UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

THE ECONOMIC FEASIBILITY OF OPERATIONAL EARTH SENSING FROM SPACE

By Alden P. Colvocoresses

Open-File Report 82-250

Reston, Virginia

August 1982

August 16, 1982

THE ECONOMIC FEASIBILITY OF OPERATIONAL EARTH SENSING FROM SPACE*

Alden P. Colvocoresses
U.S. Geological Survey
National Center, Mail Stop 520
Reston, Virginia 22092

ABSTRACT

Earth-Sensing satellites designed to follow Landsat involve spatial resolution in the order of 10 to 30 m as compared to the 80 m of the Landsat Multispectral Scanner (MSS). At these higher resolutions such satellites will perform inspection functions of high importance to government agencies and which are beyond the capabilites of the Landsat MSS.

There is considerable evidence that nations that cannot afford their own Earth-sensing satellites are willing to pay a suitable price for the capability of inspecting their own land and adjacent sea areas. A unit price of 25 cents per square km per year is suggested as a reasonable fee which would provide economic viability to a well defined satellite system such as the Mapsat defined by the U.S. Geological Survey.

This concept and pricing involve only the satellite and its data acquisition and transmission capability. Data reception, processing and distribution would remain a separate function to be implemented on a local or regional basis as is now done.

INTRODUCTION

Much has been written on the benefits, tangible and intangible, to be gained from an Earth-sensing satellite system. These studies concentrate on the benefits to disciplines such as agriculture, oil and mineral exploration, and land management. However, these studies generally ignore the fact that Earth-sensing systems with resolution elements in the order of 30 meters (m) or better, are in fact, basic information sources for a wide variety of man's activities. In other words such satellites become inspection tools of high importance. The capability of looking at a nation's own land areas and its surrounding waters at resolutions of 10 to 30 m makes such satellites a vital tool of government capable of accomplishing many functions not currently associated with satellites such as Landsat.

RATIONALE

Countries with their own earth sensing satellite programs can accomplish such inspection functions in a proprietary manner, but such satellite systems cost in the hundreds of millions of dollars, which is beyond the capability of all but a few nations. However, an Earth-sensing Sun-synchronous satellite periodically covers the entire Earth, except for minor polar exclusion areas. For those countries which cannot afford their own satellite system, there is an increasing need for access to a system which will permit them to view their territories. The proliferation of Landsat receiving stations, of which their are now 16 operating or under construction (and others planned), exemplifies this demand even though the

*Approved for publication by Director, U.S.G.S.

principal Landsat sensor has only an 80 m resolution pixel or cell size. Moreover each receiving station, with associated processing capability, may cost up to $10,000,000. It may be argued that systems in the 30 m or better resolution class should not be operated with unrestricted access. This argument has already lost its meaning since the U.S., Europeans, and Japanese are building Earth-sensing satellites with resolution capabilities in the 30 to 10 m range and are planning to make the data available to whomever is willing to buy it. It is not a question of whether such satellites will be launched but who will do the best job and capture an ever expanding and potentially lucrative market. This market may not be reflected in the sales of satellite imagery or tapes which can be copied at nominal cost, but more likely in the capability of obtaining the data in the first place.

MODES OF EARTH SENSING FROM SPACE

There are basically four modes for electro-optical sensing of the Earth's surface from satellites. The photographic (film camera) mode is not included because it does not offer the near real-time acquisition nor data manipulation capability required for many applications.

Mode 1. The Sun-synchronous systematic coverage mode demonstrated by Landsat. This mode can be extended to include stereo coverage and thus define the third dimension of height. Such a system has been proposed by the U.S. Geological Survey in the form of Mapsat.

Mode 2. A Sun-synchronous selective coverage mode whereby the satellite or sensor can be pointed towards specified areas within its field of view. The French SPOT satellite has this capability which will permit more frequent coverage of selected areas than will Mode 1. Such a satellite can provide stereo coverage of selected areas, but its ability to quantitatively resolve the third dimension of height or precisely map sizable areas will be quite limited.

Mode 3. A geosynchronous system of three or more satellites with sufficiently powerful optics to resolve pertinent earth surface detail. Such a system calls for a tracking telescope and is very expensive to build and operate. However, such a system can look at any given area (other than the polar regions) on a continuous basis subject only to illumination and cloud cover conditions. Any phenomenom which may be of short duration or which changes significantly within a week or so requires this type of system to be properly monitored. The geosynchronous weather satellites now demonstrate this mode but do not resolve sufficient detail for most applications related to the Earth's surface.

Mode 4. The radar or active microwave mode which can image the Earth regardless of illumination or cloud cover conditions. This mode has obvious advantages over the other three but radar imaging of the Earth from space is still in the research and development stages and requires very expensive acquisition and processing procedures. The application of radar data to the civil disciplines is also in the research and development stage but its potential value as an inspection tool, such as for offshore areas, is high. The radar mode is suitable for either Sun-synchronous or geosynchronous orbits.

Each of these modes has its own unique characteristics and it appears likely that they all will eventually be implemented to permit man to properly inspect, monitor, and better understand this Earth and the natural and manmade occurences taking place thereon. When SPOT flies in 1984 it may well demonstrate the effectiveness of Mode 2 with its pointable sensor capability. Modes 1 and 2 are highly complementary but it is highly unlikely that their respective capabilities can be combined into a single satellite system. Mode 1 is the only one which has so far been demonstrated to the point where its viability is obvious and thus deserves immediate consideration for development into an operational cost-effective system. Thus the remainder of this paper concentrates on the economic feasibility of Mode 1.

EXAMPLES OF ECONOMIC UTILITY

Offshore Regions. Today the so called "Law-of-the-Sea" and related claims are providing most maritime nations with economic, territorial, or fishing claim zones of 200 nautical miles beyond their coastlines. Policing the huge ocean areas involved is prohibitively expensive by conventional ship or aircraft but it can be done at reasonable cost by satellite. Shipping activities, including many of those related to fishing and mineral (including petroleum) exploration, can readily be detected by a 10-m to 30-m resolution satellite system. A classic example of offshore inspection occurred with the IXTOC-1 oil well blow out in the Gulf of Mexico in 1979. Landsat clearly recorded the spread of the huge oil slick as it moved across the Gulf and up to the Texas coast. To the governments of Mexico and the United States this data was invaluable,even though the sales of the data itself amounted to only a few hundred dollars. A system of higher resolution could monitor oil slicks a fraction of the size of the IXTOC-1 spill, including those created by mishaps to tankers as well as oil rigs and offshore loading/unloading facilities.

The same satellite which inspects these offshore regions can also provide a valuable service by the actual mapping of shallow seas as has been demonstrated by Landsat. The world's shallow seas, except for areas of high ship traffic, are inadaquately mapped for their proper development and even for ship's safe passage. Several previously uncharted reefs have been identified and positioned by Landsat and are now shown on hydrographic charts. The dollar value of these additions to the charts is impossible to estimate but surveying these shallow seas by conventional methods involve the use of survey ships each of which costs several million dollars per year to operate.

Inspection of Developing Land Areas. Countries with extensive undeveloped or developing land areas also face inspection problems. The ability to periodically inspect land areas is of high economic and social importance, regardless of the public sale of the products. A well defined satellite system, such as the French SPOT, Japanese ERS-1, or the USGS defined Mapsat, can in near-real-time inspect many activites such as those of mining, oil, and lumber companies which relate to land use. The benefits from such inspection are in addition to those related to crop surveys, geologic investigations, and land mapping. Whenever man's activities result in a sizable disturbance to the Earth's land or sea surface, a properly defined satellite can record it--subject, of course, to weather restrictions and the duration of the disturbance. Obviously pertinent disturbances are not caused solely by the activities of man.

Inspection of Natural Disasters. Nature as well as man calls for constant inspection on a global basis. Volcanic eruptions, floods, forest fires, droughts and the incidence of snow and ice--to name a few--can greatly affect man's capability to cope with nature. Inspection (and monitoring) of such phenomena may not avert an immediate disaster but may reduce damage by early warning, aid in disaster relief, and will permit man to better understand and plan for future events of a similar nature.

General Purpose Mapping. A well-defined stereo satellite system can produce data suitable for the production of accurate multicolor topographic image maps at scales as large as 1:50,000 with contour intervals as close as 20 m. Mapping at such scales and contour intervals is acknowledged as essential to the development of a country. Image maps do not have the definitive information depiction of line maps and for highly developed areas (urban and small plot agricultural areas) the image map must be of much larger scales and of closer contour interval to meet the mapping requirements for such areas. However most of the Earth's land areas are not highly developed and to a large extent not mapped at scales approaching 1:50,000.

Conventional topographic line mapping is a slow and costly operation normally involving several years between project initiation and completion. Production of a standard quadrangle map of the 1:50,000-scale class cost approximately $20,000 to produce in the United States. A contoured image map lacks many of the line map refinements but it can still meet a large percentage of the mapping requirements for the lesser developed areas of the world. Moreover, based on the data acquisition costs set forth in the next section, and known digital processing costs, such maps could be produced for considerably less than $1,000 each and in a matter of days or weeks rather than years.

FUNDING CONSIDERATIONS

Experimental civil satellites with resolutions in the 10-30 meter range will soon be viewing the Earth on a constant basis. Most nations cannot afford to fly their own but they are certainly willing to pay a reasonable fee for the capability of inspecting, monitoring and mapping areas of concern to them. The French have already recognized this market by offering to transmit SPOT data at so much per mega bit of data. It appears more realistic to charge for turning the satellite on over a given area because the capability to inspect, monitor, or map an area may be of equal or more importance than the actual data itself. Today a good satellite system may cost $100 to $300 million to build and operate for a 7 year period (exclusive of receiving and processing). Thus at least 20 and possibly 60 million (1982) dollars per year would have to be recovered to make such a system economically viable. One obvious way to recover costs is by charging an appropriate receiving station license fee. However, the cost of installing satellite receivers is actually going down and within a few years unlicensed stations capable of receiving satellite data may well be in use. This problem might be solved by data coding but it may be more appropriate to charge a fee based on the size of the area involved regardless of who receives the data. Countries which did not chose to put in their own receiving stations could thus make arrangements with a neighboring country which had or was putting in a station, or they could have the data tape recorded, received at some central station, and then shipped or retransmitted to them via communications satellites. In any case the satellite would be turned on over a specific area providing a country or agency had paid the fee involved for such coverage. Thus the system would be open to any who paid for the area to be covered or otherwise acquired the data in accordance with the open-skies precedent set by Landsat. The land and 200 miles offshore areas of the world involve over 200 million square kms and to recover 50 million dollars per year the annual rate would have to average about 25 cents per square km. This fee would commit the satellite operator to turn it on over the area in question a certain number of times (perhaps 10) per year with additional fees charged if more frequent coverage or some special mode such as high-resolution stereo is required. Likewise an area which required less frequent, or lower resolution, coverage might warrant an annual charge considerably less than 25 cents per square km. Obviously some areas of the Earth are of much greater interest than others, and areas of high interest should produce higher revenues than areas of little interest. Thus the 25 cents per square km is taken as a nominal annual fee received. Moreover, a minimum charge of several thousand dollars should probably be charged for coverage of any requested area of limited size.

Australia and the U.S. land areas each involve about 9,000,000 sq km and thus a 25 cent unit charge would amount to $2,250,000 per year to cover either Australia or the U.S. Adjacent sea areas would probably be requested on a selective basis and involve perhaps $750,000 per year. Thus Australia or the U.S. with adjacent sea area coverage might involve annual fees of $3,000,000.

Assuming $50 million per year were recovered from such area fees, and the annual satellite operating costs were in the order of $5 million, $45 million per year would be available to offset capital investment and launching costs. Even with today's high interest rates this sum is considered more than adequate, although continued inflation would undoubtedly alter all such figures in time. Note that none of these funds are earmarked for reception stations or processing. As is done today, reception, processing, and distribution is a "local" problem which may or may not pay for itself but which should be funded separately from the satellite system. It is suggested that an Earth sensing system that meets the requirements indicated should be defined and proposed to the world as a whole. Obviously, if current and expected users of the data, as represented principally by governments, are not willing to pay a reasonable fee for the service (such as 25 cents per square kilometer per year) then the economic feasibility of earth sensing from space has not arrived. However, there are indications that the payment of such fees would be made in return for the proposed services.

SUMMARY AND CONCLUSIONS

- Of the four described modes for earth sensing, Mode 1 as demonstrated by Landsat can now be developed into one of higher multispectral resolution with stereo capability and thus meet a multitude of applications in addition to those defined by Landsat.

- In the 10- to 30-meter resolution range the inspection of man's activities as well as the monitoring of natural phenomena become obvious applications of importance throughout the world.

- The economics of sensing the Earth with a well-defined Mode 1 type satellite system calls for cost recovery (for perhaps 10 recordings per year) in the order of 25 cents per square kilometer on the average for the land and surrounding sea areas of the world.

- Tweny-five cents per square kilometer is a relatively small price to pay for such a capability and it is believed that users can readily be found who will pay this price for capabilities such as defined by Mapsat.

- Earth sensing from space, at least in so far as Mode 1 is concerned, is now considered to be cost effective and should be implemented on an operational basis.