

The Landsat Program: Recent History and Prospects

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The current course of the Landsat Program was set by the Land Remote Sensing Policy Act of 1992. Two key events in the fourteen months after enactment of the law, the loss of Landsat 6 and the decision by the Department of Defense to withdraw from the program, led to a review by the Administration of program goals and implementation strategy. As a result of that review, several changes in the structure of the program were instituted, but the Landsat Program is continuing, and Landsat 7 is under development.

The Landsat Program is the longest running exercise in the collection of multispectral, digital data of the earth's land surface from space. The program has operated continuously since Landsat 1 [then the Earth Resources Technology Satellite (ERTS) 1] was launched on July 23, 1972. More than 3 million images from the Multispectral Scanner System (MSS) and the Thematic Mapper (TM) on Landsats 1-5 have been acquired and stored at the National Satellite Land Remote Sensing Data Archive (NSLRSDA) at EROS Data Center (EDC), Sioux Falls, South Dakota and the Landsat international ground stations. The temporal extent of the collection, the characteristics and quality of Landsat data,

and the ability to collect new data directly comparable to that in the archive, make Landsat data a unique resource, one used extensively to address a broad range of issues in earth science, global change science, and monitoring and assessing land and coastal zone resources.

Although the value of Landsat data is generally recognized, the goals and management of the program have changed significantly during its twenty-two year history. Conceived originally for research, the Landsat Program was reorganized as an operational system in 1979 in response to intense interest in the data by the science and nonscience communities. Concern about the cost of the program and the proper role of government in space-based remote sensing led to Congressional authorization to commercialize Landsat in 1984 (P.L. 98365). Between 1985 and 1992 the need to continue the program and the manner in which to do so were questions subject to on-going debate among the user community, the commercial operator of Landsat, the federal agencies involved with oversight of the program, management of Landsat data, and the US space effort, the Congress and the Administration. Final resolution of those questions appeared to be at hand, and the

program established on a firm foundation, with passage of the Land Remote Sensing Policy Act (P.L. 102-555) in October, 1992.

The Landsat Program is evolving in an environment of changing priorities and budgetary constraints. The Landsat data user community will benefit from careful attention to the course of the Landsat Program and taking advantage of opportunities to make clear its requirements and concerns. The program has changed already in ways not anticipated or envisioned in 1992, although, as of this writing, the program is alive, reasonably healthy, and striving to meet the intent of the law and expectations of the user community.

Familiarity with the law is essential to understand the current status of the Landsat Program. When P.L. 102-555 was passed, the Landsat Program was reconstituted and revitalized. The law embodied policy goals, strategy and implementation guidelines for the Landsat Program established by National Space Policy Directive #5.¹ The "findings" of the law recognized the scientific, national security, economic and social utility of "land remote sensing data from space." The law reversed the 1984 decision to commercialize the Landsat system. It acknowledged that commercialization had not worked,

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because the commercial price of data hindered distribution. Perhaps of primary importance, the law committed the US to maintain "continuity"² of Landsat-type data into the next century, and it identified mechanisms to implement that commitment.

The Land Remote Sensing Policy Act of 1992 addressed the near term and long term need of the Landsat Program. The law created an entity called "Landsat Program Management" populated by the Administrator of the National Aeronautic

Concern about the cost led to Congressional authorization to commercialize Landsat in 1984.

and Space Administration (NASA) and the Secretary of Defense (and, "...any other United States Government official the President designates...") and authorized to carry out the following functions (in the order in which they are described in the law):

- Establish a management plan
- Develop and implement a Landsat Advisory Process
- Procure Landsat 7
- Negotiate with the current Landsat 4-6 contractor (EOSAT) on a data policy for Landsats 4-6
- Assume Landsat Program responsibilities from the Department of Commerce (DOC)
- Conduct a technology demonstration program
- Assess options for a successor land remote sensing system

P.L. 102-555 called for the participants in Landsat Program Management (LPM) to draft a plan for implementing the provisions of

the law. The management plan, written and signed prior to passage of the law, identified the programmatic and funding responsibilities of NASA and the Department of Defense (DoD)³. Primary provisions were:

- DoD accepted the lead role in procurement and launch of Landsat 7, i.e. the Landsat 7 space segment.
- NASA accepted the lead role in development of the Landsat 7 ground system including data acquisition, processing, archiving, and distribution.
- NASA and DoD would fund the portion of the program for which each was responsible.
- The Landsat 7 satellite would be functionally equivalent to Landsat 6 with the addition of a Tracking and Data Relay Satellite System (TDRSS) communications capability.
- Any improvements beyond the functional equivalent of Landsat 6 would be paid for by the sponsoring agency, or shared if desired by both participants.
- DoD and NASA would work together on a technology development plan for post Landsat 7 satellites.
- Baseline program funding levels (for the 10 year life of the program) were established: DoD: \$470, NASA: \$410M.

The management plan was the organizational instrument that defined the rules for cooperation between NASA and DoD on Landsat.

Recognizing the Landsat data user community as broad-based, numerous, and replete with different information gathering requirements, the law instructed LPM to, "...seek impartial advice and comments regarding the status, effectiveness, and operation of the Landsat system, using existing advisory committees and other appropriate mechanisms.⁴ Those to be consulted were specified. They included government, at all levels, academic institutions, nonprofit organizations, commercial interests, agricultural and industrial users, and the general public.

From these users, a broad range of views was expected on basic and applied science and operational needs. The result of the process was to be (and will be) a series of reports, the first due to Congress one year following enactment of the law with subsequent reports every two years thereafter. Each report was to contain comments received about the program, responses to the comments from LPM and recommendations, when appropriate, for policy or programmatic changes.

The law authorized LPM to contract with the US private sector for development and launch of Landsat 7⁵. The system was to be launched no later than the end of the design life of Landsat 6 (i.e. five years after launch of Landsat 6.) In addition, LPM was to ensure data continuity by making Landsat 7, at a minimum, the functional equivalent of Landsat 6, and incorporate in Landsat 7, performance improvements to meet USG

needs if such improvements would not jeopardize data continuity.

P.L. 102-555 required LPM to enter negotiations with the Landsat 6 contractor (EOSAT Corporation) to, "...formalize an arrangement with respect to pricing, distribution, acquisition, archiving, and availability of unenhanced data for which the Landsat 6 contractor has responsibility under its contract."⁶ The primary goal of the negotiation was a "phased transition" to a data policy consistent with the data policy for Landsat 7. In the final phase of that transition, the following goals were established for the data policy:⁷

- Unenhanced data to US Government and affiliated users (USGAU) at the cost of fulfilling user requests (COFUR) when data is used solely for non-commercial purposes
- Instructional data sets made available to educational institutions for non-commercial purposes at COFUR
- Data made available from international ground station archives as easily and affordably as practical
- Data adequate for global change research and national security requirements should be acquired
- Data acquired by USGAU shall be free from restriction on reproduction or dissemination within USGAU for non-commercial purposes
- A mechanism shall be put in place to provide unenhanced data to non-profit, public interest en-

tities at COFUR when that data is used for non-commercial purposes

- A viable role for the private sector in the promotion and development of a commercial market for value added and other services using unenhanced data from the Landsat system is preserved⁸
- The NSLRSDA shall receive unenhanced Landsat data at no more than COFUR.

The goals of the negotiations include tacit acceptance of a multi-tiered price schedule for Landsat data from the existing Landsat systems (i.e. Landsats 4 and 5). Landsat Program Management was instructed to seek a better deal for a subset of the data users - USGAU, users of instructional data sets, and non-profit organizations. The law is silent regarding efforts on behalf of other users. The negotiations resulted in the agreement described later.

The responsibilities assigned to the Secretary of Commerce for Landsat 6 and executed through the contract between the DOC and the Landsat 6 contractor were to be transferred to LPM.⁹

The data policy goals for Landsat 7 listed in the law defined clearly the character of the Landsat Program in the long term.¹⁰ The primary goals were:

- Provide unenhanced data to all users at cost of fulfilling user requests
- Provide unenhanced data in a timely and dependable manner to all domestic and international

users and to the NSLRSDA

- Ensure that the USG retains ownership of all unenhanced data generated by Landsat 7
- Support the development of a commercial market for remote sensing data
- Maintain the provision of value-added services in the private sector
- To the extent possible, ensure that the data distribution system for Landsat 7 is compatible with the Earth Observing System Data and Information System (EOSDIS)

These goals *eliminate multi-tiered pricing for Landsat 7 data*. When data from Landsat 7 becomes available, *all users will pay the same price*. Concurrently, the price is constrained to the cost of fulfilling user request, defined, in the law, as, "...the incremental cost associated with providing product generation, reproduction, and distribution of unenhanced data...and shall not include any acquisition, amortization, or depreciation of capital assets originally paid for by the United States Government or other costs specifically attributable to fulfilling user requests."¹¹ As of this writing, the estimated cost for unenhanced data from Landsat 7 has not been determined, but it is likely the cost will not exceed several hundred dollars per scene.

Another goal of the law is to seek to launch an advanced land remote sensing system, within 5 years of enactment of the law, that demonstrates the value of new technology in land re-

When data from Landsat 7 becomes available, all users will pay the same price.

note sensing and that could serve as a less expensive follow-on to the Landsat system after the year 2000.¹²

The law required LPM to assess the potential capabilities of future land remote sensing systems and the alternatives for building, launching and operating such systems in the private sector.¹³

Those are the major provisions of the law. Any discussion of the Landsat Program has to accommodate the law's requirements.

Much has occurred on the Landsat Program since October, 1992. The major events, roughly in chronological order were:

- Signing a contract to build Landsat 7
- Initiation of the Landsat Advisory Process Initiation of a program for a successor land remote sensing system
- Resolution of budget issues for FY94
- Loss of Landsat 6
- Withdrawal of DoD from the Landsat Program
- Administration review of Program requirements and options

- Re-structuring of the Landsat Program
- Agreement on a data policy for Landsats 4/5

Space precludes discussion here of all the major events. Instead, the focus will be on those events that affected Landsat 7 and the Landsat 4/5 data policy.

As indicated in the management plan, DoD, as part of LPM, assumed responsibility for the space segment. In that capacity, DoD entered into a contract with GE Astro (now Martin Marietta Astro Space (MMAS)) in December, 1992 for the construction and launch of Landsat 7. The contract called for the Landsat 7 spacecraft and:

- the Enhanced Thematic Mapper Plus (ETM+) instrument
- the High Resolution Multispectral Stereo Imager (HRMSI) instrument as an option
- all systems integration and test
- system processing software

The primary improvements in the baseline instrument (ETM+) over the instrument built for Landsat 6 (ETM) were ground resolution in the thermal band (60 vs. 120 meters) and absolute radiometric calibration (5%). The Thematic Mapper-type instruments on Landsats 4,5,6 and 7 are compared in Table 1.

Neither the DoD/NASA management plan nor P.L. 102-555 specified the instrument or instruments to be included on Landsat 7. Both documents stated that Landsat 7 must be functionally equivalent to Landsat 6 with

Table 1: Comparisons Among Landsat TM, ETM, and ETM+

| CHARACTERISTIC | TM (LANDSAT 4/5) | ETM (LANDSAT 6) | ETM+ (LANDSAT 7) |
|--|---------------------|--------------------|--|
| Swath Width | 185KM | 185KM | 185KM |
| Spectral Bandpass and Resolution | | | |
| VNIR (4 bands) | 30M | 30M | 30M |
| SWIR (2 bands) | 30M | 30M | 30M |
| LWIR (1 band) | 120M | 120M | 60M |
| PAN (1 band) | None | 15M | 15M |
| Absolute Radiometric Accuracy | 7-17% | 7-17% | 5% (full and partial aperture calibrators) |
| Geodetic Accuracy Without Ground Control | 500M (90%) | 1000M (90%) | 400M (90%) |
| Band-to-Band Registration | 0.2 pixel (90%) | 0.2 pixel (90%) | 0.2 pixel (90%) |
| Data Rate | 85Mbps | Two 85Mbps | 150Mbps |
| Power | 440 Watts | 720 Watts | 720 Watts |
| Commands | 66 | 152 | 159 |
| Telemetry Points | 108 | 210 | 275 |
| Weight | 574 lbs. | 800 lbs. | 935 lbs. |

SOURCE: Landsat Project - NASA Goddard Space Flight Center

the addition of the TDRSS capability. Both documents also stated that improvements beyond the functional capability of Landsat 6 could be entertained provided that such improvements did not jeopardize data continuity.¹⁴

In response to the management plan, DoD issued a Request for Proposals (RFP) for Landsat 7 in May 1992.¹⁵ The RFP specified performance requirements, it did not specify an instrument or instruments. The performance requirements included capabilities equivalent to Landsat 6 with the addition of TDRSS. The RFP also included, for potential bidders to consider adding to their proposals, "prioritized enhancements" and "lower priority enhancements." The former included improved spatial resolution, improved absolute calibration and

stereo mapping capability. The latter included additional spectral bands, cross-track pointing, improved radiometric sensitivity and improved line of sight (LOS) accuracy. MMAS responded to the RFP by proposing two instruments - ETM+ as the "continuity" instrument (including the enhancement in LWIR ground resolution and absolute radiometric calibration noted above), and HRMSI as an instrument that addressed many of the performance enhancements requested in the RFP. HRMSI performance characteristics included 4, 10 meter VNIR bands, a 5 meter panchromatic band, stereo imaging capability and off track pointing. MMAS teamed with Hughes Santa Barbara Research Center (SBRC) in the proposal; SBRC would build the instruments.

The MMAS proposal was accepted, but HRMSI was included as an option in the contract to be exercised, i.e., selected or rejected, by the system preliminary design review in February, 1994. Neither DoD nor NASA had anticipated that a second instrument would be proposed in response to the RFP; neither agency had accounted for the cost of a second instrument in the budget for the baseline program. Exercising the HRMSI option was dependent on both agencies securing additional funding to cover the anticipated additional cost.

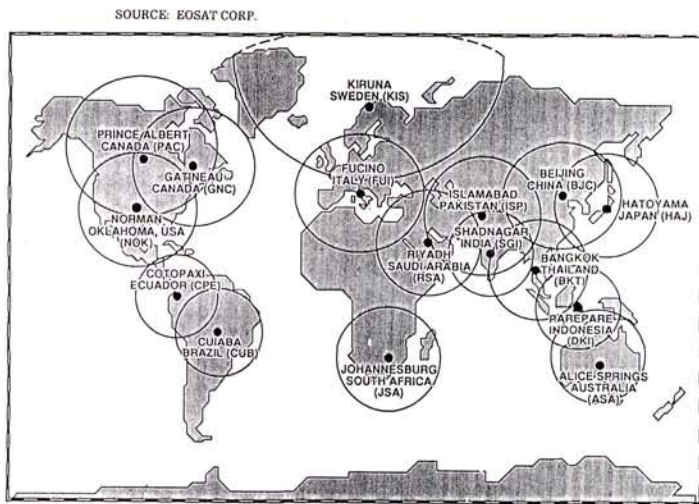
The baseline funding levels included in the DoD/NASA management plan were sufficient to build, launch and operate a Landsat spacecraft and ground system with a continuity instrument only (i.e., a Landsat 6 functional equivalent capability).¹⁶ As noted in Section 2.1, the proposal from MMAS identified ETM+ as the continuity instrument and HRMSI as an instrument that provided performance beyond the baseline requirements. The management plan defined how such improvements would be funded. In the case of HRMSI, the improvement would clearly benefit both DoD and NASA. Hence, both organizations sought funding for HRMSI above the baseline program budget level included in the management plan. DoD sought funds to build the instrument. NASA sought funds to increase the capacity of the Landsat 7 ground system to handle the substantial increase in data throughput anticipated with simultaneous operation of

HRMSI and ETM+. By September 1993, DoD was successful in getting an additional appropriation for the HRMSI instrument costs in FY94. NASA, however, was unsuccessful in getting any funding for the HRMSI ground system beyond its request for Landsat 7 baseline funds. HRMSI funding was not included in the Administration's FY94 budget request for NASA. Funding for HRMSI was included by NASA under a New Technology Initiative forwarded to Congress in June. The House responded by authorizing FY94 HRMSI funding, but neither the House nor the Senate appropriated funds to NASA for HRMSI. At the end of the FY94 budget process, baseline funding for the Landsat Program was secure; supplemental funding for NASA's part of HRMSI was not forthcoming.

Shortly after the conclusion of the FY94 budget process, Landsat 6 was launched.

The loss of Landsat 6 was a disaster for the Landsat Program and the Landsat data user community. The loss threatens the continuity of Landsat data, the fundamental justification for the program in the law, and the global market for Landsat-type data now dominated by the US. The unique capabilities of Landsat and the need to maintain continued acquisition of such data were stressed in the findings of P.L. 102-555. Since no backup system for Landsat 6 was built, continuity of data collection is now dependent on the operation of systems well beyond their design life.

Figure 1. Current Landsat 5 Receiving Stations and Area of Coverage.



Global coverage of the world with Landsat data is not achievable until another system is launched or additional ground stations are opened. Landsat 5 is the only remaining Landsat system now acquiring TM data. Landsat 5 has no operational TDRSS or onboard data storage capabilities. Data transmission to the ground is by X-band direct downlink only. Thus, only images of sites within view of a receiving station can be sent to the

ground. Figure 1 shows the locations of the stations that receive Landsat 5 data and the area of coverage of each station. Currently, the major land areas of the world for which no Landsat imagery can be collected (not including Antarctica) are most of northern Asia, central and west-central Africa, southern South America and Alaska.

Table 2 lists the transmissions of MSS and TM scenes from Landsat 5 to ground stations for the pe-

riod prior to, and after, the loss of Landsat 6. Data transmissions remain high, but the volume of data transmission is not indicative of the number of scenes received, processed or archived. While there is no known factor to prevent Landsat 5 from operating in its present configuration for several more years, the system was launched over ten years ago with a three year design life.

The magnitude of the loss of Landsat 6 was recognized by the Administration. On October 19, the Assistant to the President for Science and Technology sent letters to NASA, DoD and NOAA requesting their participation and cooperation with the Office of Science and Technology Policy (OSTP) in developing options for the program in response to the loss.¹⁷ The review of program options culminated, in early February, with a recommendation from the National Science and Technology Council (NSTC)¹⁸ to continue devel-

opment of the ETM+ instrument and the Landsat 7 spacecraft, i.e. continue the baseline program, but with a new management structure. The recommendation from NSTC was made with full knowledge and acceptance of DoD's request to withdraw from the Landsat Program.

The crisis with DoD over Landsat 7 would likely have occurred regardless of the fate of Landsat 6. After DoD contracted with MMAS to build Landsat 7, it became increasingly clear that DoD's primary interest in the system was with HRMSI. By the end of the summer, DoD was stating that its requirements from Landsat 7 were mostly for HRMSI data, and, although it retained some need for Thematic Mapper-type data, it could not justify participation in a program that did not include HRMSI. Following conclusion of the FY94 budget process, negotiations continued between NASA and DoD staff to design a program that would include ETM+ and HRMSI on Landsat 7 within the combined total Landsat programmatic budgets of the two organizations. As late as the system design review in mid-November, 1993, various approaches were being considered. These called for significant changes in DoD's approach to managing the MMAS contract and channeling all HRMSI data to DoD for processing before release to other users.

On December 8, the NASA Administrator and the Under Secretary of Defense for Acquisition and Technology met to discuss programmatic issues between the two agencies. Landsat was

Table 2: Scene Transmissions From Landsat 5 in Recent Months

SOURCE: EOSAT Corp.

| Ground Station | Sep 93 | | Nov 93 | | Dec 93 | | Jan 94 | | Feb 94 | | Mar 94 | |
|----------------|--------|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|-------|
| | MSS | TM | MSS | TM | MSS | TM | MSS | TM | MSS | TM | MSS | TM |
| Argentina | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Australia | 1274 | 1274 | 1272 | 1272 | 1284 | 1284 | 1323 | 1323 | 1094 | 1094 | 1297 | 1297 |
| Brazil | 0 | 1186 | 0 | 1168 | 0 | 1209 | 0 | 1218 | 0 | 1075 | 0 | 1210 |
| Canada | 2239 | 1757 | 42 | 42 | 55 | 50 | 57 | 57 | 53 | 53 | 1163 | 1000 |
| China | 1912 | 1912 | 1923 | 1932 | 1977 | 1977 | 2013 | 2013 | 1709 | 1709 | 1946 | 1946 |
| Ecuador | 0 | 817 | 0 | 804 | 0 | 836 | 0 | 819 | 0 | 750 | 0 | 827 |
| India | 1297 | 1809 | 1308 | 1824 | 1341 | 1821 | 1368 | 1856 | 1144 | 1545 | 1350 | 1838 |
| Indonesia | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0 | 251 | 0 | 915 |
| Italy | 1270 | 1281 | 1274 | 1271 | 1317 | 1317 | 1384 | 1384 | 1150 | 1150 | 1340 | 1389 |
| Japan | 727 | 629 | 781 | 648 | 736 | 611 | 743 | 610 | 683 | 557 | 892 | 741 |
| Pakistan | 1817 | 1817 | 1885 | 1884 | 1905 | 1903 | 1889 | 1889 | 1572 | 1572 | 1875 | 1888 |
| Saudi Arabia | 1608 | 1608 | 1498 | 1606 | 1615 | 1615 | 1674 | 1674 | 1614 | 1611 | 1920 | 2342 |
| South Africa | 741 | 741 | 0 | 748 | 0 | 780 | 0 | 773 | 0 | 647 | 0 | 823 |
| Spain | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sweden | 3885 | 3885 | 1126 | 1126 | 1155 | 1158 | 72 | 72 | 0 | 0 | 0 | 0 |
| Thailand | 1410 | 1410 | 1427 | 1427 | 1468 | 1464 | 1519 | 1487 | 1289 | 1289 | 1466 | 1466 |
| Subtotal | 18180 | 20126 | 12540 | 15752 | 12853 | 16025 | 12042 | 15175 | 10308 | 13303 | 13249 | 17682 |
| Norman, OK | 0 | 1128 | 0 | 1242 | 0 | 1206 | 0 | 1278 | 0 | 1046 | 0 | 1278 |
| Total | 18180 | 21254 | 12540 | 16994 | 12853 | 17231 | 12042 | 16453 | 10308 | 14349 | 13249 | 18960 |

one of the topics. They concluded it would be best for the program to split - NASA to assume all responsibility for Landsat 7 and the ETM+ instrument, DoD to consider going forward with the HRMSI instrument on a separate spacecraft. That decision was communicated to Congress and the Administration the following day.¹⁹

Initial Administration response to the DoD/NASA decision was to remind both agencies that an interagency review of the Landsat Program (the OSTP-led exercise) was in progress, and no decisions would be made until that process was completed.²⁰

Response from cognizant parties in Congress came after the New Year. The Chairman of the House Committee on Science, Space and Technology wrote the Vice-President expressing "great dismay" about the status of the program, the apparent inability of NASA and DoD to work together and the potential to lose both the HRMSI and the ETM+ instruments.²¹ The Administration reply to that letter reiterated its support of the purpose for the Landsat Program and the goals embodied in P.L. 102-555. The Vice-President wrote in early February: "...Landsat-type data has proven enormously valuable to the global change community as well as various commercial, civilian, and military users. In the past two months, we have been working closely with NASA, DoD, NOAA and other user agencies to map out where the Landsat program should go in light of the loss of Landsat 6... we

are coming to closure on an approach which I believe, will minimize overall costs and improve the schedule without compromising a key variable: data continuity."²² The reply noted that NASA and DoD had agreed to transfer responsibility for the Landsat Program to NASA, although DoD would remain a major user of Landsat data.

Near the time of the Vice-President's letter, DoD zeroed out its FY95 budget request for Landsat and began to dismantle the Defense Landsat Project Office (DLPO), the office responsible for management of DoD Landsat responsibilities. Those actions made DoD's decision to withdraw from the program irrevocable.

The discussions between NASA and DoD to re-structure the program were held concurrently with the program review process initiated by OSTP. A wide range of options were considered in the review including immediate cancellation of the Landsat Program, continuation of the program with HRMSI, integration of Landsat with the Earth observing System (EOS) program and procurement of Landsat-type data through a commercial data buy.

On February 7, 1994, the NSTC recommended, as the basis for re-structuring the Landsat Program, continuing Landsat 7, without HRMSI, under joint NASA/NOAA management with NASA responsible for the space segment and NOAA responsible for the ground segment (with the Department of the Interior.) The recommendation was consistent with the policy goals of P.L. 102-555, it

was achievable within the total baseline budget for Landsat (NASA and DoD), it was the best hope for maintaining data continuity, and it took maximum advantage of the money already sunk in the Landsat program.

The NSTC recommendation was endorsed by the President in Presidential Decision Directive (PDD)/NSTC-3, signed by President Clinton on May 5, 1994 and announced on May 10. The announcement, made by the Assistant to the President for Science and Technology, confirmed, again, the Administration's support for the Landsat Program and described the new strategy for implementation of the program. Specifics of the re-structured Landsat Program are described later, but the policy goals of PDD/NSTC-3 are worth noting. The U.S. Government committed to:

- a) Provide unenhanced data which are sufficiently consistent in terms of acquisition geometry, coverage characteristics, and spectral characteristics with previous Landsat data to allow quantitative comparisons for change detection and characterization;
- b) Make government-owned Landsat data available to meet the needs of all users at no more than the cost of fulfilling requests consistent with data policy goals of P.L. 102-555; and,
- c) Promote and not preclude private sector commercial opportunities in Landsat-type remote sensing.

Although the announcement of PDD/NSTC-3 came in early May, preparation for restructuring the Landsat Program began after February 7 when the NSTC made its recommendation. The implementation strategy adopted by the NSTC and endorsed in PDD/NSTC-3 can be summarized by looking at the impact of the strategy on the provisions of P.L. 102-555:

- On Landsat Program Management — The LPM remains as the organizational entity directly responsible for the Landsat Program, but its composition changes. NASA continues as a major member, joined in LPM by NOAA and the Department of the Interior US Geological Survey (USGS). DoD will transfer all Landsat 7 responsibilities to NASA.
- On the management plan — NASA, NOAA and USGS are writing a new management plan to replace the DoD/NASA plan. It will define agency responsibilities in accordance with the guidelines established in PDD/NSTC-3. NASA will assume responsibility for procuring the spacecraft, instruments and ground system. NOAA will assist NASA in the development of the ground system and share in funding that system. NOAA will also operate the spacecraft and ground system in cooperation with USGS. USGS will assume responsibility for archiving the data and will work with NOAA on data processing and distribu-

tion. A draft of the management plan has been written and is currently being reviewed by the participants.

■ On procurement of Landsat 7 — Re-structuring the Landsat program requires supplementing NASA's Landsat Program baseline budget, particularly in the period FY94-96 when the spacecraft and instrument are being built, and transfer of authority over the MMAS contract from DoD to NASA. An agreement between NASA and DoD to transfer the remaining DoD FY94 Landsat appropriation and the contract to NASA was concluded in February. However, before the terms of the agreement were made final and the proposed transfers accomplished, Congress rescinded the remaining DoD FY94 Landsat related funds, about \$139M, as part of the earthquake relief package assembled following the January earthquake in Southern California. \$90M of those funds were subsequently returned to DoD with the provision, written into law, that the funding could be transferred to NASA for Landsat, but only after the NASA Administrator certified that NASA had sufficient funds in FY95 and the out years to complete the program.²³ Certification from the NASA Administrator came on May 5.²⁴ The MMAS contract for Landsat 7 was transferred to NASA on May 17. Work on the HRMSI in-

strument ceased in mid-February when the option to buy HRMSI was not exercised.

A comparison of major system components between the baseline Landsat Program and the re-structured program is shown in Table 3. The performance characteristics of the Landsat 7 ETM+ instrument are unchanged from the baseline instrument described in Table 1. The operational configuration of the Landsat 7 ground system is shown in Figure 2. The ETM+ will be capable of collecting 250 day-lit, land mass scenes per day and transmitting those scenes to the ground via X-band direct downlink at 150Mbps. The primary ground receiving station will be at EDC. The Landsat 7 spacecraft will have on board 350Gb of solid state memory, sufficient for approximately 100 ETM+ scenes. All data received at the US ground station will be processed to Level 0R²⁵ within 24 hours of receipt and archived at EDC within the Land

Processes Distributed Active Archive Center (LP-DAAC). Landsat data, as a digital, Level 0R product, will be sold to all users at COFUR as defined in P.L. 102-555. The ground system will be capable of distributing 100 Level 0R products per day. Metadata and browse files will be generated for user information as the data are processed and archived.

The primary differences in the spacecraft between the baseline program and the re-structured program are the deletion of the wide band TDRSS link for data communication, the deletion of GPS precision positioning system (PPS) for navigation and control, and substitution of solid state memory for analog recorders. The TDRSS link and the GPS PPS were essential when HRMSI was included on the Landsat 7 spacecraft, but are not requirements for ETM+. Data will be brought to the ground by X-band only. TDRSS will still be used for narrow band communication with the spacecraft. A daily

update of the ephemeris will allow on-board calculations of location suitable to meet the geodetic accuracy requirements for ETM+. Analog recorders were likely failure points given their history in the program. It is hoped that solid state memory will be more reliable and more flexible.

For the ground system, the primary differences between the baseline program and the re-structured program are the data throughput, data products, and facilities. The re-structured program will acquire 250 scenes per day (as opposed to 300), but the rate of data acquisition will remain adequate to image all sun-lit, land area, cloud free²⁶ scenes. The baseline program called for production of 100 Level 1R (geometrically and/or radiometrically corrected) scenes per day. The re-structured program will produce only Level 0R data (except for a few Level 1R scenes generated daily for image quality assessment,) leaving the processing to Level 1R to the value added community and data users.²⁷ The re-structured system will continue to take advantage of the EOSDIS to the maximum extent possible. It will not require separate facilities for a Landsat Data Operating System (LDOS) to acquire data. Data acquisition, processing and distribution will be accomplished at the same site (EDC see Figure 2).

■ On a data policy for Landsat 7 — A data policy that addresses the goals established in P.L. 102-555 was completed by LPM last September.

Figure 2. Landsat 7; Restructured Ground System Configuration.

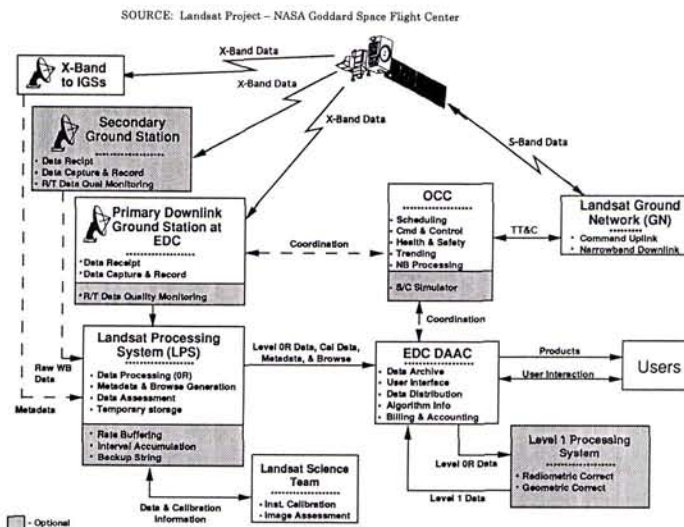


Table 3: Landsat 7, Program Comparisons
SOURCE: Landsat Project - NASA Goddard Space Flight Center

| FUNCTION /CONFIGURATION | ORIGINAL PROGRAM | RESTRUCTURED PROGRAM |
|--|--|---|
| S/C Bus | Landsat 6 heritage bus | Landsat 6 heritage bus |
| Instrumentation | ETM+, HRMSI (option) | ETM+ and flight opportunity (TBD) |
| On-board Storage | 3 - 75Mbps tape recorders, 16 minute capacity each | Solid state memory; about 40 minutes total capacity |
| Mission Downlink | 300mbps CCSDS via TDRSS | 3 - 150 mbps CCSDS X-band steerable |
| International Ground Station Support | 3 - 150 mbps CCSDS X-band steerable | 3 - 150 mbps CCSDS X - band steerable |
| Telemetry, Tracking and Control (TT&C) | CCSDS S-band TDRSS SSA; encrypted uplink | CCSDS S-band ground network; encrypted uplink |
| On-board Navigation and Control | GPS PPS | Daily ephemeris upload |
| Back-up commanding | DSN; GN; TDRSS low rate; AFSCN full-up compatible | DSN; GN; TDRSS low rate; AFSCN through GN transponder |
| Assessment/Calibration | Operations Support Facility | Landsat 7 Science Quality Assurance Team |

Distribution of the policy for public comment was delayed by the Administration review of the Landsat program. NASA, NOAA and USGS re-visited the policy in spring, 1994.

It is likely that a draft policy will be distributed for public comment in the summer of 1994.

An agreement between LPM and EOSAT on cost, processing and distribution rights for data from Landsats 4 and 5 was initiated on April 11, 1994. The agreement concluded negotiations mandated by P.L. 102-555 and described earlier.

The agreement assures the continued operation of Landsats 4 and 5, until their demise, at no cost to the government. It provides for Landsat data to be made available to the U.S. government, its affiliated users, educational institutions, and nonprofit organizations at reduced prices and with far fewer restrictions than at present on sharing of the data. The agreement also assures placement of the Landsat 4/5 data set in the

NSLRSDA. The key provisions of the agreement are outlined below:

Cost of data to US Government and affiliated users²⁶ (USGAU)

- Scenes purchased between 4/11/94 and 12/31/94: >> \$3500/Unenhanced TM scene
- Scenes purchased after 12/31/94: >> \$2500/Unenhanced TM scene
- Raw data purchased by NSLRSDA: >> \$70/scene until 5 years after demise of Landsats 4/5 >> Cost of shipping data thereafter

USGAU rights to copy data for, and redistribute data within, USGAU for noncommercial use

- Unenhanced TM scene purchased after 4/11/94 >> Unrestricted rights
- Unenhanced TM scene purchased before 4/11/94 >> Until 9/30/94: Restrictions in place at time of purchase apply >> From 10/1/94 through 10/1/95: Unrestricted rights for data sensed more than two years previous (moving window)

>> After 10/1/95: Unrestricted rights

USGAU rights to process data from NSLRSDA for USGAU for noncommercial use

- Until 9/30/94: >> Restriction in place at time of purchase apply
- 10/1/94 through 10/1/95: >> Unrestricted for data sensed more than two years previous (moving window)
- 10/2/95 through 10/1/96: >> Unrestricted for data sensed more than one year previous (moving window)
- After 10/1/96: >> Unrestricted rights

Because this agreement overlaps others now in place between EOSAT and EDC, it is probably advantageous for all USGAU users to acquire data through EDC to avoid confusion on data cost and reproduction/distribution rights.

The period from October, 1992 through May, 1994 was notable for great activity and much uncertainty in the Landsat Program. The job of implementing P.L. 102-555 spurred the activity. Much was accomplished by NASA and DoD. Work on Landsat 7 progressed significantly, the Landsat Advisory Process and a program to examine postLandsat 7 land remote sensing were initiated, an agreement was reached that lowers the cost of, and improves accessibility to, Landsat 4 and 5 data for many users, and a draft data policy for Landsat 7 was completed. Although details in implementation changed since passage of the law, the Landsat Program remained active and on course.

Uncertainty emerged after the loss of Landsat 6 and DoD's withdrawal from the program. The announcement of PDD/NSTC-3 seems to assure completion of Landsat 7 and a more robust Landsat Program, but much time and many budget decisions lie between current plans for the program and an operational Landsat 7. Meanwhile, global coverage with Landsat data is not available at the present time, and acquisition of data from those parts of the earth within view of Landsat ground receiving stations is dependent on systems well past their design lives.

It is the responsibility of the Landsat user community to make certain that its concerns, requirements, and satisfactions, with the program are known to the agencies that build and operate the Landsat system, Administration officials who draft public policy on the space program, and the elected representatives with budgetary oversight. Such involvement now is essential for the successful completion of Landsat 7, and, perhaps, even more critical, to assure acquisition of publicly accessible, low cost, global coverage, ETM+ equivalent, land remote sensing data in the post-Landsat 7 era.

In the near term, the community should be alert for news about the following items:

- FY95 NASA and Landsat budgets
- Landsat 7 data policy
- Landsat Advisory Process

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Endnotes:

- 1 National Space Policy Directive (NSPD) #5, February 5, 1992.
- 2 Data continuity is defined in P.L. 102-555, Section 3(3) as, "... continued acquisition and availability of unenhanced data... sufficiently consistent [in] acquisition geometry, coverage characteristics and spectral characteristics with previous Landsat data to allow comparisons for global and regional change detection and characterization [and] compatible with such data and methods used to receive and process such data."
- 3 "Management Plan for the Landsat Program" DoD and NASA, March, 1992. The plan was written in response to NSPD#5. Included in the introduction to the plan is the note that the agencies involved would work with Congress to obtain necessary enabling legislation prior to implementation of the plans provisions. P.L. 102-555 was the enabling legislation.
- 4 Land Remote Sensing Policy Act of 1992, Section 101(e)(1).
- 5 Ibid., Section 102.
- 6 Ibid., Section 103(a)
- 7 Ibid.
- 8 Ibid.
- 9 Ibid., Section 104.
- 10 Ibid., Section 195.
- 11 Ibid., Section 3(2).
- 12 Ibid., Section 303.
- 13 Ibid., Section 401.
- 14 "Management Plan for the Landsat Program" DoD and NASA, March, 1992, p. 2; and P.L. 102-555 Section 102(b).
- 15 DoD RFP# FA7056-92-R-0016: The executive summary (dated 1 June 1992) noted that the RFP was responsive to Presidential policy (NSPD #5) and pending legislation (P.L. 102-555) but no contract would be awarded until funding was made available and legal authority to proceed with a contract was received through enabling legislation.
- 16 "Management Plan for the Landsat Program" DoD and NASA, March, 1992, p. 3.
- 17 Letters of 10/19/93 from John H. Gibbons to Daniel S. Goldin, John M. Deutch, and D. James Baker. NOAA was asked to participate because of its role as the agent for DOC in the commercial operations of the current Landsat program, and the interest expressed by the NOAA Administrator in maintaining a role for NOAA in the Landsat Program as the agency designated by Congress to manage civilian operational satellites.
- 18 The NSTC is a new cabinet level organization recommended by the National Performance Review. Its role is to coordinate science, space, and technology policies throughout the Federal Government. The NSTC is chaired by the President and includes the Vice President, the assistant to the President for Science and Technology (John Gibbons) and the cabinet Secretaries and agency heads responsible for significant science and technology programs. It replaces the National Space Council and is, in effect, the policy making body for science in the Administration. Any decision by the NSTC on the Landsat Program is the Administration's position on the program.
- 19 Letter of 12/9/93 from John M. Deutch to George E. Brown, Jr.
- 20 Letters of 12/10/93 from John H. Gibbons to Daniel S. Goldin and John M. Deutch.
- 21 Letter of 1/31/94 from George ER. Brown, Jr. to Albert Gore, Jr.
- 22 Letter of February 4, 1994 from Albert Gore, Jr. to George E. Brown, Jr.
- 23 Public Law 103-211.
- 24 Letter of May 5, 1994 from Daniel S. Goldin to Barbara A. Milkulski, Chair, Subcommittee on VA-HUD-Independent Agencies, Committee on Appropriations, United States Senate.
- 25 Level 0R data is defined in the draft Landsat 7 Data Policy as "Reformatted instrument data, corresponding to an interval or subinterval, that are unrectified. The product is reformatted which involves fixed and predefined integer pixel shifts...[and] includes: 1) reversing the order of the reverse scan data, 2) aligning the odd and even detectors, 3) aligning the spectral bands, 4) replicating (TBR) the LWIR data, and 5) nominal alignment of the forward and reverse scans. Attitude and spacecraft ephemeris, radiometric calibration data and quality are also included. All manipulations are reversible."
- 26 <20% cloud cover.
- 27 Level 0R data will be distributed with the information required to generate a corrected product. Algorithms written to generate Level 1R for image quality assessment will be in the public domain. As noted in Figure 2, processing data to Level 1R at EDC remains a program option.
- 28 US Government and affiliated users is defined in the agreement as follows: 1) US Government agencies; 2) US Government contractors; 3) Researchers and institutions conducting scientific investigations related to global change funded by, or defined in agreements with, US CEES member agencies; 4) US Global Change Research program international counterpart programs, i.e. global change research programs in countries other than the US as well as global change research programs of the World Meteorological Organization (WMO), the United Nations Environmental Programme (UNEP), Intergovern-

mental Oceanographic Commission (IOC), International Council of Scientific Unions (ICSU), and the International Social Science

Council (ISSC); 5) Other researchers (individuals or entities conducting scientific investigations, not necessarily related to the Global Change re-

search program) that have signed with the US Government a cooperative agreement involving the use of Landsat data for noncommercial pur-

poses; 6) Educational institutions for non-commercial purposes; 7) Nonprofit, public interest entities

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