Forum

Proposed Parameters for an Operational Landsat

(An article, "Proposed Parameters for an Operational Landsat," by Dr. Alden P. Colvocoresses was published in the September 1977 issue of *Photogrammetric Engineering and Remote Sensing.* A number of letters commenting upon that article, together with Dr. Colvocoresses' responses, are presented below. *Ed.*)

Dear Dr. Colvocoresses:

I have been following with interest your letters and articles regarding the proposed parameters for an operational Landsat system, the most recent of which appeared in the September issue of *Photogrammetric Engineering and Remote Sensing.* Being on NASA's Landsat IDT, as well as Frank Press's Ad Hoc Committee for Earth Resources Satellite Systems, I am quite familiar with your concerns regarding sensors and other parameters for an operational Landsat system. There are some basic questions, and I suppose disagreements, that I have with some of these parameters and I would like to use your paper in *Photogrammetric Engineering and Remote Sensing* as a source in pointing them out.

I find the title and the contents of the article unrelated. You speak about proposed parameters for an operational system and list three fundamental criteria necessary for an operational system:

- continuity with respect to Landsats 1, 2, and C;
- full availability of data on a global basis; and
- economic practicality.

It is the first criteria, that of continuity, which disturbs me. On page 1141, just under the section entitled "Suggested Parameters," you mention "Evaluation of this system (NASA proposed system of Thematic Mapper at lower 705 km altitude) shows that such a satellite, although suitable for research, would not provide continuity or an operational test for Landsat." Yet in the right-hand column, just above "Wavebands," you state "Linear arrays now offer the most promising design for an operational Landsat, and their immediate space-use development, probably by NASA, is warranted." My question is, if the Thematic Mapper at a lower orbital altitude does not meet continuity of data with respect to Landsats 1, 2, and C, how does a new sensor, i.e., the linear array, which has never even flown in space, stand to pass the data continuity test? Even more fundamentally, most of the parameters that you outline in Table 1 on page 1142, i.e., different spectral bands and different spatial resolutions in those bands, have never been demonstrated technically. Where is the evidence to propose these sensor parameters for an operational system? The answer seems to be that these sensors and spacecraft parameters, such as different orbital altitudes and different types of sensors like the linear array, must all be tested and technically demonstrated. Thus, they are truly all experimental parameters to be tested under NASA's Earth Resources Program. The contention I have is that there are no parameters yet tested sufficiently to propose for an operational system, so let's allow NASA to get on with its job of testing these parameters and not try to jump the gun on operational parameters without sufficient evidence to support them.

You speak to the international activities involving Landsat and use the three examples: LACIE, nautical chart revision, and oil and mineral exploration. These applications, while demonstrated and certainly effective utilizations of Landsat, really speak only to the developed and the rich countries. In the 72 developing countries of the world, where a lack of resource information translates to starvation and death, priorities are quite different. Landsat and techniques like aerial frame sampling have the potential to spell the difference between life and death for many people in these countries of the world. Your lack of consideration for the social benefit of an operational system is evident on page 1143, half way down the left column, where you mention "The 40 m size is cited here because there are relatively small differences in usability between the 30 and 40 m pixel sizes." This is indeed interesting, for in the developing world the difference between 40 m resolution and 30 m resolution means the difference in being able to accurately measure from 33 percent of the agricultural fields to over 61 percent. This doubling of the available field sizes for satellite measurement implies a new capability at an orbital altitude of 700 km of providing aerial frame samples in the developing world. The potential benefits,

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not measured in dollars but in lives, are significant.

You mention at the conclusion of your paper that it will have served its purpose if those who would apply Landsat examine the proposed parameters and provide appropriate comments. Representing 72 of the poorest nations on Earth, in remote sensing applications, I respectfully submit that the increase in Thematic Mapper resolution by flying at 700-716 km as opposed to 900 km (30 m vs. 40 m) is a far more significant consideration for an operational system addressing the needs of the poorest nations than more experimentation with new sensors represented by the multiple linear array.

—Charles K. Paul, Ph.D.
Agency for International Development

Dear Dr. Paul:

Your response to my Landsat proposal is exactly the kind of discussion I hoped to create. This doesn't mean that I agree with the contents of your letter, but we have to air all sides of this matter and at an early date. Now let me rebut a few of your points.

First—continuity. To me, continuity is in the data received and has nothing to do with the sensor as long as it does the job. The continuity I am talking about is for parameters such as the orbit, data rate, and spectral bands that have proven themselves and which I have preserved while trying to keep up with sensor technology.

Linear arrays are not new or untested; in fact, the six detectors that receive each waveband on Landsats 1 and 2 are, in effect, small linear arrays. Putting together and calibrating several thousand detectors may be a complex job, but any good space sensor engineer will tell you that a linear array sensor has a much higher probability of successful operation than a complex sensor with many moving parts such as the Thematic Mapper (TM).

As for spectral bands, the changes I propose are relatively minor and are based on the experience of Landsats 1 and 2. The green band is slightly lowered to optimize water penetration and the band 6 of Landsats 1 and 2 (0.7 to 0.8 m) is eliminated as redundant (it also is not included on the TM). The planned production rate of only 50 or 100 scenes per day for the TM will in itself negate continuity for many areas.

I reiterate that the multiple linear arrays (MLA), assuming that they are properly built, flown, and calibrated, will provide continuity with respect to Landsats 1, 2, and C.

Second—resolution. I question your statement that 30 m pixels will permit the accurate measurement of over 61 percent of agricultural field sizes in the developing world as compared to only 33 percent for 40 m pixels. First, I consider it misleading to discuss percent of fields and ignore percent of acreage. Nevertheless, if the statement is true, you and the developing nations will be disappointed when trying to identify the smaller fields from TM data. As now defined, the TM will not provide an effective pixel size of 30 m. Information theory dictates that a continuous radiometric signal, such as created by the detector of a scanner or fixed linear array, should be sampled twice per pixel dimension. Landsats 1 and 2 sample 1.4 times per pixel and there is appreciable image smear in the cross-track direction. The Landsat D TM will sample only once per pixel, resulting in an estimated 30 by 52 m (or 41 m average) effective pixel dimensions. For the proposed MLA system, we can define one band at 30 m pixel size (if you really need it) and sample it 1.4 times per pixel to give an estimated 34 m effective pixel size. You will certainly do a better job of measuring small fields with such a system, for it will be the rare field boundary that is not defined in the dominant green-red waveband selected for high resolution. Furthermore, the effective mixing of high and low resolution is demonstrated daily by color TV.

As a matter of fundamentals, the orbit does not dictate ground resolution. It is a relatively simple matter to design a sensor that will give any of the resolutions we are talking about from any reasonable altitude. For example, the MLA we are defining gets better resolution from 919 km altitude than the TM will deliver from 716 km.

Third—experimentation vs. operation. You imply that the MLAs are experimental whereas the TM would be a significant candidate for an operational system. As I indicated before, I suggest that the long-lived dependable operation expected of linear arrays will come far closer to meeting operational needs than a high-risk complex system such as the TM. I'll admit that there isn't much literature available on linear arrays, but this will, to some extent, be overcome at the March 1978 ASP/ACSM meeting where several papers will be devoted to these sensors. Of course, we must continue experimentation with other wavebands, but why mix this with Landsat which is, regardless of artificial definitions, an ongoing operation?

Fourth—economics. Landsat D promises to raise the unit (scene) cost by perhaps 25 times as compared to the system we have proposed. You speak of lives vs. dollars, but I cannot see how fewer scenes—or none at all if receiving stations are not modified at much higher cost—can possibly help anyone. If you want to help the poorest nations on Earth, I suggest you look for an economically feasible way of doing it.

Landsat D cannot achieve cost/effectiveness, but since it is being touted as an operational demonstration (see *Science,* November 4, 1977, p. 469) it may convince many that surveying and monitoring the Earth from space is simply too costly.

In summary, I ask that those of you concerned with our foreign aid programs take another look at this matter. The proven value of the Landsat (ERTS) concept to mankind is high and, if the program as conceived 11 years ago by Dr. Pecora and Stewart Udall is carried out, your 72 nations of direct concern, along with all others, will surely benefit.

—Alden P. Colvocoresses
U. S. Geological Survey

Dear Dr. Colvocoresses:

I was delighted to see your article on the Operational Landsat System in the September issue of the ASP Journal. As a diligent follower of the Congressional debates and devout advocate of the "Operational Earth Resource and Environmental Information System," or 'Operational Landsat,' I must offer my constructive comments on your article, and hope for your patience and reply in kind to my unenlightened judgement. First, let me cite two references that of all of the multitude of reports I feel you may find most valuable:

(1) *Space Planners Guide,* U. S. Air Force, SAMSO, 1965. (Old but good. It gives sensor parameters that are still valid and not classified, plus best information on the cost-effectiveness analysis of these systems.)
(2) *Remote Sensing Services Requirements of the Resource and Environmental Agencies of the Rocky Mountain Region,* by Ralph A. Morrill, December 1976.

My thesis is this: This system must be developed to satisfy the users and be upgraded to the latest technology (and here I agree with you) at the earliest possible date. In this context, and knowing what I have known for the past 18 years of advanced work in remote sensing for military applications, why should we be limited in our operational use of these data to the three basic criteria that you cite in your article?

If you will bear with me a moment, I will give you some of my thoughts on these criteria, then I would like to hear your arguments as to why they are sacred.

Continuity with Landsats 1, 2, and C. The ERTS System was not an optimum design in the first place. There were many compromises in which NASA constrained the technical and budgetary considerations to the political climate at the time, which was not the best for such programs. I and many other investigators were involved in the Mission Analysis and Cost-Effectiveness studies for the system starting in 1967. The decisions by NASA were the stagnation of the field of remote sensing in this country. Go back and read some of these reports; they are most appropriate now.

Full availability of data on a global basis. This one criterion alone is the fundamental reason why the sensor systems of the ERTS System are so deficient in satisfying the user community. I believe that there could be tremendous benefits from the Operational Landsat System if this constraint were eliminated and we served our own needs for these data first. Let the rest of the world have the current system data, but do not limit our use to another compromise of this kind in the name of international relations.

Economic Practicality. We proved this over and over again to NASA in our earlier studies of the Mission effectiveness, with benefit-to-cost ratios for the Optimum System of over several hundreds-to-one. We were also able to quantify those illusive "intangibles" to which you refer in your article. And our analyses were based upon the operational use of the system, not just a research purpose (the weak argument now used by NASA to explain why this system is ineffectual).

Santayana said that those who do not know history are bound to repeat it. My critique is based on a deep appreciation of the needs of the user community, now and in the immediate future, and on an enlightened contact with the past. I do not mean to criticize you or your sources, but somewhere in the vast scheme of things I hope a voice of reason will prevail. Are you the patriarch of this cause?

—Ralph A. Morrill
Ralph A. Morrill & Associates Inc.

Dear Mr. Morrill:

Your letter on Landsat is appreciated.

There are a few points in your letter on which I do have comments.

First, as to references. The *Space Planners Guide* is certainly an excellent one and I have had a copy for about 10 years. However, it is weak with respect to digital multispectral imaging systems such as Landsat. I would appreciate a copy of your second reference, if available, with which I am not familiar.

We agree that an operational system must be designed to satisfy the users, but I doubt if we agree on who the users really are.

My reasons for selecting the three criteria for an operational Landsat are as follows:

Continuity with Landsats 1, 2, and C. First, I disagree that Landsat was not an optimum design. Because of either excellent insight or good luck, the parameters of Landsat have proved to be exceptional. Landsat opened the door to real-time multispectral electro-optical sensing as opposed to film systems. You or someone else will have to prove there are better ways of doing things before I turn my back on the Landsat concept. Of course, we have learned from Landsats 1 and 2, and our multispectral linear array (MLA) concept makes significant advances without materially changing such basic parameters as orbit, data transmission rates, and wavebands.

Full availability of data on a global basis. You object to this criterion, but again we disagree on who the users actually are. Landsat (ERTS) was conceived (by Dr. Pecora and Secretary Udall in 1966) as a global system because the problems of resources and environment are global in nature. Of course, foreign governments should contribute to any such program, but aside from international relations (which is certainly an important consideration), the global nature of Landsat is of obvious value to the United States. A check with U. S. oil companies will confirm this.

Economic practicality. Here I believe we are in agreement. I see cost-benefit studies sponsored by NASA and others, but who is concerned about the design of a truly cost/effective system? I've conducted a small study which indicates a cost/effectiveness ratio per scene of 25 to one in favor of the MLA when compared to the Thematic Mapper. I'm sure this figure will be challenged, but I'll bet it's in the ball park.

In summary, I consider Landsat to be one of the truly great happenings of my lifetime. To allow it to flounder because of jurisdictional squabbles that keep it from becoming operational is, to me, inexcusable. If the United States does not act quickly on this matter, I am sure that other countries will do so, and I have a hard time seeing why one good system cannot properly service the entire world. I'm chauvinistic enough to want to see the United States fly the first operational Landsat.

—Alden P. Colvocoresses
U. S. Geological Survey

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