1976. Civil users may purchase from Distribution Division, National Ocean Survey, Riverdale, Maryland 20840.

(3) Imagen Potosi, color image map of a portion of Bolivia published by IGM of Bolivia, 1976.

(4) La France Vue de Satellite, black and white mosaic of France published by the Bureau de Recherches Geologiques Et Minieres & BEICIP, 366 Arenue Napoleon, Bonaparte 92500, Rueil-Malmaison, France, 1974.

(5) National Geographic Society, "Portrait U.S.A." mosaic of the 48 States published as a supplement to the July 1976 issue of National Geographic Magazine and for sale as a separate item by the Society, Washington, D.C., July 1976.

(6) International Bank for Reconstruction and Development, Burma Land Cover-Lands Use Association. Land use image map covering a sizable portion of Southwest Burma, IBRS, Washington, D.C., October 1976.

(7) World Bank, Landsat Index, "Atlas of the Developing Countries of the World," published by the World Bank, February 12, 1976.

(8) National Geographic Society, 1975, Antarctica 1:8,841,000-scale map revi‥ed from Landsat imagery, 1975.

(9) A large number of other cartographic products are reported in various stages of compilation, but are not specifically

reported because published copies have not been received.

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

(a) William R.S., and Carter, W.D., 1976, "Applications to Cartography," ERTS-1 A New Window On Our Planet, USGS Professional Paper 929, 1976.

(b) Rowland, John B., 1976, USGS, Topographic Division, memo on "Scale differences along-track in Landsat images due to Earth rotation," June 2, 1976 (distributed as EC-42-Landsat memorandum dated October 8, 1976).

(c) Colvocoresses, A.P., 1976, "Status Report on Landsat as a Source of Cartographic Data," presented at the ISP, IGU, and ICA meetings in Helsinki and Moscow, July and August 1976.

(d) ______________, 1976, "Remote Sensing of Shallow Seas--A Status Report," presented at the 1976 American Society of Civil Engineers Convention, Philadelphia, Pennsylvania, September 30, 1976.

(e) ______________, 1976, "Planimetric Mapping from Spacecraft," presented at the International Symposium on "The Changing World of Geodetic Science, Ohio State University, Columbus, Ohio, October 6-8, 1976.

(f) ______________, 1977, "Proposed Parameters for an Operational Landsat," Photogrammetric Engineering and Remote Sensing, (in press).

(g) ______________, 1977, "Landsat Mapping of Offshore Regions," presented at the 1977 Offshore Technology Conference, Houston, Texas, May 2-5, 1977.

(h) Croft, T.A., 1977, "Nocturnal Images of the Earth from Space," Stanford Research Institute , contract report to USGS, order

No. 68197, March 1977 [in press].

(i) Letter from DeNoyer to Stoney (NASA) dated December 21, 1976, relative to geometric errors in Landsat imagery.

(j) Letter from Colvocoresses to Freden (NASA) dated January 3, 1977, requesting nighttime imagery over San Diego/Los Angeles area.

(k) Carter, V., Billingsley, F., Lamar, J., 1977, "Summary Tables for Selected Digital Image Processing Systems," USGS Open-File Report 77-414.

(l) Letter from Colvocoresses to Freden (NASA) dated August 30, 1976, which outlined Landsat-C requirements for the Landsat-C epoch.

4. Pertinent non-USGS letters and reports.

(a) Report of the Mapping and Cartography Subpanel of the NASA Landsat Followon and Future Mission Objective Study, 1976. Report prepared by Colvocoresses, Welch, McCulloch, Winikka, and Hammack, June 4, 1976. A revised version appears in JPL Technical Memo 33-803 of December 15, 1976.

(b) Hammack, J., 1977, "Landsat Goes to Sea," Photogrammetric Engineering and Remote Sensing, June 1977.

(c) Fleming, E.A., 1976, "The Use of Satellite Photography in the National Topographic Mapping Program of Canada," Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa, Canada, July 1976.

(d) Letter from Dideriksen, SCS, Department of Agriculture, to Colvocoresses on Landsat Followon, dated October 1, 1976. This letter indicates Agriculture's concern with the geometric accuracy as well as resolution of Landsat.

(e) Letter from President of Amoco to Administrator of NASA dated November 9, 1976. This letter requests Landsat coverage of an extensive area in the South China Seas to support oil exploration.

(f) Letter from Defense Mapping Agency to Manager, Earth Resources Survey Program, NASA, dated November 11, 1976. This letter requests over 1 million nautical square miles of Landsat coverage of shallow sea areas to support hydrographic charting.

(g) Events, 1977, "Saudi Arabia's precious water from the desert," p. 43, May 6, 1977. This article indicates that a $39 million contract has been let to Hunting Technical Services and Sir Malcolm MacDonald and Partners to evaluate water resources in parts of Saudi Arabia. Landsat will be the primary tool for mapping the area for support of this investigation.

(h) Telex, Hydrographer of the Navy (UK) to NASA dated December 13, 1976. This telex outlines sizable shallow sea areas throughout the world where Landsat data is needed for operational tasks.

(i) Letter from Saverio J. Cina (Marine Transportation Consultant) to Lou Villegas, Deputy Director, National Space Institute dated January 6, 1977. This letter outlines pertinent commercial application for Landsat relative to navigational technology and marine construction.

(j) Letter from Australian Division of National Mapping to NASA dated August 31, 1976. This letter outlines Australia's planned use of Landsat for both land and shallow-seas mapping in the Landsat-C epoch.

(k) Deutsch, M.; Strong, A.E.; and Estes, J.E., 1977, "Use of Landsat Data for the Detection of Marine Oil Slicks," proceedings of the 1977 Offshore Technology Conference, Houston, Texas, May 2-4, 1977.

(l) Turner, L.G., 1976, Division of National Mapping, Australia, "Mapping islands, reefs and shoals in the oceans surrounding Australia." Final report to NASA relative to investigation No. 2896B, November 2, 1976.

(m) Westinghouse Electric Corporation, 1974, Proposal for Solid-State MSS (AFFE), May 31, 1974.

(n) Tracy, R.A.; Brennan, J.A.; Frankel, D.G.; and Noll, R.E., 1976, Westinghouse Electric Corporation, Baltimore, Md. 21203, "Breadboard Linear Array Scan Imager Using LSI Solid-State Technology," final report prepared for NASA/GSFC for period July 1972 through May 1976, contract No. 5-21806, May 31, 1976.

(o) Letter from National Ocean Survey (NOS) to NASA dated September 16, 1976. This letter expresses NOS requirements for data in the Landsat-C era.

(p) Bernstein, R., 1977, "Digital Image Enhancement," paper in preparation for IEEE as of July, 1977.

g. Recommendations

The current use of Landsat is so extensive and of such widespread value that it should be converted into an operational system as soon as possible. Defining the management and funding procedure, which is quite complex, is beyond the scope of this investigation, but defining the performance specifications for an operational Landsat is a requirement of this investigation. Based on this requirement and other aspects of this investigation, the following recommendations are made:

1. That an operational Landsat be defined in technical terms based on the worldwide demonstrated use of Landsat during the past 5 years and the current availability of solid-state multispectral linear arrays.

2. That objective tests be conducted by NASA and/or other concerned agencies to determine optimum processing procedures. Such tests should include the full testing of the EBR as well as those based on the optical/mechanical concept.

3. That research in Earth sensing be continued as a program separate from Landsat, which by its very nature is suited to operations rather than research. Such research should, in addition to fundamental sensor and satellite technology, include the following:

(a) Earth sensing in a wide variety of spectral bands and under varying light conditions including night.

(b) Further investigation into the concept of multispatial and multisensor response which should lead to the practical correlation of the response from different sensors and different satellites.

(c) Full investigation of a 3-dimensional mapping system based on the concept of tilted linear arrays. This concept is being examined by this office on a limited basis and shows a potential for practical application on a Landsat-type satellite.

(d) Investigation of the interrelationship of polar and geosynchronous orbiting satellites for Earth sensing. There is evidence that a suitable combination would produce synergistic results far beyond the capabilities of either system by itself, particularly where time-critical phenomena are involved.