ON HOW FUTURE LOW-COST REMOTE SENSING SATELLITES COULD MEET THE INFORMATION NEEDS OF ENVIRONMENTAL MANAGERS

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ABSTRACT

This paper discusses how a low cost virtual constellation of small satellites could meet the needs of environmental managers for timely, reliable and appropriate Earth observation data. Such a constellation could be established through multiple national contributions and would address the need for more appropriate missions (cost vs performance), easier data access and information service provision. Through direct local reception of multi-satellite data, users would obtain greatly improved access to a range of data, at much lower cost. By harmonising data reception from different satellites through agreed and appropriate common data transmission protocols the key features of continuity, ease of access and timely data will become the norm. The virtual constellation would expand as national projects are realised and added, and commercial systems would also find a 'ready to go' global ground segment in touch with local user needs. The feasibility and usefulness of a constellation of small satellites has been assessed through interviews with environmental managers and EO professionals, reviews of the uses of EO in environmental applications, and a series of workshops and web-based discussion fora

1 INTRODUCTION

According to the Committee on Earth Observation Satellites over 40 satellite missions are planned for launch in the next 5 years promising a huge increase in global data sets of as many as 100 different geophysical variables. But as well as these public, global, scientific missions, led mostly by existing space-faring nations, new operators of two types will launch many other missions: large aerospace companies operating very high resolution imagers, and emerging space nations and others operating small satellites. Whilst the entry of the commercial operators promises to create $3 to $8 billion EO industry early in the 21st century, the economic and social value of the numerous and diverse small satellite systems is less clear. This paper tries to suggest how these small systems could potentially contribute to a real improvement in environment management by providing data direct to local decision-makers.

Satellite system type	Examples	Operator	Objective
High resolution land resources	SPOT, Landsat, IRS-1C	Large public space agencies	Resource mapping
Very high resolution	IKONOS	Large aerospace companies	Detailed mapping
Small satellites, medium-high resolution	SunSat, UoSat-12 Kitsat	Emerging space nations Univ. start-up companies SME's, etc	Science Technology development Industrial policy National pride, etc

Table 1. Earth resource satellite observing systems.

The space programmes of the developed world have a focus on international scientific issues, especially global change. Programmes such as the European Space Agency's Living Planet Programme and NASA's Earth Observing System have explicit scientific objectives. Land applications oriented systems like Landsat, SPOT and the Indian IRS series provide quality high resolution imagery at highly subsidised prices, fulfilling a need for thematic mapping products at scales of around 1:50,000.

With resolutions in the range 10-30m these "public-good" international programmes are generally seen as not in competition with the very high resolution commercial systems (Fritz 1999). The latter are now possible thanks to the declassification of military very high resolution imagery technologies as part of the peace dividend of the end of the cold war. Their operators are dedicated to business goals with systems offering to provide near real-time very high resolution data (1m in panchromatic, 3-5m multispectral) for many markets requiring detailed large-scale information.

In general the objectives of the existing space nations (science) and the commercial operators (profit) are clear and non-conflicting. However, the efforts of emerging space nations respond to very varied motives including science, industrial policy, technological development, strategic objectives and commercial incentives. Thanks to technological developments, especially the development of operational small satellites for Earth Observation, entry costs are much lower than they used to be, making space an affordable option for many countries. Small, focussed, low-cost missions can meet real mission objectives with only a small amount of private or public finance. Technology is also rapidly changing in the ground segment with low-cost receiving stations and bandwidth on demand data transmission.

This paper suggests that co-ordination of these multiple new entrant programmes could meet the information needs of local environmental managers. A decentralised approach, with low cost satellites and ground segment, could permit rapid and easy access to medium to high resolution environmental data at very low cost. The affordability and availability of both data and technology could stimulate the rapid growth of indigenous information services industries. Furthermore, such a co-ordinated constellation of small satellites would be complementary to existing public financed systems and would help to build the market for the data and information services offered by commercial operators.

2 LOCAL NEEDS

The need for global data sets and a long term commitment to monitoring and understanding the global environment are being addressed within the Integrated Global Observing Strategy backed by CEOS, the International Group of Funding Agencies and a number of major international research programmes. They are busy articulating a strategy based on the needs of their users: users who are international agencies and programmes like the three global observing systems. Within the IGOS framework regional, international and national agencies, like ESA, NASA, NOAA, CNES, NASDA, ISRO, INPE and many others, are able to work together with a focus on global needs.

However, whilst these international efforts progress it is increasingly recognised that sustainable development, which is intimately related to the sustainable management of the environment and for which global change is merely the background noise, requires information, programmes, capacity and understanding at the local level. Agencies such as the United Nations Food and Agriculture Organisation (He, 1999), UNEP and national programmes – notably in India and Brazil (Government of India, 1999; Barbosa, 1999) – recognise the importance of enabling local people to gain access to environmental information and to develop the ability to use this information in operational decision making.

In most cases it is the people who actually use a natural resource who must be responsible for its sustainability. Developing country governments, local authorities, resource custodians and non-governmental organisations are the "real environmental managers" playing key roles in sustainable development. It is they who must implement sustainable management practices in response to legal obligations, local and external pressures, and acute environmental problems. They increasingly frame their policy objectives in terms of quantitative goals, but this depends on their ability to monitor the environment. The local environmental managers have the best understanding of the local conditions and the problems and they are the people with most interest in achieving sustainability, yet their ability to implement sustainable development is limited by their lack of access to appropriate technologies.

The United Nations (UN, 1999, p146) has recognised that basic geographic information should be considered part of national infrastructure, as important for development as roads, telecommunications, housing and clean water. The Indian space programme (Rao, 1999) places highest priority on delivering clear and accessible information to local bodies where "once you see the right information in an image, the right decision (on development options) automatically falls into place". Similarly FAO and others acknowledge that local knowledge and locally tailored planning and analysis are essential for sustainable development. The objectives of the Indian and Brazilian remote sensing programmes are "towards developmental planning and decision-making at micro-level, in consonance with the accepted concept to 'think globally and act locally' towards sustainable management of natural resources" (Government of India, 1999, p8).

Partly in recognition of the need to think global – act local official development assistance is increasingly channeled through non-governmental organisations (ODI, 1996). NGO's have a proven ability to reach local needs. This policy also reflects concerns that in the environmental sphere governments themselves present two of the major obstacles to sound environmental management (Williams, 1999): firstly through government non-compliance with legal obligations under international treaties and conventions and secondly through their unwillingness to make environmental information publicly available. Non-government organisations have been responsible for raising awareness of green issues and are now called upon by government to help make and implement environmental policy. In Europe for instance the WWF and others are currently drawing up shadow lists of sites of European Environmental Importance as part of the Natura 2000 programme, and in the UK the Environment Agency explicitly recognises the role of non-government sources for the maintenance of their databases.

Thus in the context of sustainable development, governments and their agencies trying to make policy, regulate and monitor compliance, and resource custodians like NGOs, forest managers, water authorities, park keepers and many others trying to implement development programmes all recognise the need for appropriate geographic information for local decision making. The challenge to the space industry is to respond to this local need through global action.

2.1 User Needs Analysis

The analysis of user needs is notoriously difficult often just producing wish lists or simple incomprehension on the part of the potential users who are unaware of the value of spatial information and know little about EO. As an FAO official noted "*it is obvious that cheaper, more accurate, frequent and accessible data will be invaluable for very many users concerned with sustainable development, such as crop forecasting, precision farming, and for supporting policy relating to conventions on desertification, climate change and biodiversity*" but such broad statements do not provide much guidance for mission planners.

One approach to looking at user needs is to assess why EO data is not used more. A recent seminar on the Environment and Remote Sensing for Sustainable Development (UN, 1999 pp139-140) concluded that there are two principal constraints to greater use of EO data: the lack of capacity (especially in developing countries) for converting data into information; and problems related to prices, access and standards. The seminar also noted that planned missions by existing space-faring nations would probably just make these problems worse, although positive examples could be found in the Indian and Brazilian programmes that specifically addressed the issues of capacity and accessibility.

2.1.1 Access

Significant efforts have been made to improve access to archives and databases but, like the CEOS-IGOS initiatives, the focus is inevitably global. This is understandable because the users are the international, intergovernmental, big-science committees and agencies and not the local decision makers or private information service providers. The UN Principles Relating to Remote Sensing of the Earth from Outer Space (UN, 1986) establishes the principle of non-discriminatory access to Earth observation data and the first item of the recent Vienna Declaration (UN, 1999 p2) includes the declaration that action should be taken "to improve the management of the Earth's natural resources by increasing and facilitating the research and operational use of remote sensing data, enhancing the co-ordination of remote sensing systems and increasing *access to, and the affordability of, imagery*" (author's emphasis). Meanwhile IGOS has recognised the need to promote "more effective means of using space-based data in addressing practical problems and environmental issues of *local*, regional and global significance" (UN, 1999 p115, author's emphasis).

In meteorology open access is understood to mean just that with the public good nature of data enshrined in article 40 of the WMO (WMO undated). To put this into effect the Co-ordination Group for Meteorological Satellite (CGMS, 1999) has been called on (UN, 1999 p6) to support efforts to standardise spectra, data formats and other aspects of the ground segment. Similarly, ground station interoperability is being addressed by NASA's Jet Propulsion Laboratory for deep space missions. But for land applications there is currently neither a recognised co-ordination group (like CGMS) nor an undoubted leader in the field (like JPL) to act as the point of reference for such standardising efforts.

2.1.2 Cost

The Vienna Declaration explicitly recognises the importance of the cost of data as a key factor affecting its accessibility, especially for environmental managers. This responds to concerns of many in the developing world notably the G-77 group of countries and China (G-77 and China, 1999). Indeed these countries recognise that as well as the need for more standardisation of formats and processes, "only if the data is readily available at a reasonable cost, can there be a wider market for it among developing countries".

Surveys suggest that in the developed world the cost of data is only a fraction of the cost of the value added services required to convert the data into information (Ryerson et al, 1999; ESYS, 1999). However this is definitely not the case in the developing world, or for NGOs. As Ryerson notes "in less developed countries a satellite image can cost as much as one year's salary for an image analyst". Despite the supposed "public good" nature of the major EO high resolution systems their pricing policies have the paradoxical effect of subsidising rich commercial users whilst making them inaccessible to those in local government and civil society who could most benefit from them. It is recognised in Brazil that "the financial benefits from sales can never compare with the public benefit of everyone using this kind of data" (Barbosa, 1999) whilst the Indian ISRO notes that "you can never recover the cost from sales, it's the public benefit from improved decision making where the return on investment is obtained" (Rao, 1999).

2.2 From data to information

In a future where data will be abundant and information will be the key resource in the economy, such data policies will have to change. Landsat 7 ETM data are now available at dramatically reduced prices and ESA are changing their policy to maximise data use rather than revenue. Space Imaging, the operator of the first commercial very high resolution satellite, estimate that a $1 investment in information can be leveraged to produce a $10 benefit in the economy (Neer 1999). The US government recognises this economic fact in its policy for meteorological data, easily recovering costs from tax revenues from the value added industry (Friday et al 1996). Like Space Imaging, RapidEye, another private company planning to launch EO satellites, see themselves not as satellite operators but as information providers.

3 EXPLOITING THE COMPARATIVE ADVANTAGES OF SMALL SATELLITES

As a leading UK supplier of EO value added services has noted, the question is not whether EO can provide useful information but rather, is it good enough for specific purposes in comparison with other sources? The comparative advantages of earth resources satellites are their ability to provide regular repeat coverage of large "synoptic" areas, providing relative objective measurements under the same conditions, globally. However they also suffer from disadvantages such as the problem of cloud cover for optical sensors, and the already mentioned issues of cost and access.

Apart from such comparisons between EO and other sources of data, it is interesting to compare the relative merits of the three types of land application EO systems that are expected to operate in the near future: very high resolution commercial systems, high resolution public systems and medium to high resolution low-cost systems. The table compares these.

	Commerical VHR	Public HR	Small Satellites
Examples	IKONOS, EarlyBird	SPOT, Landsat, IRS	SunSat, KITSAT, UOSAT12
Resolution	Very high, 1-2m Pan, 3-5m multispectral	High 5-20m Pan, 10-30m multispectral	Medium to High, 30m pan and multispectral
Repeat cycle	14 days	14 days	10 days/n, n=number of satellites in constellation, ie if n=10, cycle = 1 day
Revisit cycle	1-3 days "near real time" due to agility	7-14 days, SPOT is steerable but programme request must be made 30days in advance	10/n days
Continuity	"Blue chip" financiers, but commercial viability to be demonstrated	Politically uncertain.	Unknown, but low costs are positive factor
Reliability	Operators maintain contingency satellite ready	High dependence on operating satellites	Simplicity means satellite design life >5 years.
Ground segment capacity	High set up costs, major technical challenges to industry	Dominated by centralised and monopolistic receiving stations.	Potential for very low cost, distributed receiving stations.
Accessibility	Near real time distribution to customers via bandwidth on demand	15 days – 1 month + effective delay between image acquisition and distribution via snail mail	Direct reception to low cost ground stations operated directly by user or local service provider.
Costs – satellites	$20-150M / satellite	$100M-$1Billion	$2-6M/ satellite
Costs – ground stations	$1M / ground station	$10M / ground station	$5-$100K / ground station
Costs – operations	Complex Tasking	Costly rchiving	V low
Image quality – radiometric stability	11-12 bit pixels	Stable, 8 bits	Unknown
Image quality – geometric precision	2-10m H/V, often includes stereo capability	20-50 m	Unknown

Table 2 – Comparison of operational satellite systems.

The advantages of small satellites are the potentially very low data cost and their accessibility via direct reception to low-cost receiving stations. If a set of satellites can be co-ordinated so that they have similar sensor characteristics, orbit parameters and use common formats and transmission protocols, then they will effectively form a constellation with a third advantage: high revisit frequency.

The technical feasibility of supplying quality data from small, low cost satellites has already been demonstrated by Sunsat (Milne 1999), Kitsat (SATREC 1999) and the UoSAT satelites (Fouquet and Sweeting 1998a,b). Sunsat's mission was to produce the best possible quality optical data from a microsat platform, whilst the series of small satellites built by Surrey Space Technology Ltd. have proven that space technology really is accessible with limited financial means. In the ground segment, receivers for NOAA-HRPT, and the low cost ground stations such as Rapids (Downey et al) and ScanER Personal Ground Station (R&D Center Scanex, undated) show that an alternative distributed ground segment really is possible. Such a constellation would uniquely match the characteristics of the information needs of local environmental managers:

- Low cost
- Frequent coverage
- Reliability of supply
- Rapid accessibility of data after acquisition
- Ground segment capacity to convert data into information

This final characteristic, the capacity of the ground segment, cannot be sufficiently stressed. It is not obvious how a constellation of small satellites would meet this need better than the existing public systems and potential private systems so the following section considers this issue. Although not automatic, it is argued that this approach is much more likely to lead to spontaneous provision of the required data-to-information services because it will create business opportunities thanks to the low data costs and the low capital costs of the ground segment.

4 CAPACITY BUILDING

As has been stated repeatedly, in order to use the data from EO satellites the indigenous capacity of any country to transform the data into information must exist. Those countries that have been most successful in developing EO industries are those that have seriously tackled the issue of capacity building. Examples from India and Canada illustrate how such efforts cannot be undertaken solely by government. Indeed in Brazil it is recognised that the training need (Barbosa, 1999) alone is so huge that no single national or international programme could possibly address it.

The Indians encourage a triad (Murthi, 1999) of central and local government, NGOS, and the private sector to create this capacity. The space programme explicitly acknowledges the role of the private sector in adding value by processing data, analysing it and using it in models. For many applications government and industry complement each other. For instance, whilst the government has its own programme for estimating acreages and production of staple crops, private ventures are now offering similar information services on economically important crops such as sugar. Evidence from Canada (Ryerson, 1999) shows that where the public sector does not try to provide information services directly but instead fosters the conditions for the growth of private enterprise many new jobs are created in the value added industry. In the Canadian provinces where the governmental agencies actively sought contracts outside their agencies and outside government in direct competition with the private sector, the market stagnated in the absence of incentives for private investment.

A crucial element of the business plan of Canada's Radarsat depends on the development of new markets by the operators of their receiving stations (Hebert, 1999). It is planned that Radarsat 2 will have greater communication power so that data can be received with smaller receiving stations than currently needed by Radarsat 1, thus lowering the entry costs and increasing the opportunities for local operators to develop markets. Similarly Space Imaging see their future as critically dependent on the creation and development of new markets by value added retailers.

A survey of the European value added industry (ESYS, 1999) noted two successful business strategies. On the one hand the big data suppliers, such as SPOT Image and Euromap, who not only dominate data sales but also have moved down stream to sell value added products; and on the other hand the smaller value added companies who supply services to a few key clients in niche markets. With low-cost satellites and ground stations the successful strategy of the future may combine the two: direct data acquisition to serve niche markets.

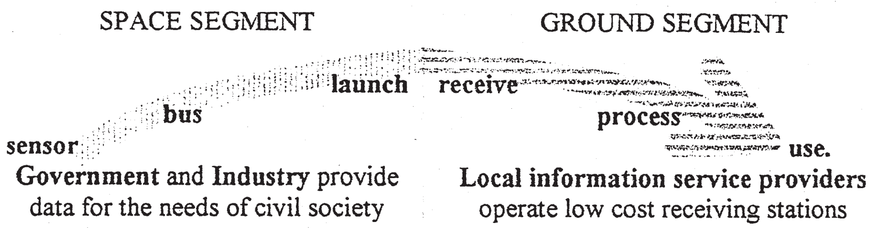

Figure 1. Direct reception of broadcast data allows the space industry to concentrate on the space segment whilst local private enterprise can grow to create markets and add value.

5 COMPETITION VS. CO-OPERATION

In an industrial sense co-operation and competition are not incompatible. Co-operation leads to lower costs and this reduces entry barriers and so increases competition. This is clearly true for the new generation of ground stations. It is also true of small satellites, as more and more organisations are capable of supplying quality and reliable satellites at affordable prices. None of the players in the smallsat and low-cost ground station sectors have tried to lock-in proprietary technologies as the pace of change is such that they all have a shared interest in the adoption of common standards and open systems. This however is not the case of the builders and operators of very high resolution commercial systems.

From the point of view of a data user or an information provider, two images are only direct substitutes for each other when they are acquired under identical conditions and at the same time. In practice this is almost never the case and for the majority of operational environmental monitoring activities developed to date, and for many more potential applications, the existence of a second image of the same area increases the value of a first image. Clearly for the operator of a small EO satellite there are benefits from co-ordinating sensor, orbit and communication characteristics with other operators. These benefits include: gaining access to much more data at the same cost; greatly increasing the uptake of the use of the system by halving the revisit period, reducing the cloud cover risk; augmenting the potential application of the data to include dynamic studies; and increasing the reliability, for the end users, who reduce their dependence on one particular satellite.

Care has been taken to draw a distinction between very high resolution data and high or medium resolution data. Fritz (1999) observes that "it is generally accepted that ten meters is the largest scale needed by international "public good" programs for monitoring the Earth". This distinction has also been made by Vibulsreth (1999), Neer (1999) and others. Although Fritz also worries about whether the commercial viability of the new VHR systems could be threatened since "some high resolution government systems, such as Cartosat (India) and Helios (France) potentially could become commercially competitive".

However the data from low cost small satellites is not likely to compete with such VHR systems. Neither are they likely to compete directly with the high resolution public systems, which should be able to exploit their greater radiometric and geometric stability and synoptic mapping capacity. Indeed, the demand for such detailed base maps will rise as they will be invaluable for fully exploiting the data from small satellites. Furthermore, the growth of the ground segment that the small satellite systems and distributed ground stations promise, could lead to a larger market for these higher specification products.

6 CONCLUSIONS

Current international Earth Observation programmes aim to meet the needs of the scientific community to better understand the Earth as an integrated system through the provision of ever more data, at higher resolutions and with more spectral content. Meanwhile, new commercial operators are setting their sites on supplying the billion dollar geomatics industries of the developed world. Though the objectives of these programmes are legitimate and important they fail to address the needs of environmental managers especially in developing countries and civil society. This paper has tried to show how the regular, reliable and low cost information required to contribute to sustainable development by effectively monitoring the environment could be provided by exploiting EO's unique comparative advantages.

The local managers of the environment including government agencies, local authorities, resource custodians and non-governmental organisations require low cost data, regularly, and reliably. It is also widely recognised that they need the capacity to convert these data into information either by visual interpretation, or by integration with other data, or through more advanced analysis and modelling.

Small satellites now offer affordable access to space for emerging space nations, many of whom are already looking to EO as a way of addressing their own particular environmental management problems. A co-ordinated constellation made up of small satellites from a number of independent national programmes could significantly contribute to better environmental management and decision making at the local level, globally

By investing in information, and fostering the capacity to convert data to information through private-public collaboration, developing countries could make a substantial contribution to their own development. At the same time, if the constellation were to adopt open transmission protocols then the rhetoric of the UN Principles on Remote Sensing, calling for open access to data, could become a reality. Furthermore, the combination of low cost data and affordable ground stations would stimulate the provision of information services by local companies thus creating the local capacity which is an essential element of any environmental monitoring system.

Looking to the future beyond an initial generic constellation, more advanced programmes could be added with, for instance, higher resolution, radar, or with data encryption and other features. These more advanced systems, like the commercial operators of high resolution data and the public high specification systems, would find a ready to go network of receiving stations and an active user community.

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