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Multispectral Linear Arrays as an Alternative to Landsat D*

Multispectral Linear Arrays would be more cost/effective than Landsat D's Thematic Mapper.†

Abstract: *Landsats have been in orbit for nearly six years and have demonstrated the effectiveness of such an Earth sensing system. Landsat D, as defined by* NASA, *is the satellite designated to follow Landsat 3, but others have proposed an Alternative based on linear arrays rather than the Thematic Mapper of Landsat D. A comparison between Landsat D and the Alternative indicates a 25 to 1 advantage of the Alternative on a cost-per-scene basis.*

Background

In 1966 Dr. William Pecora of the U.S. Geological Survey (USGS) and Secretary of the Interior Stewart Udall defined the EROS program and the Earth sensing satellite system, which became the Earth Resources Technology Satellite (ERTS), later renamed Landsat.[1] Pecora and Udall were not defining an experiment but a program aimed at sensing the Earth systematically and continuously. Their goals were "to collect valuable resource data and use them to improve the quality of our environment" and "to help plan a major effort in the exploration of the Earth for human benefit." These goals have been affirmed by various officials, such as President Nixon in 1969 and Secretary of State Kissinger in 1975. Landsat (ERTS) first flew in 1972 and has made outstanding progress towards achieving the goals stated, and today Landsat data are being applied operationally in many areas of the world. It is true that the most effective uses of Landsat are in the lesser developed countries and in the poorly mapped land and shallow sea areas of the Earth; however, even in highly developed countries, Landsat data are being applied to the solution of a wide variety of real problems.

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† Note: Since this article was prepared NASA has added the Multispectral Scanner (MSS) to Landsat D. However the MSS is of lower resolution (80 m IFOV) and the paper is still valid for those who need the higher resolution (30 m IFOV).

Status Today

Landsat-1 was recently closed down after five and one half years of spectacular performance. Landsat-2 (launched January 22, 1975) is operating but limited in tape recording capability, and Landsat-3 was launched March 5, 1978. NASA has defined Landsat-D utilizing the Thematic Mapper (TM) for launch in 1981, and others have proposed an alternative based on Multispectral Linear Arrays (MLAS).[2,3,4] Table 1 lists and compares critical elements of these two systems. The basic differences in these systems stem from NASA's charter to perform research and fly experimental missions (Landsat-D) and the growing demand for an operational Landsat which inspired the alternative. Many users throughout the world are asking for continued acquisition and global availability of data at reasonable cost. Unfortunately, no Federal agency now has the

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TABLE 1. PARAMETERS OF LANDSAT FOLLOWON

	Landsat-D (TM)	Alternative (MLA)
Sensor	TM	MLA
No. Bands	6 or 7	3
Resolution (IFOV)	30-50 m (5 or 6 bands) 120-180 m (1 band)	30-40 m (1 band) 60-90 m (2 bands)
Data transmission rate	84-100 Mb/s	15 Mb/s
Data bits per unit area (normalized)	6	1
Expected life	2-4 yr	6-12 yr
Orbit altitude	716 km	919 km
Compatible with Landsats-1, -2, & -3	no	yes
Scenes per day	100	400
Processing complexity (normalized)	10x	x
Risk factor (based on complexity)	10x	x

charter to fund for or manage an operational Earth-sensing satellite.

COST CONSIDERATIONS

Looking ahead, Landsat-D as defined by NASA will undoubtedly lead to higher acquisition costs and data prices. Landsat-D is estimated by the General Accounting Office (GAO) to cost from $290 to $330 million, and precision processing cost will be in the order of $1,000 per frame as compared with $100 for Landsats-1 and -2. Moreover, Landsat-D will acquire only 25 percent as much coverage as Landsats-1 or -2.

The alternative (MLA) proposal is for a relatively simple satellite based on the parameters of Landsats-1 and -2 but carrying an MLA sensor. The entire system can be built, flown, and operated for an estimated $100 million, but the savings in data transmission and processing are far greater than the 3:1 advantage in satellite construction and operating costs. Some of the obvious savings are indicated in Table 2.

CONCLUSION

It is easy to discount the 25:1 comparison by noting that the TM is an experiment and the MLA is an operational system—or at least an operational prototype. However, when Landsat-3 was approved in 1974, the Office of Management and Budget (OMB) took the stand that this was to be the last of the experimental satellites and that Landsat must either go operational or be stopped. However, OMB has now approved Landsat-D

TABLE 2. ESTIMATED COSTS

	Landsat-D (TM)	Alternative (MLA)
Expected lifetime	1,000 days	3,000 days
Scenes per day	100	400
Total scenes	100,000	1,200,000
Processing per scene	$1,000	$100
Satellite, launch & operation	$ 300 M	$100 M
Upgrading foreign stations*	50 M	0 M
Data processing costs	100 M	120 M
Total	$ 450 M	$220 M
Cost per scene	$4,500	$180
Cost factor per scene†	25	1

* Assumes that ten foreign reception stations will be built before launch of the TM or MLA; thus, basic station costs are not included.

† Scene value for TM and MLA is related as equal. TM has more spectral bands (six or seven to three), but with 30-m resolution (one band) MLA will have higher effective spatial resolution, higher geometric accuracy, and adequate radiometric fidelity. Moreover, MLA imagery will be acquired in a daily pattern of adjacent paths whereas TM imagery will be obtained from a generally undesirable skip orbit, with at least 48 hours between adjacent paths.

as another experiment. OMB and GAO are aware of the present and projected Landsat costs, which are those of the NASA program. The high costs of Landsat D have an adverse affect on any favorable decision for an operational Landsat. The 25:1 ratio may be too low or it may be too high, but it clearly indicates that there are more cost effective ways of imaging the Earth than Landsat-D.

Another possible argument is that the six or seven wavebands of Landsat-D (all at the same time relatively high resolution) will have much more information (and value) than an MLA scene. This appears to be unlikely since most spatial boundaries are defined in the green-red portion of the spectrum, which is the MLA band of high resolution. The additional wavebands of the TM will undoubtedly produce some valuable information in specific areas for specific purposes. However, no one today can say whether this information is of sufficient value to justify these bands on an operational satellite. Thus, we are speaking of an experiment. Experimentation with different wavebands at different resolutions is obviously needed. However, it can be done by the multispectral scanning of appropriate test areas from a flexible type platform such as the Shuttle, at a mere fraction of the cost of Landsat-D (assuming Shuttle flight costs are not included) and, if properly executed, would produce more meaningful experimental data. On the other hand, the three bands defined for the MLA (or an approximation thereof) have proved their utility over land and shallow seas throughout the world.

The TM flight suffers from an orbit height of 716 km as compared with the 919 km for the MLA. The differences between the two orbits are well documented and the lower orbit is clearly inferior for general use. In fact, a World Bank official has indicated that analysis costs of data from the lower orbits, for certain purposes, will be two or three times higher than for data from the 919 km orbit. This cost is additional to all items previously considered.

With respect to cost-effectiveness, Landsat-D suffers badly in comparison with the Alternative. Moreover, Landsat-D may not fulfill the basic concepts of Landsat as laid down by Pecora and Udall 11 years ago. To fully utilize the TM on Landsat-D, foreign countries must make some very large investments in what is obviously an experimental program. Foreign interest and willingness to invest funds in Landsat has been growing steadily since the first launch in 1972. It is unlikely that this trend will continue when Landsat-D limitations are fully understood and analysed. Any slackening of foreign interest will have a direct adverse affect on the concept that Landsat is of global value and that the program will be supported internationally. No one has ever proved that a Landsat-type mission can be cost effective for a single country, such as the United States. However, there is evidence, admittedly widely scattered, indicating that globally Landsat can be highly cost effective. Consequently, it appears that an operational Landsat will soon be defined and flown—if not by the United States then by foreign governments or groups that are already developing competitive systems. Because of its investments and experience in Earth sensing, the United States is logically considered to be the nation to define and fly an operational Landsat and thus fulfill the vision of Pecora and Udall to explore the Earth for human benefit from space.

Future Development

This discussion has concentrated on the MLA in its monoscopic mode. However MLA's mounted on a stable platform in stereoscopic mode have the potential for resolving the third (topographic) dimension in automated form, and this mode is currently under study. Evidence to-date indicates that both the monoscopic and stereoscopic systems are compatible with the same Landsat orbital parameters.

References

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