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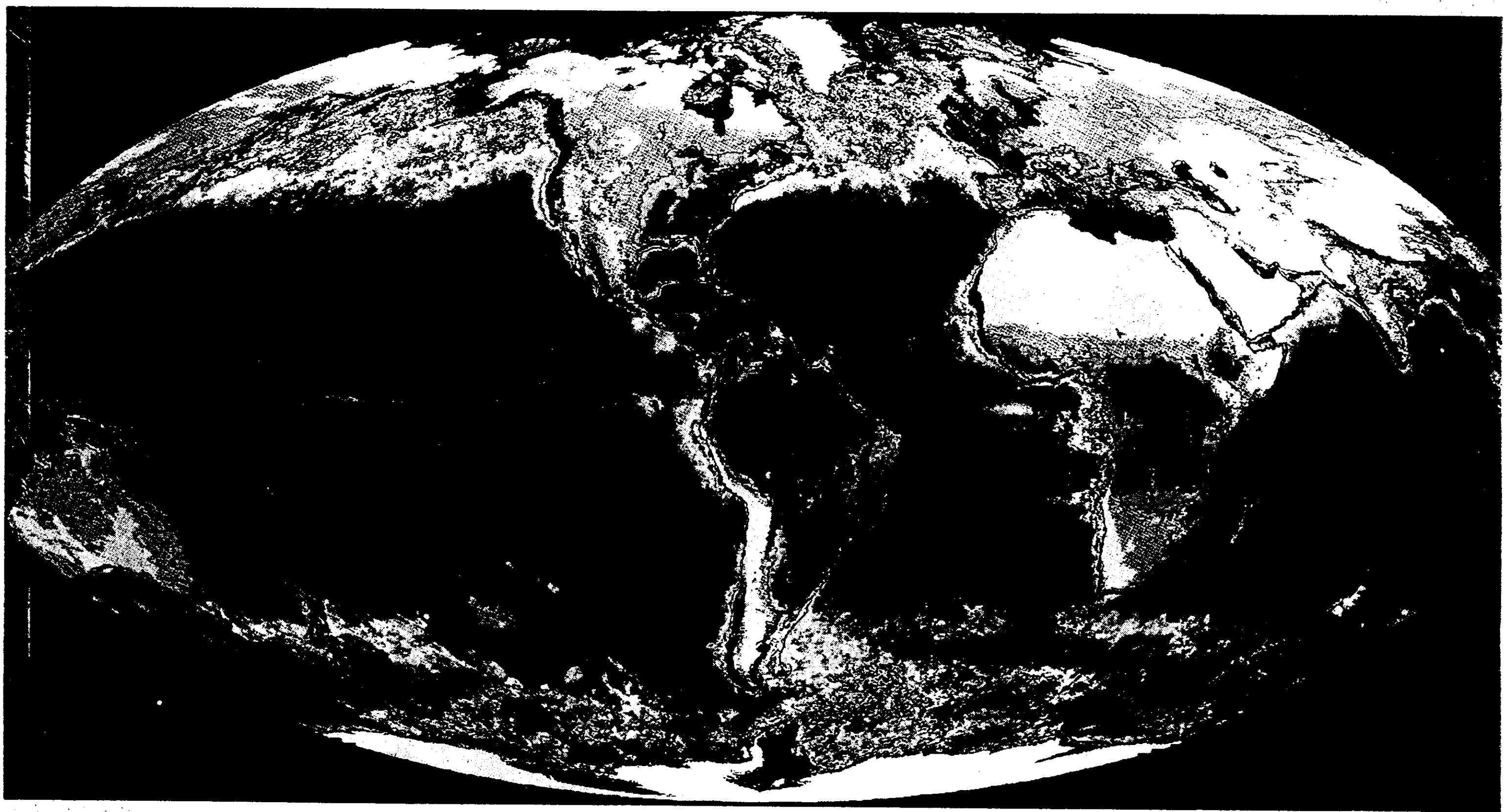

Selected Papers on Space Science Education, Remote Sensing and Small Satellites

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INTRODUCTION

Over the past several years it has become clear that there is an inextricable link between efforts to monitor and preserve the environment and humanity's ability to utilize the Earth's resources in a sustainable manner. Equally important is the realization that continued economic and social development is an essential element for promoting and maintaining international peace and security. The United Nations, through a series of global conferences that began with the 1992 United Nations Conference on Environment and Development, has been a driving force in bringing this message to the international community. As humanity approaches a new millennium, and the United Nations faces new challenges, including implementing the recommendations of the global conferences, it will be vital for the international community to bring all the resources at its disposal to bear on the problems it faces.

Space technology, and the many practical benefits that can be derived from its utilization, will play a central role in national, regional and international economic and social development efforts. New applications of space technology are constantly being discovered and spin-offs from space technologies have led to advancements in such diverse fields as medicine, materials sciences and computers. Nevertheless, the high cost of participating in space activities has hindered the ability of many countries, particularly the developing countries, to fully take advantage of the many practical benefits that space technology offers for economic and social development.

The United Nations, through the Office for Outer Space Affairs, has therefore focused its efforts on expanding access by developing countries to the practical applications of space technology. Through the Programme on Space Applications, the Office annually conducts 8-10 workshops, seminars and training courses that assist developing countries in the establishment of indigenous capabilities in space technologies. These activities bring together experts in various space-related fields and facilitate the exchange of information among experts and scientists from developed and developing countries. This publication, the eighth in an annual series initiated in 1989, is part of the Office's efforts to expand and encourage the international exchange of information and experience, which, along with other programmes and publications, promotes the United Nations goal of ensuring that outer space is used for peaceful purposes and for the benefit of all countries.

This publication comprises selected papers presented at the 1996 activities of the Programme on Space Applications that illustrate the issues related to the use of space technology for development. The scope of the publication extends from a general overview of the benefits of space technology and the role of space research and education in basic space science in developing countries, to more specific areas of applications of space technologies, including the use of remote sensing for resource management and disaster mitigation in Asia, and the development and use of small, mini- and micro- satellite systems. Because the papers are selected from workshops, training courses and seminars held in various parts of the world, they address applications corresponding to the specific needs of the regions concerned.

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BENEFITS, CONSTRAINTS AND CHALLENGES OF SPACE TECHNOLOGY APPLICATIONS IN DEVELOPING COUNTRIES*

Peter O. Adeniyi
University of Lagos
Lagos, Nigeria

INTRODUCTION

In the past two decades many conferences, symposia and workshops have been conducted by several international organisations, donor/aid agencies and the United Nations organisations on space and its related technologies. The theme of several of the meetings has often been how developing countries can benefit from the applications of space technology. The reoccurrence of this topic has two possible implications: (a) the cause for the concern has not changed substantially; and (b) most of the space technology transfer efforts may not have adequately identified and addressed some of the fundamental factors that often condition technology adoption, adaptation and application.

Set against this observation, an attempt is made in this paper to:

- briefly outline some of the benefits of space technology applications with emphasis on how the benefits are obtained
- provide a general overview of the status of space technology applications in developing countries, with particular focus on Africa
- examine the major constraints and the reasons for them
- outline the major challenges of space technology application
- discuss some strategies that could lead to beneficial and sustainable application of space technology

BENEFITS OF SPACE TECHNOLOGY APPLICATIONS AND HOW THE BENEFITS ARE DERIVED

Observations of the Earth from space is one of the most revolutionary achievements of this century. The advent of weather satellites in the 1960s and the earth resources satellites of the early 1970s by the United States and the former Soviet Union created new and unique opportunities for humankind to improve their knowledge about environmental resources. The increasing world population, accompanied by accelerated degradation and depletion of the resource base, led to "global" low-contribution of the environmental resources to socio-economic development as well as the global concern for sustainable development (Agenda 21 of UNCED, 1992), resulting in the development of many earth observing systems with

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enhanced radiometric, spectral, spatial and temporal resolutions. (Appendix 1). Complementing these efforts was the development of various communications satellite systems.

The primary objective of space technology applications is essentially to provide resource and environmental data, which when organized and processed, leads to the generation and transmission of information in support of development decision making. The need to organise, process, store, analyse and present intelligent information generated through the data delivered by various earth observing systems led to the development of analytical and integrative technology called Geographic Information Systems (GIS).

Benefits of Space Technology Applications

The benefits of space technology applications have largely gone to those nations that have largely organised themselves to apply national perspectives to the development of scientific and technological competence for the application of the technology to their national development goals, priorities and supporting policies. In those nations (e.g. the United States, Canada, the European Countries, Japan, China, India and Brazil), space and its related technologies have been nationally applied for various purposes including:

- Land cover characterisation;
- Natural Resource inventory and management;
- Agricultural planning and crop production;
- Environmental monitoring and impact Assessment;
- Timely provision of climatic and meteorological information;
- Physical infrastructure and utilities planning and management;
- Urban and rural planning;
- Natural and human-induced disaster assessment;
- Capacity building and education (Appendix 2)

An attempt to establish how much of a country's socio-economic growth and environmental enhancement is a result of the application of space technology is "like trying to distribute the credit for the flavour of a cake between the flour, the butter, the eggs and the sugar."[OCED, 1980] However, experience has shown that those nations that have nationally implemented and applied space technologies have been able to obtain relevant and reliable information that:

- reveal the available resources and their character, location and potential

- provide opportunities to tailor development activities in a manner compatible with the resource base

- permit an individual, a group and organisation to enter into a mature, mutually beneficial resource exploitation relationships with others

- provide the government, donor/development agencies and the citizens the opportunity to exercise good judgement in the selection of appropriate policies and programmes

- provide the citizens opportunities to debate, react and participate in development programmes and projects
- increase the capacity of the people to organise themselves for a common purpose and provide a credible channel to persuade them to change those habits and perceptions that are inimical to progress
- reduce the opportunity for misunderstanding, frustration and disruptive conflicts

In addition to these benefits, the applications of space technology have made it possible for:

- National, State/Provincial and Local governments to better able to cost-effectively manage their natural and environmental resources with collaboration among ministries and agencies
- increased job opportunities in both public and private organisations
- Non-Governmental Organizations to have access to sustainable development information
- local communities to have relevant and timely information about their resources which give them greater opportunity to manage their resources with increased productivity
- the citizens to realise, not only that the environments within which all developments take place are multi-purpose environments, but also the interdependence and relationship of environmental components and attributes as well as the interdependence of local, national and global environmental resource issues

The Mechanism Adopted for the Derivation of the Benefits.

Given the fact that the whole idea of space technology is an outgrowth of the knowledge of the industrialised countries, and in order to appreciate the constraints and challenges facing the implementation and application of space technology in most developing countries, it is pertinent to outline the mechanism adopted by some of these countries to derive the benefits of space technology. The examples of the United States, Canada and Western Europe (e.g. the United Kingdom) are used here for illustration.

United States

The Earth Resource Technology Satellite (ERTS), later renamed LANDSAT, was developed by the United States Government through the activities of two U.S. agencies—the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). Prior to the advent of the Landsat programme, the applications of aerial photography for surveying and resource mapping had been developed.

In order that the expanded technology of remote sensing be accepted and utilised by the people, the U.S. Government, through agencies such as NASA, NOAA, and USGS, mounted experimental studies in the universities and other public and private organisations were involved. With the cumulative and available scientific base, the activities of these various bodies were directed toward the development of applications methodologies that would increase the speed, efficiency and economy as well as modify the classical aerial photographic interpretation methods and products. Funds were made available to universities to carry out research and to mount educational and training programmes. And barely after a decade of Landsat, nearly 700 courses in remote sensing had been introduced.

The results of the research and applications oriented projects were disseminated through several conferences, seminars, symposia and workshops. The professional associations, especially the mapping/geo-computer sciences, worked together with the government in the propagation process. The industries also actively participated by developing appropriate software and hardware for image analysis as well as promotional activities.

In spite of these achievements, Lillesand (1982), writing on "The Trends and Issues in Remote Sensing Education" in the United States, concluded, in parts as follows:

> *"Overall, there is a need to continue support of a data base amenable to analytical assessment of remote sensing and the other mapping sciences. There is a need to better synthesize these sciences within our institutional programmes and technical societies. There is a need to better prepare our students (and ourselves) in both visual and digital image analysis. There is a dire need to facilitate the education of our future remote sensing educators. There is a need to teach more students about remote sensing at all levels, and on a continuing basis. Definition of, and support for, remote sensing research must be greatly improved in many application areas. Finally there is an extreme need for remote sensing educators, agencies and industries to get their collective act together. Technologically, we have accomplished a good deal in remote sensing in the recent past. We now have some profound institutional questions before us. The quality of life for future generations may well depend upon how we respond to them."*

Today, space technology application has become an integral part of all programmes on sustainable development. And apart from NASA, NOAA and USGS, numerous bodies have been established to further improve the development of the technology and delivery of information, including CEOS, EDC, EOS of NASA, EOSAT and FGDC.

Canada

In Canada, the former Director of the Canada Centre for Remote Sensing (CCRS) remarked that one of the reasons the Canadian government approved their proposed ERTS programme so quickly was that some of their lawyers became very concerned about sovereignty implications. The attitude was "we can't have the Americans knowing more about our natural resources than we do." Consequently, the Canadian government established CCRS in 1971 to coordinate all remote sensing activities and to ensure the rapid transfer of the technology to the provinces. Training courses were organized by CCRS to university professors, and resources managers. The industries were encouraged to participate in the development and application of the technology. In addition, the government as well as private organisations encouraged and support the mounting of remote sensing programmes in Canadian universities.

Today, satellite data is commonly used in various fields. In addition to the manufacturing of various hardware devices and the development of many software packages, Canada has launched its own satellite—Radarsat.

Western Europe

The acceptance and utilization of satellite remote sensing in Western Europe had a slow start. The intensity of land use and the low spatial resolution of the earliest space imagery were partly responsible for the slow start. However, their strong scientific base quickly enabled them to realise the expanded advantages of space technology, in general, and remote sensing in particular. While their governments singularly and collectively support the utilization of Landsat products, they also supported the development of satellite programmes that would better meet their needs. An outcome of such an endeavour is the SPOT satellite developed by France in conjunction with Belgium and Sweden. Other cooperative efforts include the establishment of the European Space Agency (ESA), the European Association of Remote Sensing Laboratories (EARSel) and the Joint Research Centre (JRC) of the European Economic Community. These various bodies, including the council of Europe, have been the major force in developing an awareness of the potential of remote sensing by conducting research, conferences, workshops and by promoting education and training in remote sensing.

Apart from these and other joint ventures, most of the countries have their own national programme. In the United Kingdom there is a National Remote Sensing Centre (NRSC), which was established in 1980. The realisation by the government of the benefits derivable from space technology and the activities of the Remote Sensing Society (RSS) gave birth to the NRSC. The primary functions of the NRSC are to provide potential users with image and image processing facilities, to demonstrate how satellite data can be used for a variety of applications in areas such as agriculture, forestry, geological surveying and pollution monitoring, and to assist industry to develop these into operational procedures. [RSS News, December 1986] As a way of increasing the awareness of the people—the ultimate user of remote sensing—the NRSC came up with a programme called "The Road Show." This was a mobile exhibition where appropriate project results and instruments were taken to different groups at various locations. Mondays and Fridays were for school groups and other days for local authorities and business groups. The evenings were set aside for the teachers, with emphasis on the integration of remote sensing into the classroom. All the local newspapers, radio stations and television were invited to participate in the road show, which has met with great success.

Today in the UK, many of the universities now have undergraduate, postgraduate and diploma/certificate courses in remote sensing. In setting up some of the programmes, the multi-disciplinary nature of remote sensing was duly recognised.

It is not possible to examine the situations in every industrialised country. However, despite their high degree of literacy and strong scientific and technological/industrial base, the countries were able and continue to derive the benefits of space technology because:

- the governments of these countries play major roles in establishing responsive scientific, technological, economic and social policies that help the applications of the technology in their respective countries and regions

- the professional bodies in the fields of mapping sciences work hand-in-hand with their governments and other associations to promote and perpetuate the development and utilization of the technology

- the governments as well as private organisations support the mounting of new programmes in the colleges and universities

- the governments, the scientific community and the private sector create tremendous channels for the dissemination of research and application oriented project results

- they all believe in constant self-examination and accountability

STATUS OF SPACE TECHNOLOGY IMPLEMENTATION/APPLICATION IN AFRICA

Since the advent of space technology and in recognition of its potential benefits for land resource and environmental planning, management and monitoring, many international organisations, development/donor agencies and UN organisations have continued to carry out programmes aimed at transferring the technology to developing countries. The level of achievement in these efforts is lowest in Africa. For this reason, the summary of the status of space and related technology applications in Africa is chosen for illustration. The summary is essentially based on the recent study conducted by ECA. The study was conducted in 25 resource/environmental/mapping institutions in seven African countries and 13 educational institutions in six African countries. The 10 criteria used and the summary results obtained are presented below.

The Level of Priority Given to GIS/LIS & Remote Sensing (RS)

With regards to GIS/LIS, 76 percent of the institutions (19) recognised it and classified it as either one of their primary (52 percent), secondary (16 percent) or marginal (8 percent) disciplines. Eighty-eight percent of the institutions (22) classified RS as either primary (44 percent), secondary (32 percent) or marginal (12 percent). It is instructive to note that eight of the institutions that classified GIS/LIS as one of their primary disciplines also classified RS in the same way.

How RS/GIS was Introduced to the Institutions

RS/GIS has been established in one form or another in 19 of the 25 investigated institutions. The establishment of RS/GIS in 10 (52.6 percent) of the 19 institutions has been largely influenced by externally funded projects.

ɔf Proficiency in Digital and Manual Data Processing

As shown in Table 1, 60 percent of the institutions claimed to have high proficiency ɪn manual processing against 32 percent in digital processing.

Available Hardware and Software and How Obtained

A wide range of hardware devices and software packages are available in those institutions that have actually started to operate RS/GIS. Most of these institutions have PC machines ranging from 286 to 586. Seven of the institutions have at least one workstation. The most common GIS software is PC Arc/Info. Given the mission and mandate of these institutions, the available hardware and software is generally inadequate. More important, most of the institutions, with the exception of those from South Africa, obtained their hardware and software either through external grants, externally funded projects or through donations. Although the providing facilities have assisted the institutions in embarking on the application of RS/GIS, the sustainability of this process, given the sudden death of such processes in the recent past, tend to reduce the value of this achievement. (Appendix 3)

Available GIS Staff in the Institutions

Only 16 of the institutions provided information on the number of staff directly involved in RS/GIS. A total of 192 RS/GIS served the 16 institutions, out of which 169 (88 percent) are indigenous staff. Again, with the exception of very few institutions, especially in South Africa, most of the institutions have inadequate staff to really make meaningful contributions. This notwithstanding, this achievement is a notable improvement.

Perceived Impact of RS/GIS

The impacts of RS/GIS have been claimed to be largely positive. Specifically, 72 percent of the institutions claimed that RS/GIS has led to better integration of information; 68 percent indicated improved planning and management activities; 60 percent indicated increasing inter-disciplinary interactions; 56 percent indicated better coordination of projects and programmes; 52 percent indicated increased productivity, 32 percent indicated that it has led to the restructuring of their institutions while 24 percent claimed to have increased the cost of their operations. Finally, all the institutions claimed that the introduction of RS/GIS has not led to unhealthy rivalry among the staff of their institutions. However, the observed situations in some institutions and experience from other places tend not to support the last claim by the institutions. The lack of basic infrastructure and the cost of data base creation often increase the initial cost of RS/GIS establishment and operation. Thus the above finding is not unexpected. Also the fact that most of the institutions are currently engaged in project-type RS/GIS explains the relatively lower percentage of those institutions that have had cause to carry out necessary restructuring.

Policy and Arrangement for Human Resources Development

Of the 25 institutions, 22 (88 percent) claimed to have a policy on human resource development. However, of the 22, 60 percent claimed to rely essentially on external grants, fellowships or on externally sponsored projects for the implementation of this policy. This type of dependency is not only at variance with the requirements for technological development and application, it also reflects the level of priority given to this critical success factor for sustainable development.

Data Sharing, National Data Quality Standard and the Availability of National Information/GIS Centre

Twenty-one institutions claim to share their data with other organisations; one claimed not to do so while two others did not express any opinion on this and one institution claimed that it has just started and thus has no data to share. The mode of data sharing is as follows:

- Free as a service only (nine institutions)
- Partly free and partly subsidised (three institutions) and the proceeds are returned to the national account)
- Subsidised only (eight institutions, two of which used the proceeds internally while the other six returned the proceeds to the national account)
- Subsidised and commercial (one institution and the proceeds are also returned to the national account and/or line ministry)
- Commercial only (one institution and the proceeds are used internally)

Data quality standard is claimed not to exist in all the countries except in South Africa, where the existence of a National Standard for Exchange of digital geo-referenced data was mentioned. Similarly, none of the countries have a national resource information centre even though references were made to national department of statistics or the survey organisations as playing this role.

Perception and Receptivity of the Institutions with Regard to the Establishment of National Resource Information/RS Centre

The response of the institutions to this issue is largely positive. The summary of their responses is shown in Table 2. In spite of the relatively low percentage responses on some critical elements, such as computer linkage and the readiness of the institutions to modify their data format to make it compatible with the national centre as well as the willingness to send staff to the centre for training, the responses seem to indicate a general agreement on the establishment of such national centres. The very low percentage response to the issue of financial support to the centre is understandable because most of the institutions are themselves suffering from inadequate financial resources.

Local Education and Training Opportunities

Out of the 13 educational and training institutions that responded to the survey questionnaire, two of them claimed not to have any programme in the field of Geo-information technology (GIT). Although the results obtained from the remaining 11 institutions cannot be fully representative, they are nonetheless indicative of the relative status of local education and training in GIT in most African countries. The findings revealed that:

- There is a measure of awareness about the need to mount GIT programmes at individual and departmental levels. This awareness has, unfortunately, not led to general institutional policy to support, maintain and expand the initiatives.

- With the exception of South Africa, almost all the available enabling infrastructural facilities for teaching and research in the field of GIT, especially RS and GIS/LIS, were acquired through externally funded research projects or grants from Donor/Aid organisations. The facilities are, in most cases, at variance with the requirements for running meaningful educational and training programmes.

- In all the institutions, courses in RS and GIS/LIS are only offered (or listed) as part of other degree programmes. The only exception is the University of Cape Town in South Africa, where an MS degree programme is offered in GIS.

- In almost all the institutions, programmes in RS and GIS/LIS are mounted by the departments of Surveying/Geodetic Engineering and Geography. Unfortunately, these disciplines are least recognised in Africa. The more resource and environmentally based faculties/departments in the Universities have largely remained passive with regards to the adoption and mounting of appropriate programmes in GIT.

- All the institutions indicated the lack of qualified lecturers to teach the various courses; thus only very few students were graduated in the last two years. The magnitude of the problem can then be imagined when the institutions that are expected to produce the necessary expertise for the operational users of the technology are themselves unable to meet their own manpower needs.

Although the samples on which the above analysis are based may not completely represent the status of space technology application in Africa, the level of achievement is certainly at variance with the level of the technology transfer efforts. Notwithstanding the number of space and related technology projects that have been carried out and the on-going ones, the analysis above tends to show that no solid foundation has been created for their sustainability.

CONSTRAINTS AND THE REASONS FOR THEIR PERSISTENCE

The implementation and application of space technology in Africa has largely been constrained by:

- inadequate skilled and experienced manpower at all levels

- lack of awareness of the potential of space technology by the decision makers at all levels, as well as the operational user community

- poor access to, and relatively high cost of, satellite data. In this regard, Africa has the largest area not covered by any ground receiving station

- lack of appropriate national institutions to plan the adoption, adaptation and the national objectives and priority areas for which the technology will be applied

- lack of clear national strategy and policy for resource and environmental information collection and use

Given the over two decades of efforts at transferring GIT to Africa, and in view of the level of achievement and identified constraints, it is quite plausible that the level of achievement might have been greater if the above factors that often condition technology transfer were recognised or not assumed during the transfer process. In order to guide future efforts, some of the implicit assumptions of the transfer process are presented below.

(A) The products of conventional surveying and mapping are routinely and legitimately used for resource planning and management prior to the advent of modern GIT.

This assumption was based on the limitations of conventional surveying and mapping techniques and the potential advantages of RS, GIS and GPS. Unfortunately, at the advent of these modern GITs, conventional surveying and mapping are little recognised and their products were hardly used for planning and management. Even today, the situation has remained largely unchanged. This assumption is false and has negatively affected the adoption of modern GIT.

(B) There exists an appreciable measure of scientific and technical knowledge in conventional mapping and that the adjustment and adaptation to the modern GIT would be easy.

The summary result of the status of space technology applications in Africa has proved this assumption to be false. The lesson of experience of the industrialised countries, where the initial priority was given to education and training as well as institutional building, was not brought to bear on the transfer process.

(C) Traditional wisdom that states that "Science knows no boundary," which has therefore been interpreted to mean that research for development and for developing countries is best done by outside experts.

While this traditional wisdom is not being contested, its interpretation is based on the belief that many of the resource problems facing Africa have already been faced and solved by researchers in the industrialised countries and that such problems are better tackled by the researcher from the industrialised countries.

However, the experience of the industrialised countries, and those of some countries in Latin America (e.g. Brazil) and Asia (e.g. India, Indonesia) has shown that there are limits to the transferability of technology by doing for others what they should do for themselves; and less so, of scientific learning. This assertion is based on different ecological, resource endowment and socio-cultural factors.

The point being made here is not against the use of external experts; rather it is meant to emphasize that development is not something that can be imported and that self-sustaining development is inconsistent with the assumption that the answer to every problem can be found externally. More important, sustained and self sustaining progress in a country has generally followed the application of technology controlled by, and responsive to, the needs and endowments of the country.

(D) There is value and demand for resource and environmental information and that the institutional arrangements are appropriate for the adoption and application of space technology.

Experience has shown that the form, structure and the operational guidelines by which resource management institutions are formed and evolved clearly affect the implementation of resource policy, both as to the range of choice adopted and the decision attitudes of personnel involved.[11] And as "Human Values," according to McAllister (1980, p. 13) "serve as guides for personal decision making, attaching significance and importance to objects and events, directing choices toward things considered desirable or good and away from things considered undesirable or bad," the general view of resources in most African countries only relates to their perceived abundance and decisions and policies are directed essentially to the consumption of the resources with inadequate consideration for their sustainability. This perception does not recognise the interrelationship and interdependencies of both human and natural resources.

Since the perception of the discrete decision making elements in a society determines how an issue is regarded as significant or otherwise, the perception of decision and policy makers which have several fundamental implications for the adoption and the application of space technology are:

(1) The continued preoccupation with a sectoral view of resources such that policy decisions are commonly made in a setting where the interdependence of both the natural and human resources is ignored and sectoral interests dominate all activities.

(2) The rigid compartmentalisation of responsibility, which in turn, has led to fragmentation and duplication of efforts, poor coordination, confusion, turf protection and significant misuse of valuable time and borrowed money. The old ecological axiom that "everything is connected to everything else and that one cannot do just only one thing" is yet to be embraced.

(3) The same sectoral and compartmentalised approach with its attendant problems is also extended to the educational structure such that individual disciplines largely operate in isolation. Yet, the complexity of resource analysis suggests that more than one disciplinary view point—the hallmark of RS/GIS—is required to conduct the necessary research whereby the *problem* rather than the *disciplinary orientation* is the overriding concern.

(4) The low value attached to traditional mapping (land surveying, photogrammetry, cartography) is largely responsible for the very slow adoption

of, and in some cases passive resistance to adopt, the contemporary technologies of remote sensing, GPS and GIS. The close association of the development of these modern technologies with the traditional mapping technology as indicated above and geography, which are themselves given little or no recognition in several countries in Africa, compounds the situation.

(5) In the Lagos Plan of Action, reference was made to cartography and remote sensing under Chapter 3, which deals with natural resources. The views of the continental body reads:

> *"The strategy for development in cartography and remote sensing is geared towards providing the means of achieving self-sufficiency in qualified personnel in all branches of cartography, to bringing to light the present position of Africa's attainment in mapping and to provide the means to establish and strengthen national surveying and mapping institutions in order that Member states may be in a position to undertake surveying and mapping projects which are essential for development."*

This narrow view of remote sensing technology has shown that the field is seen as a residual rather than a core scientific and technological programme. The effect of this is reflected in the fact that many African countries do not have national policy on space technology or its remote sensing component. In several African countries, what is taken as national remote sensing centre are agencies established for specific natural resources/environment sector (e.g. ecology, water resources, forestry) where projects (usually funded by donor/aid organisations) are being carried out. Such agencies do not have legal instruments other than the one that established them. In effect, many of the so-called national remote sensing agencies in Africa do not have the capacity and legal authority for the implementation of space technology programme.

The combined effects of the above factors have been (and continue to be) one of the greatest obstacles for the adoption and application of the technology for land resource and environmental planning and management in Africa. Specifically it has been responsible for:

- lack of legitimacy for information generation, usage and management; and thus the application of space technology

- mandates given to sectoral organisations which often do not reflect the need, not only to collect and process data for the generation of information but also to share such information with other organisations

- lack of appropriate legislation that involves explicit specification of the needs to be met, requirements for meeting the specified needs (e.g. financial, human and material resources); actions to be taken; establishment of organisational structure within which specified actions would be taken; priority and target setting as well as setting of standards for products and mechanism for coordination.

Because of the problem of legitimacy of space technology, these crucial actions often do not feature in the legislative organs of governments in most African countries. Thus, institutions are generally left to interpret and implement their mandates without any instrument of accountability or how to adapt institutional mandates to meet the environmental, social, economic, political, technological and global challenges. Thus, as all resource problems—overpopulation, food security and hunger, health and disease, poverty, environmental refuges, resource depletion and degradation and pollution—are fundamentally institutional problems that warrant institutional solutions, the requirements of space technology, and its ability to enhance resource planning and management cannot be met under the prevailing institutional arrangements to which the technology is being transferred without appropriate restructuring.

(E) The provision of hardware and software, as well as some basic materials, to persons who have been trained through technical assistance overseas would lead to the subsequent adoption of the technology on their return to their respective countries.

In several cases, this assumption has worked. However, in many other cases, the assumption failed because of the problem of the legitimacy of the technology and the lack of institutional support.

(F) The provision of data sets would lead to their utilisation for planning and management of the resources.

This assumption was partly responsible for the establishment of UNEP Global Resource Information Database (GRID). To the best of my knowledge, very few African countries and Africans have not requested these data sets. Some of those who have requested for some data sets have no means of using them. Even products of resource inventory carried out through externally borrowed money are hardly used for development purposes.

The constraints being faced by African countries regarding the adoption and application of space technology and the reasons discussed above also affect other developing countries. However, in those countries, such as Brazil, China and India, the first five years of the introduction of the technology was devoted to human resource development. This approach allowed them to become active participants in the development and application of the technology. Because they understand the contextual issues in their environment, they were able to demonstrate the utility of the technology to the highest decision makers in their countries. This, in turn, paved the way for the legitimisation of space technology. The lack of this approach, and the inadequate understanding of the socio-cultural issues in Africa by the technology transfer agents, has contributed to the slow pace of the technology application as well as the current total dependence on international organisations and donor agencies.

Since development decisions are basically investment decision—investment in people and resources—it follows that those who identify problems, assess the risks, set the priorities and make the decisions should be the people of the society where the development is to take place.[4] Thus, development projects largely based on technology acquisition and extensive collection of data without a national policy on what the data will be used for is not sustainable.

In this context, the statement made by the President of Zimbabwe during the African Association of Remote Sensing of the Environment (AARSE) sponsored conference on the "Application of Remotely Sensed Data and GIS in Environmental and Natural Resource Assessment in Africa" in March 1996, is instructive. He states:

> *"Halting environmental degradation today requires both dedication and co-operation between the North and the South. For us in the South to be able to make any meaningful contribution to the control of global environmental degradation, there is need to access technologies for remote sensing such as those available in the North. Many conferences have been held on this subject. What remains is the implementation of programmes that will strengthen our technological capabilities. Technology transfer is not just a question of acquiring high technology tools. The solution also lies party in having sustainable development without limiting our ability to industrialise and rightfully realise our optimum potential. Technology transfer, research and development have to be skillfully tapped for our special needs in the South. Without the requisite inputs and the ability of own scientists and technologists to assess the new technologies, the process will not succeed...*
>
> *The problem in Africa is that, though the use of remotely-sensed data for environmental management is gaining ground, the training of personnel for the field is still largely being done in the developed world. Yet the need to involve African scholars and scientists in the development of indigenous expertise is increasingly becoming evident. This is, at it should be, because scientists who have a better appreciation of the local environment are better placed to tackle Africa environmental problems than their counterparts from the North."*

CHALLENGES AND STRATEGIES

From the preceding sections, a number of challenges facing developing countries, especially those in Africa, regarding the beneficial application of space technology in furtherance of sustainable development have been indicated. Space technology has brought with it changes in the way we view our environment. These changes, which are largely at variance with the way we conduct our management activities, equally demand that we adjust the way we do things if we are to derive optimal benefits from the technology. The changes required constitute the major challenges. Some of these challenges include:

- National legitimation of space technology and its related technologies
- Human and organisational capacity-building
- Incorporation of environmental resource information in development decision making
- Access to geospatial data
- Establishment of national data quality standards and inter-agency networking

- Institutional and organisational restructuring

- How to cope with rapid technological changes

No attempt is made in this paper to examine each of the above challenges. Rather, a strategic framework that encompasses all of the above challenges is presented. The framework is based on the following six components required for management of changes:

- Context
- Legitimation and Credibility
- Functions
- Structures
- Organisational Culture and attitudes
- Processes and Mechanisms

Each component is briefly discussed and the actions required under each are outlined.

Context

Since the environment in which all development takes place are multipurpose environments, and for development to be sustainable, it is required that each country should have (or develop) a broader contextual and long-term perspective view about the nature and character of the natural environment (the supply system), the human activities (the demand system), the interactions between the two systems and the means by which the full range of the functions provided by the environment and natural resources can be obtained and sustained for the developmental priorities, goals and objectives of the country. It is against this that the role of space technology must be defined.

Legitimation

For space technology application to be effectively and efficiently implemented at the national level, it must be regarded as legitimate, credible and a critical factor for national resource planning, management and sustainable development. This legitimation must involve the incorporation of space technology in institutional mandates; commitment to, and provision of, financial and material resources; the establishment of policies and guidelines on information use and access; arrangement for human resource development through special support for education and training; the provision of subsidies or other economic measures; the establishment of new agencies and the strengthening of the existing ones; priority and target setting; the establishment of operational procedures and standards; and the establishment of guidelines for vertical and horizontal coordination of activities among agencies and between agencies and the community, including accountability. These attributes of legitimacy make it the single most important requirement for the development and implementation of national space technology programme.

How to obtain legitimacy for space technology

Ideally, legitimacy can be given by legislative, political, administrative and/or financial means. It can also be brought about by the collective effort of the scientific community and professional organisations. This is one of the major programmes of AARSE.

However, given the prevailing situation in most developing countries, especially those in Africa, the assistance of all technology transfer agents will be required with regards to:

- the need for better coordination of their activities and programmes

- the need to shift emphasis from direct project implementation to human resources development through special support for formal education in Universities and more result-oriented training programmes as well as support for professional organisations at both continental and national levels

- the need for some possible (corrective) forms of sanctions for any country that has not given visible support for the implementation of space technology

In furtherance of the above, the United Nations Office for Outer Space Affairs may take a leading role by organising a special meeting with all the major space technology transfer agents and the United Nations Economic Commissions in the developing countries to deliberate on the most appropriate strategy.

Functions

Since management functions must be performed to implement any policy or programme, appropriate decisions must be made regarding the allocation of functions among different institutions, organisations agencies and individuals.

Thus, for the idea of space technology to be accepted and supported, all the critical elements of the society, top public and private decision makers at all levels should be involved in designing the functions the technology will be expected to perform.

Structures

Once the functions have been defined, the institutional and organisational structures must be designed to facilitate functions. In this regard, criteria for institutional and organisational performance (jurisdiction, enforcement powers, fiscal adequacy, administrative discretion, flexibility, accountability and structural compatibility) must be properly addressed.

However, given the nature of the technology, and in consideration of the suitability of existing organisations, the following actions may be taken:

(1) Strengthening of the existing organisations with regards to functions, processes and mechanisms of operation and organisational culture and attitudes

(2) Rationalisation of existing institutions in line with new functions, processes and mechanisms (e.g. making survey organisations as autonomous national organisations)

(3) Establishment of new organisations to cater to specific function(s) that existing organisations do not have the capability to undertake or for which they will underachieve if such functions are assigned to them

Organizational Culture and Attitudes

The effectiveness with which any policy or programme is implemented is influenced significantly by the culture and the attitudes of the organisations and the people involved. Thus, if these people don't have the requisite education, training and management skills and no incentive or encouragement, the probability of cooperation and coordination of activities becomes low. As instrumental values are determined by the knowledge on the linkages between means and ends, the inadequate knowledge of personnel about the requirements, concept and the goal of space technology, may inhibit the adjustments to the required attitude. To change the current organisational culture and attitudes will require, among others:

(1) Education infused with a sustainable development ethic

(2) Incorporation of space and related technologies into the educational programmes of schools, colleges and universities

(3) Establishment of the culture within organisations at the Federal, State and Local levels, and at senior, intermediate and junior levels to view cooperation and coordination as valued and desired

(4) Development of a corporate view of information, a common information model and a system that supports the mandate of the organisation as well as people in their business activities

(5) Careful selection of personnel at all levels. In this regard, the type of management leaders required should:

- understand the context of the operating environment
- understand the problems involved in implementing geoinformation technology
- appreciate the cultural background of the people and have the capacity to plan the process of cultural change required for effective implementation of space technology
- have persuasive ability to gain support from colleagues, superior and relevant organisations
- be able to motivate policy makers as well as the staff
- have the capability to create optimal conditions in which the demands for GIT products and services can be satisfied timely and cost effectively
- have respect for other organisation mandates and view points

- recognise the need for human development and ensure that sufficient resources are allocated for it

Processes and Mechanisms

Notwithstanding the "initial" supremacy of legitimation required for the establishment and application of space technology for national resource planning and management, its actualisation and the successful accomplishment of the tasks involved in the other components discussed above depend largely on the adopted processes and mechanisms.

Given the variety of resource and environmental institutions/organisations, the equally varying functions which they are expected to perform in an integrated manner as well as the different attitudes and cultures of personnel, the designing of appropriate processes and mechanisms requires political will, management capability and the active participation of all stockholders at all levels. Accordingly, the design to deal with processes and mechanisms is often assigned to an inter-institutional committee, national steering committee or a national commission/council.

With regards to the multipurpose and interdependent benefits of space technology, the establishment of a National Commission on space technology is strongly recommended for the designing of the processes and mechanisms.

The members of the proposed commission should include top senior administrative, financial and professional/technical/scientific officials from environmentally-based sectors (e.g. forestry, water, soil, geology and mineral resources, agriculture, meteorology and national environmental protection agency); senior officials from the national survey organisation, ministries of finance, science and technology, commerce and industry, national planning commission and national statistical department; as well as representatives from the Private sector, National Bank, Universities, National Labour Unions, Media organisations, Women organisations and Resource/Environment-based NGOs.

Among other things, the mission and mandate of the Commission should be to work out the modalities of establishing a national space technology programme that will support the short-, medium- and long-term national priority development goals and objectives, taking into consideration the need for self reliant and sustainable development by focusing on:

- identifying and proposing the technical, institutional and technological requirements for the institutionalisation of the process

- establishing necessary and essential regulations for the process

- advising on priority issues such as the technological needs of user organisations, operational databases, system configurations, staff and financial requirements, education and training, data access and use policy, cost recovery (revenue generation), implementation phases, accountability, relationship among agencies and between national regional/international organisations and agencies

- preparation of memoranda of understanding (MOU) for the endorsement of the heads (Ministers) of all the resource and environmental sectors as well as all the heads of the relevant organisations

The endorsement of the MOU by the heads of the sectors and organisations provides a basis for the legitimation of space technology and the commitment to the institutionalisation of the process. The responsibilities of such a commission are usually carried out through the establishment of Working Groups (WGs) and may include: Working Group on Education and Training (WG1); Working Group on Funding (WG2); Working Group on Inventory and Assessment of Existing Data and Infrastructures (WG3); Working Group on Standards (WG4); Working Group on Institutional Arrangements and Organisational Structure (WG5); Working Group on Data Access and Use Policy and Revenue Generation (WG6); Working Group on Pilot Project (WG7); Working Group on Promotional Activities, Public Participation, Liaison with Private Sector, Local, National, Regional and International Organisations (WG8).

Because of the range of activities to be performed by each WG, a variety of experts who are not members of the commission may be co-opted into appropriate WGs. The assistance of the international organisations and donor agencies is required for this process.

It must be emphasised that to obtain legitimacy for space technology, develop the necessary organisational structure and culture, provide effective and efficient education and training at the level required and to establish efficient inter- and intra-institutional relationships with adequate support of the research community, international organisation and donor agencies and the private sector will take time. But to delay the implementation will increase the problems of sustainable development.

The strategic framework for the process is shown in Appendix 4.

CONCLUSION

An attempt has been made to outline the benefits, constraints and challenges of space technology application in developing countries, with the main focus on Africa. The factors that influence the adoption, and beneficial application, of the technology have also been identified. A critical message is that the real problem is not in the "seed" (the technology); rather, it is the ground where it is sown. If the seed is to germinate, the nature, character and the capability of the "ground" must be well understood.

In other words, the development of an internal capacity by developing countries and the understanding of the fundamental issues in developing countries by the technology transfer agents are required for beneficial application of space technology. The persistent call and encouragement for the implementation and application of space technology at the national level are dictated by the need to improve the quality of decisions that are made regarding resource and environmental planning and management. A national implementation of space technology permits and/or encourages the decision-making processes to be:

- **long-term**, in order to anticipate and prevent/reduce future problems

- **multisectoral**, by including the full range of the components of the environment to be managed

- **ecosystem-based**, by recognising the cumulative and synergistic effects of their actions

- **wider**, by recognising the effect of their actions on other sectors, region and communities

- **deeper**, by recognising that the causes and consequences of the problems they seek to solve may involve others and other institutions

- **full-cycle**, by considering the full context of resource use from extraction to processing, to end use, recovery and re-use[9]

This new direction requires, at a minimum, the collaboration of all interest groups in resource and environmental planning and development; joint identification of shared values (i.e. common appreciative values); recognition and incorporation of local knowledge systems; continuous learning by devoting explicit attention to improving group learning skills; continuous evaluation, modification and documentation to enhance adaptive learning; and organisational re-organisation such that:

- analytical problem solving is integrated with a holistic approach allowing system parts to be related to the whole through the capture of system connectedness

- technocratic bureaucracy is replaced with holographic principle such that the whole is present in the parts that are self-regulating through interdependence. This principle is information based and thus, it requires not only the availability of information but also ready access to it

- design principles based on prospective planning with capacity for prediction, exploration and continuous adaptation

"To achieve a breakthrough, we must learn a tough lesson. While it is often all right to adapt through small steps, improving an established course through "fine tuning," there are times when one must do an "about turn," and take more drastic corrective action. The tale of the French schoolchildren and their experimental frog is salutary. They took the frog and dropped it into saucepan of boiling water, whereupon the frog skipped right out—instant rejection of an environment that proved distinctly unsuitable. But when the school-children dropped the frog into saucepan of cold water, and slowly heated it up, the frog swam round and round, adapting itself to the rising heat...until it quietly boiled to death."[10]

We are not all yet dead like the experimental frog, but weakened. We still have a chance to "jump out" of the current unproductive resource management if we make the effort now.

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Table 1: Level of Proficiency in Spatial Data Processing

Processing Techniques	Relative Proficiency Level									
	High		Average		Least		No Response		Total	
	# of Inst	%	# of Inst	%	# of Inst	%	# of Inst	%	# of Inst	%
Digital	8	32	3	12	7	28	7	28	25	100
Manual	15	60	2	8	3	12	5	20	25	100
Digital & Manual	8	32	7	28	-	-	10	40	25	100

Table 2: Institutional Response Regarding Their Possible/Probable Relationship to the Centre

Elements of Relationship	# of Institutions in Agreement	%
Supply Data to the Centre	16	64
Request and Use Data from the Centre	16	64
Have Computer Link with the Centre	13	52
Send Staff to the Centre for Training	12	48
Modify/Change Data Format for Standardization	13	52
Render Financial Support to the Centre	7	28

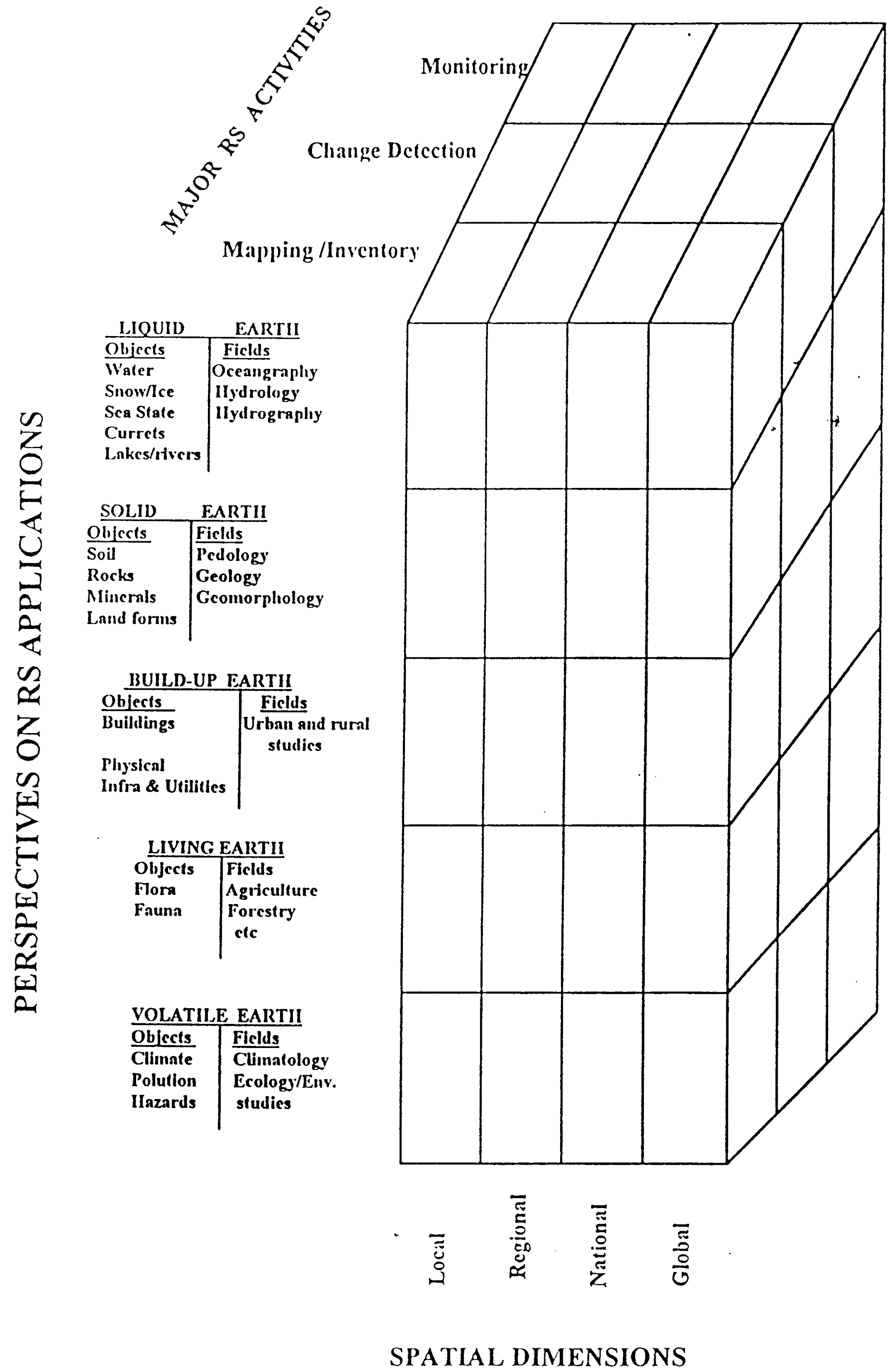
Appendix 1: Current and Future Remote Sensing Satellites

Country	Owner/ Object	Program	Date	Instr. Type	Resolution (in meters)			Color Bands	Stereo Type
					P	M	R		
India	G/O	IRS-1A	'88	P&M		36 72		4	
	G/O	IRS-1B	'91	P&M		36 72		4	CT
	G/O	IRS-P2	'94	M		36		4	
	G/O	IRS-1C	'95	P&M	10	20		4	CT
	G/O	IRS-1D	'95	P&M	10	20		4	CT
Japan	G/O	J-ERS	'92	R&M		24	30	4	CT
U.S.	G/O	ADEOS	'96	P&M	8	16		4	CT
	G/O	Landsat 5	'84	M		30		7	
	G/E	TRW Lewis	'96	P&M	5	30		384 (?)	
	G/E	CTA Clark	'96	P&M	5	15		3	FA
	C/O	Earth Watch	'96	P&M	3	15		3	FA
	C/O	Earth Watch	'97	P&M	3	4		4	FA
	C/O	Eyeglass	'97	P	1				FA
	C/O	Space Imaging	'97	P&M	1	4		4	FA
	G/O	Landsat 7	'98	P&M	15	30		7	
	C/O	Space Imaging	'98	P&M	1	4		4	FA
	G/O	EOS AM-2 L-8	'04	P&M	10	30		7	FA
U.S./Japan	G/O	EOS AM-1	'98	M	15	15		14	FA
France	G/O	SPOT 3	'93	P&M	10	20		4	CT
	G/O	SPOT 4	'97	P&M	10	20		4	CT
	G/O	SPOT 5a	'99	P&M	5	10		4	FA
	G/O	SPOT 5b	'04	P&M	5	10		4	FA
ESA	G/O	ERS-1	'91	R			30		
	G/O	ERS-2	'95	R			30		
	G/O	ENVISAT	'98	R			30		
Russia	G/O	Resours-02	'95	M		27		3	
	G/O	Almaz 2	'96	R			5		
China/Brazil	G/O	CBERS	'95	P&M	20	20		7	CT
	G/O	CBERS	'96	P&M	20	20		7	CT

Canada	G/O	Radarsat	'95	R			9		
Korea	G/O	KOMSAT	'98	P&M	10	10		3	FA

M-Multispectral; P-Panchromatic; G-Government Funded; C-Commercially Funded; O-Operational; E-Experiment; FA-Fore & After; CT-Cross Track; R-Radar

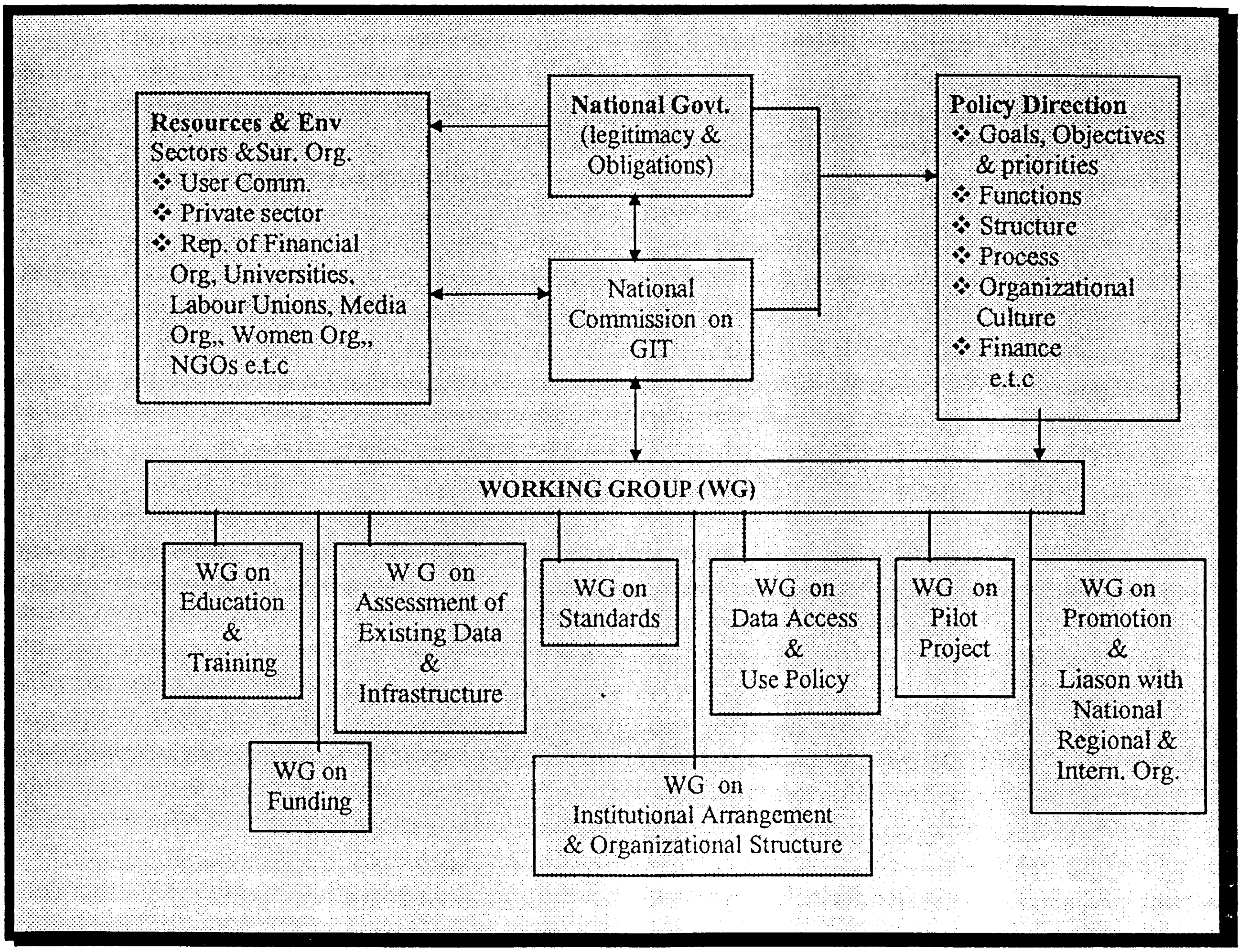
Appendix 2: Matrix of Remote Sensing Applications



Appendix 3: Sources of Software and Hardware in Some African Institutions

COUNTRY	INSTITUTION	SOURCES OF HARDWARE & SOFTWARE
Benin	CENATEL	External Grant
Cote D'Ivoire	CNTIG	Donated by French Gov't & Direct Purchase
Ethiopia	EMA	External Grant
	WBISPP	Direct Purchase through World Bank Funds
	NEPA	N/A
	NMSA	Donated
	OMO-GIBE	External Grant
Kenya	DRSRS	World Bank & French Technical Assistance
	KEFRI	Mississippi State University
	KFMP	Donated
	KMD	Direct Purchase, Donated, External Grant
	KMA/AGRIC. DEPT.	N/A
Nigeria	FSD	Direct Purchase
	FRIN	N/A
	NMSD	Donated
	FORMECU	N/A
	FEPA	Donated, External Grant
South Africa	(a) ENPAT (b) GIS	(a) Direct Purchase (b) Direct Purchase
	CSIR/FORESTEK	Direct Purchase
	GIMS	Direct Purchase
	ISCW	Direct Purchase
	CDSLI	Direct Purchase
Zimbabwe	ERSI	GTZ Funded
	DEPT. of NAT. RESOURCES	Donated
	FORESTRY COMMISSION	Donated

Appendix 4: Strategic Framwork for the Processes and Mechanisms of Establishing Space Technology at the National Level



TRAINING AND EDUCATION ISSUES FOR IMPROVED USE OF SPACE SYSTEMS IN DEVELOPMENT PROCESSES IN DEVELOPING COUNTRIES*

J.B. Williams and C. Conroy
Natural Resources Institute
University of Greenwich
United Kingdom

INTRODUCTION

Technology for the generation and communication of data and information is now developing so fast that it is almost impossible to keep up-to-date, let alone plan for specific future capabilities. As potential users of such technology interested in sustainable national development, we need to look at the real needs for data and information in developing countries and help enable access to those aspects of space (and other) technology which help meet these needs in cost effective and sustainable ways.

Information is the lifeblood of industry, commerce, sustainable development and education. Ours is the Information Age, with the Information Superhighway and the Data Explosion. Since one must be Information Organised to take advantage of these opportunities, perhaps the primary purpose for Education and Training, in this context, is to help people and institutions to organise themselves to be able to make best use of the tremendous range of space assets, current and planned, for the purposes of national development. This is not a trivial task and the problems are primarily institutional. This is because while information needs are complex and changing, and our technical capacity to meet these needs is changing very rapidly, governmental institutions are much slower to change in response to both demand and supply. This is both a problem and major opportunity for training and education.

Background

The views presented here are derived from three sources:

1. First, a distillation experiences of the Local Application of Remote Sensing Techniques (LARST) approach to meeting the information needs of resource managers through direct "local" access to appropriate satellite data streams. Over the last eight years NRI and LARST collaborators have worked this way in more than 30 developing countries in early warning, resource management and environmental protection domains.[13]

2. Second, from participation in an *Analysis of the Constraints and Opportunities for Cost-effective Implementation of Earth Observation Techniques in Developing Countries* for the Commission of the European Communities: DG XII [5], which required a global perspective. A summary of conclusions is

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This paper, which was presented at the UN/IAF Workshop on "Education and Awareness: Space Technology and Applications in the Developing World," 3-6 October 1996, in Beijing, China, does not necessarily reflect the views of the United Nations.

presented in Annex I.

3. Third, a look at generic factors influencing the use (or non use) of natural resource and environmental information in national development processes, which examined institutional issues in some depth.[2]

Basic Issues

There are two important issues arising from the above work which need restating as the basis for any discussion of the role of space technology in developing countries:

1. **Surfeit of data.** In most countries there is already a glut of data. At the same time there is often a severe shortage of useful information in developing countries and in particular, a chronic under-use of NR information in high level decision making.[3] As planned space communication links and Earth Observation System satellites become operational, the glut is likely to become a vast super-abundance. This is both a problem and an opportunity. It also has bearing on data policy issues.

2. **Widespread Ignorance.** The level of ignorance concerning the potential utility of Earth Observation on the part of "people who should know better" is still extremely high. Satellite remote sensing for the majority of people is not considered an option; it is seen as either irrelevant or prohibitively expensive or both. For the majority of people in developing countries who have considered using EO data, it is seen as both expensive and difficult to access.

Positive Points

The many positive outcomes from the different works include:

1. There are very many potential users of EO techniques and other data sources who do not need sophisticated processing of data or high-powered telecommunications links. Remote sensing techniques can be straightforward, practical, inexpensive and effective.

2. Satellite data can be very powerful with several comparative advantages over other data sources. Technology development is completely changing the information environment, making many current working practices inappropriate.

3. Where satellites provide new sorts of data for which "user structures" do not already exist, it will take time and assistance for institutions to evolve and make best use of these opportunities.

4. While Natural Resource and Environmental Information is not well used by many governments (especially in developing countries) and EO potential is grossly under-utilised nearly everywhere, it is imperative for the future of our planet that this situation be rectified.

5. India presents an excellent example of what can be achieved by becoming information organised through the use of space techniques.

6. If space systems are to contribute more to national development processes in developing countries, then an understanding of an understanding of the role of information in these processes is important. The following analysis, although not specifically targeted at space technology, does carry some important generic messages.

INFORMATION AND NATIONAL DEVELOPMENT PROCESSES: AN OVERVIEW

Developing countries tend to be information poor in spite of the vast amount of data currently being generated globally. The capacity of persons and institutions to process data sets, assimilate them and use the derived information can be very restricted. Without doubt there is a need to improve information structures in developing countries in order to ensure better decisions at all levels. Such structures must remain in proportion to the capability of institutions to respond in accordance with the information gained. This is the essence of organic growth and balanced development. It is not correct to assume that because information is in short supply, any new source of data will be beneficial. Unless it is recognised as a priority, new data may only serve to distract trained people and resources from more productive activities. It is equally erroneous to see donors as end-point customers with significant needs for data separate from those of developing countries.

Problem Statement

Ever growing pressure on natural resources and the environment requires a spectrum of better, more harmonious and timely political, economic, social, technical and managerial decision making. Such increasingly complex decisions are more likely to be appropriate and effective if they are based on reliable, well organised and up to date information. In particular, effective incorporation of environmental considerations into developmental planning is hardly possible without well informed decisions. Unfortunately, in many developing countries existing data networks are decrepit and weak, the institutions concerned are unable to cope with changing needs, and information "systems" are fragmented and slow.

While the products of the information revolution offer unprecedented opportunities for enhancing technical capacities of institutions, improving data flows and information management processes (e.g. through using PCs, remote sensing and GIS), better and more information does not automatically lead to better decisions, better plans or better management.[8] Good environmental information may be a necessary condition for good environmental management, but experiences have shown that difficult issues associated with decision support, together with problems of institutional structure, capacity and sustainability (the vital but often fatally weak links in the chain) also need to be addressed. Strengthening these weak links, and helping less developed countries better organise their information and decision-making processes, is a high priority requirement for improving national development processes.

Why Information is Important

Reliable information is essential for a number of functions in the natural resources and environment sectors: policy formulation, planning, investment, management, regulation; and project appraisal, monitoring and impact assessment. These functions require a continuous effort to monitor the qualitative and quantitative characteristics of the resource base and environmental conditions. It is critically important that governments are able to keep track of progress (or setbacks) toward achieving policy objectives in the environment and renewable natural resources sectors so that corrective action can be taken when necessary. Unless decisions are well-informed it is unlikely that they will enhance the sustainability of development and all too likely that they will undermine it.

Good government

The provision of environmental information is an important aspect of two characteristics of good government—competence and accountability.[10] The utilization of accurate and up-to-date environmental information is an essential ingredient of the competence of governments to formulate sound policies, and make timely decisions, in the renewable natural resources sector. The political and executive elements of government can only be held fully accountable for their actions if relevant information is available in the public domain. Overall, public access to environmental information is a powerful tool for democracy and good governance.

Growing Demand for Environmental Information

Demand for better information in-country often stems from senior economists running the economy right through the resource managers in different disciplines and on into Non-Governmental Organizations and educational establishments.[7] In addition, during the last few years there has been a growing recognition of environmental information needs, and a corresponding increase in demand for environmental information.[4,11] This is reflected in the fact that UNCED Agenda 21 devotes a whole chapter to the subject, and that recent international conventions make numerous references to it. Another area of increased demand comes from donor agencies and their increasingly thorough requirements for information throughout the project cycle, and particularly at the appraisal and impact assessment stages.

Previous Problems

Environmental information projects or initiatives have a generally poor track record in delivering useful products and development benefits.[8] One of the main problems has been the failure to identify priority user needs at the outset, with the result that the information supplied to potential users has not satisfied such needs. Another problem has been that technicians processing data have often failed to pass on information to potential users; or, where they have done so, it has not been on a timely basis or in a user-friendly, easily understandable form. Lastly, often little or no consideration has been given to the capacity of the intended user to make effective use of the information once it has been received and understood.

Co-ordination problems between different institutions are common and major constraints on effective use. They include overlapping mandates, misunderstandings between information suppliers and users, and barriers to information exchange of a technical, political or financial nature.

As with projects in other sectors, there have been major problems in sustaining benefits (in this case the continuing effective use of environmental information technologies)—relating to finances, technical problems and the availability and retention of skilled personnel. This applies particularly to high-tech projects, which have been introduced largely through donor support; when this support has ended the capacity to utilize the technology erodes.

The Way Forward

The effectiveness and sustainability of environmental information provision can be greatly increased if lessons are learned from previous experience. Drawing on experience to date, five guidelines are identified to help make future Environmental Information projects effective, which, though obvious, have frequently been overlooked. They are:

1. Make sure that all components of meeting environmental information systems (EIS) are geared to meeting users' priority needs

2. Check that users have, or are likely to have, the mandate, political will and resources to act on the information generated

3. Promote ownership of the system through the participation of relevant stakeholders

4. Check that all of the information required to make a system effective (e.g. social and economic data) is, or can be made, available

5. Optimal sequencing; start at an appropriate level and demonstrate early "success," through benefits to participants

It is essential that EI initiatives include capacity development measures to remove or overcome any factors likely to act as major constraints on their effectiveness and sustainability. Appropriate capacities are required at several levels, from the macro to the micro, namely:

(a) the broad action environment (the milieu within which organisations operate);

(b) the public sector context (e.g. the legal, regulatory and policy environments);

(c) the task network (the linkages among organisations that facilitate or constrain the performance of particular tasks);

(d) organisations and their management (structure, systems and processes);

(e) training and education of relevant staff.

In the past, environmental information projects have tended to focus on constraints at the micro end of the spectrum (d and e, notably training), while ignoring higher level capacity constraints. Ultimately, capacities at the higher levels are likely to determine whether or not environmental information initiatives are effective and sustainable.[1,12]

For example, at the level of the public sector context, the mandates of institutions involved in the supply of environmental information must be consistent with their new roles and modes of operation (e.g. charging for products) if their efforts are to be effective and sustainable. At the same time, at the task network level, there must be appropriate linkages between information users and information suppliers that enable the former to exert an continual influence over the latter, thereby ensuring that the suppliers are responding to their priority needs with quality products on a timely basis.

The Strategic Development of Information Networks

The adoption of a well thought-out capacity development strategy provides a coherent, organised framework for the evolution of an integrated and broadly-based network approach to the supply and management of environmental information. Such an approach has the potential to greatly enhance the benefits obtained, as information may then have several applications instead of just one. In addition, by involving stakeholders from different sectors (such as different RNR ministries) in the sharing of information, an integrated system can facilitate better understanding between them and move towards a common, mutually acceptable information base for concerted negotiations, policy formulation and decision-making.

Until now many sponsors (e.g. donors) have tended to prefer projects that are relatively narrowly focused in terms of the application of environmental information, such as the installation of a remote sensing system in a forestry department for forest protection and management. This sectoral approach has many advantages for the donor and recipient organisation. Since there is often relatively little co-ordination between "information" projects, and among donors supporting such projects, implementation is somewhat piecemeal. Consequently, benefits are less than they would have been if the inputs had been considered as part of the whole process of improving environmental information and decision-making in the country concerned.

A more coordinated, broadly-based and evolutionary approach to the development of environmental information and its management would be more effective, especially one that takes account of the overall institutional context, and any plans to develop it (e.g. national environmental action plans [NEAPs] or sustainable development strategies). This would enable both indigenous (host government) and donor support in specific sectors to complement other efforts in a much more co-coordinate manner. As more countries adopt NEAPs, national sustainable development strategies and the like, opportunities for this kind of coordinate approach are increasing.

Within the above analysis, many points can be drawn both for the role of space technology, and the needs for better research, education, training and awareness raising.

CHANGING INFORMATION NEEDS: CHANGING OPPORTUNITIES

The priority information needs of decision makers guiding national development processes are changing. Today, the pressure on resources is much greater than it was only twenty years ago, and rates of change (e.g. in population growth, urbanization, demand for fuel-wood or water, terms of trade) can be much faster and more unpredictable than before. While in decades past the requirement on senior decision makers was more to assess resources and plan to avoid future conflict in a relatively stable paradigm, plans today are often out of date by the time they have been formulated, and response management is becoming the order of the day in many sectors, as demonstrated by the number of food early warning systems. Economists and businessmen have adapted their procedures accordingly; they monitor economic conditions more or less continuously and intervene accordingly. For example, in many countries seasonal variation in the natural resource base (e.g. drought) is a highly significant perturbation to the economy. Where intervention options exist, demand for timely information on the changing seasonal state of the resources base is growing. The more that coherent and reliable information can be made available to meet the needs of such decision makers, the more it will become an essential requirement. This synergy, or combined development process is a matter of commencing with something practical, and improving the service in parallel with educating the decision maker as to what else might be provided, if and when required. It takes time, requires a concerted research, training, education and awareness raising effort, and the benefit of the output must clearly justify the cost of the service.

The three principal institutional domains, i.e. Government; Commerce, Business and Industry; and NGO/Education/Community, all contribute to the national development process and all have important information needs, as indicated in Figure 1. This figure maps out in a rather generalised way some of the important areas of information use across the public and private sector, but does not show which uses of information are more time sensitive, beyond the major decision/knowledge distinction. This latter distinction is of fundamental importance, because decisions of consequence need to be taken whether or not sufficient information is available, and the primary value in having data or information is not realised until it is used to improve decision making. With the current data glut, activities that add to the stock of knowledge are usually a lower priority in the development process than enabling better resource management decisions, for example. This is not to downgrade the importance of education and training, but rather to insist that they be relevant and related to national development needs.

Business. The specific information requirements of the private sector in development processes are not of primary interest here. Business persons are usually quite capable of looking after themselves. Investment decisions cost real money, so successful businesses use information to guide investments and their management. Where appropriate, they make good use of satellite or airborne remote sensing to meet their specific requirements, their specific needs usually being purchased from other private sector information services. When satellite remote sensing first became practical, many companies (e.g. oil and mineral exploration) invested in remote sensing equipment and personnel. This quickly changed as they found it more economic to buy in the services from specialised companies as and when required.

PUBLIC SECTOR								.... PRIVATE SECTOR					
GOVERNMENT						NON-GOVERNMENTAL			BUSINESS COMMUNITY			Decision Levels	
ECON	MOD	AGRI	ENV	WATER	HEALTH	UNIV INST.	SCHOOLS	NGO/PRESSURE GROUPS	INDUSTRY	AGRI BUSINESS	INFO SUPPORT SERVICES		
★★	★	★	★	★	★	★		★				Policy	INTERVENTION
★★	★★	★★	★★	★★	★★			★				Planning	INTERVENTION
★★	★	★	★	★	★				★★	★		Investment	INTERVENTION
★		★★	★★	★★	★★	★		★	★	★★		Management	INTERVENTION
★		★★	★★	★★	★★	★		★				Regulation	INTERVENTION
★	★★	★	★		★	★		★				Security	INTERVENTION
★★	★★	★★	★★	★★	★★	★★		★	★	★	★★	Data	KNOWLEDGE
★	★	★	★	★	★	★★		★				Research	KNOWLEDGE
★	★	★	★	★	★	★						Training	KNOWLEDGE
						★	★	★★				Awareness Raising	KNOWLEDGE
						★	★★					Education	KNOWLEDGE

Figure 1. Organisational Responsibilities and Decision Levels : Needs for Information

Government. The information needs of government are intimately linked to decision making. Figure 2 is designed to demonstrate that in most countries the greatest numbers of decision makers and decisions are likely to be found at local and community scales. While these decisions may not have the importance of a national statement on policy or require the same level of data processing, in their accumulated abundance they are of fundamental importance to the national development process and represent a market largely ignored by remote sensing specialists. They are arguably unserviceable through the big business approach to Earth Observation, which seems to find processes at regional scale more attractive, in spite of the absence of regional decision makers.

	Administrative units: typical number per nation				
Decision Purpose	local community 10000	district 100	province 10	nation 1	regional / global
Policy			←——	——→ ······	······→
Planning	←······	······←——	————	——→	
Resource Management	←——	——→ ··	······	······→	
Regulation	←——	→······	······	······→	

Figure 2: Decision Making Scales: Natural Resources and Environmental Management

NGOs, Educational Institutions and Community. Until now, the needs for information in this sector has not been a prime target for the marketing arms of space systems, and yet this is where the greatest number of potential users are to be found. The market is of little commercial interest because the individual quantities of information required are usually small and numerous. Although the value of satellite imagery for social forestry and community conflict resolution is well established, it is difficult for NGOs to find funds to purchase images commercially. Similarly, in an educational sector starved of resources, the educational value of local up-to-date data may be recognised but access and price force it to remain remote.

CHANGING SPACE TECHNOLOGY: OPPORTUNITIES

From the developing country user viewpoint, space technology comprises telecommunications, earth observation, position fixing and message relay, with a bewildering array of potential. Satellites, which are reputed to be ideally suited to filling in the gaps left by terrestrial services, will certainly be looked at from that point of view by the user. If it is faster, cheaper and less hassle to obtain aerial photography than the equivalent satellite imagery, then so be it. On the other hand if it is less expensive to use pay-as-you-use satellite phones to service the need of remote areas than to put in expensive and little used terrestrial infrastructure, then so much the better.

Telecommunications (including message switching and position fixing)

Some of the more interesting opportunities, depending critically on cost, accessibility and socio-political acceptability in particular countries, that are now coming over the horizon include:

- The Information Superhighway/Satellite INTERNET links. Both asymmetric (1 year away) and symmetric (2-3 years off), which through competition are highly affordable and for which one only pays for the connection time that one uses

- Global coverage with mobile hand-held telephones

- Competitive commercial digital television everywhere

- Near real-time message switching from everywhere to anywhere

- High precision position fixing

Many developing countries, especially in Africa, have next to no real Internet access yet; communications are restricted by poor infrastructure. Soon getting even large data sets from anywhere to anywhere should become easy at low cost. To go from nothing to full interconnectivity (as was proposed under COPINE, for example) provokes questions. Is there currently available on the Internet much of use to decision makers in developing countries? Will the improved communication and all the extra data benefit developing countries when better and more information does not automatically lead to better decisions, better plans or better management? The advantages for education are easier to see, but how will political systems cope with sudden loosening of communication control? Implications for data policy, security and democracy can be seen as threatening.

Earth Observation/Remote Sensing

In a similar way, the exceedingly rapid developments in earth observation technology offer the user a bewildering array of opportunities. Besides the existing constellation of EO satellites (including the meteorological GMS series, NOAA polar orbiting series; high resolution optical: LANDSAT, SPOT, IRS -Series, MOS, ADEOS; and radar: ERS-1/2, RADARSAT, JERS) there will soon be:

- Commercial 1-m resolution images available within months (to supplement the Russian 2-m data)
- Direct reception of sub-10 metre resolution data onto PC due 1997 (Annex 2)
- Many Mini- and Micro- satellites, including those with the imaging capability of SPOT due 1997-98
- Chinese Brazilian Earth Resources Satellite (CBERS) due 1997-98
- U.S. EOS series starting in 1998 with AM-1, LANDSAT 7 and LANDSAT
- Supplementation and convergence of meteorological and POES satellites over the next 10 years

Four highly significant points from the above, for developing country users include:

- The data glut is set to increase several orders of magnitude
- Much more data will be freely accessible, or available at low cost
- The cost of producing high powered small satellites is decreasing by orders of magnitude
- The cost of the ground segment through direct access is decreasing by an order of magnitude

In the EU study, high cost and difficult access to data were widely recognised as major constraints on use of EO in developing countries. With ongoing and planned developments, the major comparative advantages of satellite remote sensing for national development purposes (i.e. timely, cost effective overview with easy repeat coverage for change detection) now seem set to become much more real for users all over the world, particularly with the spread of PC-GIS. In addition, reduced costs and better access will give users much greater say in the kinds of data needed, and hence design of future satellites. They have the option of joining the rapidly increasing number of space nations with their own cost-effective EO micro-satellites. Already, the big business technology push in EO is on the wane, and it is difficult to see how the restrictive and self-defeating European data policy can be sustained under evolving circumstances.

INSTITUTIONS MUST EVOLVE

It is essential that institutions evolve and keep pace with changing circumstances. In many countries, government technical institutions involved with data gathering and processing are not only out of touch with the changing needs of decision makers, but also have great difficulty adapting to the increasingly rapid changes in information technology. This raises the whole question of "institutional evolution in the information age." The radical changes in working practices now taking place in many industrialised and post industrialised countries are not achieved without trauma; in countries with more traditional working practices and less disposable resources, the problems of institutional reform can be even more problematic unless managed wisely. Rates of change are such that perhaps the famous "continuous revolution" called for by Chairman Mao will characterise our future in the information age.

During the EU study [5] it was recognised that profound institutional weaknesses in many developing countries restricted the effective use of satellite imagery (as many other sources of data) for improving governmental decision making. In the decision chain (Figure 3) it is the weakest link, which frustrates the effectiveness of the whole process. Before EO data can be used effectively to help with complex multi-sectoral decisions in national development processes, it is essential that large parts of the national information system be improved, integrated and made useful. This can be done with vision from the top, as in the Indian National Natural Resource Management System, or incrementally by providing incentives for existing technical institutions to evolve and harmonise their working practices towards common ends. In either case it can be argued that earth observation has a role in providing an framework for the process of organising the multiplicity of detailed data from diverse sources. In addition it must be asked whether, given institutional inertia and difficulty of training and retaining skilled IT staff in the public sector, there would be advantages in governments making greater use of more flexible private sector information service providers to help with reform and redevelopment of the national information system.

Networking

In areas where access is easily available, the Internet is used by all sectors of society: government, business, education, health, NGOs, media organisations, research institutes and private individuals. Participants benefit by taking out what they want and by making their data available for others to take as they may need: a cooperative information exchange. It is useful to reflect on the attributes of this free data market and how useful order developed out of near anarchy. A first step in improving developing country national information systems is to improve the data exchange network involving government, business and non-government/education (Figure 4). It is important that data of importance to national development processes be easily available and used by as many people as possible to improve the quality of their actions.

Government Technical Network

LARST has much experience working with many institutions struggling to improve environmental monitoring and information flow with very mixed success. Impact on decision makers could be very much larger with institutions tuned to today's requirements. Incremental network development for data integration is possible but needs careful planning and execution after extensive exploration of user needs and comprehensive institutional mapping. Institutions need incentives to share data, and incentives to evolve in harmony with changing needs. In many countries the clarity of vision and political will to address complex institutional reform does not exist.

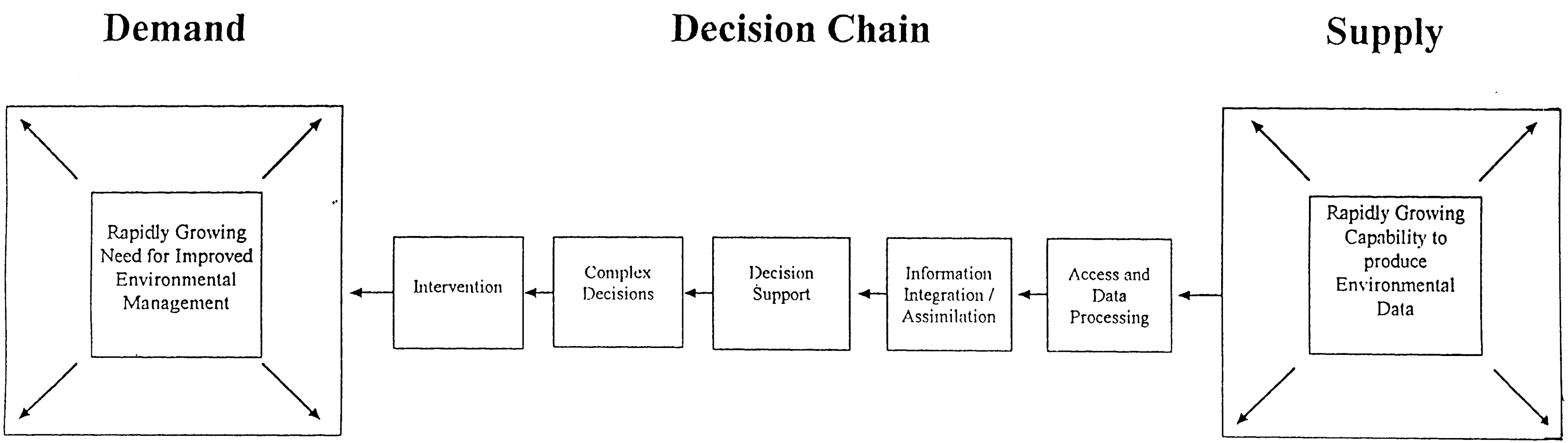

Figure 3. The Decision Chain. The growing need for better natural resource and environmental management especially in developing countries, is more than matched by the very rapidly growing capability to produce data. Intervening links in the chain however, are often weak.

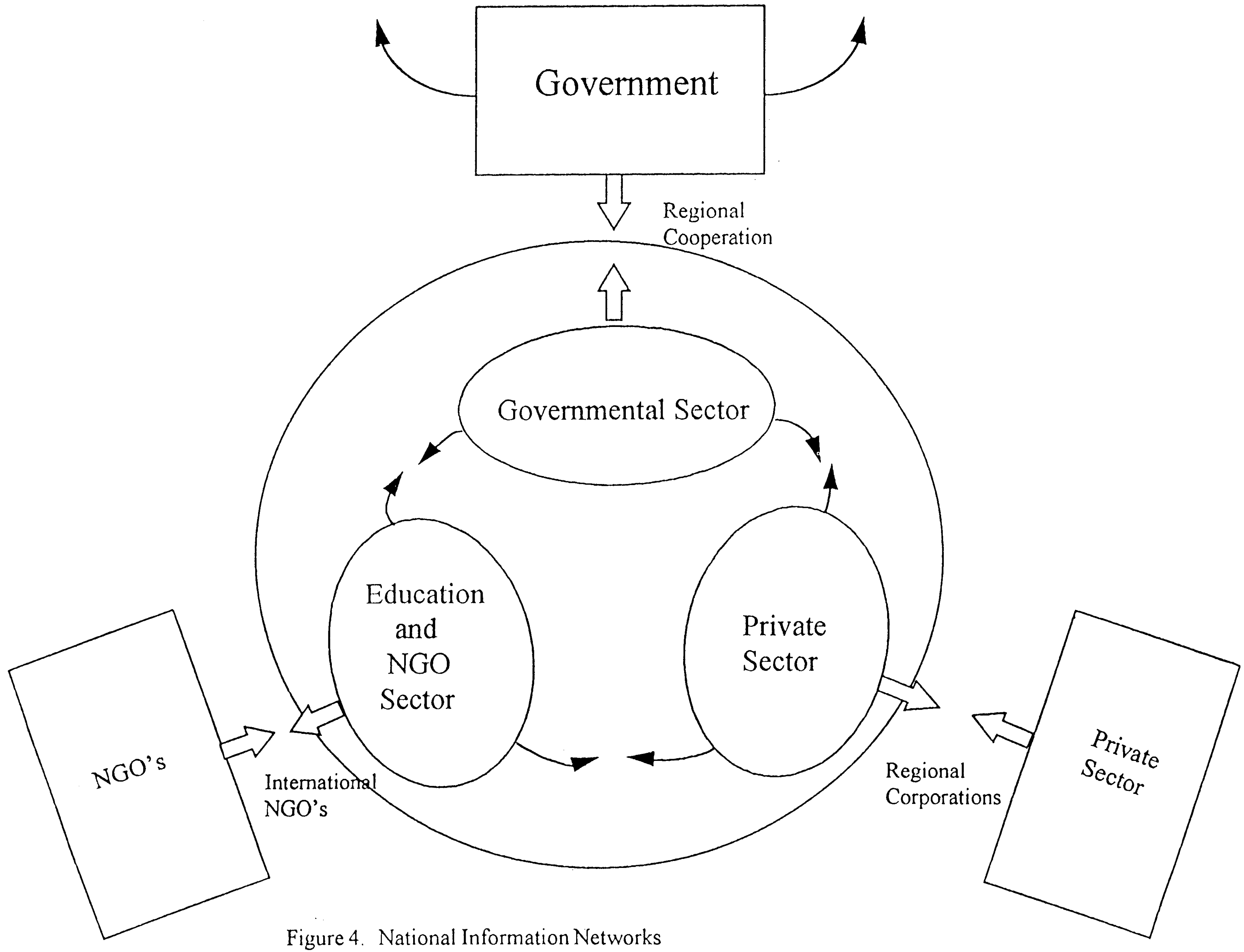

Figure 4. National Information Networks

IMPLICATIONS FOR AWARENESS RAISING, TRAINING, EDUCATION AND RESEARCH

Training and education in the use of EO techniques is an important and controversial issue. Van Genderen[6] summarised the issues well for the World Bank, and while many of the respondents to the EU study questionnaires identified lack of appropriate training opportunities, particularly in local languages, as a major constraint on proper uptake and use of techniques, the impact of large training programmes at regional centres, for example, is not always in proportion to the investment. Kabbaj and Mehrez[9] showed that little relation exists between the numbers who received training and the resulting development of the science in their home countries. Lack of application after training is usually blamed on subsequent transfer of trained staff to other posts, which while undoubtedly a problem, does tend to imply that either the wrong people were sent to be trained or the training received is not valued by the parent organisations concerned.

There is undoubtedly a great need for a relatively large number of resource managers and technical specialists in developing countries to know how to use practical EO techniques. In most countries there is little need and very few posts for highly educated/trained EO specialists, and a limited, if any, career structure to ensure such people remain operational. This inefficiency, coupled with direct loss of trained staff, is a really major problem for government departments considering or embarking on activities involving remote sensing. It is exacerbated by the high value of computer skills on the commercial job market. The priority must be to improve in-country practitioners (generalists) rather than remote sensing specialists. The greatest need is for people who can communicate across boundaries, assimilate data from a variety of sources and help with integration for practical decision making, rather than learn sophisticated theory. As institutions evolve under pressures to reform government, it seems more likely that much of the specialist roles will move to the private sector, rather than be kept under-employed and under-paid in government.

Remote sensing specialists, though extremely well-intentioned, are without doubt very much part of the problem. They tend to have academic backgrounds and are used to producing detailed, geographic, time-insensitive studies without experience of obtaining information for making practical decisions or providing advice for such. The result is misdirected development and application of EO techniques using overly complicated and expensive techniques and in a language unintelligible to the potential customer. Along the way much of the very real comparative advantage of using satellites to provide useful information has become overlooked.

Awareness Raising, Decision Makers Development Processes

Awareness raising is absolutely vital, but if it is not done sensitively then it will be counterproductive. It is particularly important that the senior decision makers in organisations are aware of what can be done to meet their precise information needs in cost effective and timely manner, without the need for major investment. Awareness raising is best undertaken by discipline specialists (e.g. agricultural, or water resource, or protected area managers trained to use RS techniques) rather than remote sensing specialists. It must also be borne in mind that in most countries one is starting from a point of near total ignorance on the part of the decision maker. This process of educating the user applies in Europe as much as anywhere. The major exception is in India.

Awareness Campaign. There is need for an organised awareness campaign showing many practical examples of exactly how natural resources and the environment are better managed, and the vital role of gathering and using good information from available sources (as EO) for the decision processes involved.

Media Dissemination. Television is spreading very rapidly in many developing countries and is ideally suited to dissemination of awareness on EO techniques which are visually attractive. The scope for better targeted media dissemination is considerable, both promoting EO and using EO to promote environmental awareness.

Honest Broker. Potential and new users of remote sensing often need a relatively impartial source of advice on the many practical options available to satisfy their requirements in the most cost effective and sustainable manner. Finding an honest broker is not easy, especially in a fast changing world, where increasing competition encourages vested interests to press for short term gain.

Training

As discussed above, and exemplified by the Indian example, the most productive training is that targeted at local resource managers, decision makers and people with a need to know. EO needs to be considered as a tool or technique (like word processing) that anybody, ordinary people, take up and use when appropriate. As such, training courses need to be highly practical, based on local examples and local facilities, with the emphasis on simplicity rather than virtuoso complexity. The most sustainable way to encourage this is through local universities. The record of regional institutions in this arena is mixed, particularly when training is divorced from needs, facilities and services available back home. Although remote sensing is ideal for regional and trans-boundary resource management, the number of supra-national or regional decision makers is not large.

There is evidence from many countries that universities are developing the important capability to provide a practical local introduction to EO techniques. There is need to concentrate on training these university trainers to make best use of the materials available to them, for as wide a variety of local applications of EO techniques as possible. As government institutions evolve (or not) with changing pressures, the need for well targeted short course training and provision of information services is certain to increase. Scope for an enhanced role for local universities across the board—in awareness raising, training, education, research and even consultancy—appears highly promising, given a practical lead and amenable policy environment for such initiatives.

Education

It is particularly important that as many graduates as possible are both aware of the rates of environment change and aware of how to make use of straightforward EO techniques for long term improvement in environmental management when required. Again, emphasis needs to be on EO techniques as tools to be used rather than on the technology alone. Developments in communications and direct reception of EO data appear highly promising in this domain. The LARST group is working to reduce reception costs sufficiently to get them within reach of universities in areas where the Internet is not yet sufficiently reliable.

If remote sensing is to have impact at community levels then it is also important that schools also start the process of raising environmental awareness through introducing straightforward EO techniques to their pupils, as has started in India. There are many virtues in the use of hard copy rather than digital imagery, as came out in the EU study, particularly for resource conflict resolution at community level. Use of Space technology does not have to be complicated, expensive and riddled with jargon.

Research

Satellite data is ideal material for research activities and geographical studies, as evinced by the extremely high proportion of academic activities bearing no relation to decision makers needs reported at remote sensing conferences. There is real need to bring more of these techniques and skills into practical application. One of the problems being that under many educational and research regimes most merit goes into individual development of novel techniques rather than collective assimilation (integration) of activities into a coherent whole. In country after country one sees environmental scientists struggling to generate new data rather than starting at the decision makers needs and working backwards to see what data is available to meet these needs, and what extra is required. Local reception of timely data provides a cornucopia of opportunities for applied research oriented towards adapting proven techniques to meet local conditions for operational monitoring and resource management. It can only lead to greater utilization of techniques.

The Indian Example

The whole approach to EO adopted in India is refreshingly productive. The Indians frankly acknowledge their initial debt to ITC in the Netherlands for helping them to adopt and adapt techniques being developed in the 1970s. From then on they steadily developed their applications under the direction of the user ministries. Their awareness raising of decision makers, incorporation of short- and long-course training for discipline specialists through local Universities, and outreach to schools is all exemplary. Research on new techniques is led by discipline specialists. Conflict between government and private sector is avoided by the data being sold inexpensively to the private sector service companies, which are left alone to meet the needs of commercial enterprises. The net result is that through the NNRMS, the Ministry of Rural Development feels that it has an active say in the running of the Indian Space program, which is more than can be said for most other countries in the world.

LARST Experiences

Our own experiences with awareness raising and training on the LARST programme has been informative. It is clear that as a tool, remote sensing is best learned on the job in practical situations. Remote sensing specialists have been found remarkably impractical in the main. Discipline specialists learning to use this powerful tool for their own purposes is by far the most effective means of transfer, and frequently enables totally new applications to be developed. In addition, young people, keen to learn and apply their knowledge for the national benefit can attain quite remarkable levels of achievement and innovation, given the tools and access to data streams. Under these circumstances, workbooks and computer-based training packages are remarkably effective at transferring skills in an unstable labour market.

CONCLUSIONS

1. Space Systems already offer much to national development processes in the more organised developing countries. The future appears burgeoning with further potential.
2. Outdated institutional practices and weak national information systems are the major constraints to better uptake and use of satellite EO and telecommunications by developing country governments. In order for the new information technologies to be used most effectively for national development processes a country's institutions need to be well organised. Further technological push without addressing institutional weaknesses is unlikely to achieve much.

3. Information technologies can be used to help institutions evolve and become more focused and organised, where there is sufficient political will and appropriate data policies.

4. Open and efficient data exchange networks are likely to be particularly useful in developing countries, to maximise use of data and information available and minimise unnecessary duplication. Countries need to combine the best efforts of government, private sector, educational institutions and NGOs. Incremental development of systems is possible given adequate direction and incentives for participators.

5. The role of awareness raising, training and education is integral to the whole process of transforming institutions to cope with the information age, and the process of improving the national information system. Awareness raising in the higher levels of the decision processes in parallel with clear understanding of needs and demonstration of existing capabilities is an essential first step.

6. There is need to invest in educational institutions, NGOs and private sector in association with practical project activities directed towards improving information management and integrated decision making in government. It is better to train discipline specialists to use the new tools, and empower them with good access to satellite data, rather than train remote sensing specialists and hope.

7. Better incorporation of universities in the environmental management process is a major opportunity for the future. Education, training, research and awareness raising need to be coordinated better. Opportunities exist for encouraging university departments to establish commercial capability in the environmental consultancy market. Local expertise making use of local EO can be very powerful and provides a useful counterweight to the often overbearing relative strength of government structure. Informed and independent "whistle blowers" are an important part of environmental management. Universities can also make good use of data sets available within national information networks. Their role in independent analysis, checking data consistency and as guardians of quality control should not be underestimated. They need access to local data and distance learning packages designed for local conditions.

8. Remote sensing is easy. Attempts need to be made to introduce relevant local material for use in schools, so that NGO and community use of EO data becomes easier.

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ANNEX 1: EOS 1996

Analysis of the Constraints and Opportunities for Cost-Effective Implementation of Earth Observation Techniques in Developing Countries: Conclusions

A. The main conclusions of the study for EU DGXII were:

1. Existing EO resources are not well used. While cost-effective implementation of EO techniques is feasible and uptake and use are definitely on the increase, there is a major bottleneck which requires positive intervention for its removal.

2. The main constraints on operational utilization of EO techniques in developing countries are:

    - the present centralised ground segment and data "marketing" system which effectively restricts access to data

    - the lack of adequate information management and decision making structures to benefit from improved information flows

    - the inappropriate technology push of poorly focused EO projects

As a consequence, EO has a poor reputation, especially with donors.

B. Circumstances are becoming more favourable for the use of EO data:

- The need for timely resource management information is becoming greater as a consequence of increasing rates of environmental change

- Environmental monitoring and management are very much higher on national and international political agendas than five years ago, and the need for better national information management is widely recognised

- There is growing recognition of the need for (and advantages to be gained from) better organisation of the global observing systems

- New technology allows all these needs to be satisfied very much more cost-effectively than ever before

C. There are several actions that the European Union could take to remove current constraints and to ensure that in future developing countries derive much greater benefits from EO data:

- **Policy Actions** to improve accessibility to basic data. Europe needs the vision to join the Americans and Japanese in promoting a more open EO data policy.

- **Development Assistance Actions** to help develop structured national and international information systems that prioritise the decision making needs, processes and capabilities of the user community, and the transfer of EO techniques as appropriate.

- **EO Technical Actions** to improve both ground segment efficiency and space segment orientation. Advances in micro-electronics now permit high volume/low cost "personal remote sensing." Europe needs to liberate EO from its mainframe past and enable the millions of potential small users worldwide to participate in using EO data to help meet their needs. The future comprises direct local data reception from multiple low cost small satellite missions with product dissemination via the information super-highway.

ANNEX 2

The Local Applications of Remote Sensing Techniques Approach to Integrated and Sustainable Environment Monitoring (ISEM)

LARST activities seek to empower resource managers and aid decision making and response interventions in developing countries through direct access to satellites by means of PC based receiver systems. The most immediate development objective of the LARST group is to develop methodologies for environment monitoring in developing countries that are both integrated and sustainable. While originally LARST projects tended to address narrow or single factor resource variation, more recently direct reception and use of NOAA data has been increasingly accepted and made use of by a wider range of specialist colleagues, and is increasingly incorporated as a small but vital component of much larger projects. The basic idea with ISEM is to use the benefit realisable from better management of natural resources to sustain routine, operational satellite data reception activities. Simultaneous use is made of the same data for other environmental monitoring purposes (the benefits of which may be more difficult to quantify, or not able to justify significant investment until proven, or of lower priority today, but which are relevant to decisions made today). While such an approach may be attractive to decision makers in country, and in principle to donors, in practice they present administrative problems, and raise complex (but not insurmountable) institutional difficulties on the ground. LARST has made considerable progress in this direction since starting in Sudan in 1988. An interesting outcome arising from the economically important seasonal variation in resource quality and quantity as a result of the weather, together with their easy access to meteorological satellite data, is that national meteorological services are increasingly being seen as real-time environment monitoring units with a vital role to play.

LARST low-cost High Resolution satellite data Reception Systems (HIRRS)

Recognising the need for inexpensive local access to higher resolution satellites in developing countries, LARST has been working for some years now on developing lower cost access to higher resolution satellite data such as ERS-SAR, JERS, ADEOS, SPOT etc. Applying the same principles that were used for access to the NOAA data, (i.e. that most users can be found within a few hundred kilometres of the receiving station) to design and build a multiple satellite, high angle receiver system with the smallest dish size possible. Development is completed and commercial manufacture of systems is underway for early 1997 production. A price tag of around $500,000 will provide above 45° reception from three satellites onto PC, in a user friendly and easily transportable system. This tool is expected to become an important part of LARST activities in developing countries, and an integral part of integrated and sustainable environmental monitoring.

ENHANCING THE USE OF SPACE TECHNOLOGY IN DEVELOPING COUNTRIES: A Review of the Formal Recommendations Made at Meetings Organized by the United Nations Office for Outer Space Affairs*

H. George
United Nations Office for Outer Space Affairs
Vienna, Austria

INTRODUCTION

The United Nations Office for Outer Space Affairs (OOSA) each year organizes approximately seven to 10 meetings in different geographic regions of the world (Asia and the Pacific, Africa, Latin America and the Caribbean). These meetings are aimed at enhancing the use of space technology for supporting national development and include regional conferences, workshops, seminars and training courses covering subjects ranging from applications of space technology to basic space science.

In general, the theme of each meeting is selected to respond to specific current regional needs. An example was the 1995 Workshop in Zimbabwe on "The Applications of Space Techniques to Prevent and Combat Natural Disasters." This theme was particularly relevant to the needs of countries in southern Africa that had been suffering through severe recurrent drought conditions over several years. Another example is the 1995 Training Course in Libreville, Gabon, on "The Use of ERS-1 Data for the Mapping and Inventory of Natural Resources." One of the main objectives of this course was to train specialists from French-speaking countries within the sub-region in the analysis of satellite radar images being collected by the mobile receiving ground station located in Gabon.

Following formal discussion and debate, recommendations for addressing specific problems are usually formulated at the conclusion of each meeting. These recommendations often reflect the diverse backgrounds and origins of the various participants, for whom work settings at both the national and regional levels may differ considerably. Nevertheless, it appeared that many similar recommendations were repeatedly being made at the various meetings organized by OOSA, regardless of the specific geographic region of the developing world. This implies a broad similarity in the nature of problems confronting a large proportion of developing countries in the use of space technology. A more formal analysis of the recommendations of recent meetings could therefore reveal some potentially useful clues to national and international entities involved in space-related activities in order to refine and/or reorient their programs in ways more responsive to the evolving needs of developing countries.

This paper presents an analysis of the formal recommendations made at 12 OOSA meetings held between 1994 and 1995. Of the meetings analyzed, one was held in the Asia and Pacific region, two each were held in the Africa and the Latin America and Caribbean

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**This paper, which was presented at the UN/Sweden International Training Course on "Remote Sensing Education for Educators," 6 May to 14 June 1996, in Stockholm, Sweden, does not necessarily reflect the views of the United Nations.*

regions, while the remaining seven meetings were held in different locations throughout the world where participants from all three of these regions were present.

Recommendations are usually directed to entities which, by their respective mandates and activities, are in a position to make interventions serving to remedy the problems identified. Examples of such entities are international organisations, including OOSA and members of the United Nations family of agencies; space agencies and national organisations involved in space-related matters.

SUMMARY OF RECOMMENDATIONS

The detailed recommendations from the 12 meetings held in 1994-95 were retained for analysis. The recommendations have been grouped into five main subject categories: (i) information access and exchange, (ii) national framework, (iii) training and education, (iv) cooperation, and (v) introduction of space technology.

The principal problems or issues targeted by the various recommendations and the proposals for suitable remedial mesures are summarized in the paragraphs below. The relative frequency of recommendations by category is presented in a subsequent section.

Information

One of the major obstacles in the use of earth observation data is the high purchase price of high spatial resolution satellite images *when these are available*. Other concerns relate to the inadequacy of satellite receiving stations in certain geographic areas (e.g. Latin America and central Africa), and the need for continuity in the collection of earth observation data over developing regions. The cost of images often place the operational use of high-resolution satellite imagery outside the limits of affordability for many end-users, especially public institutions in developing countries faced with severe budgetary constraints. Various suggestions for remedying the situation include the reduction of copyright restrictions, and the introduction of a multi-tiered, more liberal, pricing policy by space agencies.

Recommendations also focussed on the need to improve information access and exchange for a variety of end purposes, including policy formulation, education and training, regional collaboration as well as decision making in various development sectors. Some of the suggested solutions include the creation of permanent regional programmes or clearinghouses of information on specific subjects, the creation of national focal points, and the creation of national, regional and international electronic networks.

At a number of meetings, calls have been made for developing countries to increase the opportunities at the regional scale for the sharing or pooling of expertise and operational experiences. These opportunities would allow developing countires to learn from each other, and thereby better promote the use of space technologies for solving problems which are common to countries within a given region.

Also related to the general question of availability of information, is the issue of the need for increased awareness by the public, in general, and decision makers, in particular, on the potential contributions and cost-effectiveness of space technology to national development objectives. Recommendations for improving awareness include the introduction of appropriate curricula at universities, the use of roving "ambassadors" from countries which have benefited from the use of space technology, and simply better publicity of space technology.

Education

Participants at a number of meetings have indicated that potential users of space technology lack sufficient training. In addition, there is a need to organize the content and duration of training courses in such a manner that would result in immediate operational application of the techniques learned. Consequently, recommendations have been made for more opportunities in short- and long-term training and education in space technology, as well as an increase in the number of available fellowships and opportunities for on-the-job training. Calls have also been made for access to inexpensive software and self-study training packages.

Several recommendations also emphasized the need for continued and effective transfer of appropriate space technologies, the provision of technical assistance in certain applications, and the need for developing countries to conduct more research in aspects of space technology that are immediately, or ultimately, relevant to their development.

National Framework

Many participants felt that national regulatory, policy, institutional and legal frameworks have a significant impact on the use of space technology (e.g. restrictions on access to data and trans-border movement of equipment). Calls have therefore been made to revise these frameworks in a manner that would facilitate the integration of appropriate space technologies in the various development activities (e.g. disaster management and rural improvement). It has been recommended that these modifications be detailed in a national space policy for the introduction of space technology. Some recommendations also emphasized the need for senior prominent political support and the involvement of end-users in the development of space technology.

Cooperation

A number of recommendations highlight the point that the needs of developing countries were not being adequately reflected in the development of space missions. Suggestions for improving the situation include the creation of a cooperative mechanism between space agencies and developing countries for ensuring more input of the user community in these countries in the design of new sensor technology and ground systems.

Many recommendations also reflect the view that more regional cooperation is very desirable. In particular, greater cooperation at the regional scale would allow the sharing of operational experiences and enable access to scientific facilities. It would also facilitate the funding of programmes of regional interest as well as permit better access to regional data sources by national institutions.

The Introduction of Space Technology

In general, the recommendations relating to the introducton of space technology indicate that a progressive approach to the selective application of space technology that takes into account the merits of existing local technologies and practices is best. Furthermore, the recommendations stress that any planned space technology programme should respond to the objectives of national development and be designed with the benefit of impartial advice. Recommendations also call for greater involvement of the private sector and the initiation of pilot projects in the promotion of space technology.

RELATIVE FREQUENCY OF RECOMMENDATIONS

The theme selected for a meeting will influence to some extent the character of a recommendation, its categorization and by consequence, its frequency. Nevertheless, themes are sufficiently broad in scope to allow certain conclusions to be reasonably drawn from a comparison of the relative frequency of recommendations made for each of the five categories examined.

Based on relative percentages, it is clear that improved information access and exchange in matters relevant to space technology is of greatest concern to developing countries. (Figure 1) Almost 40 percent (45 of 114) of the recommendations made concerned information access and exchange. This subject was of concern at 11 of the 12 meetings analyzed. The majority of meetings (6 of 11) that made recommendations in this category were those where the participants came from all three of the developing regions of the world targeted in this study (Africa, Latin America and the Caribbean, and Asia and the Pacific). The results therefore cannot confirm whether information access and exchange is of greatest concern in each one of these regions.

Further breakdown of the nature of the recommendations made in the information category reveals that improved information exchange and better access to earth observation data are the major information needs. An important number of recommendations concerned the need to improve conditions pertaining to education (18 percent of total recommendations) and to regional and international cooperation (17 percent). (Figure 2)

OOSA'S RESPONSE

OOSA has long recognized the general need to improve conditions of information access and exchange in developing countries. This has led the Office to undertake a number of important steps consistent with meeting this need. Among these steps are the preparation of the COPINE proposal [1] and the placement of important sets of information on the World Wide Web, accessible through OOSA's home page (see box), the URL for which is:

http://www3.un.or.at/OOSA_Kiosk/

Other measures aimed at improving access to information currently under consideration or already being introduced gradually by OOSA include:

- dissemination by electronic mail of information on OOSA activities, including training opportunities
- development of introductory self-study electronic training courses in aspects of space technology
- use of e-mail conferences instead of conventional meetings or phone conferences
- fostering greater coordination, using innovative technology, with other units having space-related programmes
- use of live/taped sessions of meetings
- use of CD-ROM versions of conference proceedings
- dissemination of meta-information useful for initiating projects or other activities of regional to international cooperation in space technology (e.g. technical or policy aspects)
- preparation of concrete proposals for improving access to satellite data
- undertaking specific steps for improving access by developing countries to scientific and technical information related to space technology

Given OOSA's finite financial and technical resources, responding to the recommendations for better information access and exchange would entail some progressive re-orientation of current office activities. Thus, for example, it is now envisaged that the responsibility of organizing several training courses and workshops each year would be gradually transferred to the regional centres in Space Science and Technology Education, which are being established at the initiative of OOSA.[2] This transfer would yield the added benefit of enhancing regional collaboration among institutions, thereby responding to one of the concerns raised by developing countries discussed earlier under "*Cooperation.*" Regional centres for Latin America and the Caribbean, Africa, and Asia and the Pacific have already been selected.

CONCLUSION

The majority of recommendations made at OOSA-organized meetings in 1994 and 1995 indicate that better information exchange is the predominant need in developing countries in matters that relate to the use of space technology. Other important areas of concern are those pertaining to (i) adequate education and training, (ii) the regulatory, policy, institutional and legal frameworks, and (iii) cooperation at the regional and international levels. It appears appropriate for national and international entities involved in space-related activities to concentrate their efforts in these priority areas.

OOSA has already initiated a number of activities which go some way toward improving the problems of inadequate information access and exchange in matters related generally to the peaceful uses of space. Several new measures which will serve to further enhance OOSA's capability to aid developing countries in gaining improved access to information needed for development are being planned.

REFERENCES

1. George, H. 1995. Enhancing the complementarity of information-exchange networks in Africa: the COPINE initiative. Presented at the United Nations/European Space Agency Symposium on Space Technology for improving life on Earth, held at Graz, Austria, from 11-14 September 1995.

2. United Nations, 1993. Centres for Space Science and Technology Education. Document Number A/AC.105/534, 56p.

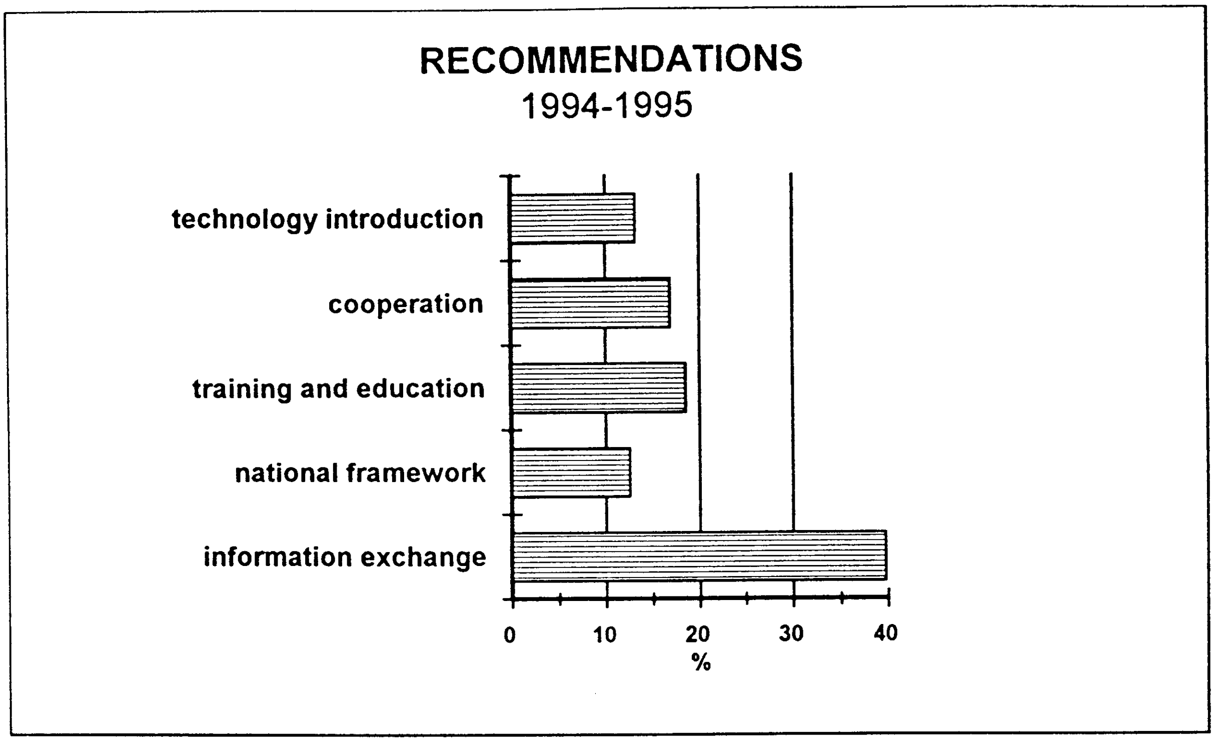

Figure 1: Percentage of recommendations made by subject category.

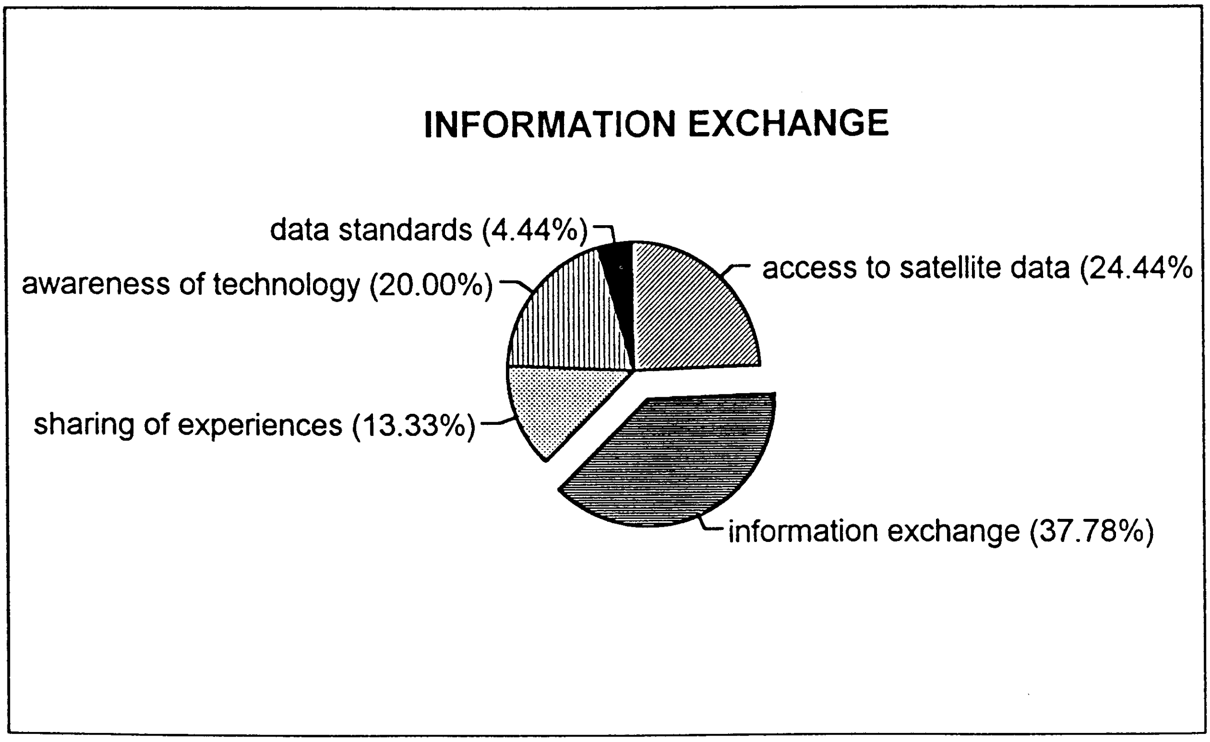

Figure 2: Breakdown of the types of recommendations made in the information-exchange category.

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List of meetings analyzed

Reference	UN document number A/AC.___/__	Number of Countries/ Participants	Event, location and theme
1/95_AP	105/623	14/14	Training course, Frascatti, Italy Applications of ERS satellite data to natural resources, renewable sources of energy and the environment
2/95_AF	105/613	9/25	Training course, Libreville, Gabon The use of ERS-1 data for the mapping and inventory of natural resources
3/95_LC	105/622	66/24	Regional conference, Puerto Vallarta, Mexico Space technology for sustainable development and communications
4/95_GB	105/624	21/52	Conference, Trieste, Italy Optics in Space science and technology
5/95_GB	105/615	38/64	Symposium, Graz, Austria Space technology for improving life on Earth
6/95_GB	105/612	38/77	Workshop, Oslo, Norway Space technology for health care and environmental monitoring in the developing world
7/95_AF	105/610	14/44	Workshop, Harare, Zimbabwe Applications of Space techniques to prevent and combat natural disasters
1/94_GB	105/589	12/?	Symposium, Israel Benefits of space technology for the developing world
2/94_GB	105/586	31/42+	Workshop, Graz, Austria Enhancing social, economic and environmental security through space technology
3/94_LC	105/596	12/24	Workshop and Training Course, Lima, Peru Workshop on global change and Training course on microwave remote sensing applications
4/94_AP	105/588	19/85	Workshop, Beijing, China Microwave remote sensing applications
5/94_GB	105/580	22/95	Workshop, Cairo, Egypt Basic space science

DEVELOPMENT AND APPLICATION OF AEROSPACE TECHNOLOGY IN POLAND*

Janusz B. Zieliński, Józef Jarosiński, Zbigniew Kłos, Zygmunt Krawczyk
POLSPACE Ltd.
Warsaw, Poland

HISTORICAL BACKGROUND

Science

In discussing the history of space research, one can hardly forget to mention the father of modern astronomy, Nicholaus Copernicus. Born in 1473 in the northern Polish town of Torun, he studied in Cracow, and at Italian universities in Bolonia and Padua. Copernicus also worked in Poland as a clergyman until his death in 1543. In about 1510, he formulated a theory for a heliocentric system of the universe; however this work was published only after his death. This great idea significantly contributed to the renaissance in scientific thinking and led later to the succeeding milestones in the human understanding of nature: the discovery of Kepler's laws in 1618, and Newton's theory of gravitation in 1687.

The influence of Copernicus' work can be seen and sensed in Poland in past centuries and today. Sciences like astronomy, physics and geodesy have always been at the center of interest in the research and university communities. The first full-scale Polish satellite experiment was launched in 1973 in commemoration of the 500th anniversary of Copernicus' birth and was named Copernic-500.

Aviation Traditions

In 1918, shortly after World War I, the first aviation factory in Poland opened in Warsaw, and the first indigenous prototype was ready by 1920. Regular production started that same year on Italian and French licenses. During the next few years, a significant aviation industry emerged, producing military and civil aircraft for domestic and for export needs.

Especially famous was the series of airplanes named RWD, after names of its builders: Rogalski, Wigura and Drzewiecki. They began working together in 1927 and designed a number of aircraft that posted many aviation records. In 1932, the pilot F. Wirko and engineer St. Wigura won the International Challenge, the most prestigious competition of the era, flying the RWD-6. The next year, two world records were set by a RWD-7 for speed (178 km/h) and altitude (6023 meters). In the 1934 Challenge, RWD-9s captured first, second, seventh and eighth places and set a new speed record (278 km/h). It is interesting to note that Stanislaw Rogalski, one of builders of the RWD model, took part in the design of the Lunar Rover as a member of the Grumman Laboratory team.

This paper, which was presented at the UN/USA "International Conference on Spin-off Benefits of Space Technology: Challenges and Opportunities," 9-12 April 1996, in Fort Collins, Colorado, USA, does not necessarily reflect the views of the United Nations.

In 1938, the PZL Mielec factory started to produce a bomber named Elk, which was a very modern bomber at that time. Also, Polish pilots maintained a glorious record during World War II, fighting on all fronts with the allied forces. Their contribution in 1940 to the defence of London against German air attacks in the Battle of Britain was acknowledged by Prime Minister Sir Winston Churchill.

MODERN AVIATION AND SPACE RESEARCH IN POLAND

Aviation Industry and Aeronautics

After World War II, aviation became one of the predominant industries in the Polish national economy, producing airplanes, helicopters, gliders, engines and parts. At its peak in the 1980s, the aviation industry employed more than 200,000 workers. The Transport Equipment Corporation PZL-Mielec at that time employed more than 20,000 workers. Some of the factories sprouted new towns nearby, with these towns becoming very dependent on the factories.

During the post-war era, the development of the Polish aviation industry changed dramatically, adhering to a strategy dictated by cold-war policy that turned the industry into a chief supplier and producer of military equipment to the Soviet Union. For example, the same PZL-Mielec Company was building more than 400 MIG-17 fighters a year during the '50s and '60s. Even though some time later, production of civilian products replaced military aviation production, companies from the former Soviet Union and its satellite states remained the basic customer. The PZL-Mielec Company, for example, changed from production of fighter jets to light transport airplanes and initiated cooperative production of the rear part of the fuselage of the IL-86. At the same time it entered into production of electric battery golf carts.

In 1989, the iron curtain came down and the new process of transforming the Polish economy to a free market was initiated. This retooling and its effects on the Polish aviation industry felt like an earthquake. The Eastern-bloc market was closed, the market of some Third World countries were not available because most of them were on the United Nations blacklists and budget funds, previously the basic source of financial support of the aviation industry, were withdrawn. The jurisdictional functions of ministries were changed and the entire system of compëtence, connections and interdependencies were destroyed. As a result, all segments of the aviation industry underwent dramatic changes. Production of the passenger turboprop An-28 was suddenly disrupted. The PZL-Mielec Company was forced to cut employment by 25 percent to a few thousand workers, resulting in more than 20 percent unemployment in factory areas and the threat of social unrest.

This forced the Polish aviation industry to concentrate on the development of high-quality products, as was expected on the open market. Such developments made possible the transfer of up-to-date technology previously forbidden by political embargo. Entering the space technology market became the *sine qua non* condition of existence of the Polish aviation industry. The consortium POLSPACE Ltd., a private enterprise representing the scientific and technological institutes in the fields of space, avionics and electronic industries and smaller private firms, was established to simplify the industry's transformation.

Space Physics

Though Poland may not be ranked among the space powers, its scientists have been involved in important space research for many years, including the Copernic-500 project, the VEGA mission to Halley's Comet, the PHOBOS mission to Mars, and the IONOSOND, ACTIVNY and APEX projects, all under the auspices of the INTERCOSMOS Program. Until 1989, this program was the only avenue for participation in space activities outside of Poland. It enabled Polish scientists access to space technologies and cooperation with the Russian space research community continues today. The last few years have also seen more cooperation with NASA, the European Space Agency (ESA) and the Central European Initiative (CEI) space program.

Polish participation in multilateral programs has usually been a combination of scientific and technical involvement. In general, the scientific experiment is proposed, and the technical team works on the practical design of the necessary instrumentation. The project gets approval and financing if the technical realization can be accomplished in Polish laboratories. Software development, data processing and scientific analysis and interpretation are included in the complete scheme of the project. In this way, apart from scientific results, Polish scientists very often gain the technology experience and can maintain technical teams competent in the application of advanced space technology. Two projects are particular examples of such activity: the Huygens/Cassini Mission to Saturn and its moon Titan, sponsored by ESA and NASA, and the CESAR Project under the CEI program.

In the first example, scientists and engineers from the Space Research Centre in Warsaw are working within a group coordinated by Kent University, in the United Kingdom, and are responsible for preparing the temperature sensor on board the Huygens probe. The probe is supposed to land on Titan in 2005. The mechanical and electronic design, engineering modeling, mission testing, and manufacturing of the flying model are all sources of extremely useful experience.

In the case of the CESAR Project, it is internationally structured, with two Italian organizations in the leading role—the Italian Space Agency and Alenia Spazio. Besides Poland, the Czech Republic, Slovakia, Hungary and Austria are cooperating countries.

The Cesar mission is designed to perform a wide range of investigations in the physics of the near-Earth environment. Both scientific and application subjects are planned. Experiments will address such topics as the characterization of the near-Earth neutral and man-made VLF and RF electromagnetic fields, the detection of ozone and pollutant gases in the atmosphere and solar X-ray radiation. The satellite will fly in an orbit with a 400 km perigee, 1,000 km apogee and 70 degree inclination. The technical involvement in this program is even more intensive and is extends to the mission objective definition, planning, organizational problems and full participation in all phases of evaluation.

Satellite Geodesy

Geodetic application of space technology is mainly related to problems of geodetic networks, mapping and navigation. Because the space segment exists, national interest is directed to the ground instrumentation and methods of measurement and data processing rather than to the satellite experiments in space.

Such works consisting of GPS measurement are performed in Poland to a large extent. In 1992, a large GPS observation campaign was effected in order to establish the geodetic control network linking the Polish national geodetic system to the system of a united Europe. This project, called EUREF-POL, was under the responsibility of the Space Research Centre in Warsaw. The next campaigns will be devoted to the densification of the network, determination of the vertical datum, the geoid a.s.o. Most of the European countries participate in the EUREF project. The cooperation is very intensive, on the level of the network definition, the measurement campaigns, data analysis and exchange of results. Navigation application of GPS is fully applied for marine users as GPS technology is becoming more widespread for land and air navigation.

Other Directions in Space Research

A few other space research projects include the Institute of Geodesy and Cartography in Warsaw using remote sensing to research topics such as agriculture, forestry, meteorology, hydrology and environmental pollution problems. Again, international cooperation with ESA and other national agencies is very developed.

In the field of telecommunications, Poland is active in international organizations like Eutelsat, INMARSAT, Intersputnik and Intelsat.

Space biology and medicine brought very interesting results, in particular in connection to the preparation of the Polish cosmonaut Miroslaw Hermaszewski to the space flight in 1978. Some methods and instruments were applied later on to the routine pilot checking or just to diagnosing of ordinary patients.

APPLICATION OF SPACE TECHNOLOGY

POLSPACE Consortium

POLSPACE was established in 1993 with the main purpose of commercializing space technology and making full use of the existing technical and scientific potential to promote advanced technology and create new job opportunities in Poland.

POLSPACE is a private consortium of number of scientific institutes and industry enterprises interested in space technology. In this capacity POLSPACE is able to provide the following products and services:

- construction of scientific instrumentation for satellites and probes
- tracking systems
- mechanical structures
- board electronics
- data collecting, processing and transmission
- ground support equipment
- space telecommunication subsystems
- environment protection with space technology
- satellite geodesy and navigation

- other space related applications

Two activities of POLSPACE in particular are of interest to this conference.

GPS Manufacturing and Application

GPS is a domain in which new applications and ideas appear almost every day. POLSPACE is a producer of the universal handheld receiver NAVI-NT04, with many possible applications. It is a single frequency L1, C/A code receiver with or without autonomous batteries. It was tested on boats and ships, on helicopters and planes, cars and land vehicles. Accuracy and reliability were checked in different environmental conditions. POLSPACE is selling this unit to different categories of users, most of them professional.

An interesting application of this receiver is its connection to a digital map and the data transmission link in which the motion of the vehicle can be tracked from the central facility if the system is mounted on the car.

CESAR Project

On the basis of a grant from the Polish State Committee for Scientific Research, POLSPACE Ltd. is involved in the CESAR satellite project. The concept of the satellite was elaborated by ALENIA SPAZIO, Torino, Italy. POLSPACE is working on the following subsystems of the satellite: Structure, GPS position determination subsystem, deployment mechanisms, mechanical ground support equipment and electromagnetic compatibility.

Analysis of the satellite structure was made by the computer center in PZL-Mielec Company on a basis of MSC/NASTRAN software package. Complete analysis (statistical and dynamic) of the structure has been done. Its mockup has been built (honeycomb technology). Additionally a project of small satellite below 100 kg is also developed, and it is considered to be carried into effect in Poland.

This work carried out under the guidance of Alenia Spazio gave us extremely valuable experience and opened the new prospects of the development of space technology in Poland.

CONCLUSION

There is no question that space research is a very powerful stimulus for the development of advanced technology, especially in smaller countries. However, it seems that some preconditions should exist in order to facilitate the beginning and continuation of this process, including: (1) a sufficient level of existing experience and education for quick absorption of the new knowledge; (2) the organization of existing groups and institutions in such a way to enable cooperation and information flow; (3) close collaboration of research groups with engineering teams creating synergic increase of effectively; (4) international cooperation, in particular cooperation with more experienced partners is essential for successful technology transfer; (5) subsidies from the government or some other source, at least in the beginning; and (6) the possibility of entering a growing market in the foreseeable future as more and more of human activity begins to rely on space systems.

COMMERCIAL USES OF OUTER SPACE*

Michael J. Gianelli
Vice President
Hughes Space and Communications Company
United States

Communications and navigation are the only viable commercial uses of space in existence today. Of the two, communications is the space application that continues to shrink our world and drive international cooperation as few commercial undertakings can.

The globe began shrinking in the 15th century with the advent of movable type and the printing press. Ocean liners, and later air travel, accelerated the narrowing of the geographic gaps that separate the nations of the globe. The telegraph, telephone and eventually trans-oceanic cable drew the world into an even tighter circle.

It wasn't until 1963, with the launch of the geosynchronous communications satellite that a truly new millennium in telecommunications capability emerged. Syncom, from its position 35,700 km above the equator and moving at the same speed as the earth rotates, changed our lives forever. Today, the phrase "Live via satellite," is seldom used even as we witness the world's events in real time, because satellite communication is so commonplace that it is almost taken for granted. So we don't say "live via satellite," any more than we would say "calls via telephone."

It is this concept of a shrinking world that has created the global village that encourages, in fact demands, that the peoples of the world cooperate for their mutual benefit. Communications satellites have fueled the concept of the global village as few other inventions have and they have thus played a major role in creating a world without boundaries.

One of the first thing that comes to mind is television program distribution. News, sports and weather are all staples on the information and entertainment menus of people around the world.

While it is easy enough to comprehend that television programming is one of the primary uses of satellites, we don't often think of satellites as being the source of a number of newspapers and magazines.

Nor do we often think that when we put down a credit card to make a purchase at a department store our transaction is likely being approved via satellite.

Likewise, thousands of stock and bond transactions each day, as well as numerous hotel and airline reservations, are transmitted via satellite. And a number of large corporations around the globe use satellites to control inventory, conduct training and conduct research.

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In the United States, the Commonwealth of Virginia and several other states use satellites for distance learning, and a number of satellite-delivered learning programs are offered for elementary school students to enhance educational opportunities for the nation's children.

Satellite-based telemedicine programs are enabling expert medical diagnosis and treatment assistance for those living in remote areas that are medically under-served.

The blueprint for the future is being created today and without question, the three fastest growth areas for satellite communications are direct-to-home television, mobile communications and broad-band services.

Few, if any, Americans haven't heard of DIRECTV or the DSS System. With the small 18-inch dish and DSS set-top receiver more than 1.3 million American families are receiving up to 200 channels of television programming in their living rooms direct from spacecraft flying 35,700 km over the equator. Viewers can select pay-per-view hit movies that start as often as every half-hour, as well as sports programming, news, financial and market information, history, travel, and crafts instruction when they want it.

In Europe, the Society of European Satellites is providing direct-to-home delivery of television and radio programming through its Astra fleet of satellites. And direct-to-home services are emerging in Latin America, Japan, Indonesia and Malaysia.

The first satellite dedicated solely to mobile communications in North America was launched last year. Later this month, another MSAT will join it, providing seamless mobile communications capability for travelers in automobiles, trucks, boats and aircraft throughout the United States, Canada and Mexico.

Last year, ICO Global Communications, an INMARSAT affiliate, ordered 12 high-powered satellites that will provide hand-held mobile communications services around the globe. That system will become operational in 1998.

Several companies have applications pending before the United States Federal Communications Commission (FCC) to build and operate fleets of high-powered Ka-Band satellites that will provide high-speed data transmission and a full range of interactive services, including personal teleconferencing and medical imaging, to a global community. When these satellites are launched, the Global Information Infrastructure will be in place. Once again, on-board digital processing technology originally developed for the military is being used as the back-bone for a highly complex commercial application.

Collectively, these new applications hold tremendous promise for the world's developing nations. The technology that enables mobile communications and private networks can be used also to provide instant communications infrastructure to developing nations.

For example, using satellites and a small earth station, a village in central Africa can establish economically viable telecommunications links with the outside world in a matter of days instead of the years and millions of dollars it would take to lay cable to establish similar capability. A regional government can use small inexpensive dishes linked to digital satellite systems to establish multi-site educational facilities. Governments can utilize such systems to provide enhanced educational opportunities to their children by offering a wide range of subjects taught by a small core of master educators.

Medical imaging technology that will be available through Ka-band satellite systems will serve as the backbone for telemedicine services for remote regions. Doctors, nurses and other paramedicals can obtain expert advice from specialists around the globe. With micro-cameras and small affordable uplink dishes, surgeons could remotely guide procedures that save lives.

And remote sensing imagery will tell farmers the best times to plant crops to increase crop yields. By understanding long range weather patterns, farmers can avoid planting seeds that would be washed away by heavy rains before they have a chance to take root.

Global cooperation, however, is required in order to maximize these services. Cooperation is not new in civil and commercial space activities. Certainly foreign scientists and engineers have been frequent passengers on the U. S. space shuttle fleet, often conducting experiments that could lead to full-blown commercial uses of space. And Americans astronauts have also flown in the MIR space station. Likewise, other nations have cooperated to provide emergency landing options for shuttle crews. And a number of nations have participated in joint operations with NASA.

In the commercial communications satellite industry, international cooperation was present from day one. The world's first commercial communications satellite, Early Bird, did, in fact, belong to the world community. Operated by Intelsat, the international telecommunications satellite consortium, the Early Bird satellite was launched in 1965 and ushered in the new millennium referred to earlier. Today, Intelsat is made of more than 120 of the world's nations, in cooperation to serve the communications needs of the world's peoples.

The Intelsat consortium was created to provide satellite communication services to the nations of the world. It was quickly realized, however, that ours was also a global maritime community and that satellites could also provide communications services to ships at sea.

In 1976, three Marisat spacecraft were launched, creating the world's first non-military mobile satellite communications system. Today, INMARSAT's global commercial mobile satellite communications fleet provides telephone, telex, facsimile and data transmission services, including distress and safety communications services, to ships at sea and to mobile users both on land and in aircraft aloft. Headquartered in London, INMARSAT is a consortium of more than 60 member countries.

In the cases of both Intelsat and INMARSAT, the satellites purchased by the consortia have been built using components from around the globe. Cooperation, however, is not solely the province of the international communications consortia, nor should it be the tool that enables technologically advanced nations to exploit the developing world. Cooperation must provide global benefit.

For example, as part of the contract to build Indonesia's first domestic satellite system, Hughes agreed to train Indonesian engineers and technicians in satellite design and assembly. That cooperation has carried over through each of the two successive generations of Palapa satellites. Today, Hughes is involved in an effort to upgrade the science curricula of Indonesian universities to enhance the country's technology development plan.

In fact, engineers from Canada, Brazil, Mexico, Thailand, China, Japan, Malaysia, Australia, Hong Kong and Indonesia have all worked alongside Hughes personnel in the El Segundo, California, facility to produce the satellites built for their countries.

The explosion in satellite communications applications is driving cooperation in ways previously unthought of. As the world moves rapidly toward the privatization of telecommunication infrastructure, new opportunities provide, and often demand, a new kind of cooperation between suppliers and service providers.

While it may be immediately clear that few service providers have either the engineering expertise or the facilities to build their own hardware, often overlooked is the fact that this rapid expansion requires greater access to space than at any other time since satellite communications began. More and different kinds of launch vehicles are needed. More efficient, more affordable access to space is the linchpin in every model for the expansion of satellite communications services currently on the drawing board.

Fortunately, in the last few years we have seen ventures emerge that promise to meet this increasing demand. But these new ventures, while challenging from an engineering perspective, are also extremely expensive, and that is where cooperation is helping to accelerate this trend.

When a new version of the Delta rocket, the Delta 3, was under consideration, McDonnell Douglas needed a guaranteed initial market for their new product to make that decision economically viable. Last year, Hughes agreed to buy 10 Delta 3 launches and to take options on more. That decision allowed McDonnell Douglas to proceed with this project, and now the first launch of a Delta 3 is planned for 1998.

Likewise, when Boeing decided to develop a totally new launch concept called Sea Launch, it could do so only with the cooperation and participation of an extensive team of international partners. But again, predictions for success required a guaranteed initial market. In October, Hughes struck a deal with Sea Launch to purchase their first 10 launches and took additional options.

These deals don't represent corporate beneficence. They are the foundation upon which we are securing our future as a satellite manufacturer and service provider. We will use some of these launches to expand our current service business, while others will provide prospective customers an economical, efficient route to orbit

Just as new launch vehicle development requires cooperation, the increasingly private service provision industry also often depends on cooperative alliances for success. Both AMSC and ICO, as providers of new mobile communications services, had capital-intensive establishment and expansion plans. In order to pass the first hurdle on the path to long-term financing, both needed a series of initial investors. The same was true of Motorola's Iridium project. In each case, satellite manufacturers provided some initial funding guarantees to jump-start those projects.

Just as it was in the early days of satellite communication, international cooperation remains the crucial ingredient in the recipe for the future success of the commercial communications satellite industry.

For the world to enjoy the rewards of the technologies described requires international cooperation not just among the manufacturers and service providers, but cooperation among and within governments as well.

As international systems such as the Global Mobile Personal Communications System come on-line, the satellite communications industry finds itself where the airlines were years ago when they were in the position of having to negotiate landing rights. For these systems to be most effective, they must be available to the world's citizens without border considerations.

Global systems can only work if the using community adopts product and system standards which apply internationally. Mobile telephones that work in New York should also work in Tokyo. Data transmitted from Senegal should be easily received and used in Istanbul. The challenge facing our industry is the design and delivery of seamless end-to-end systems.

To help bring focus and attention to these cooperative issues as Global Mobile Personal Communications Systems become reality, the International Telecommunications Union will hold its first World Telecommunications Policy Forum this October in Geneva.

The primary focus of the forum, a three-day gathering of private and public sector leaders, is to reach agreement on policy and regulatory measures at the national, regional and international levels required to facilitate deployment of the systems and to promote access to the services they offer at the most reasonable rates possible.

Communications applications and cooperation is truly a closed loop system. The applications drive cooperation and cooperation can in turn drive the creation of even more effective beneficial applications. While we may be a world of many nations, we are, in fact, a global village created under the umbrella of communications.

COMMUNICATION POLICIES AND REGULATIONS AND THEIR IMPACT ON AFRICA'S SOCIAL AND ECONOMIC DEVELOPMENT*

Henry Chasia
Deputy Secretary-General
International Telecommunication Union (ITU)
Geneva, Switzerland

INTRODUCTION

There is no doubt that space technologies offer enormous potential to improve the economic and social development of the countries of Africa through improved management of natural resources, preservation of the environment, delivery of health care and education services and the mitigation of the effects of natural disasters. Indeed, communication of information underlies all of these applications of space technology.

The information obtained from sensors and other instruments and apparatus in whatever application needs to be conveyed to the scientists who will interpret and communicate it to the user population over the public telecommunication infrastructure. The inadequacy of this infrastructure is often the weak link that stymies and frustrates the work of many people.

For this reason, the adoption of space technologies in Africa must go hand in hand with the development of an active and thriving communications sector. The adoption and effective use of space applications in Africa demands an efficient and dynamic telecommunication infrastructure.

Africa: Falling Behind

Africa faces a daunting task in developing its telecommunications sector. The world's developing regions experienced unprecedented telecommunications growth in the first half of the 1990s; compared with the last half of the 1980s, the growth rate in telephone lines almost doubled. Africa has not shared in this boom and growth rates have remained static. Consequently, Africa is falling behind other developing regions. Fifteen years ago it would have been easier to find a telephone in Accra than in New Delhi. With growth rates of over 26 percent in Asia in the 1990s, that is no longer the case. If Africa is to catch up with other developing regions, it needs to begin to achieve growth rates two to three times their current level.

An International Telecommunication Union (ITU) study published this year shows that the 700 million inhabitants of the continent have access to just under 12 million main lines. Furthermore, in sub-Saharan Africa, which is home to around one-eighth of the world's population, there are less than two and a half million main lines—a teledensity of less than

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0.5 main lines per 100 population. This figure is less than 10 percent of the telephone density of Asia and less than one percent of the telephone density of the rich industrialized nations that comprise the Organization for Economic Cooperation and Development (OECD).

It is not just in the fixed-link network that Africa lags. There are more mobile telephones in Thailand than in the entire African continent. In the area of Internet penetration Africa is doing better, but that is almost entirely due to the high level of Internet usage in the Republic of South Africa.

Some African countries, of course, are doing better than others. Over the past decade, teledensity has doubled in Northern African countries. In South Africa, teledensity has increased by two percent and is approaching 10 lines per 100 population, although the distribution of telephones within the country needs to be improved. In Sub-Saharan Africa, however, teledensity has stagnated. The result is that within Africa itself there is a growing disparity between the information rich and the information poor.

Poverty and Investment

It is common to blame Africa's predicament on its poverty but, for telecommunications at least, this argument does not stand up to examination. The evidence shows that it is the supply of telecommunication services that is not keeping pace with demand in Sub-Saharan Africa. By the end of 1993, there were over 700,000 people waiting for a telephone line who could afford to pay for one. Current average waiting times, which stand at more than five years, are unacceptable for a society that wishes to move forward, a society that intends to promote commercial and social development.

In order to understand the problem of telecommunications underdevelopment, it is necessary to look at the basic network infrastructure upon which telecommunications services can be developed.

That infrastructure is woefully inadequate in three respects: firstly, it is not extensive enough; secondly, it does not have enough capacity to meet the needs of those who use it and thirdly, it does not have enough of the modern technology that is necessary to make it flexible and adaptive to the needs of the modern business and professional sector of society.

What this infrastructure needs are three things: investment, investment and more investment.

It is tremendously important for African official policy to place a high priority on investment in the telecommunications infrastructure. There will be absolutely no progress in African countries unless official policy picks up this message.

Those elsewhere in the world who have understood this message are behaving in quite a different way. The four Asian dragons—Hong Kong, Taiwan, Singapore and Korea—are approaching and exceeding the OECD countries not only in the numerical indicators of network performance, but also in the technological content of their networks. In other words, they have technologically more advanced networks than the OECD countries.

Another example is China. In Africa, today there are 12 million telephone lines; 12 million lines installed since Alexander Graham Bell invented the telephone in 1876. In 1995, China installed 20 million lines and intends to continue at this rate so that by year 2000, 100 million lines will have been installed.

Now, there is no law of man or of nature that says the Chinese can install 20 million lines in one year, while Africans can only manage 12 million in 120 years.

The reason may be that Africans have decided to place priorities elsewhere while the Chinese have decided that the "Great Leap Forward" will come from an adequate telecommunication network for the Chinese people. And they are directing their energies and their resources to this endeavour in a very significant way. In other words, they have placed a high priority on investment in their telecommunication infrastructure.

Investment in telecommunications infrastructure does not mean not just money, but also technology and human resource development. All these three will flow from the right government policies. A properly functioning telecommunication network will have not only the equipment with the right technology, but also the people who have been or are being trained and developed to manage and operate such a network: people who understand the technology and equally understand that serving customers well is good business.

A frequently cited goal for Sub-Saharan Africa is to raise teledensity to one line per 100 inhabitants by the year 2000. Using an investment cost of US$1,000 per line, the industry yardstick, more than US$2.5 billion would be required between now and the turn of the century for Sub-Saharan Africa to reach this goal.

But where will the money for this investment come from? Clearly the sums are too large to be obtainable from governments or other public sources, including the World Bank, which has already phased itself out of this kind of funding. Nevertheless, these numbers would surely represent a level of business that should be interesting for many companies such as banks and equipment makers who wish to sell their equipment. The ITU is not oblivious to the difficulties of doing business in Africa. But at the same time, there are profits to be made. Revenue per line installed in Africa exceeds US$1000 per year. The 2.5 million new lines alluded to earlier could generate US$2.5 billion worth of business annually for network operators and service providers.

Clearly, successful development will require private and public sector collaboration. The ITU's Development Sector aims to provide a forum for this collaboration. Already, 100 private entities have joined the ITU's Development Sector and are putting their ideas together with those of the 187 government members of the ITU in the Development Conferences and Study Groups and project activities that we hope will make a difference.

Restructuring in the African Telecommunication Sector

Attempts to improve the performance of the sector, however, are being made. The ITU is working with African Administrations on regulatory reform aimed at creating an environment that is stable and welcoming of private capital and of competition. The African Green Paper written under the auspices of the ITU by experts with a knowledge of African conditions and providing advice on telecommunication sector reform was adopted by the African telecommunication Administrations in May this year. The key recommendations of the paper include:

- Separation of regulatory and operational functions
- Separation of postal and telecommunications functions
- Creation of a separate national regulatory authority
- Provision for financial and managerial autonomy for telecommunication operators
- Opening to regulated competition those markets in which demand remains unsatisfied
- Investment in the development and management of human resources
- Creation of a consultative mechanism involving users and other parties to improve efficiency

More work is required and the ITU and other bodies are continuing their efforts. In a number of African countries telecommunications is being separated from posts, telecommunications operators are being established as joint stock companies, regulatory agencies are being created and private participation in the cellular industry is growing.

New Technologies, New Opportunities

Despite the enormity of the task, the development of telecommunications in Africa remains optimistic for three reasons. First, there is ample evidence of demand for telecommunication services. Second, there is the political commitment to sector reform. To these two trigger mechanisms add the fact that a vast array of new technologies, including space technology, are becoming available that can assist African countries to modernize their networks in a cost effective manner.

Radio-based technologies are an attractive alternative to wireline technologies. They can be deployed quickly and for an investment cost that compares very favourably with wirelinetechnologies in urban and rural environments. They have proved their worth in South Africa, where growth of mobile communications has been explosive since the launch of a digital GSM system by two competitors in 1994.

Sub-Saharan Africa is an ideas environment for cellular technology and there are a number of developments that could transform the African cellular landscape. First, the success of GSM in South Africa suggests the possibility of an extended GSM zone stretching to Namibia in the northwest and Uganda in the northeast. Such a zone could provide roaming in about a dozen countries.

Second, the advent of fixed cellular or wireless local loop (WLL) technology which uses cellular radio in a stationary mode just like a fixed line. WLL will continue to fall in price and is rapidly becoming a viable alternative to copper wire. In Ghana, for instance, Capital Telecom is installing WLL systems under a Build-OperateTransfer (BOT) project that should serve up to 50,000 subscribers in rural areas by 1998.

Third, and most significantly, seeing satellite technologies developing which truly will be able to offer cost-effective communications in remote and rural areas in developing countries.

The Satellite Communications Revolution

The advantage of satellite systems is that unlike conventional systems, their cost is not dependent on distance. This one factor is crucial to the role of satellite technology in the implementation of cost-effective telecommunications in remote and rural areas. However, it does depend on the cost of satellite ground terminals and the links between them being low enough and the terminals themselves being small and easily installed, economical in their consumption of power and robust enough to require minimal maintenance.

Until recently, satellite technology did not offer these capabilities. The INTELSAT system, for instance, was intended primarily for transoceanic international voice traffic. Its space stations had limited capabilities in terms of power generation and delivery of signal power to the Earth necessitating large earth terminals with antenna diameters of between 10 and 30 metres.

More recently, space stations in geostationary orbit, including those of INTELSAT, have attained much greater capability. This is in part due to the availability of more powerful launch vehicles enabling the placement of larger payloads into the geostationary orbit. These space stations not only carry larger antennas but they also have much larger and more efficient solar arrays with the capability to generate much more power than previous generations of satellites.

These satellites are also designed to focus their power into spot and other more limited coverage for the purpose of providing service to much smaller earth terminals with antenna sizes of less than one metre. Such terminals, known as VSATs (very small aperture satellite terminals) are much cheaper and easier to install and thus very suitable for conditions in rural and remote areas.

Reductions in antenna sizes have also been accompanied by developments in transmission and techniques such as thin route DAMA and digital TV compression, which are more cost-effective and more appropriate for rural conditions. The cost of space segment capacity has also come down in the past decade by several orders of magnitude. Prices of the order of 10 cents per minute for DAMA applications are now possible and may be expected to decline further.

In addition to existing satellite solutions, a number of international consortia are planning to deploy low-Earth orbiting satellites (LEGS) in the next few years aimed at mobile subscribers. Global Mobile Personal Communication Satellite Systems (or GMPCS as they are now commonly known) could bring significant benefits to users. They can provide voice and data communications to handheld terminals located anywhere on Earth.

But GMPCS systems raise many policy questions and the stakes are high. For GMPCS system operators, the billions of dollars typically invested in the construction and deployment of satellite systems and in the development and marketing of services may be at risk unless they have easy, equitable access to national markets. National policy makers and regulators view them with concern, because of their potential for infringement of national sovereignty and for their adverse impact on the revenues of national PTIs. Potential users of GMPCS may not be able to take advantage of the benefits offered by these systems if national policy makers and regulators and GMPCS system operators and service providers are unable to agree to measures that will facilitate availability of and access to GMPCS services.

The complex issues raised by GMPCS were discussed in October 1996 in Geneva at the first ITU World Telecommunication Policy Forum (WTPF). Considerable progress was made at the Forum and a common set of voluntary principles was agreed on the way forward. The Forum recognized the important role that GMPCS could play in developing countries and the need to ensure that the interests of developing countries are taken fully into account. There was also general agreement on the need to reduce impediments to transborder use and the early introduction of GMPCS terminals. Finally, there was considerable discussion on the policy and regulatory issues, particularly related to interconnection with a view to achieving equitable and standard conditions of access.

The achievement of the WrPF should not be underestimated. Few now doubt that the provision of ubiquitous voice or data communications to a handheld or portable terminal, regardless of the user's location, will become a large scale commercial reality by the end of the century. GMPCS will ultimately provide a complete range of narrow and broadband communication services at any time, in any place, everywhere in the world.

However, the potential contribution of this technology to Africa should not be overemphasized. Projected prices are still high and they will have to come down by one or two orders of magnitude before they have a truly major impact. Nevertheless, they can play an important role even at current prices in community tale-centre applications and also for emergency communications.

SPACE LAW RELEVANT TO ASTRONOMY*

G. Lafferanderie
Legal Adviser
European Space Agency
France

INTRODUCTION

What would the astronomers who laid the foundations of our knowledge of the universe have thought if they had been asked what law was applicable to their space scientific research?

The question arises today for two main reasons:

- The use of observation facilities (like the Hubble telescope) carried on-board space objects is a question of access to, and use of, outer space for the purpose of astronomical research; and

- International cooperation in space exploration and the exploitation of its results must be carried out for the benefit of all mankind. Currently, space activities are still the prerogative of the space powers. How can the benefits of these activities be shared? There is also the question that the pursuit of astronomical research on Earth can possibly be hampered by activities in space.

The sources and nature of space law

The law governing space and space activities was born on 4 October 1957, with the first launch of a man-made satellite, Sputnik 1. Space law was first developed under the auspices of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), which was officially established in 1959.[1] Subsequently, two sub-committees, one pertaining to scientific and technical questions and one pertaining to legal matters, were also established. The UN General Assembly adopted a series of Resolutions on the subject, in particular Resolution 1962 (XVIII) of 13 December 1963, followed by the "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space." This Declaration was the forerunner to the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (OST)," which was adopted on 19 December 1966 and entered into force on 10 October 1967.[2] This treaty, which is in force for 91 States, is the cornerstone of "space law," laying down the basic principles applicable to all human activity in space. It was followed by a series of legal instruments, all of which were also adopted within the framework of the United Nations: the "Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space" (3 December 1968); the "Convention on International Liability for Damage Caused by Space Objects" (1 September 1972); the "Convention on the Registration of Objects Launched into Outer Space" (15 September 1976);

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and the "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies." To these five treaties we can add the "Test Ban Treaty of 1963," plus Principles adopted by the General Assembly concerning: direct broadcasting by satellite, observation of the Earth's resources and the use of nuclear power sources in space. Debate is still continuing on the question of the "boundary" between air space and outer space and on the definition of outer space, with reference to the opposing legal principles of freedom versus sovereignty—by which they are governed—as well as on the concept of activities conducted for the benefit of all mankind (Article 1 of the Treaty, on which a Declaration has just been adopted and should be approved by a Resolution of the UN General Assembly in December). There is also continuing debate on space debris (confined for the moment to the Scientific and Technical Sub-Committee).

That is UN law in the strict sense. In a broader sense, we must consider contributions from other branches of international law, in particular the law on radio frequencies (Convention and Rules on radio communications) established under the aegis of the International Telecommunications Union (ITU), without which satellites could not be used. Alongside this body of international public law developed within the framework of international intergovernmental organizations (UNO-ITU-UNESCO), there are also legal texts concerning disarmament: for example, the Treaty which entered into force on 10 October 1963, banning the testing of nuclear weapons in the atmosphere, in space and under water; and the ENMOD Convention of 1977 on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques.

Today, multilateral and bilateral cooperation agreements (Memorandum Of Understanding–MOUs), particularly between space powers, constitute one of the main foundations for governing space activities. Some noteworthy examples include the Intergovernmental Agreement (IGA) on the international space station, the first draft of which was signed in September 1988, and will be replaced by a much revised text following the admission of Russia to the partnership), the MOUs between the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA) and the Russian space agency (RKA), and the MOUs concerning the Hubble space telescope, ISEE, IUE, Cassini and others.

Other examples of space law also include "charters" between national or international agencies that are neither treaties nor MOUs, an example being the international cooperation arrangements for the encounter with Halley's comet; and recommendations by scientific bodies such as the Committee on Space Research (COSPAR) or the International Council of Scientific Unions or International Astronomical Union (IAU).

Space astronomy is a key element of space activities. This is clear from the very first lines of the Treaty of 1967, which place special emphasis on the interests of the international scientific community—a term used widely in this Treaty and in the Agreement concerning the Moon—reflecting one of the primary concerns that gave rise to the creation of COPUOS.

All the provisions of the Treaty of 1967 and of the various ensuing Agreements and Conventions of course do apply to scientific activities carried out in space and hence to astronomy. It goes without saying that scientific satellites have to comply in the same way as other satellites with the provisions of the Convention on International Liability, the

Convention on Registration, the ITU Convention, and with the principles governing the use of Nuclear Power Sources and those being formulated on space debris.

THE BASIC PRINCIPLES

The principles governing the legal regime applicable to space, space objects and activities in outer space are reflected in the Treaty on Outer Space and the Agreement on Activities on the Moon.

The Main Principles of the United Nations Treaty on Outer Space (OST)

Status of outer space [3]

Article I (three basic principles):

(1) *Free for exploration and use.*

(2) *Free for scientific investigation with international cooperation encouraged.*

(3) *Its exploration and use to be carried out for the benefit and in the interests of all countries.* A major component of this legal regime and now to be covered by the next Declaration promulgated by COPUOS.)

Article II (non-appropriation/geostationary orbit):

(1) *Outer space is not subject to national appropriation.* An important principle in relation to the utilization and extension into space of national laws. Worth mentioning here is the Bogota Declaration of 1976 in which eight equatorial countries laid claim to the geostationary orbit as an integral part of their territory.)

Activities in outer space

Article III and IV (peaceful uses/international law):

(1) *Activities to be pursued in accordance with international law.*

(2) *Used for peaceful purposes.* Though the use of military personnel for scientific research is not prohibited.

Article VI (authorisation and supervision of national activities):

(1) *State parties have international responsibility, even if activities are performed by private entities.* Such as a scientific entity.

Articles VII and VIII (liability and registration):

(1) *Should be seen in conjunction with the Convention on Liability (which lays down two sets of provisions depending on whether damage is caused in space or on the surface of the earth) and with the Convention on Registration.*

Article IX (cooperation/protection of the environment from pollution):

(1) *Principle of cooperation and mutual assistance and corresponding interests.*

(2) *Conduct studies and undertake exploration of outer space in a manner that avoids contamination.*

(3) *Avoid potentially harmful interference, which should result in international consultations.* Opening the debate on space debris.

Article XI (requirement to inform, particularly the international scientific community):

(1) *Promote international cooperation.*

(2) *Inform the public and the international scientific community.*

Article XII (the Moon):

(1) *Moon base open to representatives of other Parties on the basis of reciprocity.*

Agreement Governing Activities on the Moon (entered into force on 12 July 1984)/The Moon as a Unique Site for Astronomy

The Agreement repeats much of the content of the OST, but only eight States are party to it.

- Article 4.1: The exploration and use of the moon to be the province of all mankind carried out for the benefit and in the interests of all countries

- Article 4.2: The principle of cooperation

- Articles 5.1 and 5.3: Information on results, including scientific results, discoveries

- Article 6.3: Exchange of scientific personnel on expeditions to the Moon

- Article 7.3: Areas of the moon having special scientific interest

- Articles 11.4 and 11.6: Equal access to Moon, discovery of natural resources

SPECIFIC LEGAL QUESTIONS

(1) The launch of radioactive materials (i.e. nuclear power sources [NPS]) into space is attracting the attention of environmental groups. Radioactive material is needed as a power source. Nuclear reactions and RTGs have been flown so far.

(2) Preservation of the environment is an important issue. Mining on the Moon or industrial activities on the Moon might make it impossible to study the Moon or pursue science from the Moon. The idea was presented at the International Institute of Space Law (IISL) Symposiums in Jerusalem (1994) and Oslo (1995) to preserve a lunar zone for SETI purposes. Setting up an observatory on the Moon would be extraordinarily expensive.

(3) Radioastronomy observation from the Earth is beginning to be restricted by pollution caused by various human activities. A number of projects are taking shape which may make astronomical observation impossible from the Earth, such as luminous advertising in the night sky.

(4) Projects for constellations of satellites, like Iridium or the Teledesic project of 800 satellites, are sources of major concern. A science journal has even raise the question "Are we killing astronomy?" (*New Scientist*, 24 August 1996).

(5) Access to and use of scientific data and intellectual property rights

CONCLUSION

Astronomy benefits from various general provisions of outer space law (through reference to the international scientific community) but no special provision has been made in its favour. Astronomy is therefore coming into more competition with other space activities, especially the growing commercial activities, for use of frequencies and other matters.

It may be advisable to devise a set of principles based on Article I of the OST to reinforce the "benefit of mankind" concept by safeguarding the scientific interests of space astronomy; for instance, in a combined effort by the United Nations, International Telecommunications Union and the International Astronomical Union that protects the electromagnetic spectrum

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TEACHING ASTRONOMY IN A NETWORKED WORLD*

Anil K. Bagchi
College of Engineering
Sultan Qaboos University
Al Khod, Muscat, Oman

INTRODUCTION

Certain prevailing economic situations inhibits the spread of astronomy education in developing countries and these economic problems will remain there until developing countries overcome many obstacles. Yet even after surmounting these obstacles, the situation regarding astronomy education in developing countries may not improve much because the vast number of small and very small countries that eventually become rich may still not be able to offer astronomy as a regular course of a reasonably high standard.

The solution lies in cyberspace. It is time to consider a radical change in the organization and administration of organized teaching. This is true for the entire education system but is especially true for subjects like astronomy. The initiative in Sri Lanka in building astronomy education around a small telescope is a first step in an attempt to globalise astronomy education for the benefit of all the inhabitants of our small, blue planet, especially those in smaller developing countries.

THE ECONOMIC SITUATION

Education in developing countries is pursued mostly in order to eventually earn a living. This is all the more true in science or science-related education. Possibly, this economic bias may also largely be true for education in developed countries, but there is a difference in scale. In the so-called developed North, some students may take astronomy purely as an answer to their cultural quest, but in developing countries, this is a relatively rare occurrence and this is the reason: Students majoring in astronomy in rich countries with developed industrial bases can reasonably hope to find a job; but in the developing South, no student believes that they can get a job by learning astronomy. It is good to realize and accept that, realistically speaking, nothing can be done about this economic situation. We must plan our efforts in universal astronomy education accordingly.

Astronomy Education

Let us consider the case of a small developing country with a population of a million or two. There will perhaps be one or two universities, with teaching stress on engineering, medicine and agriculture. There will be a college of science, which will be mostly a service course facility. Very few students will opt for a major in physics, chemistry or mathematics. In fact, there are examples where classes for biology majors are entirely, or almost entirely, female. Again, the reason is that many students perceive that it is not possible to get a job, other perhaps teaching school, with such a degree and many female students may not be in

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the job market anyway.

In a situation like this, it is not reasonable to expect that the authorities of the state or the university will back any scheme aimed at opening an astronomy department. A possible solution may be to associate the subject with physics or mathematics. However, math departments often offer specializations like statistics or computer science, and similarly, physics departments offer specializations like applied physics and applied optics. The aim would be to give astronomy a technology or application bias in order to make it more marketable. Thus, it is unlikely that a department will opt to offer subjects like astronomy in a major of physics and astronomy. Some possible solutions to this problem are:

1. *Offer astronomy course(s) as university elective(s).* These courses should not aim at any specialization; astronomy can be taught as a cultural subject. This approach was taken up in the United States and developed after World War II into the concept of science for non-science majors. Thus, there may be 1,000 non-science majors paying fees sufficient enough to support an entire Ph.D. program. This is what led to the extraordinary success of astronomy education in countries like the United States. Here is a case where a large number of first-year undergraduate students supported a small nucleus of astronomical research.[1] However the situation in small developing countries is entirely different.

2. *Offer astronomy as a part of courses on environment.* Studies in environmental sciences can now accept a reasonable extent of solar, and perhaps planetary, astronomy.

3. *Utilize and share existing data.* The cost of large telescopes can be quite daunting to education planners. But every university need not have a big, astronomical telescope. Existing ground-based and in-space observatories are churning out massive volumes of data, which can be shared. This sharing can be on-line or archival. What is required is establishing an appropriate administrative mechanism and formulating a proper protocol for sharing this data. Also necessary is the wide-scale training of potential users of this data. Perhaps the International Astronomical Union has a specific group working in this area. The IAU and the United Nations can contribute much toward smoothing out the process. It can be noted that even today, though many facilities do share astronomical data, it has its problems; even knowledgeable users have to find a way of sorting them out.[2]

UNIVERSITY EDUCATION IN THE CHANGING WORLD

Certain developments in communications, and as a result, in business organizations, warrant some discussion of education in the future. That future may not be far off; maybe that future is upon us now. As the lifespan for people increases, and there remains a desire to stay in one's profession even longer, there is a growing awareness that education is continual. People begin to find their educational background increasingly inadequate. Job changes and profession changes also highlight this point Therefore, continuous education, and reeducation, must be considered just as seriously as normal educational programs. It is time to consider if classical educational systems based on established campuses is the answer. There are now so-called virtual commercial organizations where the registered office may be in a particular place and the staff members located all over the world, meeting face-to-face infrequently. Customers may also be scattered in wide geographical areas. Future educational institutions may also be organized on this model.

Changing Structure of Universities

A number of developments have taken place in the field of university education field. They include: (a) rising costs, (b) increased demand on quality in university education, (c) greater competition for students, who are now greatly mobile and come from far-off places and (d), an imbalance between the location of the students and the higher class universities specializing in scientific and technical education. Students from a population base of more than three billion would like to be trained in English-speaking countries like the United States, United Kingdom, Canada and Australia. These developing countries are also becoming increasingly education-conscious and somewhat prosperous. However, this demand from developing countries for the best English language-based Western education cannot be met; if nothing else, visa restrictions would not allow such massive movement. In addition, (e) there has been a considerable change in the perception of fund an education. Society in many countries is increasingly demanding that education be self-sufficient, with a corresponding reduction in government support. This trend looks to continue. Also (f), increasing specialization has introduced considerable difficulty in finding the suitably qualified teacher and lastly (g), the competition between commercial organizations and universities in attracting the best talent is sharpening.

To overcome these difficulties, many universities, and not always the worst ones, are looking for ways to attract full-fee paying students. It is now a common sight to find university agents regularly visiting and canvassing for foreign students, that is, students from developing countries. Many universities are now becoming less conservative and are looking for, and actually entering into, collaboration with universities from the developing countries. I quote specific examples below:

- The International Medical College in Kuala Lumpur, Malaysia, is in a partnership with twenty universities from Australia, Canada, the United Kingdom and the United States. Students spend half the year studying in Kuala Lumpur and the other half in one of the partner universities. They get the degree from the partner university.

- Students of Cyprus College spend half the time in Cyprus and the other half in the United States, where they get the degree.

- There are department to department arrangements at many institutions so that facilities can be shared.

There are many other examples where established universities have entered into different collaborative arrangements. These are the reactions of universities to the difficulties facing them in a changing world. This also indicates that people are boldly taking advantage of the new world situation and the new technologies.

TECHNOLOGY DEVELOPMENTS

Considerable developments have taken place in the area of communication. Many call it a revolution. It is certainly going to bring revolutionary changes in every aspect of society with implications no one can foresee. It is now possible, and almost certainly by the turn of the century it will be commonplace and perhaps universal, to send large volumes of data, voice mail and pictures from anywhere to everywhere. Commercial organizations, banks, the entertainment industry, publication houses, sports organizations and the media, are all getting geared to face the challenge of matching their organizational structure and working style to this changing scenario. An alternative way of looking at it is that all these organizations are preparing themselves to take full advantage of the new technology. It is interesting to see what is happening in the university education field.

Telecommunications and Education

There is awareness everywhere about the need, suitability and inevitability of the introduction of new information technology to the classroom. But only a few classrooms are actually connected by high-speed communications networks. Though all of us know that a teacher sitting in his office in New York can conduct oral examinations of students in classrooms situated in places like Japan, in actual practice this is not a reality. We may take note of a speech delivered on 11 January 1994 by United States Vice President Al Gore to communication leaders: "I challenge you. . .to connect all our classrooms, all of our libraries, all of our hospitals and clinics by the year 2000."[3]

It appears the United States is serious about the development of a National Information Infrastructure (NII) for students and professionals in that country. Hopefully, others will not be far behind. It is a fair guess to say that by the early 21st century there will be a universal facility giving students access to all the unclassified information. Also, perhaps the problems of bandwidth, frequency allocation, satellite deployment, speed of communication, protocol, copyright and security will be sorted out as fast as the societies, or individual governments, are ready to face the revolution.

Astronomy Education

Where does astronomy education figure in this new situation? The answer lies in the will of the astronomers to take advantage of these facilities. A free journey to higher consciousness is possible for those who hold the passport. And imagination is the passport. Astronomy education may follow a path like this:

1. Establish linkage between all the willing academic and research institutes

2. Establish contacts with all willing observatories via the information superhighway

3. Codify appropriate protocols understood by all

4. Find a way of financing the project

5. Approach smaller countries with the offer of access to the facility. Offer training.

6. Ask the universities of the smaller counties looking for ways to establish astronomy education at sufficiently high and sustainable levels to introduce rules so that a course or courses offered by one university will be acceptable to the other. The important point is that the student from the smaller countries should be able to carry on with his astronomy education--including experiments, tutorials and examinations--without moving.

The United Nations or the International Astronomy Union may have the burden of establishing a suitable body to initiate, sustain and supervise the project.

THE FUTURE

Will the dream of globalised education using the information superhighway ever materialize? To find an answer we may apply what we know about the technological situation to technological education as well. There are two approaches, exploratory and normative. Exploratory forecast is technology orientated. We localize areas of underdeveloped capability in a system and try to visualize its future possibilities. In a normative approach, the future goals and needs are assessed and then the present means are worked back. The approach is from future to the present. The full potential of technological forecasting is realized only where exploratory and normative components are joined in an iterative, or ultimately, in a feed-back cycle. Even without taking the visionary view that the future of humanity is in space and space travel, we can locate a very considerable need and interest in astronomy in the time to come. There are also enormous blocks of unused or underused capabilities in the communication system now available. All these point to the certainty of developing a systematic all-world astronomy education.

CONCLUSION

The initiative to develop facilities around a small telescope in a country like Sri Lanka is a most welcome development. However, because of the enormous possibilities of the current phase of developments in communication, agencies like the United Nations and the International Astronomical Union may take this opportunity to initiate a program of globalised astronomy education.

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THE ROLE OF PUBLIC OBSERVATORIES IN ASTRONOMICAL OBSERVATIONS*

Tomokazu Kogure
Bisei Astronomical Observatory
Bisei, Okayama, Japan

INTRODUCTION

Astronomy in 18th- and 19th-century Europe was often promoted by advanced amateur astronomers who constructed large telescopes, made observations of non-stellar objects, and engaged in other activities. In the 20th century, particularly in the latter half with the dawning of the era of space science, activities of amateurs and professionals are separated greatly from each other. In Japan, activities of advanced amateurs have long been confined to some specific fields such as comet hunting or scouring the sky for finding variable objects like novae and variable stars. In general, they have had no close connection with research institutes.

Recently in Japan, however, situation is changing toward the stimulation of amateur activities and the promotion of amateur-professional collaboration (Kogure 1994). This new trend, which become clear in the late-1980s and accelerated in 1990s, can be summarized as follows:

1. Public Observatories equipped with large telescopes have been constructed by local governments (prefecture, city, town, village) and private persons or groups. Not only has the number of telescopes been increased, but also the size of the telescope. Also, professional astronomers, including graduate students, began finding jobs in public observatories, a stimulating factor for carrying out astronomical observations in such observatories.

2. CCD cameras, new high-sensitivity detectors in imaging and spectroscopy, are gaining importance in astronomical observations, even for amateurs, as observing power of telescopes has increased remarkably. Today, telescopes with 1 m apertures have capabilities of astronomical observations comparable to large telescopes of more than 3 m apertures decades ago and many public observatories provide the latest observational instruments, such as CCD cameras, photoelectric photometers and spectrographs.

3. Variable objects such as novae, supernovae, variable stars, comets and active galaxies currently make an important field of astronomical observations and attract amateur astronomers. These many objects are suitable for promoting amateur-professional collaboration at public observatories with large telescopes.

4. New waves of astronomy education and popularization using large telescopes. Public observatories with large telescopes offer the opportunity of close-up star

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* *This paper, which was presented at the UN/ESA Workshop on "Basic Space Science," 11-13 January 1996, in Colombo, Sri Lanka, does not necessarily reflect the views of the United Nations.*

gazing for children, families and citizens. These experiences have valuable effects, particularly on young people. Large telescopes are also effective in training young astronomers, graduate and undergraduate students.

These developments have currently enabled amateur astronomers to participate in astronomical observations of stars, nebulae and galaxies according to their own interest. In the future, it is hoped these amateurs astronomers will be able to participate in some domestic and international network observations and observational campaigns.

ACTIVITIES IN PUBLIC OBSERVATORIES

Table 1 lists the main public observatories established in recent years in Japan and active in the popularization, education and various astronomical observations. These are the "new-type" of observatories. There are also many other public and private observatories not listed here but active in these works.

Popularization

The proper task of any public observatory is to popularize astronomy and educate the local people. There are many forms of activities differing by observatories such as:

- Nightly sky-watching with large telescopes. Close-up views of planets, nebulae, star clusters and galaxies
- Astronomical events, star-watching, festivals and photographic contest
- Public lectures and seminars for the public or students
- Guidance and support for local star-watching clubs or groups
- Activities with associated facilities (see Table 2)

Many observatories are associated with facilities such as planetariums, science centers (for exhibition), lodges or school dormitories and parks (field athletics, camping sites and cultural halls)

Astronomical Observations

New-type public observatories with large telescopes are ordinarily equipped with some observational instruments, such as cooled CCD cameras, photoelectric photometers, video cameras and spectrographs according to their observational programs.

These public observatories were established in the 1990s, so their observational instruments are mostly still in the testing stage of observations. Among these are:

- Nishi-Harisa A.O., which is the first new-type public observatory. It is active in CCD-imaging of nebulae and galaxies and CCD-photometry of variable stars. It has started regular publication of their research activities

- Bisei A.O. has a 101 cm telescope equipped with a cooled CCD camera, photoelectric photometer and a spectrograph. The spectrograph can be used in two modes of high- (13 A/mm) and low- (100-160 A/nm) dispersion by changing the grating and CCD camera. Recently, this observatory has carried out some astronomical observations in collaboration with amateurs and university staffs, among which include (a) remarkable multi-color imaging observations of the Jupiter-SL9 comet impact sites and (b) collaborating observations of Nova Cas 1995, discovered by amateur astronomers and followed-up with photometric observations by amateurs. Spectroscopic observations have also been carried out at Bisei A.O.

- Saji A.O. is now preparing CCD observations with a 103 cm reflector and solar observations with a 15 cm Solar refractor, which has four telescopes mounted simultaneously

- Ayabe A.O. has a 96 cm telescope equipped with a CCD camera and a low-dispersion spectrograph. Future activities under consideration include occultation of stars by asteroids and searches for novae and supernovae

- Misato A.O. has a 105 cm telescope equipped with cooled CCD camera, and effective observations in imaging and photometry are expected. This observatory is also active in the promotion of an imaging network system through the Internet

International cooperation

Among public observatories, Bisei A.O. is active in international cooperation with other Asian countries. Their activities include:

- Organization of a mini-workshop on "Astronomy Popularization in Asian Countries," held 23 July 1995. Its Proceedings were published by the Observatory

- Invitation of foreign astronomers for monthly public lectures, with interpretation into Japanese. Recently an astronomer was invited from the Yunnan Observatory in China for a short stay. Public lectures and a scientific colloquium on AGN were organized at the Observatory

- A proposed training program for young astronomers from Sri Lanka

It is expected that international cooperative activities will be promoted by other public observatories in future.

DISCUSSIONS

Activities of the new-type public observatories in Japan can be summarized as follows:

1. *Local center for popularizing astronomy.* Most public observatories are associated with some planetariums or science centers or parks, all of which are attract families and citizens and assist the activities of public observatories located in prefectures, cities and towns

2. *Promotion of astronomy education and its popularization.* The basic purpose for public observatories lies in the popularization of astronomy. Some Observatories (e.g. Nishi-Harina A.O.) have regular contact with surrounding primary schools, accepting pupils for several days for science education. Public lectures are regularly organized in most of observatories

3. *Promotion of astronomical observations in collaboration with amateurs and professionals at research institutes.* Some observatories (e.g. Bisei A.O.) are effectively promoting these collaborations

4. *Participation in campaigns and network observations in the future.* The development of domestic and international network observations can be expected in the future. A proposal has been made to link some public observatories and universities in a campaign for the search of supernovae in early-type galaxies. However, for effective observations, it will take some time because most of the public observatories were established only recently and their instruments are still in test observations; also, public observatories are afflicted with a shortage of manpower (Table 2). Strong support from surrounding advanced amateurs and from research institutes is highly expected.

ACKNOWLEDGEMENT

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Table 1: Main public observatories

Name of PAO	Year	Telescope	Instrument
Nishi-Harima A.O.	1990	60cm refl. 50cm Solar tel.	CCD LyoFilter
Bisei A.O.	1993	101cm refl.	CCD, Pe, Sp
Saji A.O.	1994	103cm refl.	CCD, Planetarium
		15cm Solar refl.	4 tel.mounted.
Ayabe A.O.	1996	95cm refl.	CCD, Sp.
Misato A.O.	1996	106cm refl.	CCD, Planetarium
Toyama A.O.	(1997)	100cm refl.	CCD, Sp, Video.
Gunma A.O.	(1998)	150cm refl.	(CCD, Sp. IR)

Abbrev.: CCD = cooled CCD camera, Pe = photoelectric photometer, Sp = spectrograph, IR=infrared detector.

Table 2: Situation of the public observatories

Name of Obs.	Year Est.	Popul.	Staff			Associate facilities
			Perm.	Part	Admin.	
Nishi-Harima A.O.	1990 Pref	Millions	5	0	1	Ast.Park
Bisei A.O.	1993 Town	6000	2	2	2	Hist.Park
Saji A.O.	1994 Village	3300	5	6	4	Ast.Park
Ayabe A.O.	1955 City	40000	3	2	2	
Misato A.O.	1995 Town	4700	3	1	2+4	Ast.Park
Toyama A.O.	(1997) City	320000	4	2	0	Sci.Center

Note on staff: Staffs are counted by permanent (astronomer), part-time (astronomer) and administrative staff.

GNAT: A Global Network of Small Telescopes as a Resource for Astronomical Research and Education*

David Crawford
GNAT Inc.
Tucson, Arizona, USA

INTRODUCTION

There is no question that relatively small telescopes are powerful tools for astronomy, just as they always have been. With the new detectors and full usage of computers they have become even more powerful, enabling us to do more with a 1-meter aperture telescope today than what a 4- or 5-meter telescope could do only a few decades ago. New imaging detectors allow us to work both fainter than with our older photometers or with traditional photographic methods. And the small ones cost much less to build and operate than the large ones. As such, small telescopes are the main or only hope for observation time for the many astronomers worldwide who need them as part of their research or educational tools.

In addition, the advances in communication technology allow us to be in nearly real-time effective communication with each other and with our telescopes. We can truly envisage a multi-user multi-telescope multi-site observatory. Thus, small telescopes can be located at excellent remote observing sites and operated by many users automatically.

These technology changes empower us to conceive of a global network of astronomical telescopes. In an effort to bring such a facility to reality we have incorporated a new non-profit organization, GNAT Inc. The rest of this paper summarizes the goals and the status and the viable future of GNAT.

THE TECHNOLOGY

There have been many improvements in telescope technology over the last few decades. We now have lightweight mirror banks, active optical surface and wavefront control, fast focal ratios for the primary, smaller and lighter-weight mountings, full usage of computers in telescope control and data handling, smaller and thermally more friendly housings and many other items.

It is important to note that many of the items listed above also come into play in the design and operation of small telescopes. As with the larger ones, it also means that costs are less for a given aperture than in the older generation telescopes. While the costs of telescopes scale with some relatively high exponent of the aperture (about 2.6 for example, all things being equal), the costs for telescopes of all apertures are much lower. We are now seeing computer controlled, automatic and remotely operated small telescopes in routine operation at a number of observing sites. The technology is still changing rapidly, and it is sure to bode well for both large and small telescopes.

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The state of art in astronomical instrumentation has improved greatly in recent years. An imaging CCD photometer is a powerful tool for a small telescope, making a 1-meter aperture telescope more powerful for many research problems than the 5-m telescope was only a few decades ago.

The improvements in electronic communications, E-mail, the Internet and the World Wide Web have also been of great benefit to astronomy. We can now communicate rapidly with colleagues most anywhere, sending data back and forth and accessing available data bases in a very efficient manner. We can also control our new generation telescopes remotely and get data.

It is easy to envisage a global network of automatic small telescopes, operated remotely from a "Homebase." These type of telescopes would be very powerful tools for many important problems in astronomy, such as monitoring all sorts of variable objects from quasars and lensing galaxies to nearby stars and even the planets and asteroids. They would be most valuable for many sorts of surveys and a critical resource for improvement in photometric systems and standard stars. Finally, they would be able to supply a good deal of observing time for all of us who find our programs to be sadly lacking in adequate observing hours.

There is also no doubt that such a system of telescopes, and the astronomers involved, would be able to make a major impact on the quality of scientific education everywhere. Images and data would be accessible to all, as well as many high quality tutorials, lists of active research programs and who is involved, and so forth. It is easy to imagine that such a system, when in full operation, would be able to make a significant positive impact on more than 100 million students.

It can be done at relatively low cost; new generation small telescopes are not tremendously expensive, and they provide an essential and balanced complement to larger telescopes, to radio and space astronomy, and to education at universities and other schools. We think that GNAT can help in providing such facilities at a significantly lower cost than everyone "doing it themselves." It can be a big help in linking users together in many other ways as well, not duplicating nor wiping out what anyone else is doing, but being a complement and a link to all of them.

GNAT

It is just such considerations that have led a number of us to propose the formation of GNAT, a Global Network of Astronomical Telescopes. It has now been incorporated as a tax-exempt, non-profit organization, with the stated goal of being a catalyst and information source for all those interested in research and education using relatively small astronomical telescopes. GNAT expects to have a number of new generation small telescopes operating at several excellent observing sites worldwide. It will also be a networking contact for any other small telescope users or individuals and organizations interested in the issues.

GNAT may be of great help in insuring homogeneous and accurate data for all. Consider the gain that would be made by the volume purchase of high quality, matched filter sets. GNAT will often not be at the cutting edge of technology development, which occurs with many of the large telescopes. It can't afford to be. Its goal will be to get 80 percent or more of the performance of the frontier instrumentation at 20 percent or less of the cost, and with high reliability. A key item is "Value Per Cost."

GNAT is currently operating according to its Bylaws, and developing a formal Business Plan. The Business Plan will also result in a Proposal to fund a number of GNAT-owned new generation telescopes, based on the current state of the art in small telescope design. GNAT has been actively discussing such designs and the potential with telescope manufacturers and with potential users of such telescopes. The Proposal will be for at least 12 telescopes located in at least six observing sites, three in the northern hemisphere and three in the southern. Naturally, the GNAT network can and will grow in other ways, perhaps by incremental funding from different funding sources and from different countries. It should be easy to add to the initial complement of telescopes and to increase the range of telescope apertures. Many telescopes owned and operated by other organizations can and will also participate in GNAT activities.

The following are the GNAT Bylaws concerning GNAT's objectives:

1. Service to the public and to astronomy via scientific research, education, and public information concerning the development and operation of a global network of (small) astronomical telescopes for astronomical research and education, for developing national and international cooperation, and for archiving and standardizing essential astronomical data and information.

2. Service to the membership and others via collection of information, distribution of information, education on all aspects of the use of small telescopes and related topics and assistance with members' problems by sharing knowledge on a local, national, and international basis.

3. Any monies or funds from membership, programs, or services shall be used totally for research and education, and to further the goals of GNAT. No funds shall be used for personal gain except for reimbursement of expenses for program activities.

4. GNAT has been organized exclusively for educational and scientific purposes within the meaning of Section 501(c)(3) of the United States Internal Revenue Code.

STATUS

While some aspects of the status of GNAT activities may be gleaned from the above discussion, it may be worth listing a few specifics here:

1. At the end of 1995, GNAT already had several formal organizational members: Colorado State University, San Diego State University, the College of Charleston, Grasslands Observatory, and the University of Bradford (UK), as well as a number of commercial companies involved with small telescope technology. Other organizational members are pending. A growing number of

individuals are also formal members. There is a dues structure, and those interested in membership are most welcome to inquire. As of September 1996, GNAT has over 40 official members in the fold.

2. A 0.5-meter telescope has been obtained under an option-to-buy arrangement with a commercial company supplying telescopes. The telescope is now in Tucson undergoing tests and software development. It should be available for routine operation, including collection of data with a CCD imaging photometer, in early 1997. This prototype telescope, as well as others not formally part of GNAT, should supply good data and the operating experience useful in the preparation of the Proposal for the full GNAT telescope system.

3. GNAT-hosted meetings were held in April and November 1995 in Tucson to discuss issues, in particular the viability of standardized designs for small telescopes of several aperture sizes. We think that it is essential that such designs exist, and that they be accepted as a fact by the astronomical community, in order to obtain high quality telescopes at relatively low cost. The most recent meeting was held 20-22 April 1996, in Ft. Collins, Colorado, with the principal topic, "The Science and Education Potentials of a GNAT." The announcement, agenda, and notes taken at the meetings appear on the GNAT Web site. Additional meetings are planned. Those interested individuals who cannot attend these GNAT meetings are most welcome to offer their questions and feedback both before and after the meetings, or to send a paper for presentation.

4. GNAT has a World Wide Web page, which hopefully will become a mechanism of information exchange for those interested in small telescopes. It is quite new, so its usefulness will grow with time, in both quality and quantity. Feedback about content, input for posting, and questions are welcome at any time. The address is: http://www.gnat.org.

5. We are in the beginning stages of preparing a Business Plan for GNAT, as well as a Proposal for 12 new generation small telescopes to be located in at least six world-wide observing sites. We expect drafts of both of these documents to be finished by the end of 1996. We welcome your involvement in this effort.

6. We are now actively promoting the idea of GNAT Working Groups. These should be of great value in developing and implementing GNAT programs. The first several are now in the formative stages, including Standard Systems and Standard Stars, Open Clusters, and Photometry of Active Galaxies. We welcome input about these topics, and any others. The Working Groups will each have their own pages on the GNAT Web pages, in the near future.

CONCLUSION

There are many other aspects to the issues of small telescopes in a balanced and rational approach to astronomical research and education and we have just outlined a few of them here. We welcome your questions and your input. There is no doubt that the technology and the need and the potentials are all ripe for a viable global network of small telescopes. GNAT is one mechanism to help make it happen. It can be done, and it should be done. It is of very low risk, of relatively low cost, and of "astronomically" high potential. The Value Per Cost ratio is enormous. We hope that all those interested individuals and organizations will join us in helping to bring GNAT to a reality.

APPENDIX

A list of the "Standardized Specifications" for a 1-meter new generation small telescope, as discussed and agreed upon at a GNAT meeting on 22 April 1995. It is subject to change and further input is welcome.

1. Imaging and photometry are the main roles for the telescope.
2. An imaging CCD photometer is the main instrument, but one or two other ports exist.
3. Value per Cost is a critical item. High quality at low cost.
4. /N and 80/20 and 1+1>2 are important issues.
5. Keep it simple.
6. Uniformity in design and fabrication and software is essential. Standardize.
7. Reliability is critical. Low maintenance costs are as important as low capital costs.
S. Alt-Az and Equatorial are both acceptable designs for NGT small telescopes.
9. The primary mirror focal ratio is to be in the range 1.5 to 2.0.
10. The secondary focal ratio is to be in the range 6 to 9.
11. A possible flavor is to have a considerably wider field telescope (PF?).
12. Field of View (FOV): Design for a potential 4000 sq CCD, implement for a 2000 sq.
13. Match pixel size, seeing, and field of view.
14. Image quality: Between 0.6 and 0.8 arc-sec FWHM. Smooth surface.
15. Pointing: Open loop: Approx 10 arc-sec. Closed loop: Approx 1 arc-sec.
16. Tracking: Approx.1 arc-sec over several minutes. How?
17. Telescope control system (TCS) to allow for full automatic and remote operation.
18. Telescope scheduling. Multi-user, multi-telescope software needed.
19. Documentation.
20. Housing and site issues: Mainly a local issue, and not in the standardized design.
21. Other essential items that must be specified in a standardized design?

ASTRONOMY IN SRI LANKA*

K.P.S. Chandana Jayaratne
Department of Physics
University of Colombo
Colombo, Sri Lanka

G.H.P. Dhannaratna
Deputy Director
Department of Meteorology
University of Colombo
Colombo, Sri Lanka

USE OF ELECTRONIC AND PRINT MEDIA IN SRI LANKA TO EDUCATE THE PUBLIC AND SCHOOL CHILDREN ON ASTRONOMY

Astronomy, in simple terms, is the study of the night sky. And the night sky is as good a science laboratory anybody can access, any time, free of charge, because astronomy contains all the sciences. When you study a planet, the solar system or a comet, you have the opportunity to learn about its motion, constituents and possible life forms; this means that you can also learn about other subjects like mathematics, physics, chemistry and biology. In developing countries and remote areas that lack laboratory facilities, astronomy is the best way to teach science from the basic levels on up. The present paper describes an attempt to popularize astronomy in Sri Lanka and use it to educate the public and school children.

Sri Lanka has a population of 18 million people and most of them believe in astrology. Sri Lanka's biggest cultural event—the Sinhala and Tamil New Year each April—is based on the crossing of the sun from the constellation Pisces to Aries. To get into the heart of the people and teach astronomy, and thereby science, one can use such cultural events and astrological auspicious times as lead-ins to explanations about astronomy. For example, a half-hour television programme on, "The Sinhala and Tamil New Year From an Astronomical Point of View," was used to describe a map of the sky, constellations, the history of astronomy, what makes a star, the sun, the motion of the planets around the sun, the zodiac, the first point of Aries, precession of the equinoxes, and finally the motion of the sun from Pisces to Aries. There were no discussions of whether astrology is actual science, in order not to turn away astrology believers from the programme. Choosing the electronic media allowed illiterates to understand the programme, by watching television or listening to the radio, even though Sri Lanka's literacy level is greater than 89 percent. And to demonstrate planetary motion and eclipses, objects such as an orange, a tomato, a potato and a lime were used so anyone that became interested could try it on their own.

Moreover, special events like Halley's Comet, meteorite showers, or solar eclipses were used extensively to impart a greater knowledge on astronomy. Newspapers were used mainly as supplementary articles to television and radio programmes. The partial solar eclipse on 24 October 1994, is a very good example of how television and radio broadcasts and newspaper articles were published about two months prior to the event, describing its

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These papers, which were presented at the UN/ESA Workshop on "Basic Space Science," 11-13 January 1996, in Colombo, Sri Lanka, do not necessarily reflect the views of the United Nations.

importance and ways of observing it. On the actual day of the solar eclipse, an observational camp was conducted at the planetarium premises and a live radio broadcast was made for nearly 1½ hours, describing eclipse-observing techniques, the history of eclipses and some scientific background. Nearly 10,000 schools all over the country conducted miniature observational camps, simultaneously keeping at least one radio in each campsite. A similar weekly programme is planned on the "night sky," where the listener can go out with a radio at night, and from Colombo listen to an expanation of the night sky.

In addition, during the past 10 years, two television series on astronomy at were completed at the Sri Lanka Rupavahini Corporation. One series, produced in 1988, had 12 half-hour programmes on the beginning of the universe to its end. The other series, completed in 1994, had 24 10-minute programmes with modern computer graphics and satellite pictures. Those programmes were rebroadcast more than four times each because of the strong public demand. A similar series of radio programmes on the Universe was made in 1986, with 52 half-hour programmes.

Developing countries do have a lack of expertise. But the Sri Lankan experience shows that even a single person with an interest in astronomy is sufficient to educate an entire nation on astronomy the creative use of the electronic and print media.

OBSERVATION OF HUGE GLOBULAR-SHAPED REGIONS OF SUB-ATOMIC PARTICLES CHURNED UP BY THE JUPITER SHOEMAKER-LEVY 9 IMPACT USING A 28 CM REFLECTOR TELESCOPE AND A VIDEO CAMERA

A 28 cm CELESTRON reflector telescope with ATLUX SC280L driving system was used to observe the Jupiter-SL-9 collision that occurred between 16-22 July 1994. Though the telescope was equipped with a D-type skysensor 3 (computer controlled), it had no CCD camera facility for recording purposes.

The telescope was modified to fix a CCD video camera on the eyepiece end by constructing an additional adjustable mounting system. A VHS Panasonic NV-M10 CCD video movie camera (lens F1.2/8.5 - 68 mm) was fixed at the eyepiece end. The size of the CCD image sensor of the camera was 1.25 cm, with minimum required illumination of 1 Lux. With this set-up, continuous recordings of celestial objects were made possible on VHS video tapes with tape speed 23.39 mm/s.

The telescope was mounted on the flat rooftop of the 14.5 m New Physics building at the University of Colombo (6.90° N, 79.86° E). Jupiter was observed and video recordings were made virtually every night during the month of July 1994. No filters were used for observations. Of the 21 SL-9 chunks, only three fragment (E, P2 and S) collisions were observable from Sri Lanka. The rest of the impacts occurred during the day in Sri Lanka. Due to the prevailing cloudy sky conditions in July, none of the collisions were observed at the exact collision times. However, on 20 July 1994, at 20:38 local time onwards, Jupiter was clearly visible and at 20:40 local time, two huge globular shaped aural effects were observed along the same line northwest of Jupiter. The one closer to Jupiter was 326,100 km away from the planet and had a diameter of 275,900 km, while the furthest aural globe was 827,800 km away with a diameter of 250,840 km. The aurals were glowing in red, orange, green, blue and violet colours and lasted only 28 seconds. This observation was made about 8 minutes after the predicted impact time of fragment P2.

Considering the position of these aural regions with respect to the Jovian magnetosphere and the distances they appeared from the planet, it can be concluded that these were aural effects caused by the clouds of subatomic particles emerging from the Jupiter atmosphere/surface due to high energetic impacts. It is very unlikely that they were originated from the interaction of the incoming SL-9 fragments (with velocities of approximately 60 m/s) with the Jovian magnetosphere.

CASSEGRAIN TELESCOPE AT THE DEPARTMENT OF METEOROLOGY

A 10-inch Cassegrain Telescope has been housed at the Department of Meteorology since late 1972. This telescope was received through the Ministry of Scientific Research and Housing by Mr. Herschel Gunawardena under a grant approved for a project entitled, "Planetary and Lunar Observations and Photography from Ceylon." This reflector was purchased from the Astronomical Equipment Ltd., of Luton, the United Kingdom.

The telescope consists of the following:

- Telescope assembly consisting of fiberglass tube, 10 inch aperture f6 primary mirror, optical window with secondary mirror and eyepiece tube.
- Tripod stand with "B" type head with motor drive in right ascension, manual driving declination.
- 12V DC Oscillator
- Shift 3" refractor guide
- 6 x 30 finder
- 3 nos. eyepieces with power (X127, X254, X423) and a right angled prism assembly
- A reflex camera with adaptor
- Solar projection screen and rod assembly

A Cassegrain reflector has some special features that make it a very versatile telescope and can be used for different types of astronomical observations. The compact size of this telescope, with the folded optical system with a secondary mirror, enabled it to be housed in a relatively small enclosure with a roof that can be rolled off when observations are in progress.

In any given telescope, the magnifying power is controlled by the eyepiece. The magnifying power is given by the formula:

power=focal length of objective/focal length of the eyepiece

In theory, any telescope can be made to give any magnifying power simply by inserting an eyepiece of short enough focal length. However, in practice, three effects limit the magnifying power that can be used. First, because we look into space through turbulent air, higher powers magnify air turbulence and too high a power causes the image to shimmer. Second, as the magnification is increased, the image gets fainter and fainter since the light received is spread out over a larger and larger area. Third, due to fundamental properties of waves, a telescope with A-cm aperture cannot resolve details smaller than 12/A seconds of arc. Thus a telescope with a 10-inch aperture can resolve 0.44 seconds of arc.

The maximum useful power for most telescopes on an average night is about 20 power per cm of aperture. Therefore, with this telescope the maximum magnification that can be used is of the order 500x.

The other important function of a telescope—gathering light—is controlled solely by the aperture size. Many astronomical objects such as nebulae and galaxies are very faint. To see their details one needs light more than the magnifying power. In fact, the best visual impression of faint nebulae comes from large telescopes used at low power. For this purpose, one might use only 4 power per centimeter of aperture; for instance, a 10-inch (25.4 cm) Cassegrain telescope at 100 power.

The objects to be viewed may be either extended bright surfaces, such as the Moon, or bright points of light, such as stars, which are too far away to give an image showing a disc. In the case of a star, all the light falling on the object is collected into a point image. The brightness of the image is proportional to the area of the objective or, as is more usual, to the square of its aperture.

Generally, the amount of detail that can be seen on astronomical objects depends ultimately on the stillness and clarity of the air and on the telescope aperture, since these control both the useful magnifying power and the light gathering power.

Although any visual telescope can be used to observe the heavens, certain designs and techniques are best suited to certain purposes. To observe the Moon and the planets, magnification is the most important function, because one wants to get a big enough image to see detail. Some of the sights which can be observed using the 10-inch Cassegrain Telescope are the mountains and craters of the Moon, the phases of Venus, the satellites of Jupiter, the satellites of Saturn, the rings of Saturn, the cloud bands of Jupiter, divisions in the rings of Saturn, the phases of Mercury, the polar ice caps of Mars, the dusky markings of Mars, the cloud bands on Saturn, and the dusky markings on Mercury.

Several observational programmes have been arranged at the Department of Meteorology during the past for interested parties, among them schoolchildren, teachers and the general public. And during periods of important astronomical events, such as Halley's Comet, regular observational programmes are arranged for interested groups.

BENEFITS OF SPACE TECHNOLOGY: Remote Sensing and Global Health*

Arnauld E. Nicogossian, M.D.
National Aeronautics and Space Administration (NASA)
United States

By the year 2025, the world's population is expected to increase by 3.2 billion people. Nearly 95 percent of this growth will occur in equatorial regions where vector-borne diseases account for almost half of the world's burden of illness. Even though we are talking about a measurable geographic area, the entire world is at risk of becoming infected because of rapid and frequent travel and/or widespread natural disasters, which can occur in an endemic area and initiate new outbreaks. Recent examples of this type of concern are the resurgence of traditional bacterial infections resistant to antibiotics and the spread of plague, ebola, cholera, tuberculosis, and the potential for the reintroduction of malaria to California. In response to this threat, national and international health agencies have called for the development of innovative approaches to the control of such widespread diseases as malaria, schistosomiasis, filariasis, trypanosomiasis, and leishmiasis.

NASA is making important contributions to global heath through a space technology called remote sensing. Remote sensing is the use of satellite technology to create detailed visual images of the Earth's landscape. We know that each living species has its own habitat signature: temperature, vegetation, rainfall and so on. Using remote sensing technology, we began to characterize the habitats of different species. This in turn led us to consider studying habitats which harbor living vectors capable of transmitting diseases from one species to another, including humans. Since the diseases mentioned earlier are closely associated with particular landscapes and environmental conditions, using remote sensing data to study these associations are providing us with the research knowledge and tools capable of identifying the time and place of future global human disease outbreak.

In 1984, with a $50,000 investment, NASA initiated the Global Monitoring and Human Health Program to determine the applicability of remote sensing in malaria surveillance programs. The first phase of this program, which took place in California, showed that satellite remote sensing data could be used to identify high mosquito-producing rice fields weeks in advance of actual mosquito population increases.

The program is ongoing; on an international basis, similar data are being used to map mosquito habitat and human settlement patterns in southern Mexico and have identified areas of high-potential risk for malaria transmission. This is an important breakthrough because it allows ground control agents to plan in advance and use available resources to control the extent or severity of the outbreak, thereby reducing the cost of effective disease control.

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While malaria has been the major focus of our efforts to date, there are other applications of remote sensing and health issues currently being addressed. One project we are working on is the study of lyme disease in Westchester County, New York, just north of New York City. This area has an unusually high incidence of the disease. The county has a very diverse landscape; it is urban in some parts and quite rural in others. What we have learned from using remote sensing technologies in this region is that proximity to deciduous forest areas appears to have a direct correlation to the likelihood of contracting Lyme disease.

We are also conducting studies to determine the role of plankton in the Bay of Bengal and how it relates to cholera, and we are studying outbreaks of yellow fever and the deadly ebola virus in Africa. The use of NASA-derived technologies to target the temporal and spatial application of control measures offers new potential for reducing the global burden of malaria and other arthropod-borne diseases. The additional application of telemedicine will allow for instantaneous consultation between agents in the field, scientists, doctors, and other health care workers in the event of disease outbreak or natural disaster. Natural disasters frequently cause disease outbreaks; for instance, when the Mississippi river flooded in recent years, standing water led to outbreaks of St. Louis encephalitis transmitted by mosquitos.

Our results to date have been quite promising. NASA plans to continue its effort in this important global health area and even potentially increase the scope of the project with the completion of the international Space Station in 2002. This is vital research and another example of how space research and technology brings tremendous benefits to life on Earth.

NASA's Office of Life and Microgravity Sciences and Applications has established an institute at the Ames Research Center in Mountain View, California, called the Center for Health-Related Applications of Aerospace Technologies (CHAART). Through this institute, we are able to offer instruction in the use of disease-related, remote sensing technologies.

EDUCATIONAL ASPECTS OF INTRODUCING REMOTE SENSING/RADAR TECHNOLOGY IN DEVELOPING COUNTRIES: The Case for Malaysia*

Khairulmaini Bin Osman Salleh
Associate Professor
Department of Geography, University of Malaya
Kuala Lumpur, Malaysia

INTRODUCTION

The growing demand for information to support Spatial Information System Databases (SISD) and map production has led Malaysia to undertake a very rigorous and positive approach in developing remote sensing programmes. This demand is deemed to be crucial, as natural resources exploitation and urban expansion changes so very rapidly since the 1980s. Frequent updating of information becomes useful for natural resources inventorying and development planning. The National Remote Sensing Programme (NRSP), with specific objectives to (1) strengthen the capabilities and coordinate the activities of remote sensing technologies in the country, and (2) promote greater utilisation of remote sensing and related technologies for resources management, environmental protection and strategic planning, have thus been operationalized.

Manpower training still precedes NRSP objectives, especially to increase local expertise and skill. Since the establishment of the Malaysian Centre For Remote Sensing (MACRES) under the Ministry of Science, Technology and Environment, a number of workshops have been organised and cooperation programmes, between countries such as China and Sweden, have been implemented to provide further training and expertise in the use and application of remote sensing techniques. These collaborative programmes cover research topics and transfer of remote sensing technologies in the field of environmental modeling and monitoring and landuse mapping. Selected personnel from the centre and other government departments are also sent for short- and long-term courses overseas. One notable programme is the United Nations-Sweden Training Course on Remote Sensing. Advanced training courses are also being organised and planned in the country with the help of experts from foreign countries such as Australia, Canada and the United States.

DATA ACQUISITION AND MANAGEMENT

MACRES has initiated the process of acquiring various types of remotely sensed data to meet the requirements of research, inventorying and the updating of spatial data bases. The Remote Sensing Division of the National Research Council of Thailand (NRCT), through its ground receiving station, is the main source of data for Malaysia. Recent data acquired through NRCT includes almost whole country coverage of U.S. Landsat Thematic Mapper (TM) data and France's SPOT-1 data for the northern states of Peninsular Malaysia. MACRES

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has also acquired MOS-1 data from the Remote Sensing Technology of Malaysia of Japan (RESTEC). Apart from this, the 50 m resolution MESSR data acquired cover about 90 percent of the coastal region of Malaysia. Visible and Thermal Infrared Radiometer (VTIR) data will also be purchased on a selective basis for sea surface temperature studies. Discussions have been carried out with SPOT IMAGE and Russia to purchase high resolution satellite data coverage of Malaysia.

Facilities installed at MACRES is configured specifically to integrate image processing and the Geographical Information System (GIS). (MACRES 1991) Accordingly, as indicated in Figure 1, the facilities consists of four major components: the Image Processing System (IPS), GIS, PC-based facilities for image processing and GIS, and a remote sensing photo laboratory for high quality hardcopy outputs. Software architecture is given in Figure 2. The IPS, which uses Meridian Software and a Geocoded Image Correction System (GICS), runs on Microvax II. Other than raw satellite data, the system also accepts scanned and converted analog-to-digital data. Raw Radar data is also accepted by using Generalized Synthetic Aperture Radar (GSAR) software.

The GIS component consists of Image Graphics System (IGS) built around an Advance Mapping System (AMS), which accepts manually digitized thematic maps as input data and is capable of generating plotted maps and graphics as outputs. Software for the PC-based component, which are used mainly for training purposes, are Meridian PC for image processing and Tydac-Spans for GIS.

OPERATIONAL FRAMEWORK

The operational framework of the NRSP is shown in Figure 3. User agencies include those from the Educational, Quasi-Governmental Bodies, Utilities and the Military. Data is made available through computer data files and hardcopies geocoded to the locally adopted referencing system of the country. In Malaysia, all spatial data derived from remote sensing/digitized thematic/topographic maps and imported from any GIS must be referenced to the Malaysian Rectified Skew Orthomorphic (RSO) projection. Additionally, the software should be capable of transforming digital files in the RSO system to the Universal Transverse Mercator (UTM) projection or other geographic referencing systems. The conversion of RSO to UTM and vice versa is still considered to be at a semi-operational stage. This is because most of the land information data in Malaysia is based on the Cassini Solder Projection (CSP). In Peninsular Malaysia, cadastral maps have nine different coordinate systems based on the CSP. To incorporate all land-related information and to support a fully operational remote sensing and GIS, the software must have the following capabilities: (1) conversion of RSO to UTM and vice versa; (2) conversion of all nine different states of the Cassini Soldner-based coordinate system to RSO and vice versa, and (3) conversion of RSO to other geographical coordinate and vice versa. To facilitate the establishment of a fully operational RSO-based IPS and GIS database in Peninsular Malaysia, the parameters listed in Table 1 are required.

TRENDS IN APPLICATIONS

The application of remote sensing technology spans a wide field, but in Malaysia photogrammetry and thematic air photo interpretation are firmly established technologically

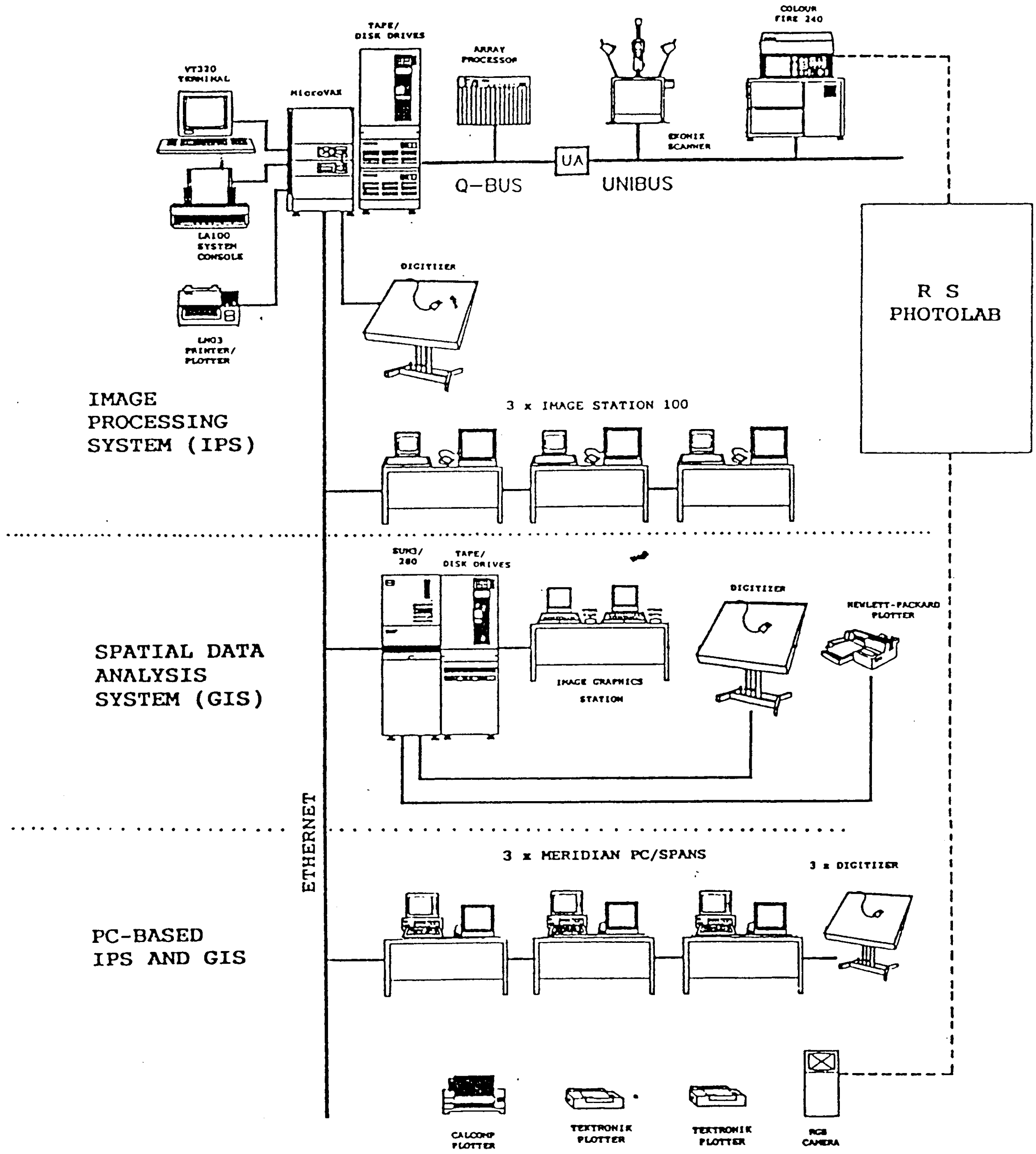

Figure 1: Hardware Configuration at MACRES

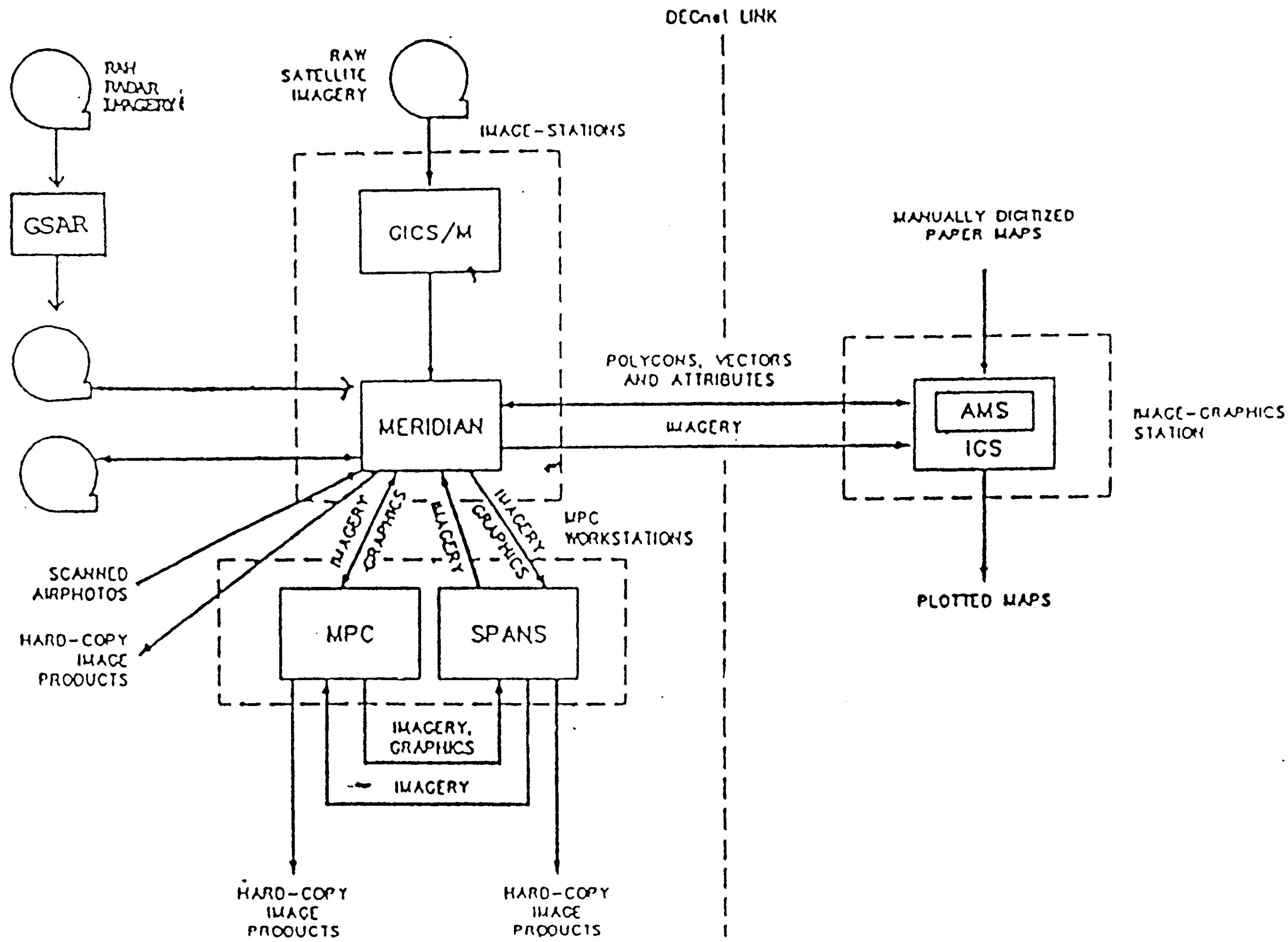

Figure 2: Software Configuration at MACRES

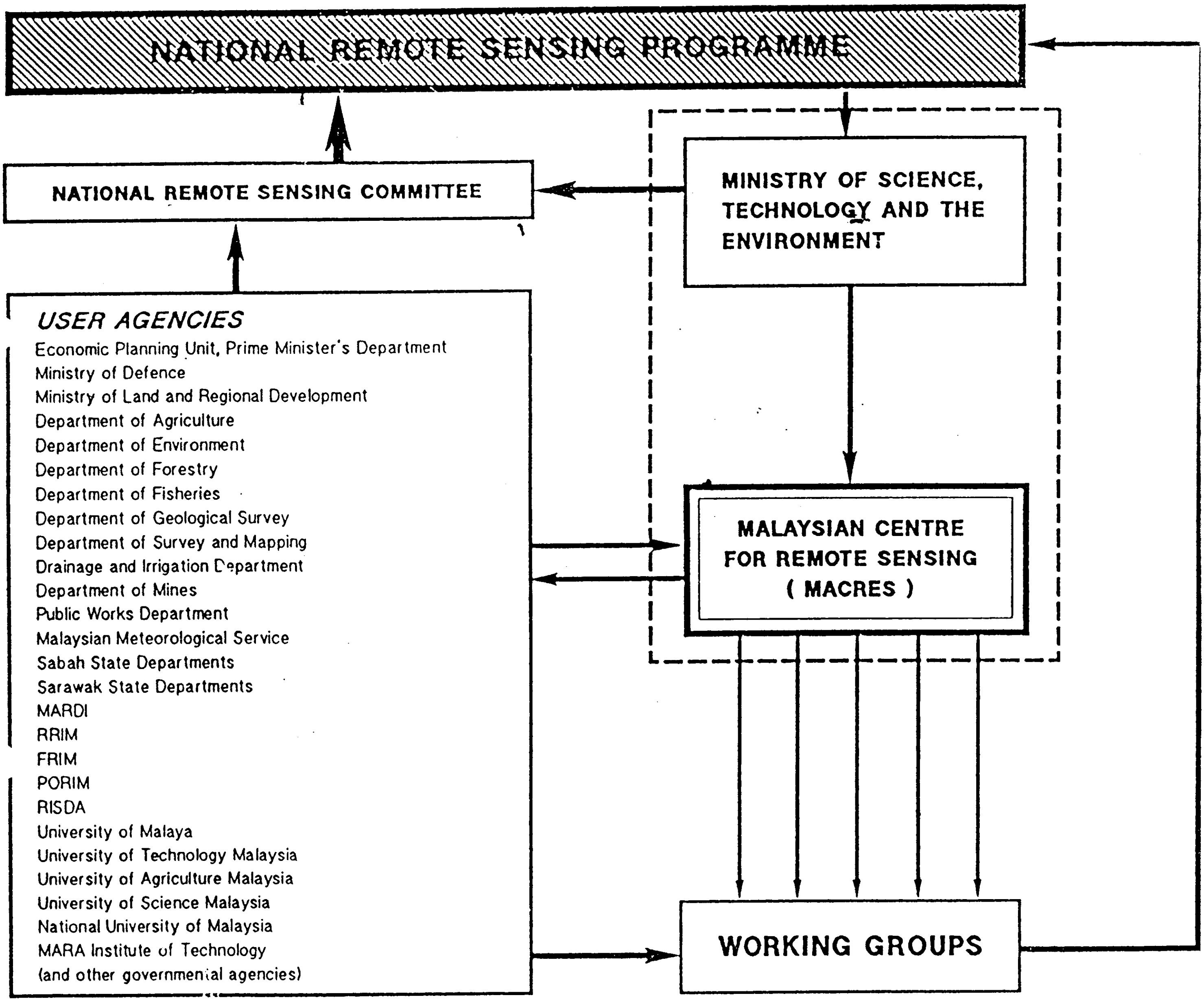

Figure 3: Operational Framework of the National Remote Sensing Programme

and their importance would not diminish significantly in the near future. The strength of air photo interpretation and photogrammetry techniques have been in spite of their often cumbersome methodologies, supported by large organizational networks built at the national level. The military and strategic importance of maps has meant that the Department of National Survey and Mapping (DNSM) had played significant roles in topographic and landuse inventorying of the country. Large scale thematic maps (of scales 1:10,000 and 1:25,000) are being prepared by the department as well as the updating to 1:40,000 of the 1966 1:63,360 topographic maps of the whole country. The DNSM is able to do this as staffs are fully trained and geared to thematic mapping and the availability of facilities for interpretation of the varied and multifaceted data from the air photos. These maps have provided sufficient inputs as prerequisites to various development planning carried out by government departments as well as researchers from the local Institution of Higher Learning.

The modern age of remote sensing in Malaysia begins in 1989 with the inception of MACRES, acting as a pivotal point within the overall organizational framework. If the use of satellite imageries are associated with this modern age, then Malaysia could be considered an infant as compared to China, for example. However, this does not mean that the full potential offered by this new technology is not realised. The main problem is "coping up" with the ever changing supply of technology and endless availability of remotely sensed data. Significant usage of SPOT and Landsat TM data have been used in ground inventorying, change detection studies, environmental consultation studies and general undergraduate academic exercises. However, the resultant maps produced, though depicting spatial distribution and temporal changes, do not compare well with the interpretation from large-scale aerial photographs.

The availability of microwave imagery through SEASAT, SIR-A, SIR-B, SIR-C, ERS-1 and JIR-I satellites would greatly expand the scope of operational remote sensing and allow insight into phenomena of wind and waves and those affected by cloud cover.[4] Furthermore, a Synthetic Aperture Radar (SAR) system provides oblique illumination and can record information at different polarization. This would greatly influence research in "stereo imagery" for relief mapping and extraction of thematic information.[2] Mapping of geomorphological features could infer geological processes and is highly feasible in stereoscopic mode. The utility of SAR imagery for geological mapping and cartography has been well documented, and the techniques for application of SAR imagery to these disciplines are established.

The sensitivity of SAR imagery to surface roughness, slope and the presence of water make it an ideal instrument for geomorphological studies, for delineating structural and tectonic features, for discriminating lithological boundaries, and when stereo-pairs are available, for radargrammetric mapping. The experiences with space-borne stereo radar are still limited, because there exist worldwide only a few stereo pairs and triplets of radar imagery from SEASAT and Shuttle Image Radar A and B (SIR-A and SIR-B). Longer-wavelength SARs (e.g. L-band) are also capable up to several meters in very dry aeolian sheets. The use of SAR to characterize the effects of faster-paced geologic and geomorphological phenomena could become invaluable, particularly where cloud cover commonly associated with the Equatorial Tropics limits the use of optical data. Radar sensors can operate independent of weather and illumination, which implies that neither daylight nor the season of data acquisition plays a role. This makes radar especially useful for future surface observation and monitoring in countries handicapped by problems mentioned earlier.

However, the use of SAR data is not without limitations. Among the noted disadvantages are (1) the processing of SAR data, which is very complex and time consuming, although real-time processing is now feasible at special installations, (2) shadows occurring where ground objects obstruct the passage of a radar pulse, and so information is lost, (3) variable resolution variable with distance from the ground track, although this can be corrected by resampling, and (4) serious geometric distortions are created in the imagery of mountainous areas.

Thus, the last five years or so, a wide variety of remote sensing tools, including radar technology, have been made available to Malaysia to add to the already well-endowed arsenal of aerial photo interpretation and photogrammetry. Yet there is also a disturbing aspect to this endowment. Although the full potential of remote sensing data are generally understood, the use of data from such passive and active microwave sensing systems for inventorying of ground characteristics and in academic research are severely lacking. In the latter case, it is still considered more practical to use large scale B/W panchromatic air photos (1:10,000) in change detection studies, studies relating to vegetation and urban landuse changes.

However, five years is a very short period to judge the impact of this technology in Malaysia. Yet, as a yardstick, the numbers of research cum-usage of radar data (for that matter other forms of satellite imageries) and publications in established journals are at a very minimum. However, the technology is here to stay in Malaysia and it all depends on what kind of future actions should be taken amidst the rapid growth of the technology to fully utilise its potential.

EDUCATIONAL BACKGROUND AND HUMAN RESOURCES DEVELOPMENT

Human resources development is a key issue for future development in remote sensing applications in Malaysia. Radar technology, compared to other satellite imageries considered not to be affected by weather constraints, for example, is a difficult technology to master without basic educational skills. Two basic scientific requirements are need. First, the remote sensors should be able to interpret the visual images—the holistic education that the geographer has undergone fits him very well for this purpose. However, thematic interpretation could also be carried out by a geologist, soil scientist and botanist. These disciplines lack the holistic ability to relate man as part of the spatial distribution as well as other environmental factors. Second, and a bit more difficult if the interpretation is based on digital processing, a firm understanding of computer processing and applied statistics becomes crucial. It thus becomes clear that two categories of basic educational skills are needed—visual interpretation and technical/computer skills. The young modern scientist should possess sufficient educational background and training which is holistic in approach.

Basic Educational Background

The concept of "phenomena in space," to be more precise "man in his environment," becomes a central issue in understanding the relationships of the spatial distribution patterns as been depicted by images derived from air- and satellite-borne sensors. This has always remain the central focus of Geographical studies—what, where and why are objects as they are shown in the images (manmade or natural) are distributed accordingly, systematically or chaotically in space. The training of the geography student, beginning from standard primary level education up to the tertiary level, provides the necessary expertise and knowledge to meaningfully interpret such distributions. Geographical education provides the basic spatial overview of phenomena in space and time, especially that relating to "man and his environment" and is thus seen an important prerequisite for anyone to be fully appreciative and understanding to the use of spatial imageries. After all, maps have always been the geographer's basic tools and close friend.

In Malaysia, geographical studies in schools have taken a back seat. Geography, compared to other arts-based disciplines such as history and economics, has been down graded from a once core-subject in primary and secondary schools to just being an elective. This change occurred in the late 1980s when the country's education policy favoured subjects such as history to be core-subjects in secondary education as it was envisaged to create a more responsible citizen of the country. Furthermore, upper secondary science students are discouraged from taking geography in their fourth and fifth year, and those students taking geography are generally arts students from a range of subjects from religious studies to understanding living skills.

The number of student taking geography has dwindled to 17,000 in 1995, from about 40,000 students before the late-1980s. This marked reduction in student numbers would greatly influenced the quantity and quality of students wanting to pursue tertiary education in the country. The best students from this pool either proceed to economics, law and religious studies, while the average-to-mediocre students go for arts-based subjects like history, social administration, gender studies and geography, to name but a few. These students usually have no Malaysian Higher School Certificate (MHSC) mathematics and generally a credit at the Malaysian Certificate Examination (MCE). The scenario is set at least for the three premier universities in the country, The University of Malaya (UM), The National University of Malaysia (NUM), and the Saints University of Malaysia (SUM). In these universities, remote sensing is formally taught in the department of geography under the techniques module, usually with minimum resources available.

Analytical Capabilities

Analytical capability is a prerequisite to successful data analysis using satellite imageries and any technology transfer effort between developed and developing countries. However there is a serious lack of rigorous technical training in the local universities and thus constrain their ability to impart technically based knowledge when securing jobs with government departments and private companies. Usually such students have to undergo further on-the-job training before familiarizing themselves with the technical aspects of remote sensing. However, science-based students (usually with no formal education in geography at the secondary level) entering the departments of geology, physics, civil and electrical engineering, have also been exposed to remote sensing, though the numbers are very small. Furthermore, the number of written project papers by undergraduate and postgraduate students on subjects relating to remote sensing are generally very few. The Technical University of Malaysia (TUM) offers courses in remote sensing but is rather limited in its scope of teaching. However, the universities do produce undergraduate and graduate students competent in the technical aspects of remote sensing.

It is imperative that those associated with data management operations must be exposed not only to the interpretation, analysis and applications of environmental and natural resource data available from satellite imageries but sufficient technical skills made available through an intensive educational process. Only an in-depth and continuous education programme can provide such knowledge and skills. Such an approach should provide an appropriate environment for the assimilation of fundamental principles of remote sensing technology, which would include the basic technical know-how and interpretation, critical to the successful development of knowledge in the discipline.

Applications-oriented short-termed courses are usually conducted abroad, or on-the-job training at home. Such individuals are taught skills that are tailor-made for specific tasks. In most instances, it is impossible to adapt such skills to other tasks without fundamental knowledge and understanding of the basic principles and methodology involved. On the other hand, technical experts or technical graduates having gone through short-term courses or tertiary education in the technical and statistical aspects of remote sensing would be unable to apply the training gained to solve real-world problems. These graduates usually lack knowledge in basic environmental processes and man-induced changes.

It is for this simple reason, too, that the research application of remote sensing technology in water resources studies, forest and crop inventories, geological and mineral exploration, environmental management, including weather forecasting, agro-meteorology, cartography and mapping and their subsequent use in the development of roads, pipelines, powerlines and related engineering applications, land use and urban development, oil pollution survey and monitoring, and management of coastal/marine environment and ocean resources, disaster assessment and the general monitoring of environmental impact of human activities is indeed seriously lacking.

Remote Sensing Education at UM

The use of aerial photographs in ground surface interpretation and mapping has always been associated with the departments of geography and civil engineering since the mid-1960s. The latter, especially, stresses the photogrammetric aspects of air-photo interpretation while the former on visual air-photo interpretation. Courses on remote sensing were taught at the department of geography in the early 1980s. However, the departments of civil engineering and physics are beginning to show interests in the importance of satellite technology, but maybe for the wrong reasons, especially when it pertains to Information Technology (IT). Usually these are single unit courses involving 20 to 24 hours of lectures supplementing the overall course structure of the departments.

By the end of 1995, a number of undergraduate exercises on inventorying and change detection, especially on the changing land use patterns in the Klang River Basin, have been carried out mainly by students from the department of geography. The main source of data used in such exercises is usually Landsat TM imagery either through hard copy maps or digital data. Research activities and consultation studies, mainly on preliminary environmental impact assessment, have also depended on visual interpretation of Landsat TM imageries. There have been no attempt so far to use radar-based imageries in class practicals and research work.

The scope and potential for using radar imagery in classroom practicals and research is limitless. The subject matter of specific fields in geography—for example, geomorphology, urban and regional planning and water resources studies—are always in need of new as well as more accurate techniques. The capability of stereoscopic viewing from SAR data, for example, could prove very useful in geomorphological mapping and terrain analysis and thus in the environmental impact assessment of an area.[3]

The running of a remote sensing course in the department of geography is not without its problems, not to mention, too, the type of remote sensor it is to produce. Remote sensing, especially radar remote sensing, is a highly technical and scientific field. It would involve some understanding of the basics of optical physics, especially that relating to the electro-spectra of solar and terrestrial radiation. These fundamental principles might then influence one's understanding of spectral signatures and absorbtivity of objects on the ground surface and the images formed.[1] In relation to this is the skills and knowledge in image analysis. Again, there is a need here for a certain standard of computing ability and analysis. As technology advances, the complexity of underlying principles and computing requirements also increase. On a non-technical aspect, the holistic ability to thematically interpret ground features would also form an important prerequisite.

Basic MCE standards in mathematics, physics and geography would form the necessary fundamental qualifications needed to undertake any remote sensing courses. Unfortunately, this criteria has never been the case with students associated with the departments attributed to remote sensing at the UM. A number of reasons account for these limitations. First, the Ministry of Education's policy to make geography an elective arts-subject at the secondly education level; second, geography is not a subject in the science stream at the secondary level; and third, the market generally affects the students' choice of courses either in science or arts based-departments. The better arts students with better geography grades (at the MHSC) are interested in pursuing a career in law or economics, while the science students pursue careers in mathematics, chemistry or physics. All of these factors would influence the pool of qualified students that would be available to pursue courses and research in remote sensing.

As an example, in the department of geography at the UM, there are two full courses in remote sensing: Fundamentals of Remote Sensing and Remote Sensing applications. In to addition, there is a non-compulsory graduation exercise where students apply remote sensing skills in studying geographical processes. The academic background of the students is basically arts-based with a few science students (the department of geography offers a BA and BSc in Geography). The science-based students are small in numbers, with minimum science subject qualifications, and do not study geography at the MCE/MHSC level. Usually the science students fare better than the arts-based students and have found work with MACRES. The number of science-based students in the future will diminish as a result of Government Policies and the main pool of geography students would come from the arts-based curriculum Generally, these students are very weak in mathematics and statistics and have difficulty in understanding the fundamental principles of remote sensing.

The quality of student alone does not determine whether a balanced remote sensing education could be achieved by any department. Other factors should also be considered. Among the other important requirements which are generally lacking is the availability of qualified teachers and support personnel, the number of remote sensing courses that are offered (theoretical as well as practical), basic infrastructural facilities, and finally accessibility to computer hardware and software. In most cases, these facilities are shared with other courses, which disrupts the teaching schedule of the remote sensing courses.

The problems discussed above are not easily solved, as they involve government policies, student perception and preference, priority in allocation of funds for human resources development cum training, and not of least importance, the availability of funds for setting up the basic infrastructure and computing facilities. These limitations remain the major obstacles that need to be overcome in the immediate future if a more balance education in remote sensing is to be realised. For these basic reasons, there needs to be support for the points raised in 1993 by the United Nations Committee On The Peaceful Uses of Outer Space concerning education and pertaining to the development of skills and knowledge of university educators and formulating a long-term curriculum structure for in-depth remote sensing education at both the primary and secondary levels.

CONCLUSION

The enormous importance of remote sensing in the acquisition, transmission, processing, analysis and utilization of environmental information in natural resources development, environmental monitoring, implementation of social and economic programmes is very well understood in Malaysia. However, the utilization of the technology itself in research and pure applications is at a minimum. Many reasons can account for this but the most immediate problem is getting the right quality of student to undergo a tailor made remote sensing programme at the undergraduate level supported by able teachers and physical infrastructures (hypothetically these students would form the core thinkers and users of the technology). These problems need to be solved if Malaysia is to move as fast as the technology itself. It seems that from the very small number of published works and research conducted by the universities in Malaysia, the utilization of remote sensing technology will generally lag far behind the advancements made by the technology itself.

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Table 1: RSO parameters for Peninsular Malaysia

Spheroid	**Modified Everest**
Semi Major Axis	6377304.1m
Flattening	1/300.8017
Eccentricity squared	0.006637846630200
Origin	4°00'00" N,102°15'00" E of Greenwich
Scale factor at Origin	0.99984
False Coordinate Projection	E =804671.28 m N=000000m
Initial line of projection	Passes through the origin in an azimuth of 323° 01' 32.8458"

THE CONTRIBUTION OF IRS-1C TO COASTAL MONITORING AND OCEAN DYNAMICS STUDIES*

V.S. Hegde, Shailesh Nayak, H. Honne Gowda, K. Ganesh Raj, R.N. Kishore, V. Jayaraman and M.G. Chandrasekhar

Indian Space Research Organisation
Bangalore, India

INTRODUCTION

Coastal zones are among the most dynamic areas of our planet, where land, sea and air converge. Because of the existence of diverse and productive habitats important for human settlements, development and local subsistence, there has always been hectic human activity coupled with many developments in this zone. Recently, problems such as erosion, accretion/siltation, over-population, salt water intrusion, flooding, pollution, devastation of natural habitats, and sea-level changes are endangering coastal areas. Rational development of coastal areas, which form the habitat of over 50 percent of the global population living within 60 kilometres of the shore line (and expected to reach 75 percent by 2020), can only be achieved by understanding the various interactive processes that are operative in the coastal environment.[20] The major issues requiring immediate attention to prevent degradation of coastal areas include: (a) monitoring short- and long-term trends of dynamic changes, (b) planning and implementing coastal protection, (c) formulating proper criteria for the location of industries, ports and harbors, aquaculture and recreational activities, (d) monitoring and conservation of critical environmental features (mangroves and coral reefs), (f) assessing the affect of reclamation of land from the sea, sand mining, dredging and recreational activities on coastal ecology, (g) optimal management of renewable and non-renewable marine resources, (h) controlling pollution of in-shore and estuarine waters, and (i) the improvement of navigation systems.[19]

The major requisite for coastal zone monitoring and management is the availability of information on existing conditions and changes that may have occurred over the years. For example, the mangrove forests (mangals) in India now occupy less than 2000 km^2 of area,[12] having suffered a loss of 85 percent since pre-agricultural times. Around the world, the loss of the mangrove forests is about 60 percent during this same period. One of the possible explanations in India is that unplanned expansion of aquaculture along the coastline has resulted in the destruction of mangroves and other areas of critical concern, in addition to causing floods during the monsoon. Continuous monitoring of these consequences, along with other coastal changes, calls for integrated studies based on the availability of information with respect to space and time on a regular basis in order to understand the interactive process of the coastal zone and properly evaluate the exploitable potential benefit of the resources on a sustainable basis. The United Nations Conference on Environment and Development (UNCED) in June 1992 in Rio de Janeiro also emphasised the importance of integrated management and sustainable development of coastal areas, exploitation of marine resources on a sustainable basis, protection of the marine environment and the study of the effect of the

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marine environment on the climate.

Several national, sub-regional, regional and global initiatives launched in this regard have revealed that the limitations posed by the conventional means of information gathering, with respect to space and time, have been among the major constraints in achieving these goals. On the other hand, several scientific studies carried out using satellite data for addressing various issues related to coastal zone have proved to be extremely useful in mapping, detecting, quantifying and monitoring of these features. [1,2,4,5,6,7,9,10,11,13,14,15,16,17,21,22,23] This is mainly because satellite remote sensing has the advantage of providing multispectral, synoptic information over large areas, including inaccessible regions, on a repetitive basis, the essential requirements for studying the coastal zone on an integrated basis. The Indian Remote Sensing Satellite, IRS-1C, which is the latest addition to the remote sensing family and considered to be the most advanced compared to other contemporary satellites in the world, has further facilitated coastal zone studies. In the present paper, a brief description of the IRS-1C and its capabilities for coastal and ocean applications are highlighted, along with a few case examples pertaining to the Indian coast.

INDIAN REMOTE SENSING SATELLITE: IRS-1C

Convinced of the capabilities and the inevitable role of satellite remote sensing in national development, the Indian Space Research Organisation/Department of Space (ISRO/DOS) has successfully developed and placed five operational Indian Remote Sensing Satellites in orbit: the IRS-1A and -1B, -P2, -P3 and -1C. The first-generation Indian remote sensing satellites, the identical IRS-1A and -1B, were launched in March 1988 and August 1991, respectively. These satellites carried two imaging payloads of:

- a LISS-I camera operating in four spectral bands in the 0.45 - 0.86 m region with spatial resolution of 72.5 m and a swath of 148 km

- two LISS-II A/B cameras operating in four bands, similar to LISS-I but with a spatial resolution of 36.25 m and each with a swath of 74 km. The field of view of the two LISS-II cameras were displaced laterally so as to provide a combined swath of 145 km with an overlap of 3 km

In October 1994 and March 1996, respectively, the IRS-P2 and -P3 were launched using the Polar Satellite Launch Vehicle (PSLV) developed by ISRO. The IRS-P2 carried only a LISS-II camera, with similar applications potentials as the IRS-1A and -1B, while the IRS-P3 carried two remote sensing payloads—the Modular Opto-Electronic Scanner (MOS) and the Wide Field Sensor (WiFS)—and a payload for X-ray astronomy for applications related to land-ocean-atmosphere.

The second-generation Indian Remote Sensing Satellite, the IRS-1C, was launched on 28 December 1995, and has the capability of addressing even those applications previously in the domain of aerial photography. It marked a new beginning in the utilization of remote sensing technology for natural resources management. The IRS-1C, with its unique combination of payloads and capabilities, and the resultant application potential, including coastal and ocean applications, is presently considered the best civilian remote sensing satellite launched by any spacefaring nation to date. (Table 1) Also, for the first time, an

Indian Remote Sensing Satellite has been designed for a global mission and efforts are underway to ensure the availability of data the world over by establishing a network of ground stations.

The IRS-1C carries three distinct and mutually complementing imaging payloads: the Panchromatic Camera (PAN), the Linear Imaging Self-Scanning Sensor (LISS-III) and the Wide Field Sensor (WiFS). These payloads that operate in push-broom scanning mode using Charge Coupled Devices (CCD) as detectors are unique in terms of their resolution, revisit period and application potential. It also carries a tape recorder on board for recording the data when data is not being transmitted in real time.

The PAN camera provides a spatial resolution of 5.8 m at nadir and operates in a single (0.5-0.75 μm) panchromatic spectral band. This camera covers a ground swath of 70 km which is steerable up to ±26° from nadir in the across track direction. This off-nadir viewing provides the capability to acquire stereoscopic pairs from two different orbits and an ability to revisit any given site once every five days.

The LISS-III camera is a multispectral system operating in four spectral bands, three in visible-near infrared (VNIR) range which are identical to the B2 (0.52-0.59 μm), B3 (0.62-0.68 μm) and B4 (0.77-0.86 μm) of the IRS-1A and -1B, and one in short-wave infrared (SWIR)-band B5 (1.55-1.70 μm). The LISS-III provides a spatial resolution of 23.5 m in VNIR and 70.5 m in SWIR with a swath of 142 km and 148 km, respectively, for VNIR and SWIR.

The WiFS camera has a spatial resolution of 188 m and covers a swath of 774 km. This wide swath coverage provides repeatable observation of the same area once every five days. The WiFS operates in the B3 and B4 spectral bands of the LISS-III (0.62-0.68 μm and 0.77-0.86 μm). Table 2 summarizes the specifications of the three IRS-1C camera systems.

IRS-1C APPLICATIONS IN COASTAL MONITORING AND OCEAN STUDIES

The unique combination of data available from IRS-1C sensors covering different regions of the electromagnetic spectrum have opened up new vistas of applications to cater to the varied requirements of the remote sensing community. The following section deals with the capabilities of the IRS-1C for coastal and ocean applications along with a few examples pertaining to the Indian coast.

Coastal Wetlands

Tidal wetlands form the vital link in the marine energy-flow through the transfer of solar energy into forms that are readily usable by a wide variety of estuarine organisms.[18] Wetlands—the feeding, spawning and nursery grounds for a variety of fish population—are responsible for monitoring reproductive fisheries. They also serve as a buffer to the mainland against cyclonic storms and protect the coast from erosion. Mangroves and coral reefs are of significance for ecological, environmental and socio-economic reasons. Continuous degradation of these resources at an alarming rate results in severe ecological imbalances in the coastal environment. To prevent further deterioration, it is imperative that these fragile resources are conserved and managed appropriately. An important step in wetland management is the classification of wetlands based on their significance. The major tasks involved include: (a) mapping or making an inventory of all wetlands, (b) timely detection of changes in wetlands and (c) identification of plant communities.

Several significant studies on coastal wetland management have been carried out using satellite remote sensing data to obtain information on the areal extent, condition and boundary of wetlands and other coastal features. The analysis of the IRS-1C LISS-III data of 8 January 1996, of the Goa coast on the west coast of India, revealed better demarcation of coastal features such as mudflats, beaches, fringe mangroves, creeks, dunes and dune vegetation. Mangrove patches were observed to be about 20-40 m wide and 100-150 m long and bordering creek areas were clearly distinguishable as compared to satellite data from the IRS-1A and -1B and Landsat.[14] The merged product of the IRS-1C PAN with the IRS-1B LISS-2 for the tuticorin coast on the east coast of India showed improved accuracy in boundary delineation of tidal flats, beaches, dunes, categorisation of reclaimed areas, delineation of jetties, and built-up areas. The comparison between the PAN, LISS-II and merged product is given in Table 3. These merged products are extremely useful in providing detailed information on a 1:25,000 scale, which is required for regulating activities in the coastal regulation zone. (In the Indian context, it is the area between the high- and low-tide line and 500 m from the high-tide line.)

The analysis of the IRS-1C LISS-III data of February 1996, of the northwest Gulf of Kachchh, has helped to identify various features related to the mangrove ecosystem. Use of the middle infrared band was attempted essentially to distinguish tree and shrub mangroves. The combination of red, infrared and middle infrared bands helped in distinguishing tree mangroves, *Rhizophoro* spp and shrub mangroves, *Avicennia* spp. This discrimination was possible because of the different spectral properties of the canopies of the two types of mangroves produced by a combination of individual vegetative components, effects of plant growth, density and height. This new information will be extremely useful for bio-diversity studies. This combination also helped in distinguishing between: (a) sandy area, salt pan and saline area; (b) high tide, intertidal and sub tidal mudflats; and (c) terrestrial vegetation, mangroves and dune vegetation. The delineation of small sand bodies (smallest is of size 0.25 ha), which demarcated past positions of shoreline, provided vital clues in understanding the growth pattern of this coast.[14]

Mangrove zonations based on species association and density has been carried out using LISS III data (a combination of Red, NIR, SWIR bands) for the Bhitarkanika Mangrove Forest, Orissa, which is rich in mangrove species diversity. Using band combination G, R, NIR (without MIR), three zones of mangroves were distinctly separated by differences in canopy structure and location. The R, NIR, SWIR band combination showed significant improvement in community discrimination. (Fig. 3) Seven mangrove zones were distinctly separated: (a) *Avicenia* alba, (b) *Phoenx paludosa*, (c) *Sonneratia apetala*, (d) *Aviecennia association*, (e) *Rhizophora association*, (f) Mangrove scrub and (g) Mangrove scattered. The discrimination was possible because of the different spectral properties of canopies produced by a combination of individual vegetative components, effects of plant density, height and canopy moisture variation.

Coral reefs are being destroyed by siltation, logging, mining and pollution. Sedimentation of reefs reduces live coral and species diversity as well as fish biomass. The knowledge about various zones and their condition will help to plan preventive and conservative measures to protect this fragile ecosystem. Coral reef zonation was attempted using the IRS-1C PAN and the LISS-II merged product for Van and Koswari reefs, located seven to 10 kilometres northeast of the Tuticorin coast in Southern India. Unsupervised K-Mean clustering algorithm was used for classification. It was possible to delineate four categories of reef based on depth (between 1-20 m), beach and terrestrial vegetation. Sea grass beds and live coral zones were identified visually. Live coral areas as small as 50 m^2. were possible to identify. The sea grass bed, only 15-20 m wide, was clearly mapped. This will help in estimating total sea grass and seaweed resources available in an area. The advantages of using the merged product for demarcation of coral reefs is given in Table 4.

A coral pinnacle about 2 km^2 north-by-northeast of Okha in the Gulf of Kachchh on the northwest coast of India was studied using the LISS III data. It was possible to delineate, for the first time, sea grass and seaweed beds, reef flats and sand clay on a coral pinnacle. This will certainly help improve the understanding of coral reef ecology and geomorphology.

Brackishwater Aquaculture Development

Sustainable development of aquaculture requires accurate assessments of land, water, economic and human resources available in a region, and synoptic integration and analysis of these resources. Remote sensing techniques coupled with Geographic Information System (GIS) are gainfully used for such a comprehensive analysis, leading to the identification of suitable aquaculture sites. By using remote sensing techniques and GIS, the advantage is not only in time- and cost-effectiveness but also in achieving a more comprehensive and integrated treatment of aquaculture development criteria, which is difficult through conventional techniques alone.[8] The use of the IRS-1C PAN stereo-data enables the generation of digital terrain models and contour maps with smaller intervals, in addition to providing detailed information on coastal features, such as, mudflats, tidal flats, salt pans, creeks and lagoons, land use/land cover and other features. The LISS-III data with combinations of bands 2, 3 and 4 will be useful in providing water quality information such as suspended sediment distribution and the general productivity of the area. Other major factors influencing aquaculture site selection, such as technological inputs and socio-economic data available from conventional sources, could be integrated with the satellite derived parameters. The flow diagram for selecting aquaculture sites using remote sensing techniques coupled with GIS is given in Figure 1. The potential of the PAN data for mapping at the cadastral level will also help in arriving at engineering solutions to complex problems associated with microlevel planning of aquaculture development.

Coastal Processes

The coastal processes of erosion, transportation and deposition, flooding, periodic storms and sea-level changes, continuously modify the shoreline. Detailed information on each of these processes would greatly facilitate the planning of developmental activities. The parameters that need to be studied in order to understand coastal processes are: (a) shoreline change, (b) coastal land-forms, (c) tidal boundary, and (d) offshore bar and underwater features. The earlier experiences of using satellite data have shown that multi-date data could be advantageously utilized for monitoring both short- and long-term changes of coastal processes with limitations in mapping unit size. With the availability of the PAN data, it is

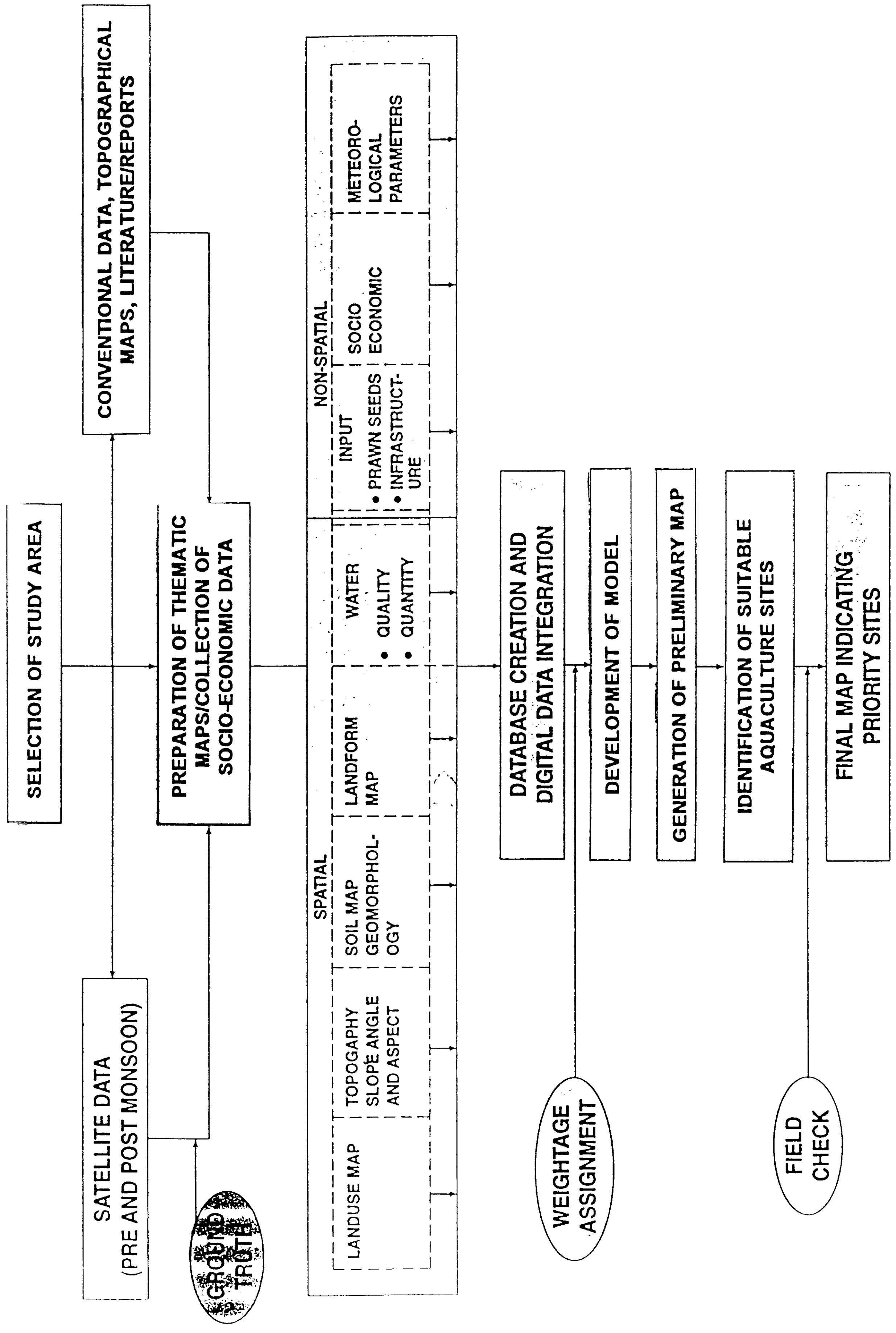

Figure 1: *Flow Diagram Showing Methodology for Selecting Brackish Water Aquaculture Sites*

now possible to map and identify the coastal processes changes such as geomorphic process of erosion and sedimentation, flooding and sea-level changes up to a 1:12,500 scale. The availability of stereoscopic data has been found to be useful for studying landforms such as the coastal plains, spits, bars, beaches, sand dunes, sand flats, estuarine systems, tidal/mud flats, and off-shore islands in finer detail. Submerged coastal features such as bars, shoals and reefs could be demarcated using both the PAN and LISS-III data, depending on the type of features and availability of the satellite data. Merged products (PAN + LISS-III/II) will have edge over PAN or LISS-III individually in identifying certain coastal features in view of the fact that it has the advantages of having improved spatial resolution and multispectral information.

Suspended Sediment Distribution

Although the IRS-1C has limited applications for studies related to ocean dynamics, it is useful for understanding the distribution of suspended sediment concentrations in near-shore waters. Knowledge of the distribution of suspended sediment is important and always has been of interest to coastal geomorphologists and near-shore oceanographers, as it is a basic solution for various problems such as the modification of harbour basins, beach erosion/accretion, the sediment balance of enclosed bays or the use of suspended sediments as a tracer for studying the circulation in coastal and near shore environment. The studies carried out using the IRS-1A, -1B, -P2, Landsat and SPOT have indicated that although measurement of suspended sediments or turbidity is possible, these measurements cannot be used operationally because of their poor temporal resolution. The IRS-1C WiFS data having five-day repetitivity has overcome this lacunae, to a certain extent.

The WiFS data of the Hoogly estuary in eastern India of 24 and 30 January 1996, were analyzed to study suspended sediment patterns. These two images were taken at high- and low-tide. During high-tide, large amounts of sediments are in suspension, compared to low-tide, essentially due to the high turbulence prevalent during high-tide. During ebb tide, the sediments were concentrated in alternate high and low concentrations. This also indicates that the flood and ebb currents follow in different paths. It would be necessary to analyze more images of different tidal conditions to understand the effect of tides on the movement of suspended sediments. The WiFS data of 6 January 1996, from the Kerala coast in southern India indicated that a sediment plume from the Kochi harbour made a sharp contrast with the sediments along the coast, indicating two different water masses. The gradual decrease in concentrations in sediments away from coast suggest a regular dispersal pattern along the coast. The high turbidity in the backwaters was clearly visible. This has clearly demonstrated that frequent repetitive coverage will provide information on sediment dispersal. Efforts are underway to use modelling techniques to quantify the suspended sediment concentration. Based on the tendrils of the suspended sediment distribution, it is also possible to demarcate the coastal current patterns prevailing in different seasons with an analysis of a large number of satellite data sets.

Ocean Pollution

Pollution of coastal waters is now generally recognised as a serious global problem with the in-shore waters becoming a dumping ground for waste products containing hydrocarbons, heavy metals, pesticides, sewage, heated waste water and pollutants from various industries. Remote sensing data from satellites have been successfully used in identification of oil spills. However, limitations in the regular monitoring of oils spills using high resolution satellites are due to constraints in the repetitivity of data, while satellites with higher repetitivity are constrained by the size of mapping. The WiFS data with moderate resolution and repetitivity overcomes these problems. Studies have also shown that ocean waste and water quality can be assessed using remotely sensed data based on associated features. While positive identification of a pollutant is difficult, remote sensing data including, the IRS-1C, has become an indispensable tool in detecting areas in the ocean affected by pollutant discharge and the general characteristics of the dispersion pattern of pollutants.

Coastal Zone Management Model

Coastal zone management is a dynamic process in which a co-coordinated strategy is developed and implemented for the allocation of environmental, socio-cultural and institutional resources to achieve the conservation and sustainable use of the coastal zone.[3] It aims to promote sustainable use, balance demand for coastal zone resources, resolve conflicting uses, promote environmentally sensitive use of the coastal zones and promote strategic planning for coasts. Any effort in this regard requires a holistic view on the assessment of the coastal natural resources and environment as well as an understanding of their mutual inter-dependencies. This could be achieved through proper coordination between planners, managers and users, through an integrated approach of analysing the number of parameters collected and generated through various means. In India, efforts are being made to develop a coastal zone management model based on the information derived from satellite data, coupled with other collateral information, for demarcation of areas for preservation, conservation and utilization and development, on a sustainable basis; detailed spatial information on coastal zones thus derived, are being utilized for developing management strategies for micro level planning. (Figure 2)

Realising the capability of satellite remote sensing to offer viable technological solutions to the problems of imparting environmental integrity to developmental processes at all levels, a unique programme called, "Integrated Mission for Sustainable Development (IMSD)," has been launched in India. The major objective of this mission is to arrive at locale-specific action plans and developmental prescriptions at the micro level for achieving sustainable development of natural resources of the region - through effective use of space-based remote sensing and collateral, socio-economic and meteorological information, merged using Geographic Information system. Based on highly encouraging results obtained from pilot scale studies, this mission has since been launched in 174 problem districts of the country (covering nearly 45 percent of India's geographical area), which are perennially affected by drought, flood and are hilly and tribal and other things.

The newer application potentials of the IRS-1C with unique combination of sensors is now being advantageously utilized for generation of various thematic maps related to coastal areas to realise the objectives of IMSD. They are: (a) the PAN data in preparation of detailed cartographic data base, Digital Terrain Model (DTM), Digital Elevation Model (DEM), updation of existing topographical maps and mapping at cadastral level; (b) the LISS-III in studying crop canopy water status, estimation of leaf area index, better separability amongst various crops and vegetation and (c) the high repetitivity data from the WiFS in monitoring the dynamics of natural resources, especially the vegetation, flood, drought, forest

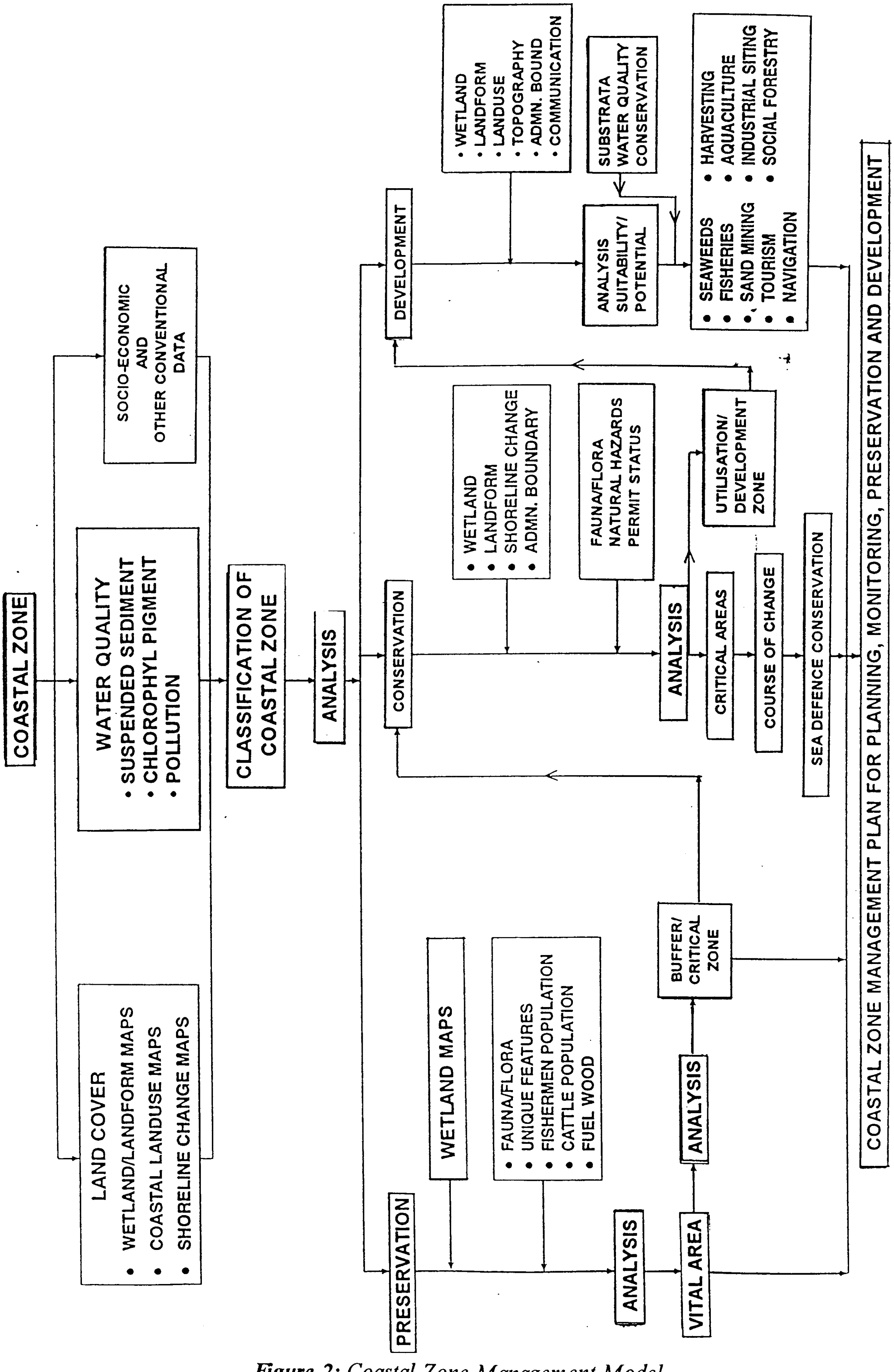

Figure 2: Coastal Zone Management Model

fire and suspended sediment distribution. These will significantly contribute toward micro-level planning and development as well as sustainable utilization of natural resources.

FUTURE INDIAN REMOTE SENSING (IRS) SATELLITE MISSIONS

Realising the gap/thrust areas of applications as well as taking into consideration various users requirements and state-of-the-art technology developments, several IRS satellites have been defined for development and launch during 1996 to 2002. They include:

The **IRS-1D**, identical and a follow-up to the IRS-1C, scheduled for launch in 1997 to provide continuity of IRS-1C type data to the users beyond 2000.

The **OCEANSAT-1**, scheduled for launch in 1998 with payloads of the Ocean Color Monitor (OCM) and the Multi-frequency Scanning Microwave Radiometer (MSMR) optimised for ocean applications. The OCM will have eight narrow spectral bands operating in visible and near-infrared (NIR) bands (402-885 nm) with a spatial resolution of 350 m and swath of 1500 kilometres. The MSMR, with its all-weather capability, is configured to have measurements at eight channels (6.6 GHz V&H, 10.6 GHz V&H, 18 GHz V&H and 21 GHz V&H) with an overall swath of 1500 km. The spatial resolution will be 120, 80, 40 and 40 km for the frequency bands of 6.6, 10.6, 18 and 21 GHz, respectively. The OCM will provide unique regional and global observation for measuring biological constituents, such as chlorophyll pigments, and assessment of primary productivity, while MSMR will be useful for measuring sea surface temperature (with poor resolution of 140 km), atmospheric water vapour and sea surface winds. Both of them will provide the data once every two days, which will be useful for operational ocean applications.

The **CARTOSAT-1** is expected to have improved technology in terms of sensor systems as well as application potentials. It will carry only one payload—a PAN with 1-2.5 m spatial resolution and 10-12 kilometres swath. It will have fore-to-aft stereo capability. The order of 1-2.5 m spatial resolution data will cater to the specific needs of cartographers and terrain modeling. It would be possible to map elevation differences of better than five meters. It is also expected to further facilitate the coastal application studies. The CARTOSAT-1 is slated for launch at the end of 1999.

The **AGRISAT-1**, with improved state-of-the-art payloads optimised mainly for agricultural applications, is planned for launch by 2000. This will carry a 3-band multispectral LISS-IV camera as well as an improved version of the LISS-III and WiFS cameras to provide enhanced applications for agriculture such as multiple crop and species level discrimination and vegetation dynamics studies. The LISS-IV camera will have a spatial resolution of better than 6 meters and a swath of about 25 kilometres with across-track steerability for selected area monitoring; it is also expected to provide improved capability for coastal zone applications.

The **OCEANSAT-2, ATMOS-1 and CLIMATSAT-1** are being readied for an integrated mission, which would cater to the global observations of ocean, climate and atmosphere, and are planned for launch during the time frame of 2001-2002. The major oceanographic payloads include: Ku-band scatterometer, Ku-band altimeter, microwave radiometer, thermal infrared monitor and ocean color monitor. It will also carry other payloads such as microwave sounders, radiometers and Scarab, for applications related to atmosphere and climate. This mission will provide a complete set of oceanographic observations such as wind field, wave spectrum, sea surface topography, ocean surface currents, internal waves, sea surface temperature and chlorophyll pigments, useful for providing operational oceanographic related services to the users.

CONCLUSION

The IRS-1C, the latest addition to the remote sensing satellite family, is considered as the best civilian remote sensing satellite launched by any spacefaring nation to date. The demonstrated application capability of the IRS-1C with its unique combination of sensors have further facilitated the coastal zone monitoring and ocean related studies such as coastal wetland mapping, identification of brackish water aquaculture sites, changes in coastal processes and suspended sediment distribution and integrated management of coastal areas to arrive at environmentally effective management information database.

The new and additional information available from the merged PAN and LISS-III/LISS-II data has been found to be extremely useful in providing detailed spatial information on development activities such as reclamation of mud flats, identification of ecologically sensitive areas, coral reef zonation, and information on the bio-diversity of mangroves, which are vital information for the coastal zone regulation activities. The availability of high temporal resolution WiFS data has been helpful in studying the distribution of suspended sediment concentrations, oil pollution mapping and regional scale studies of coastal features - towards understanding the various interactive processes operating in the coastal system. These varied advantages of the IRS-1C with newer application potentials will contribute to the regional and national efforts both toward assessing and monitoring the coastal and ocean ecosystems and also toward formulation and implementation of policies and measures to mitigate the undesirable effects of the development activities. These activities would receive further boost with the availability of data from the future, more advanced IRS satellite missions.

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Table 1: IRS-1C vs other major remote sensing satellite missions

Capability	Landsat (USA)	SPOT (France)	IRS-1C (India)
Sensors			
Panchromatic	-	✓	✓
Multispectral	✓	✓	✓
Wide-field	-	-	✓
Stereo	-	✓	✓
Resolution (m)			
Panchromatic	-	10	5.8
Multispectral	30	20	23.5
Wide-field	-	-	188
Swath (km)			
Panchromatic	-	60	70
Multispectral	185	60	142 &148
Wide-field	-	-	774
Coverage	Global	Global	Global

Table 2: Salient features and specifications of the IRS-1C cameras

Parameter	Specifications PAN	LISS-III	WiFS
Instantaneous geometric field of view (m)	5.8	B2 } B3 }23.5 B4 } B5 } 70.5	188
Swath (km)	70	142 (VNIR) 148 (SWIR)	810
Spectral band (μm)	0.50-0.75	B2 0.52-0.59 B3 0.62-0.68 B4 0.77-0.86 B4 0.77-0.86 B5 1.55-1.70	B3 0.62-0.68 B4 0.77-0.86
Quantization (bits)	6	7	7
SNR (at saturation radiance)	≥64	≥128	≥128
Saturation radiance (mw/cm^2-sr-μm)	47±2	B2 29±1.5	B3 28±1.5
		B3 28±1.5	B4 31±1.5
		B4 31±1.5	
		B5 3.5±0.3	

Table 3: Comparison of the IRS-1C PAN, IRS-1B LISS-II and merged (PAN + LISS-II) data for the Tuticorin coast, South India

Category	PAN data	LISS-II	Merged FCC		
Tidal flats	Distinct	Indistinct	Distinct		
Beach	Distinct with sharp boundary	Indistinct boundary	Distinct sharp boundary		
Spit	Clearly demarcated	Demarcated	Clearly demarcated		
Mangroves	Indistinct	Demarcated	Demarcated		
Salt pans	Distinct	Distinct (larger ones)	Distinct		
Jetty	Clear with precise details	Detection possible	Clear with precise details		
Built-up area	Clearly demarcated	Demarcated (larger ones)	Clearly demarcated		
Plume	Clear with direction	Indistinct	Clear with direction.		

Table 4: Comparison of the IRS-1C PAN, IRS-1B, LISS-II and merged (PAN + LISS-II) data for the coral reef areas, Gulf of Mannar, South India

Category	PAN data	LISS-II	Merged FCC
Reef extent	Distinct	Distinct	Distinct
Live coral zones	Demarcated	---	Demarcated
Coral reef zones based on depth	4 zones	2 zones	4 zones
Vegetation	Demarcated	Demarcated	Clearly demarcated with sharp boundary

ACTIVE MICROWAVE RESEARCH OF SOIL MOISTURE ESTIMATION AND CROP STUDIES*

P.V.Narasimha Rao
Soil Survey and Land evaluation Division
Agriculture & Soils Group
National Remote Sensing Agency (NRSA)
Hyderabad, India

INTRODUCTION

For several years, using remote sensing techniques for soil moisture estimation has been one of the key research areas, in view of its importance in diverse fields such as agriculture, hydrology, meteorology and global climate change studies. Spaceborne microwave remote sensors provide viable options for soil moisture estimation and continuous monitoring over large areas. Microwave remote sensing observations depend on two set of parameters: sensor—frequency, polarization and look-angle; and target—dielectric constant, surface roughness, crop cover and local incidence angle. Hence, suitable sensor parameters specific to an application need to be identified. Early studies by using ground-based scatterometers by Ulaby [6,7], Dobson et al. (1994), Bernard [1] and Mohan et al. (1984), show that C-band microwave sensors operating at near nadir look-angles of 10-17° with like polarization are optimum, with minimal effect of surface roughness and crop cover, for soil moisture estimation. Despite the availability of data from different platforms at various sensor configurations (eg. SEASAT INTERA X-SAR etc., SIR-A, NIR-B), the launch of ERS-l in 1991 and JERS-l in 1992 assured continuous data flow for sustained research efforts for soil moisture estimation and validation of earlier results. However, spaceborne imaging microwave sensors like ERS-1 Synthetic Aperture Radar providing data at 25 m resolution requires more intensive ground truth collection to account for scene variability due to surface roughness, terrain slope, vegetation cover conditions and soil types; and image characteristics such as speckles, identification of ground sampling points, and their location with respect to the incidence angle over a swath of 100 km.

The major constraints faced previously with optical remote sensing—all-weather capability, sensitivity of microwave data to crop water content and crop geometry—make it an attractive tool for crop identification and for continuous monitoring for condition assessment. In addition, synergistic use of cloud-free optical and microwave data shows promise for more accurate crop classification. A few attempts made to identify and study the temporal signatures of different crops and processing techniques applied on ERS-1 SAR temporal data for better accuracies have been summarized in the following sections.

SOIL MOISTURE STUDIES

Attempts to estimate soil moisture have been made at the National Remote Sensing Agency, in Hyderabad, under the ESA Announcements of Opportunity at different test sites. For several ERS-1 passes, real-time ground truth was collected for soil moisture, surface

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roughness and vegetation cover conditions. The sampling locations are easily identifiable and represent uniform conditions over an area of 2 hectares as recommended by Narasimha Rao et al. (1994).

Regression analysis of ERS-1 SAR data acquired during a crop season for soil moisture estimation has shown that developed models are season- and site-specific as seen from the sensitivity of ERS-1 SAR backscatter coefficient to soil moisture. Similarly, the cultivated row directional effects in one of the study areas are prominent; high backscatter coefficient for N-S rows (perpendicular to SAR look direction) and low backscatter coefficient for E-W rows (perpendicular to SAR look direction). The regression models could explain only 55 to 60 percent of the dependence of backscatter coefficient on soil moisture conditions in the study areas.[8] It was also observed that the estimated soil moisture is in good agreement for fields with moderate surface roughness conditions, overestimated for rough fields and underestimated for fields with very smooth surface and N-S row orientation. The influence of soil texture on soil estimation was studied for one of the study areas characterized by a wide range of textures (Venkataratnam et al. 1993). It was observed that when soil moisture is expressed in percent field capacity as suggested by Schemugge (1980) and Ulaby et al. (1982), there is a tendency to overcompensate the texture effect on backscatter coefficient. However, as observed by the author, when soil moisture is expressed in percent available water, the backscatter dependence on soil texture has reduced significantly. This may be explained by the basis of differences in bound water fraction of soils, a dependent parameter on soil texture.

Using empirical models developed for one of tile test sites, soil moisture conditions were mapped and evaluated. The evaluation showed locations with moderate surface roughness are in good agreement and those with high surface roughness showed an error of 10 percent or above. Based on these studies, it may be inferred that:

- it is mandatory to estimate surface roughness conditions by radar observations made at near and wide look angles to account for row direction influence on radar backscatter coefficient using cross polarized radar data; and use of soil water retention characteristics to minimize soil textural dependence of backscattering coefficient.

CROP STUDIES

Attempts have been made to study the suitability of space borne imaging radar data for crop growth monitoring in several test sites in Andhra Pradesh using ERS-1 C-band and JERS-1 SAR data (Venkataratnam et al. 1995). The study areas are characterized by the presence of crops like paddy, pulses (blackgram and greengram), cotton, tobacco, current and permanent fallows, orchards like cashew and mango, coconut and settlements.

The ERS-1 SAR data acquired at 35-day intervals during the major crop seasons, viz. kharif and rabi, and two scenes of JERS-1 SAR data acquired at 44-day intervals have been used in the study. These data sets have been analysed by visual and digital classification techniques and in combination with optical data from IRS-1B LISS-II.

VISUAL ANALYSIS OF RADAR DATA

Visual analysis of single and multidate BRS-1 SAR data

A comparative analysis of different crops and plantations was made for the single date gray level imagery and their corresponding FCC. A summary of analysis is presented in Table 1. From the table it is clear that only five broad categories could be separated in December and February gray level imagery. In the January image, more categories (about 7) could be delineated with clear discrimination between early and late paddy. It could be seen that there is a great discrimination (up to 10 categories) among different crops and plantations on the temporal SAR FCC. This clearly shows the advantage of representing the temporal variations associated with crops during their growth period on FCC.

A comparison with the IRS LISS-II standard FCC of 2 January 1993 showed that pulses (greengram and blackgram) could not be discriminated on SAR imagery from bare fields. This showed that these crops are transparent to the C-band radar operating at 23° incidence angle resulting in the backscatter from the background soil surface and soil moisture content (Rao et al. 1993).

Visual analysis of dual frequency microwave data

The visual analysis of JERS-1, SAR L- and ERS-1 SAR C-band data in terms of tone and texture was made to understand the microwave interaction with terrain features as a function of frequency. Table 2 provides a summary of the analysis. On L-band SAR image. cotton crop appeared in medium-gray with coarse texture due to greater penetration and insignificant volume scattering in the crop canopy while on C-band data it appeared in very light gray tone with coarse texture. Paddy on the other hand, appeared light gray with medium texture on JERS-1 SAR image due to multiple scattering at standing water surface and paddy crop during October 1993. Comparison of these data sets acquired at two frequencies showed the application potential in the area of crop identification and acreage estimation (Venkataratnam et al. 1995).

DIGITAL ANALYSIS OF MICROWAVE DATA FOR CROP CLASSIFICATION

Multidate ERS-1 SAR data

Crop classification using multi-date ERS-1 SAR data was attempted for two test sites for the 1992-93 and 1995-96 crop seasons. One of the test sites, Rajahmundry, is characterized by a wide variety of crops listed in previous section. Another test in the Kurnool district of Andhra Pradesh is characterized by the presence of cotton, paddy as major crops and current fallows, water bodies and settlements. The digital classification of two date ERS-1 SAR data showed that paddy could be classified with more than 90 percent accuracy in both test sites. However, misclassification of cotton is observed with current fallows. The misclassification has been mainly due to the wet soil moisture conditions prevailing in the second site resulting in high backscattering coefficient and signature overlap.

Dual frequency microwave data

Digital analysis of multidate data for crop identification leading to acreage estimation was based on the requirement of optimum data set. To arrive at the optimum data set, various combinations—L-band data acquired at 44-day intervals; L- and C-band data acquired around the same period; L- and C-band data acquired over a period and C-band data received at 35-day intervals during the cropping season—were used in the class separability analyses. The separability measure, Bhattacharya Distance (BD with upper limit being 2.0), was computed for major classes—early sown paddy, late sown paddy, cotton, sugarcane, plantations fallows, water and settlements. The Bhattacharya Distances for various classes are given in Table 3, where entries with bold-type indicate the confusing classes that lead to misclassification. Based on these BD values the following points could be made:

- Discrimination between sugarcane-plantation, cotton-fallows and cotton-sugarcane was poor, with data sets 1, 2, 3 and 5 shown in Table 3. Poor discrimination between water and fallows could be due to wet and smooth soil conditions at the test site, leading to specular reflection for both the classes.

- Data set 4 with L-band SAR data acquired at 44-day intervals and C-band SAR data of 17 October 1993 during the middle of the cropping season was found to have maximum separability for all classes.

- Data set 5 with multidate ERS-1 C band SAR data acquired at 35-day intervals showed poor separability among major classes, including cotton, early paddy, settlements, plantations, water and fallows.

In a separate study by Rao et al (1994), it was observed that paddy crop identification and acreage estimation was possible with ERS-1 C-band SAR data acquired at the transplantation, maturity and head development and grain filling stages of the crop. Poor discrimination observed with the current data set in the present study confirms the need for data acquisition to cover early growth stage (after transplantation) of the crop for paddy acreage estimation using C-band SAR data in the absence of cloud free optical data.

Table 4 shows the corresponding classification accuracies obtained using a maximum likelihood algorithm. The individual class accuracies are given in terms of percentage of correctly classified pixels of the test areas marked during the groundtruth collection campaign of the study area. The C- and L-band data acquired during October to November 1993 had shown maximum accuracy and is in agreement with the maximum separability observed for the same data set.

Separate study has been carried out using the spatial Gray Level Co-occurrence Matrix method by Rao et al. (1995) to compute texture features using ERS-1 SAR data covering parts of the Krishna and Guntur districts. The analysis in terms of class separability and classification accuracy showed significant improvement in the classification of coarse textured classes such as sugarcane (44.5 to 56.6 percent), plantations (39 to 52 percent) and settlements (89.6 to 94 percents) when texture measures were used in classification along with the filtered SAR data.

CONCLUSION

Recent attempts made with ERS-1 SAR data to estimate soil moisture have shown a linear relationship of backscatter coefficient with soil moisture. However, soil surface roughness, cultivated field row direction, vegetation cover and soil texture reduced the sensitivity of backscatter coefficient to soil moisture. Response of ERS-1 SAR to crop growth has been observed. However, 35-day repetivity of ERS-l SAR was found to be inadequate to identify some critical changes with the crops. Multidate ERS-1 SAR data has been found useful in paddy crop identification and acreage estimation at several test sites. Texture analysis and use of dual frequency data improved, in general, the classification accuracy of coarse textured classes.

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Table-1 : Discriminability of crops and plantation on single and multi-date SAR imagery by visual intepretation

	17 December'92	21 January'93	25 February '93	Temporal SAR FCC
1.	Early Paddy	Early Paddy	Early and Late Paddy	Early Paddy
2.	Late Padd, Early Tobacco, Sugarcane Coconut, Banana	Late Paddy	Sugarcane, Banana, Coconut, Mangroves	Late Paddy
3.	Pulses, Sunhemp, Late Tobacco, Mangroves, Tapioca	Early Tobacco Sugarcane, Banana	Pulses, Tapioca, Sumhemp, Early & Late Tobacco, Cashew	Early Tobacco
4.	Cashew	Late Tobacco, Sugarcane, Banana		Late Tobacco
5.	Mango, Forest Eroded lands	Late Tobacco, Eroded lands	Mango, Forest, Eroded lands	Mango, Forest Eroded lands
6.		Tapioca, Cashew		Pulses, Tapioca Sunhemp
7.		Mangroves, Coconut		Coconut, Banana
8.				Sugarcane
9.				Cashew
10.				Mangroves

Table-2 : JERS-1 L-band and ERS-1 C-band SAR image characteristics for various land cover features (October,1993)

Feature	JERS-1 L-band SAR	ERS-1 C-band SAR
Cotton	Medium gray tone with coarse texture	Very light gray tone with coarse texture
Paddy	Light gray tone with medium texture	Medium gray tone with coarse texture
Sugarcane	Medium gray tone with coarse texture	very light gray tone with coarse texture
Mixed crop areas (Redgram,cotton, chillies)	Dark gray tone with medium texture	Light gray tone with coarse texture
Fallows	Very dark tone with smooth texture	Very dark tone with smooth texture
Water bodies	Very dark gray tone with smooth texture	Very dark to gray tone with smooth to medium texture
Settlements	Very light gray tone with medium textue	Very light gray tone with coarse texture

Table-3 : Separability of major classes based on Bhattacharya Distance for five combinations of C & L band data set of Guntur study area

Class	Band Combination	Early Paddy	Late Paddy	Cotton	Sugarcane	Plantation	Fallow	Water
L.Paddy	1	1.999						
	2	1.997						
	3	1.998						
	4	1.999						
	5	1.791						
Cotton	1	1.999	2.000					
	2	1.999	1.973					
	3	1.999	1.984					
	4	1.999	2.000					
	5	1.331	1.929					
Sugarcane	1	1.998	1.955	1.968				
	2	1.998	1.991	1.539				
	3	1.999	1.999	1.897				
	4	1.998	1.999	1.990				
	5	1.904	1.999	1.810				
Plantation	1	1.999	1.993	1.776	0.820			
	2	2.000	1.999	0.613	1.876			
	3	1.999	1.999	1.055	1.913			
	4	1.999	2.000	1.822	1.933			
	5	1.992	1.999	1.066	1.872			
Fallow	1	2.000	1.999	1.993	2.000	1.999		
	2	2.000	1.999	1.998	2.000	2.000		
	3	2.000	1.999	1.999	2.000	2.000		
	4	2.000	2.000	1.998	2.000	2.000		
	5	1.967	1.741	1.989	1.999	1.999		
Water	1	2.000	2.000	1.792	1.999	1.986	1.546	
	2	2.000	1.967	1.851	1.994	1.993	1.039	
	3	2.000	1.999	1.983	1.995	1.998	1.603	
	4	2.000	2.000	1.892	1.999	1.998	1.764	
	5	1.858	1.938	1.988	1.926	1.998	1.637	
Settlement	1	1.997	1.989	1.999	1.999	1.999	2.000	2.000
	2	1.998	1.998	1.999	1.998	1.999	2.000	1.999
	3	1.905	1.999	1.999	1.999	1.999	2.000	1.999
	4	1.998	1.998	1.999	1.999	1.999	2.000	2.000
	5	1.886	1.955	1.354	1.744	1.563	1.972	1.959

*

1 - 15 Oct(L) & 28 Nov(L); 2 - 15 Oct(L) & 17 Oct(C); 3 - 12 Sep(C), 15 Oct(L) & 17 Oct(C); 4 - 15 Oct(L), 17 Oct(L) & 28 Nov(L)
5 - 12 Sep(C), 17 Oct(C) & 21 Nov(C)

Table-4 : Classwise percentage accuracy of classification for different data combinations (Guntur study area)

Class	Number of pixels	Band combinations 1	2	3	4	5
Paddy	965	98.5	99.5	96.2	100.0	89.7
Cotton	1270	97.5	**57.5**	71.8	96.1	80.2
Sugarcane	225	**46.8**	81.9	77.2	70.7	60.6
Fallow	475	80.2	**16.5**	**59.9**	73.1	**49.2**
Water	205	**44.3**	73.3	**57.0**	**46.8**	**56.8**
Plantation	300	**53.4**	63.1	71.9	88.0	75.8
Settlement	170	92.3	**68.0**	**65.2**	86.7	**62.4**

*
1 - 15 Oct(L) & 28 Nov(L); 2 - 15 Oct(L) & 17 Oct(C); 3 - 12 Sep(C), 15 Oct(L) & 17 Oct(C); 4 - 15 Oct(L), 17 Oct(L) & 28 Nov(L); 5 - 12 Sep(C), 17 Oct(C) & 21 Nov(C)

WORLD ENVIRONMENT and DISASTER OBSERVATION SATELLITE SYSTEM and ITS APPLICATIONS*

Takaji Kuroda
Corporate Chief Engineer
and
Shinkichi Koizumi
Chief Engineer
Space Systems Development Division
NEC Corporation
Yokohama, Japan

INTRODUCTION

Since 1987, the authors have been studying the implementation of a World Environment and Disaster Observation Satellite System (WEDOS) and have proposed this system on every available occasion to the relevant world organizations and assemblies.

WEDOS has been proposed in order to establish a satellite system whereby any point on the Earth—s surface could be observed at least once each day in order to provide accurate information in regard to the occurrence of disasters and changes in the environment, and to ensure greater safety for all the peoples of the world.

Recent studies by the authors have shown that when any disaster occurs it is very important and necessary for disaster observation systems to be able to provide information as promptly as possible, during both the daytime and the nighttime. From such a viewpoint the authors feel that WEDOS needs further improvement in regard to disaster observation.

This paper describes an upgraded version—Version II—of the Global Disaster Observation Satellite System (GDOS) with specific focus on disaster observation, including tsunamis, as an alternative version of WEDOS. The upgraded GDOS Ver.II would allow observation from space of tsunami propagation across the world—s oceans and subsequent transmission of tsunami related information to tsunami warning centers.

GREAT HANSHIN/AWAJI EARTHQUAKE

At 5:46 a.m. on 17 January 1995, the Kobe/Awaji region of Japan experienced a large and powerful earthquake, causing great damage to the local infrastructure of highways, railroads and harbor facilities. The epicenter of the earthquake was located at a depth of 14 km and at a latitude and longitude of North 34° 36', East 135° 03'. The magnitude of the earthquake was 7.2 on the Richter Scale, and resulted in the death of more than 5,500 people and the collapse of 171,000 buildings.

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* *This paper, which was presented at the UN/ESA/Chile Seminar Workshop on "Space Technology Towards Prevention and Mitigation of Disasters for the Sake of Development in Latin America and the Caribbean," July 1-5, 1996, in Santiago, Chile, does not necessarily reflect the views of the United Nations.*

Prior to the earthquake, the emergency communication systems of the Japanese Disaster Prevention Agencies was thought to be well established, expected to be able to function as required during a disaster, providing prompt and precise communication of disaster information to the appropriate organizations.

However, the earthquake destroyed almost all of the communications facilities in the central area of the Kobe/Awaji region, and disaster information was initially reported only from the surrounding areas. Information was not received from the central area until several hours after the earthquake struck, by which time the fires had spread, resulting in an increased death toll.

In any natural or man-made disaster, minimizing the scale of secondary disasters depends on the success of the prevention and rescue activities carried out in the initial stages of the original disaster. The larger and wider the range of the disaster, the more difficult fast and precise notification becomes. In this respect, the suitability and advantages of the use of disaster observation satellites is obvious.

If WEDOS would have been available for the Great Hanshin/Awaji Earthquake, according to estimations, the first satellite image would have probably been acquired at 6:00 a.m., 15 minutes after the earthquake occurred. At 6:30 a.m., the approximate scale and status of the disaster probably would have been clarified and distributed to the relevant organizations by means of satellite image data. The provision of the data would have assisted in the initial fire fighting and rescue activities. The actions which might have been taken based on information provided by WEDOS after the earthquake are based on the fortuitous fact that the time of occurrence coincided with the time when the orbit of the WEDOS satellite was above the earthquake area. This was a coincidental occurrence, and would not generally be the case in the occurrence of most disasters.

After investigation and analysis, the authors have found that it would have required a time of 4 hours and 30 minutes (maximum) during the day for WEDOS to have acquired visible images after the occurrence of the disaster, assuming a clear and fine day. Additionally, it would have required a time of 8 hours (at maximum) during the 24-hour period after the occurrence of the disaster for WEDOS to acquire infrared images for use in fire fighting and rescue activities.

The design preconditions of WEDOS, as illustrated above, were that the frequency of observation would be once each day for observation of any point on the Earth—s surface. It can therefore be concluded that it is very difficult to acquire information within a time period of several hours or less regardless of the time of day or the weather conditions. This leads to the authors' proposal of the use of a new system—the "Global Disaster Observation System" (GDOS), which would provide a viable solution for disaster observation based on the previously proposed WEDOS.

CONCEPT OF GDOS VERSION II

The Great Hanshin/Awaji Earthquake gave the authors the opportunity to investigate and learn about the functioning and operation of disaster prevention and observation systems, telecommunications systems, fire defense systems and rescue systems during the occurrence of an actual disaster, and about the difficulties experienced by the relevant organizations in taking the appropriate countermeasures inthe initial stage of the disaster using existing systems.

The authors propose that in the event of a large-scale disaster, the requirements that need to be satisfied by an observation and communications system are:

- Prompt provision of information on all aspects of the disaster to the relevant organizations in order that a full view of the disaster can be quickly perceived (e.g. location of collapsed buildings and fires, in the case of an earthquake). A full view of the disaster should be available for use at least within several hours of occurrance.

- Observation and report of the full view of the disaster to the relevant organizations regardless of the time of day or the weather conditions.

- Detection of the location of damaged and destroyed structures such as highways and large-size buildings, including condominiums.

- Detection of fire outbreaks in residential areas.

- Efficient and continuous (non-interrupted) performance of the required functions from a location remote from and unaffected by the effects of the disaster.

Based on these requirements, GDOS was conceived as a disaster observation system and was proposed as an alternative version of WEDOS. (Please refer to references [8], [9] and [10].) In GDOS Version II, however, the authors have attempted to also include the additional functions of tsunami observation and ocean data gathering, which were included in the originally proposed WEDOS system.

Objectives of GDOS Version II

As introduced in previous papers, GDOS has been proposed as a more effective system for disaster observation, on a global scale, than WEDOS. The main objective of GDOS in the occurrence of large-scale disasters is the minimization of damage, to be accomplished as follows:

- Operation of GDOS in tandem with conventional disaster prevention systems so that a full view of any disaster over a wider area range can be obtained

- Provision of detailed disaster information to enable effective deployment of rescue and fire defence services in order to suppress potential secondary disasters to the minimum.

In addition, GDOS Version II has the additional purpose of improving the accuracy of predictions and warnings of tsunami, typhoons and hurricanes through the acquisition of tsunami and other oceanic information, and increased effectiveness in disaster minimization.

The main objectives of GDOS in ordinary times are to plan and prepare for the prevention of disasters, support rescue activities and support planning for reconstruction in disaster affected areas, to be accomplished as follows:

- Provision of data for preparation of databases for disaster prevention purposes and zone maps of potentially hazardous and disaster-prone areas

- Provision of data for the improvement of prediction accuracy of disasters, including earthquakes

- Prompt detection of forest fires and similar small-scale disasters.

GDOS Version II System Study

As studied in a previous paper entitled "A Plan for a Global Disaster Observation Satellite System (GDOS)" [10], the establishment of the GDOS system requires consideration of the number and type of observation satellites required in each orbit, the type and capabilities of the onboard observation systems, the number and type of communications satellites and facilities and the ground system, among other things.

The following descriptions are proposed for the overall design of the GDOS Version II system:

GDOS Version II desirable features

- capability to acquire a full view of the disaster stricken area within an average time of 1½ hours after the occurrence of the disaster (30 minutes at the earliest and 2½ hours at the latest)

- capability to observe the disaster stricken area with a resolution of 5 meters regardless of time of day and in any weather conditions (including cloud, rain and snow)

- capability to observe the disaster stricken area with a resolution of 2 meters and a ground observation width of 40 kilometers

- capability to observe the disaster stricken area at periodic intervals (i.e. time intervals of every 2 hours) and for extended intervals (i.e. 2 times of 25 minutes for each time interval)

- capability to promptly detect various types of disasters, such as forest fires and volcanic eruptions

- capability to detect vertical movements, variations and dislocations of ground areas to a resolution of several centimeters from data obtained by multiple observations

- capability to acquire information on ocean propagation of tsunamis occurring due to earthquakes, such as tsunami stage (water level), wavelength and geographic location and also the additional capability to acquire information such as sea wave height and wind speed
- capability to obtain data on ocean water vapor, precipitation, sea surface temperature and wind speed for use in the prediction and tracking of typhoons

- capability to efficiently create a complete and detailed map of the Earth's surface and disaster prevention maps

- capability to ensure that GDOS observation data is useful for utilization in earthquake prediction studies

The observation frequencies at local time zones of twenty four satellites having onboard TR, VN and SAR sensors are given in Table 1. (Note that the observation frequency of GDOS Version II is the same as GDOS.) In this case, two hourly observations by the onboard TR sensor are performed regardless of the time of day, and two hourly observation by the onboard VN sensor are performed during the daytime only. In the observable time zones each sensor can perform two observations with a 25 minute interval. Reception of data from the onboard SAR sensor is possible once every two hours.

The concept of the data relay satellites (DRS) for inter-satellite data transmission and for data transmission to and from the ground stations is shown in Figure 2. The constellation of the WEDOS satellites and their orbits is shown in Figure 3. A comparison of the type and number of satellites and satellite orbits for the GDOS Version II system and the WEDOS system is given in Table 2. Note that in Table 2 the letters contained in the parenthesis indicate the satellite type (given in more detail in Table 4). A summary of the major types of sensors onboard the GDOS Ver.II observation satellites and their main performance data is given in Table 3.

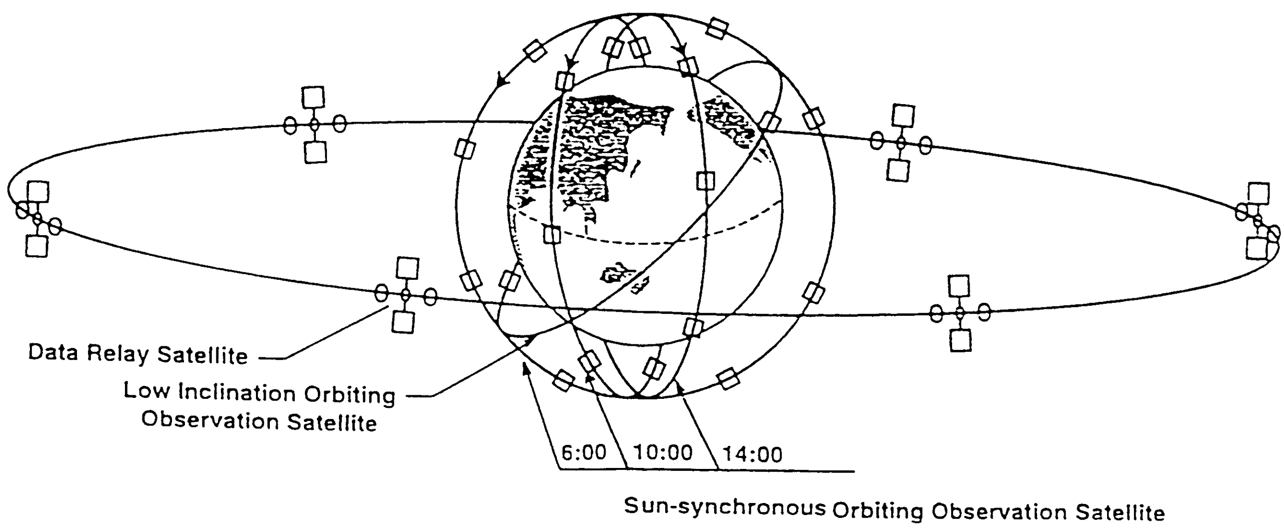

Figure1: Constellation of GDOS Satellites in Orbits

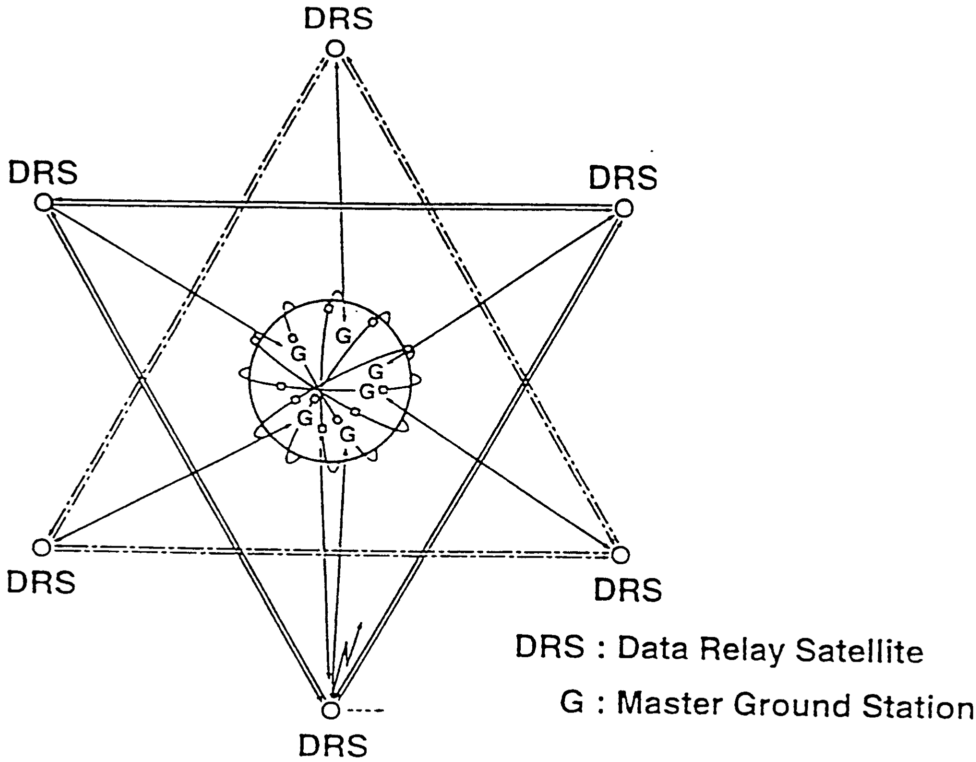

Figure 2: Concept of Data Transmission using Data Relay Satellites

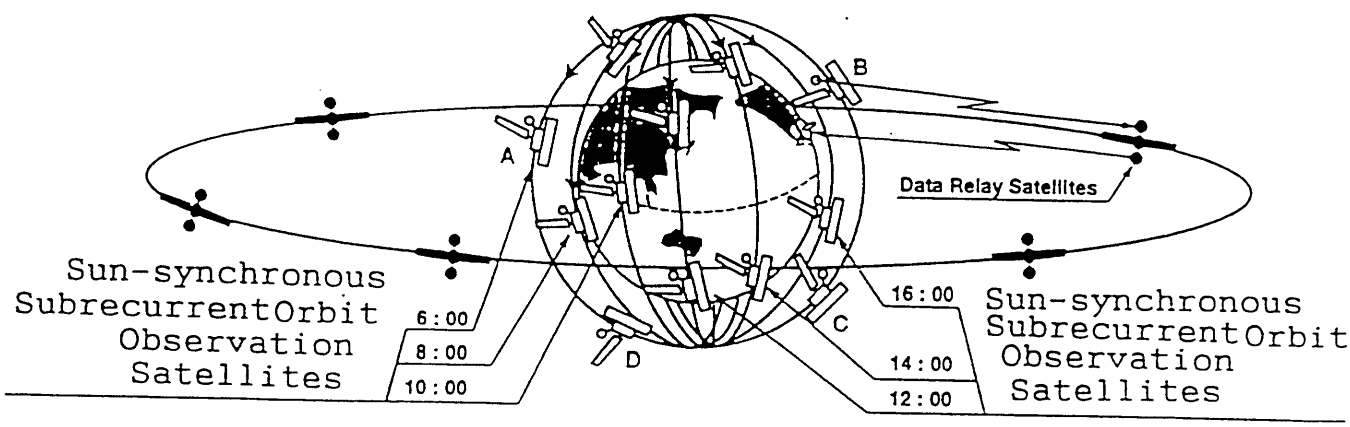

Figure 3: Constellation of WEDOS Satellites in Orbits

The following describes the features of the main sensors onboard the GDOS Version II observation satellites:

VN-1 (Visible Near-infrared Radiometer-1)

The VN-1 onboard sensor provides high resolution stereoscopic pictures for the detailed status of a disaster area.

VN-2 (Visible Near-infrared Radiometer-2)

The VN-2 onboard sensor allows monitoring of a wide area in the event of a disaster. Databases and hazard maps for disaster prevention can be created in ordinary times using information provided by VN-2.

SW (Shortwave Infrared Radiometer) and VT (Visible Thermal Infrared Radiometer)

The SW onboard sensor and the VT onboard sensor allow for the early detection of forest fires and volcanic eruptions, and can provide status information after detection.

SAR (Synthetic Aperture Radar)

Effective monitoring of disasters can be performed using the SAR onboard sensor in bad and stormy weather and at nighttime. Additionally, the acquisition of multiple observation data by the SAR onboard sensor allows for the detection of vertical land movements of the order of several centimeters.

ALT (Radar Altimeter)

Information on ocean propagation of tsunamis, such as tsunami stage, wavelength and geographic location, can be precisely acquired twice each day with am accuracy to several centimeters in relation to tsunami stage. (Local observation times are 06:00 and 18:00, each with 50-minute observation intervals.) Sea wave height and wind speed near the sea surface can also be observed.

MR (Microwave Radiometer)

Various information relating to water vapor, precipitation, sea surface temperature, wind speed and sea ice flow can be observed with an observation swath width of 1600 km and a surface temperature resolution of 1 K.

A comparison of the types of observation satellites and the onboard sensors of the GDOS Version II and WEDOS systems is given in Table 4.

The weight of each GDOS Version II observation satellite is expected to be approximately 2 tons, and the weight of each GDOS data relay satellite is expected to be approximately 1 ton.

The observation frequency using GDOS Version II observation sensors is twice every two hours for the TR sensors and the VN sensors, once every two hours for the SAR sensors, and twice each day (06:00 and 18:00 local time with 50-minute intervals) for the ALT sensors and the MR sensors. If the number of GDOS Version II observation satellites is reduced from 24 satellites to 12 satellites in order to reduce construction costs, in some cases observation using the SAR sensors becomes impossible for periods of six hours, although observations using TR sensors and VN sensors are possible every two hours.

To enable ordinary observation of the entire surface of the Earth and transmission of the observed data, a minimum of six data relay satellites are required, although observation of a disaster stricken area on a local basis can be performed by only three satellites. Another reason for this necessity is that operation commands must be transmitted to the observation satellites via the data relay satellites in the event the onboard sensors of the GDOS Version II satellites are immediately directed to the disaster stricken area or during the reception of disaster information from an observation satellite. In addition, the data relay satellites function to relay communications in the event of a disaster and to transmit the data processed at the ground stations in the broadcasting mode.

GDOS ground system

- **Mission Management Center (one station)**

The functions of the Mission Management Center are to arrange and oversee the system operation planning and management of the total system in ordinary times. In the event of a disaster, its funtion is to receive information from the relevant organizations and to send commands to the related Master Ground Stations to ready them to perform emergency observation and command control. The Mission Management Center shall have a redundant configuration to secure its reliability, and shall be located in a remote place.

- **Master Ground Stations**

Six Master Ground Stations shall be located worldwide with approximately equal separation so that the location of each of the six stations corresponds with one of the data relay satellites. The functions of the Master Ground Stations are to track and control the satellites, to transmit commands to the observation satellites via the data relay satellites, to perform reception, processing and features analysis (including information showing status change) and to transmit such information to the relevant organizations, and to transmit processed data to be broadcast using the broadcast mode to the data relay satellites. In ordinary times the Master Ground Stations monitor for the occurrence of disasters, including forest fires, and prepare databases and hazard maps useful for disaster prevention and planning.

User Stations

The User Stations allow the worldwide users of the GDOS system to receive processed data broadcast from the data relay satellites and observation data from the observation satellites.

GDOS Operations

Operation in the event of a disaster

In the event of a disaster, as soon as the Mission Management Center receives disaster information from the observation satellites or notification from elsewhere, commands are sent from the Mission Management Center to the Master Ground Station closest to the location of the disaster to ready it to perform emergency observation of the disaster stricken area. The Master Ground Station located closest to the disaster area transmits commands to the nearest observation satellite to move its onboard sensors towards the disaster area and to observe the disaster area.

The operation of the GDOS system in the event of the occurrence of a disaster is shown in Figure 4 in the form of a flow chart.

Operation in ordinary times

In ordinary times the GDOS observation satellites continuously observe the entire surface of the Earth more than once each day to detect various environmental changes, including forest fires, as they occur, acting as a "Fire Watchtower of the Earth." The GDOS system can also be used to create various maps and databases for disaster prevention. The GDOS system can also be used to improve the accuracy of disaster prediction, including earthquake prediction, by using it in tandem with existing disaster prevention systems. In ordinary times, GDOS satellite data can be directly received by not only GDOS ground stations, but also by existing Earth observation ground stations.

CONCLUSION

The outline of the Global Disaster Observation System (GDOS Version II) for disaster observation and prevention has been described in this paper in comparison with the World Environment Disaster Observation System (WEDOS), which has already been proposed and promoted as a worldwide environment and disaster observation system.

The GDOS Version II observation satellites are an improved version of the Advanced Land Observing Satellite (ALOS) currently being researched and developed by the National Space Development Agency (NASDA) of Japan. The sensors to be onboard ALOS could be utilized for the GDOS satellites after the improvement and upgrading of their performance characteristics and the expansion of their variable observation range. Therefore, realization of ALOS is a very important step in the verification and realization of the GDOS system.

The authors intend to further investigate and promote GDOS Version II, and to make their best efforts toward realization of this system, not only as an activity of the Society of Japanese Aerospace Companies Inc. (SJAC), but also as one of the main activities of the Japan-U.S. Science, Technology and Space Application Program (JUSTSAP).

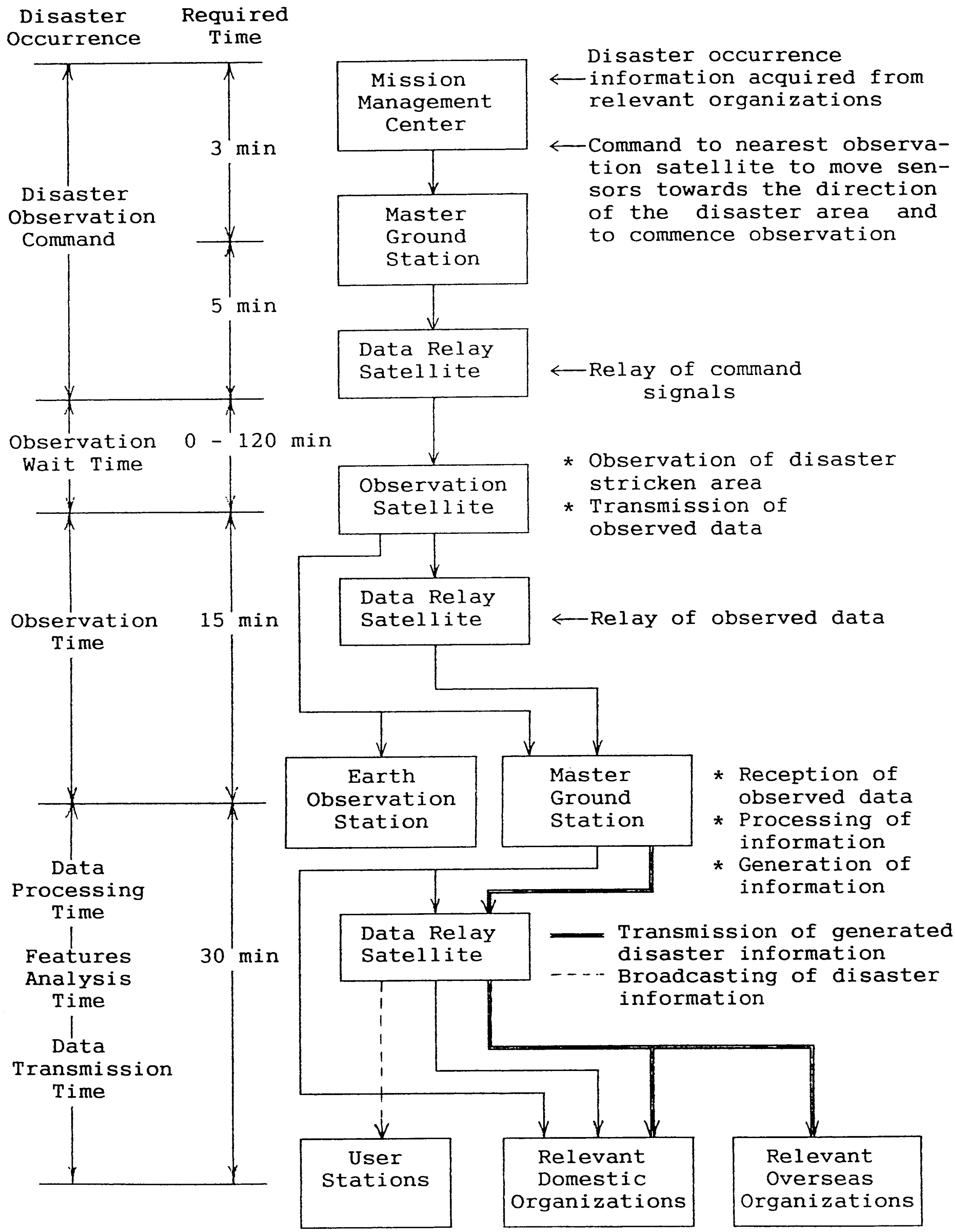

Figure 4: Example of GDOS Operation in the Occurrence of a Disaster

ACKNOWLEDGEMENTS

The authors wish to express their sincere gratitude and thanks to the members of SJAC and to the working group members of the Disaster Management Observation group of JUSTSAP, and to all other people for their tireless efforts and contributions toward the investigation and promotion of the GDOS Version II system.

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Table 1: Example of Satellite Observation Frequency and Observation Local Time Zone of GDOS

Local Time Zone		0	1	2	3	4	5	6	7
Sensor and	TR	2	-	2	-	2	-	2	-
No. of Times	VN	-	-	-	-	-	-	-	-
Observation	SAR	1	-	1	-	1	-	1-	
Local Time Zone		8	9	10	11	12	13	14	15
Sensor and	TR	2	-	2	-	2	-	2	-
No. of Times	VN	2	-	2	-	2	-	2	-
Observation	SAR	1	-	1	-	1	-	1	-
Local Time Zone		16	17	18	19	20	21	22	23
Sensor and	TR	2	-	2	-	2	-	2	-
No. of Times	VN	2	-	-	-	-	-	-	-
Observation	SAR	1	-	1	-	1	-	1	-

Table 2: Comparison of Type and Number of Satellites and Satellite Orbits for WEDOS and GDOS Ver.II

Satellite Type	Local Node Time		Satellite System	
	Descending	Ascending	WEDOS	GDOS Ver.II
Observation Satellite in Sun-synchronous Subrecurrent Orbit	6:00	18:00	8 (c)	2(f) , 2(g)
	08:00	20:00	0	4 (e)
	10:00	22:00	4(a) , 4(b)	4 (e)
	12:00	00:00	0	4 (e)
	14:00	02:00	4(a) , 4(b)	4 (e)
	16:00	04:00	0	4 (e)
Observation Satellite in Inclined Orbit	———		2 (d)	0
Data Relay Satellite in Geostationary Orbit	———		6 + 6* * Spare in Orbit	6 + 6* * Spare in Orbit

Table 3: Observation Sensors Onboard GDOS Ver.II Observation Satellites and their Main Performance Data

Type of Sensor	Resolution	Ground Observation Width	Variable Angle of Observation (ground distance)
VN-1 Visible Near-infrared Radiometer-1	2m	40km	±43° (±700km)
VN-2 Visible Near-infrared Radiometer-2	20m	120km	±43° (±700km)
SW Shortwave Infrared Radiometer	20m	120km	±43° (±700km)
VT Visible Thermal Infrared Radiometer	40m	40km	±43° (±700km)
SAR Synthetic Aperture Radar	5m	40km	18°- 50° (690km)
ALT Radar Altimeter	3cm	About 2km in diameter	Nadir only
MR Microwave Radiometer	5-60km (1K Temp. Res.)	1600km	———

Table 4: Comparison of the Types of Observation Satellites and Onboard Sensors of the GDOS Ver.II and WEDOS Systems

Sensor Type		Satellite Type						
		WEDOS				GDOS	GDOS Ver.II	
		a	b	c	d	e	f	g
VN-1	Visible Near-Infrared Radiometer-1 (high spatial resolution)	*	*			*		
VN-2	Visible Near-Infrared Radiometer-2 (high spatial resolution)	*	*			*		
SW	Shortwave Infrared Radiometer		*			*	*	*
VNT	Visible Thermal & Near-Infrared Radio meter (high spatial resolution)	*	*					
VT	Visible Thermal Infrared Radiometer (high spatial resolution)					*	*	*
SAR	Synthetic Aperture Radar	*		*		*	*	*
IS	Infrared Sounder		*					
ML	Mie Scatter Lidar				*			
MR	Microwave Radiometer		*	*	*			*
SCT	Microwave Scatterometer			*				
PR	Precipitation Radar				*			
ALT	Radar Altimeter			*			*	

A SYNTHETIC APERTURE RADAR SYSTEM ON THE ADVANCED LAND OBSERVING SATELLITE*

H. Wakabayashi, Y. Osawa, K. Toda,
T. Hamazaki and R. Kuramasu
Earth Observation Satellite Department
National Space Development Agency of Japan
Tokyo, Japan

INTRODUCTION

Many kinds of remote sensing satellites are already in orbit and many more in the planning stages. Satellites such as the NOMs and the ADEOS-II [1] are dedicated to global observation using wide-swath sensors and relatively short orbit repeat cycles, while high-resolution satellites, such as the Landsat, SPOT and JERS-1, are providing useful data for regional observation.

The National Space Development Agency of Japan (NASDA) surveyed future needs for regional observation and clarified user requirements. NASDA also conducted a feasibility study on sensors and a satellite system, and defined proposed specifications. The result was the Advanced Land Observing Satellite (ALOS), to be used to focus on regional observations. The ALOS mission instruments include a high-resolution optical sensor (Advanced Visible and Near-infrared Radiometer type-2, or AVNIR-2) and a synthetic aperture radar (Phased Array type L-band Synthetic Aperture Radar, formerly called VSAR and now known as PALSAR). The Japanese government has just authorized the phase B budget for the ALOS and the project is going into the preliminary design and BBM phases. The ALOS is currently scheduled for launch in 2002 by a Japanese H-II rocket.

This paper seeks to introduce the mission concepts and general characteristics of the ALOS satellite. In the latter part of this paper, we will concentrate on the detailed characteristics of the PALSAR system.

ALOS MISSION CONCEPT

The main missions for the ALOS are cartography and environmental and hazard monitoring by using both optical and microwave high-resolution sensors. Maps are important tools for managing a country's resources such as cultivated areas and forests. In Japan, 1/25,000 scale maps cover the entire Japanese territory and are revised approximately every five years by the Japanese Geographical Survey Institute. However, paper maps larger than 1/31,680 scale cover only 31 percent of the world. Also, more than 90 percent of developing countries are unmapped on this scale. In recent years, the Geographical Information System (GIS) has been developed in many countries; however, "digital" geographical data is still insufficient. This digital data of wide areas could be efficiently collected by remote sensing from space. The GIS is a very efficient way to manage a nation's resources and helpful toward "sustainable development" because of its capability and flexibility in making and

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**This paper, which was presented at the UN Workshop "Microwave Remote Sensing Applications," 22-26 April 1996, in Manila, Philippines, does not necessarily reflect the views of the United Nations.*

revising precise maps based on remote sensing data. These maps are also useful for environmental monitoring. According to our recent investigation, 2.5 meter horizontal resolution for determination of land conditions and 5 meter vertical accuracy for drawing elevation contours are needed to make and revise 1/25,000 scale maps. Also, multispectral bands of 10 meter horizontal resolution and L-band SAR data are required for classification of land cover, such as vegetation, forests and urban areas [2].

In early 1995, the Hanshin area in western Japan suffered severe damage from a tremendous earthquake. Dislocation of land and soil liquefaction caused by the earthquake were observed by SAR interferometry and high-resolution optical sensors, thus confirming the usefulness of this kind of satellite for hazard monitoring [3] and meeting the requirements of "as prompt as possible" and "as precise as possible" for hazard monitoring. According to our study, choosing adequate orbits and employing cross-track pointing mechanisms for the sensors allows a polar orbiting satellite to observe damaged areas within 48 hours.

ALOS SATELLITE SYSTEM

In order to accommodate high performance sensors, the ALOS satellite system should have several outstanding capabilities. The first one should be precise determination of position and attitude, and a second one should be mass data handling capability. The ALOS should be equipped with a star-tracker for accurate attitude determination and carrier phase tracking Global Positioning System (GPS) receivers for precise position determination. The position and attitude accuracies of the ALOS should be set to achieve the requirements from the geometric accuracies and the derived height accuracies of the sensor data.

To handle huge data amounts generated by the AVNIR-2 and the PALSAR, the ALOS has mass data memories on board. The memories should have 706 Gbits storage capacity and 240 Mbps data handling capability. The candidates for these mass memories are optical data recorders and solid state memory recorders. The ALOS also should be equipped with a high data rate transmission capability through the Data Relay Technology Satellites (DRTS) scheduled to be launched before the ALOS's launch. They allow us to get ALOS data in real time for hazard monitoring. Table 1 shows the ALOS satellite system characteristics, and Figure 1 gives its in-orbit configuration.

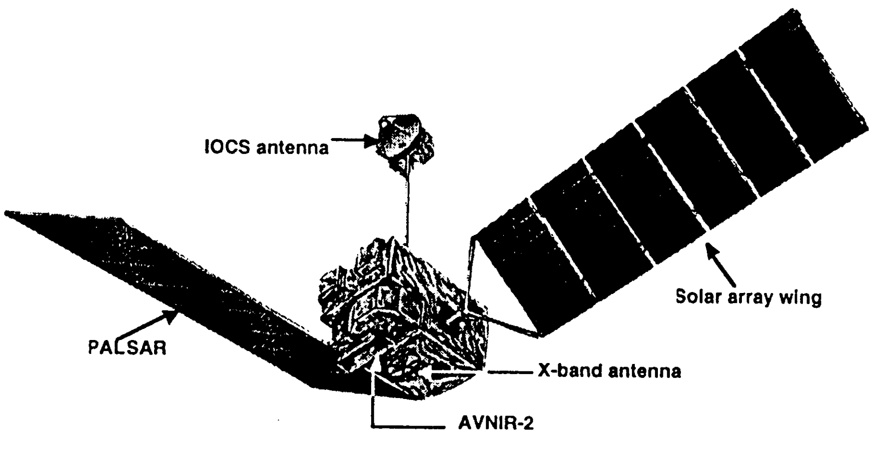

Figure 1: ALOS Spacecraft In-orbit Configuration

PALSAR CHARACTERISTICS

The PALSAR is the second Japanese spaceborne SAR using L-band frequency and we have a cross-track pointing capability from 18 to 55 degrees of incidence angle. Table 2 summarizes the PALSAR characteristics as well as the JERS-1/SAR's.

Observation Modes

The PALSAR basically has three modes of observation—fine resolution, ScanSAR, and low data rate. The fine resolution mode, a strip SAR, is a conventional mode and mainly used for detailed regional observations and repeat-pass interferometry. The goal of this mode is to achieve 10 meters of spatial resolution both in range and in azimuth directions, 70 km of swath width, -25 dB of noise equivalent backscattering coefficient (NEσ^{o}), and 25 dB of Signal-to-Ambiguity (S/A) ratio at a look-angle of 35 degrees. Its signal-to-noise ratio was determined from the average backscattering coefficient of natural targets and the accuracy of elevation determination by using SAR interferometry. The PALSAR S/A level is about 10 dB higher than that of JERS-1/SAR's, and will improve data quality especially in the coastal region. A five-bit quantization excludes a Sensitivity Time Control (STC) of the receiver and phase errors at the changing points of the receiver gain.

The ScanSAR mode will allow us to get more than 250 km width of SAR images by sacrificing spatial resolution, which is about three times wider than conventional SAR (e.g. JERS1/SAR) images and is considered to be useful for sea ice extent and rain forest monitoring. When we use an optimized orbit, by using pointing and ScanSAR capabilities, we can get the data from the same target area in less than five days.

Observed data in the low data rate mode can be transmitted directly to the ground stations by using an X-band frequency. Because of narrow band width in the X-band down-link frequency, the maximum data rate in this band is limited to 120 Mbps. By sacrificing spatial resolution in range direction, dynamic range, and swath width of the fine resolution mode, we can transmit the observation data either in 120 Mbps or 60 Mbps. Even in the 60 Mbps data, the data quality may be almost as same as the JERS-1/SAR's.

PALSAR Hardware Configuration

An elevation beam steering, which is used for look angle change in the fine resolution mode or the ScanSAR mode, is achieved by employing the active phased array technique to the PALSAR. In order to implement an active phased-array antenna, light weight T/R modules are necessary and are being developed. The antenna elevation angle is mechanically set to 48 degrees of off-nadir angle and can be steered more than 30 degrees to the nadir by controlling five bits phase-shifter in each T/R module.

In order to achieve the 10-meter resolution in the processing data, a bandwidth of 30 MHZ is required in transmitting chirp signal. For the Scan SAR and the low data rate modes, the chirp bandwidth should be reduced to around 15 MHZ. A digital chirp generator, which generates variable bandwidths (15-30 MHZ), will be used for producing high quality data.

The antenna size will be about 9.0 m long by 3.5 m wide with a mass of about 250 kg. A truss will be attached to the antenna back structure to offer firm support. Several truss structures, including deployment mechanisms such as truss shape, actuator redundancy, and deployment procedure, are under detailed trade-off study and will be soon determined.

Figure 2 indicates a functional block diagram of the PALSAR system. The PALSAR system will be jointly developed by NASDA and the Japan Resources Observation System Organization (JAROS). NASDA is responsible for PALSAR integration and the development of the antenna unit including radiation panels, while JAROS is responsible for the development of an electronics unit as well as T/R modules on the antenna unit.

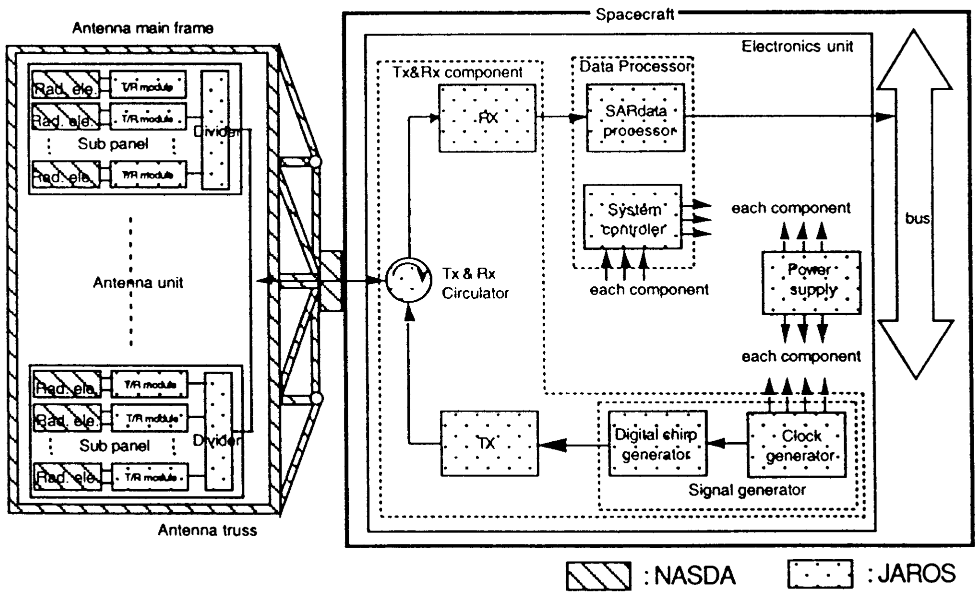

Figure 2: VSAR Functional Block Diagram

CONCLUSION

The PALSAR system is the second spaceborne SAR developed in Japan. It is scheduled to be operational in 2002 and will continue to provide L-band image data after JERS-1/SAR. During its operational period, the PALSAR system is expected to contribute greatly to many areas by using L-band frequency and its observation flexibility.

NASDA conducted the fabrications and tests for sensor's critical components, such as a T/R module, a digital chirp generator, and an antenna truss deployment structure in 1995. During the BBM phase in 1996-1997, the accuracy of beam pointing will be confirmed by a 1/1 scale model.

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Table 1: ALOS Satellite System characteristics

Launch	2002
Launch vehicle	H-IIA
Spacecraft mass	about 3,850 kg
Generated power	about 7 kW
Orbit	sun-synchronous/near recursive
-altitude	720 +/ 60 km
-inclination	98 degree
-repeat cycle	45-52 days
-local time at descending node	10h 30m am
Mission instruments	AVNIR-2. PALSAR, DCS

Table 2: PALSAR basic characteristics

Observation mode		**Fine resolution**	**ScanSAR**	Low data rate		Note	Comparison JERS-1/SAR
				1	2		
Frequency		L-band				Center freq. -T.B.D.	L-band centered at 1275 MHZ
Polarization		HH or VV				Selectable by commands	HH
Incidence angle		20-55 deg.	18-36° (3 scans) 18-40° (4 scans) 18-43° (5 scans)	20-55 °	20-55°	Look angle range 18-48°	37-42° (fixed) Look angle:35°
Spatial resolution	Range	10 m*	100*m	10m*	20 m*	* at look-angle of 35 degs.	18 m
	Azimuth	10 m (2 looks) 20 m (4 looks)	100 m	10 m (2 looks) 20 m (4 looks)	10 m (2 looks) 20 m (4 looks)		18 m (3 looks)
Swath		70 km*	250 km (3 scans) 300 km (4 scans) 350 km (5 scans)	50 km *	50 km*	* at look angle of 35 degs.	75 km
Bit length		5bits I + 5 bits Q		3 bits I + 3 bits Q			3 bits I + 3 bits Q
Data rate		240 Mbps	120 Mbps	120 Mbps	60 Mbps		60 Mbps
Radiometric accuracy		1 dB					
Noise equivalent backscattering coeff.		-25 dB*				*at look angle of 35 degs.	-20.5 dB
S/A		25 dB*				*at look angle of 35 degs.	14 dB
Mass		440 kg					228 kg
Power consumption		1100 W					500 W
				1	2		JE—1/8~AR

APPLICATION OF RADAR IMAGERY FOR FLOOD MONITORING IN BANGLADESH*

Muhammad Shah Alam Khan
Assistant Professor
Institute of Flood Control and Drainage Research
Bangladesh University of Engineering & Technology
Dhaka, Bangladesh

INTRODUCTION

Bangladesh is one of the most densely populated areas in the world. More than 75 percent of its population of 120 million live in rural areas and are dependent on the flood plains and rivers for their livelihoods. In the urban areas, the poor often live in low-lying areas affected by high floods and poor drainage.

The intensity of flood damage has increased considerably over the years due to increases in population, growth of infrastructure and other economic developments. Devastating floods are causing enormous damage and loss of life every few years. The catastrophic floods in 1987 and 1988 killed about 1,500 people and caused damage to crops, infrastructure, schools and houses estimated at about $2 billion. The subsequent disruption in the economy resulted in a reduction of the potential GDP by about 4 percent. On average, about 18 percent of the country is inundated every year. During the 1988 flood, 67 percent of the country was flooded.

Bangladesh is a large delta formed at the confluence of three big rivers—the Ganges, the Brahmaputra and the Meghna. Monsoon clouds and rains are predominant from May to October. The nature of flooding varies in different regions. The main types of flooding may be classified as (1) Flash Flood in the northeastern region, (2) River Flood in the middle of the country due to bank overflow from the main rivers, and (3) Tidal Flood in the coastal areas.

Optical remote sensing technology has been formally institutionalized since 1980 in Bangladesh at the Space Research and Remote Sensing Organization (SPARRSO). Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM), SPOT, and Advanced Very High Resolution Radiometer (AVHRR) data have been used to assess natural resources. Weather satellite data have also been used to monitor the atmospheric environment.

In comparison to optical remote sensing, radar remote sensing using airborne or space borne Synthetic Aperture Radar (SAR) sensors has drawn little attention in Bangladesh. As part of the Flood Action Plan (FAP) program of the Government of Bangladesh, one project (FAP 19) was dedicated to develop, apply, and institutionalize Geographic Information System (GIS) technology in Bangladesh. This United States Agency for International Development (USAID)-sponsored project was carried out by Irrigation Support Project for Asia and the Near East (ISPAN). This project utilized the imagery from European Remote Sensing

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**This paper, which was presented at the UN Workshop, "Microwave Remote Sensing Applications," 22-26 April 1996, in Manila, Philippines, does not necessarily reflect the views of the United Nations.*

Satellite-1 (ERS-1) to be combined with data from field surveys, in-situ point measurements and numerical models. This has been one of the first few practical applications of radar remote sensing in Bangladesh.

POTENTIAL APPLICATIONS OF SAR TECHNOLOGY IN BANGLADESH

Recent advancements in SAR technology provide the advantages of high resolution imaging capability, the opportunity to penetrate the cloud cover and to operate during both the day and night. These advantages can be fully exploited during the monsoon to monitor dynamic environmental processes.

In tropical environments, such as the one in Bangladesh, SAR technology can be effectively used to obtain valuable information for identifying flooded areas, coastal and marine features, and land use characteristics. It is evident that potential for SAR application exists in situations where optical remote sensing is either impossible or severely restricted because of environmental conditions. Primary application potential in some of the areas are:

- mapping and monitoring of river floods, storm surges, excessive rain and flash floods
- stream flow dynamics of major river Systems
- soil moisture assessment
- coastal and marine wind-wave fields

A secondary application potential, utilizing information from a primary data source, exist in areas of crop assessment, forest inventory, infrastructure mapping, terrain analysis and disaster damage assessment.

Satellite SAR data are available in a variety of formats from different sensor systems on board a number of satellites, including ERS-1 and Japanese JERS-1. Limited archival data also are available from the Russian ALMAZ and SIR-B missions of the United States. Continuation of these data is assured over the next decade with the launching of ERS-2 and Canadian RADARSAT. These facilities will be able to provide relatively frequent observations at various levels of spatial detail.

FLOOD MONITORING WITH SAR DATA

The use of SAR data in flood monitoring activities has been demonstrated by a FAP 19 project for delineating flooded areas during the persistent cloud cover of the monsoon flood season. When used in conjunction with large-scale topographic and elevation data, satellite SAR was able to provide additional information about localized flooding conditions. The overall agreement of the delineation of flooded and non-flooded areas by SAR data and the ground information simultaneously collected was over 80 percent. Some difficulties were encountered in the classification of crop canopies that were partially flooded. Additional utilities of SAR data were also explored in this project. For example, multitemporal data were used for creating a map showing changes in extent of flooding and for assessing the dynamics of hydrology, cropping pattern and agronomic practices.

Mapping the extent of the 1993 monsoon flooding using radar remote sensing data was carried out in several steps, including:

- ERS-1SAR data acquisition over selected study areas in May, July and August, 1993 and collection of relevant geographic data sets

- design and execution of a ground reference data program

- digital SAR image processing and analysis

- evaluation of results for a test area and extent of test results to larger floodplain regions

- integration of SAR image analysis results with ground reference data and other GIS data sets

The main study areas were selected near the Ganges-Brahmaputra rivers confluence in central Bangladesh and in the Sylhet region in northeastern Bangladesh. ERS-1 SAR scenes were selected for areas representing the onset and height of the monsoon season in Bangladesh. The Tangail district, located on the left bank of the Brahmaputra river, was selected for detailed image analysis and GIS data integration. Much of the land is inundated by rainfall and river water during the monsoon season. The areal extent of flooding is basically defined by topographic features within the floodplain. Flooding of low areas begins with pre-monsoon rainfall in May and June, and reaches a peak in July and August. The Tangail compartment has some flood protection from a low embankment and some means of controlled flooding from inlet sluices.

The ERS-1 illuminates a 100 km wide swath to the side of the satellite nadir track. The radar beam angle of incidence at mid-swath is 23 degrees. The nominal SAR resolution is approximately 25-30 meters, with 12.5 x 12.5 m pixel spacing in a 100 km x 100 km scene.

The SAR data were received at an ERS-1 ground receiving station near Bangkok, Thailand. The image processing and analysis exercise concentrated mainly on two scenes that were acquired for an area around the Ganges Brahmaputra confluence on 24 July 1993 and 28 August 1993. These dates cover the main flooding period for the floodplains.

According to the Bangladesh Meteorological Department, on 24 July 1993, the cloud cover was 100 percent and occasional light precipitation occurred; on 28 August 1993, the cloud cover was 100 percent and no precipitation occurred.

More than 90 site observations, measurements and associated polygon data were used as ground reference for these images. The information gathered consisted of general features, degree of flooding, crop or vegetation canopy, geographic position and reference to any on-ground photographs recorded.

Field data were systematically referenced and coded with each site categorized according to ground cover and water surface characteristics, and degree of flooding. Observation criteria for each site and category included descriptive terms, flood depth and degree of ground cover or canopy closure. Field notes were incorporated into a hierarchical classification and coding scheme that was based on prevalent land, vegetation and flooding conditions.

SAR IMAGE PROCEEDINGS

The analysis was carried out with micro computers using ARC/INFO, ERDAS, IDRISI, and EarthView software packages. This approach was done in three steps: preprocessing; classification (density slicing technique); and product generation.

The classification was based on the principle that the amount of SAR return from standing water is significantly lower than that of soil, vegetation, and other features occurring on dry land.

Flood Maps

The image classification method produced a two-class map of flooded and non-flooded areas. After analysis of the two maps corresponding to the SAR scenes of July and August, it was found that the overall area of flooding increased slightly from July to August: 48 percent and 53 percent flooded, respectively.

The detailed ground reference data, from some 45 observations on a variety of land uses, were simplified into four major categories: urban, settlement, homestead; nonflooded crops; flooded crops; and river, flood water, and bells.

These categories were compared with the two-class SAR image classification results.

Multi-date SAR imagery was used to quantify changes in the flood scenario over time. A map was produced to show changes in flood extent between July and August 1993.

CONCLUSION

This study has made an important first step in exploring the use of satellite-based SAR technology. Information on the application potential for SAR technology in Bangladesh is generally sparse and the capability to incorporate SAR data into flood monitoring activities and other areas is limited in Bangladesh. Achievement of this capability will require substantial technical and logistic support, training, and overall strengthening of one or more Bangladeshi institutions.

APPLICATIONS OF RADAR REMOTE SENSING TECHNOLOGY IN THE PHILIPPINES*

Linda S. Posadas
Philippine Council for Advanced Science and Technology Research and Development
Department of Science and Technology
Republic of the Philippines

INSTITUTIONAL ARRANGEMENT

There are a number of government institutions and organizations that use remote sensing in the performance of their mandated functions, as well as users from the private sector. Activities in space technology development and applications are coordinated by a multi-agency body called the Committee on Space Technology Applications (COSTA), one of the Committees under the Science and Technology Coordinating Council (STCC), which is a cabinet-level body chaired by the Department of Science and Technology and which sits as the highest science and technology policy making body in the country.

COSTA was born from the former National Coordinating Committee on Remote Sensing (NCCRS), but with the Philippines among the signatories of the 1994 Beijing Declaration and the of the transformation of the Regional Remote Sensing Programme into the Space Technology Applications Program, a corresponding institutional change was made. Additional members, to take care of other space technology concerns, were added to NCCRS, which was gently converted into COSTA by dissolution of STCC.

Thus constituted, the members of COSTA are as follows: the Philippine Council for Advanced Science and Technology Research and Development (PCASTRD), chairing on behalf of the Department of Science and Technology (DOST); the Department of Environment and Natural Resources (DENR); the Bureau of Soils and Water Management, Department of Agriculture (BSWM-DA); the National Mapping and Resource Information Authority (NAMRIA); the University of the Philippines (UP); the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA); the Philippine Institute of Volcanology and Seismology (PHIVOLCS); the Office of Civil Defense, Department of National Defense (OCD-DND); the Department of Transportation and Communications (DOTC); the Chamber of Mines of the Philippines; the Philippine Institute of Environmental Planners (PIEP); the Advanced Science and Technology Institute (ASTI); the Philippine Council for Aquatic and Marine Research and Development (PCAMRD); the National Security Council (NSC); the National Telecommunications Commission (NTC); and the Philippine Electronics and Telecommunications Federation (PETEF)

COMPLETED PROJECTS

The use of radar satellite data in the Philippines was spurred by the need to implement a program for rehabilitation of areas in Northern and Central Luzon that had been severely damaged by the July 1990 earthquake. This was known as the Earthquake Reconstruction

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Project (ERP), funded by the International Bank for Reconstruction and Development (IBRD) and the Asian Development Bank (ADB), and jointly implemented by NAMRIA, PHIVOLCS, and the Department of Public Works and Highways (DPWH). The project utilized Synthetic Aperture Radar (SAR) data provided by INTERA to assess earthquake damage and map potential geologic hazard zones.

This project was followed by one entitled, "Interpretation of SAR Data and Preparation of Geologic, Seismic Zonation, and Geohazard Maps for Portions of Luzon, Philippines." This project utilized interpretations of conventional aerial photographs, detailed geotechnical investigations, review of geologic and geophysical information, and interpretation of SAR data collected by INTERA. The project team included participants from the private sector. Among other very important outputs, the project team used SAR data to prepare digital base maps showing drainage and transportation for ground control registration, and digitized available geological maps for all of Luzon. SAR mosaics in the 1:100,000 scale were prepared and analyzed to produce maps showing physiography, lithology, structures, and lineaments.

These projects also had a training component as a mechanism for technology transfer. Training came in the form of intensive participation of local professionals in data review and analysis, field mapping, drilling, report writing, preparation of map layout, legends and hazard mapping, short seminars on such topics as "Engineering Seismology" and "Estimating Characteristics of Earthquake Ground Motions and Evaluating Liquefaction Potentials," a formal, short training course on SAR data interpretation, and field trips to selected study areas.

With funding support from the European Union (EU), a number of projects using ERS-1 data were undertaken in 1994, one of which was entitled, "Mt. Pinatubo Environmental Degradation Assessment Using ERS-1 SAR Data." The project produced land cover maps of Mt. Pinatubo and its vicinity. This was implemented by the University of the Philippines Training Center of Applied Geodesy and Photogrammetry.

An integral part of the collaboration with ESA was the training component, in which a national radar training workshop was held, with 32 participants from different government agencies and regions.

ONGOING PROJECTS

PAGASA also participated in this package of EU-funded projects, implementing "Application of ERS-1 SAR Data in Flood Hazard Assessment of Fluvial and Coastal Environments." Despite numerous difficulties encountered in image processing, SAR data was found helpful in delineating the extent of flooding due to a typhoon in 1993. This project will be completed within a few months.

PHIVOLCS has started a three-year project, also using ERS-1 data, with the investigation theme of "Mitigation of Volcanic Hazards in the Philippines." Four active volcanoes, namely Pinatubo, Taal, Mayon and Ragang, were selected for investigation, and monitoring of changes using the technique of inferometry. Important outputs of this project consist of geologic and hazard maps, as well as knowledge of the interferometric technique. This is sponsored by the UNESCO and the International Union of Geological Sciences.

Two member agencies of COSTA are mobilizing for the implementation of two projects under the Canadian RADARSAT Project. NAMRIA will conduct a study to examine the feasibility of using SAR data to produce an orthoimage, with the goal of producing a low-cost 1:100,000 orthoimage from a fine resolution range of 10-20 m, by designing and developing an appropriate algorithm that relates the SAR image pixel to a point on the ground (digital elevation model). RADARSAT will provide data only, while the Philippine government, through the respective implementing agencies, will provide funds for the operating expenses and equipment of the project.

Also, the Bureau of Soils and Water Management will conduct "Flood Vulnerability Assessment of the Central Luzon Basin Using RADARSAT." The project output will be presented in the form of monthly flood situation maps (1:250,000) for 1996 and 1997, pointing out flood duration, depth, and spatial extent.

FUTURE PLANS

COSTA is presently packaging a proposal to submit to the European Union as a follow-up activity to the first phase, which saw the participation of NAMRIA, UP, and PAGASA using ERS-1 data. More agencies are interested in participating in the second phase, with proposals received from the Bureau of Soils and Water Management, the International Rice Research Institute (IRRI), PHIVOLCS, the Philippine Chamber of Mines, the Mines and Geosciences Bureau, and the UP Marine Science Institute.

At the same time, COSTA is participating in discussions in preparation for the Pacific Rim Deployment of the NASA AIRSAR Mission. A Philippine proposal has been packaged and is currently undergoing review and refinement. Strategies for generating the needed financial and material resources have to be explored and actively pursued within the next few months.

THE PROGRAMME OF SMALL SATELLITES OF THE UNIVERSIDAD POLITECNICA DE MADRID*

A. Sanz-Andres and J. Meseguer
E.T.S.I. Aeronauticos Universidad Politecnica de Madrid
Madrid, Spain

INTRODUCTION

At about 6:30 p.m. (local time in Spain) on 7 July 1995, the small Spanish university satellite UPM-Sat 1 was launched in French Guyana. UPM-Sat 1, along with the small French satellite Cerise, of similar geometric and mass characteristics, travelled into space as a secondary payload on flight V75 of an Ariane IV-40 launcher, whose primary client was the military satellite Helios. Since then, UPM-Sat 1 has been operative for 213 days, follows a heliosynchronous polar orbit at an altitude of 670 kilometres, and orbits the Earth every 98 minutes, passing over Spain several times a day around 3 p.m. and 3 a.m.

UPM-Sat 1 (Figure 1) was born as an essentially educational project, although the scientific and technological development aspects were also extremely important. This satellite of the Universidad Politecnica de Madrid (UPM) was a logical consequence of the previous space experience of the promoting group. Since 1975, the Aerodynamics Laboratory of the Escuela Tecnica Superior de Ingenerios Aeronauticos has been working with the European Space Agency (ESA) on the agency's official thermal control manual for satellites (Spacecraft Thermal Control Design Data, ESA PSS-03-108), which now occupies roughly 5000 pages distributed in five volumes. Another space-related field, in which the promoting group has also been involved since 1975, concerns the behavior of liquids in low-gravity conditions. This program has included a significant number of liquid bridge experiments conducted aboard Spacelab (Missions SL-1, 1983; SL-D1, 1985; and SL-D2, 1994) and on TEXUS sounding rockets (1984, 1985, 1988, 1989, 1992, 1994). The technical aspects of the project were also important in this case: in 1990, a liquid bridge experimentation module was developed for ESA, which simulated zero gravity using the neutral buoyancy technique, and has been used by the Agency in astronaut training for mission specialists.

Apart from the technological achievement of designing, developing, building, integrating, testing and operating a small satellite at the UPM, the greatest success of the UPM-Sat 1 project has undoubtedly been the experience acquired by the team in charge of the endeavor, which included a mixture of UPM professors, students, and auxiliary personnel.

As a result of this adventure in space, the UPM now possesses a highly qualified team of technicians, and has already established excellent cooperative relationships with the domestic and international space industry. This team is already working on other space-related projects, such as the new UPM-Sat 2 MATIAS (Medidas de la Atmosfera, Telecomunicaciones, Ingenieria y Aplicaciones de los Satelites). This new project is already underway, and has obtained almost all of the necessary funding from a grant from the Spanish

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Comision Interministerial de Ciencia y Tecnologia (CICYT).

A third satellite of the UPM, the UPM-Sat 3 VENUS (Vehicle for Education of the Network of Universities in Space), is in the definition phase.

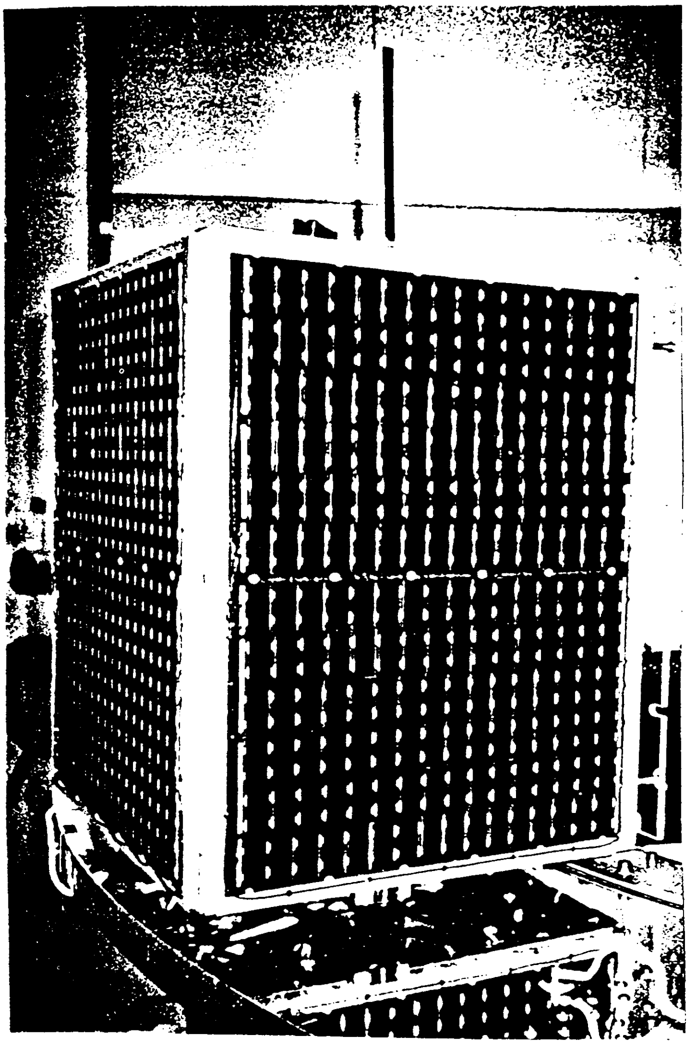

Figure 1: UPM-SAT 1

THE UPM-SAT 1 PLATFORM

UPM-Sat 1 was designed to comply with the geometric and weight limitations and the rigidity and stress requirements established for auxiliary or secondary payloads launched by Arianespace. The main characteristics of this satellite are shown in Table 1. Additional technical details on the UPM-Sat 1 platform can be found in other communications to this Conference[2], and in other papers published elsewhere.[6,8,9,10,11] The descriptions of the ground segment, the main in-flight operations and of the data obtained in orbit are reported in [1] and [3]. The total cost of the project, including the launch and ground segment was approximately US$2.4 million.

UPM-Sat 1 is a scientific and in-orbit technological demonstration satellite, but the project was essentially an educational one. The satellite was considered a means rather than an end: the idea was to create a framework in which UPM professors, students and auxiliary personnel could learn and improve their existing knowledge of aerospace engineering in order to create a core of professors specifically oriented towards teaching, research and development in the area of space-related engineering. Due to the educational nature of the project, its first goal was the satellite itself: to find out if the UPM was capable of designing, building, testing, integrating, and operating a satellite with modest technical characteristics, but whose execution would involve all the complexity of a complete space system.

In addition to this primary goal there were others concerning the use of liquid bridges as space accelerometers and new solar panel technology. The satellite's payload contains an experiment on the behavior of liquid bridges in zero gravity designed to analyze the possibility of using liquid bridges as accelerometers in space by measuring the deformation of a liquid column while subjecting it to very small accelerations. During the execution of the UPM-Sat 1 project the development of this payload was delayed for two main reasons. The first concerned the limitations of the platform itself with respect to the power available on board and its capacity to transmit information to the ground station. It was soon discovered that the usual methods used in on-earth simulation (processing the images of the liquid bridge obtained with a television camera [5]) could not be used on board and it was necessary to design a diagnosis system with more modest characteristics.

The second reason that the liquid bridge payload lost part of its initial importance was a result of the theoretical and experimental progress made by the group in charge of the theoretical support of this experiment: they found that although the use of liquid bridges as accelerometers in space is viable, its development required the creation of a line of technological research comparable in size to the team required to develop the satellite itself. In spite of the problems encountered it is worth pointing out that due to the studies conducted while adjusting the liquid bridge experiment new accelerometry techniques in microgravity conditions were developed, [7,4] thereby giving new life to the payload, which has dimensioned to a large extent both the structure and on-board electronics of UPM-Sat 1.

The mission concerning solar panels came about during the purchasing process, when an agreement was reached with the European Space Agency's Centre for Space Research and Technology (ESA/ESTEC, Noordwijk, The Netherlands) in order to use the UPM-Sat 1 as a platform for technological demonstration in orbit. As a result, the UPM-Sat I also contains three experiments with new solar panel technologies. The first involves new aluminum interconnectors for solar panels (in collaboration with DARA, Germany and ESA/ESTEC, which provided one of the silicon cell panels used on the satellite at zero cost). The second concerns gallium arsenide solar cells (in collaboration with FIAR, Italy, and ESA/ESTEC, which supplied the panel of gallium arsenide cells, also at no cost). The third experiment involves deep emitter n+pp+ silicon solar cells (in collaboration with the UPM's Instituto de Energia Solar, which provided two small solar cells mounted on the bottom of the satellite).

The team responsible for the development of the UPM-Sat 1 was directed by a project manager, who reported to a board composed of the sponsoring organizations and institutions, and a set of work teams co-ordinated by a tactical manager, who reported to the project manager. The teams, which consisted of one or two professors and several students, undertook the jobs described in the work packages. Their composition was flexible, as required by the mobility and differing availability of personnel in an university environment and the specific needs of the project during the different stages of its development.

Table 2 indicates the distribution among the different Faculties of the UPM involved in the satellite and of the human resources participating in the project. As the table shows, the satellite was the result of the efforts and dedication of a numerous group of people, including professors, students and technical, administrative and service personnel of the Escuela Tecnica Superior de Ingenieros Aeronauticos (E.T.S.I.A.), Escuela Tecnica Superior de Ingenieros de Telecomunicacion (E.T.S.I.T.), Escuela Tecnica Superior de Ingenieros Navales (E.T.S.I.T.) and the Escuela Universitaria de Ingenieria Tecnica Aeronautica (E.U.I.T.A.). The classification of personnel in the table corresponds to the situation at the beginning of 1994; since then all of the upper-division students participating in the project have their finished studies. Most of them have oriented their professional careers to aerospace, and have easily found a place in related industries and institutions. Another group, smaller than the first, has remained at the University, either as professors or to pursue doctoral studies.

THE PROGRAMME OF SMALL SATELLITES OF THE UPM

The UPM's satellite programme will continue with the UPM-Sat 2 project, mission MATIAS (Atmospheric Measurements, Telecommunications, Engineering and Satellite Applications). This project, financed in part by Spain's National Space Research Program as part of the National R+D Plan (CICYT) shares the general educational, technological and scientific goals of the UPM-Sat 1 program.

The goals of the UPM-Sat 2 MATIAS mission are scientific, technological, and educational, as described below.

- Determination of the concentration of species using near infrared spectrometry. The Instituto de Astrofisica de Andalucia is responsible for this payload.

- Accelerometry technology (microvibration measurement in orbit).

- Experimental solar panel technology. Continuation of the cooperation program with ESA/ESTEC initiated with the UPM-Sat 1 project.

- Solar cell technology, with the goal of determining the performance and resistance to radiation in orbit of solar cells produced at the UPM's Instituto de Energia Solar.

- Message communications technology between the ground stations in Spain and Latin America included in UPM-Sat 2's ground segment.

- Distribution of data on the internal status of the satellite in a communications band accessible with simple equipment, (ham radio operators, schools, etc.).

The third satellite of the Universidad Politecnica de Madrid, the UPM-Sat 3 VENUS (Vehicle for Education of the Network of Universities in Space) satellite, is in the definition phase. This satellite, as well as the UPM-Sat 2, will be based on the previous UPM-Sat 2 design. The anticipated characteristics of both MATIAS and VENUS are shown in Table 3.

It is envisaged that other European and Latin American universities will participate in these two new projects.

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Table 1: Main Characteristics of the UPM-Sat 1

Mass	47 kg
Dimensions	450 mm x 450 mm x 543 mm (antenna not included)
Orbit	670 km altitude, polar, Sun-synchronous, with a period of 98 min
Life time	7 months (213 days)
Mission summary	Liquid behavior under microgravity conditions Attitude control Store and forward communications Solar cells technology
Structure	7075 T73 machined; three layers, shear panels, Aluminum honeycomb solar panel supports Attitude control Magnetic stabilization (magnetorques plus magnetometers)
Thermal management	Passive (design plus multilayer insulations)
Data management	8 bits 12 MHz 80C31 microprocessor, 256 kbytes RAM, 64 kbytes EEPROM, watch-dog, 64 channels 8 bits DAC, 24 digital outputs and 8 digital inputs 250 mW power consumption, integral monitoring of voltage and temperature levels, asynchronous communications channel at 9600 bps
Communications	MSK modem at 9600 baud rate, 10 W onboard transmitter in 400 MHz band, omnidirectional antenna
Energy management	4 solar arrays body mounted (3 Si cell solar arrays plus 1 GaAs solar array) 30 W each, 20 W orbit averaged power; 2 batteries NiCd, 20 V bus bar; battery charge/discharge control card, power regulation, switching control card
Launch system	Ariane IV ASAP
Separation system	5ssASAP

Table 2: Distribution of the UPM-Sat 1 Team by Qualification and by Faculties of the UPM

	Prof.	Stud.	Clerks	Subtotal
ETSIA	16	25	12	53
ETSIT	6	6	-	12
ETSIN	1	3	-	4
EUITA	4	2	-	6
Total	27	36	12	75

Table 3: Characteristics of the UPM-Sat 2 MATIAS and UPM-Sat 3 VENUS Satellites

Satellite	UPM-Sat 2 MATIAS	UPM-Sat 3 VENUS
Mass	50 kg 35 kg	
Dimensions	450 mm x 450 mm x 500 mm (antenna not included) plus 6 m boom (when deployed in orbit)	
Life time	2 Years	
Mission summary	Earth atmosphere measurements Attitude control Store and forward communications Antennae technology	Store and forward communications Antennae technology
Structure	7075 T73 machined; three layers, shear panels, Aluminum honeycomb solar panel supports	
Attitude control	Gravity gradient stabilization (boom) augmented by magnetic active damping (magnetorques plus magnetometers)	
Thermal management	Passive (design plus multilayer insulation)	
Data management	8 bits 12 MHz 80C3 1 microprocessor, 256 kbytes RAM, 64 kbytes EEPROM, watch-dog, 64 channels 8 bits DAC, 24 digital outputs and 8 digital inputs. 250 mW power consumption, integral monitoring of voltage and temperature levels, asynchronous communications channel at 9600 bps	
Communications	MSK modem at 9600 baud rate, 10 W onboard transmitter in 400 MHz band (downlink) and 200 MHz band (uplink) omnidirectional antenna.	
Energy management	4 GaAs solar arrays 30 W each, 20 W average power; 2 batteries NiCd, 20 V bus bar; batterycharge/discharge control card, power regulation, switching control card	4 Si cell solar arrays 30 W each, 20 W average power; 2 batteries NiCd, 20 V bus bar; batterycharge/discharge control card, power regulation, switching control card
Separation system	5 SSASAP	TBD by INTA

FAULT DETECTION AND RECONFIGURATION CAPABILITIES FOR THE DISTRIBUTED COMPUTER ARCHITECTURE ON-BOARD THE SATEX-1 MICROSATELLITE*

E. Vicente-Vivas, M. Lopez Estrada, V.M. Melo, H. Diaz
Instituto de Ingenieria, UNAM
Ciudad Universitaria Coyoacan, Mexico
ESIME U. P. Ticoman

INTRODUCTION

The Satex-1 Microsatellite project consists of a family of microsatellites that pursues the formation of human resources in space technology and the development of test-bed systems.[1] Satex-1 is a multi-institutional project supported by the Mexican Institute of Communications; the spacecraft will be launched by Ariane Space as an auxiliary payload in a polar heliosynchronous orbit at an altitude of 800 km. The microsatellite is a 45x45x45 cm cube with solar cells on four of its faces, each of them rendering an electrical power of 27 Watts. Vehicle stabilization is achieved by means of both a gravity gradient boom and a set of six magnetic coils.[2]

The main goals of the Satex-1 mission are: the development of a spacecraft with enough technological advancements to procure the experimentation and validation of space payloads; the validation of a general purpose space bus to be utilized with minimal changes in future missions; the exploitation of previous space experiences; the integration of experienced professionals from all over the country; and the formation of new young researchers in every space field.

The vehicle contains various payloads, such as a CCD camera for remote sensing applications, an infrared optical communication downlink, and a Ka-band communications experiment. (Figure 1)

Communication between vehicle and ground station (GS) is accomplished through principal and redundant VHF communication equipment (VCE) or through a redundant link composed by a tone decoder. The latter provides limited communications with the satellite. In the vehicle, GS commands are captured from the VCE by the flight microcomputer (FμC). Depending on which destination is pursued by the command, the FμC performs either the command execution or the command retransmission to all connected nodes in the microsatellite network. To avoid the FμC to constitute a single point of failure device, a special computer architecture was developed to provide both fault-tolerance and multiprocessing. The latter enables the execution of heavy stabilization algorithms.

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* *This paper, which was presented at the UN/ESA International Conference on "Small Satellite Missions," 9-13 September 1996, in Madrid, Spain, does not necessarily reflect the views of the United Nations.*

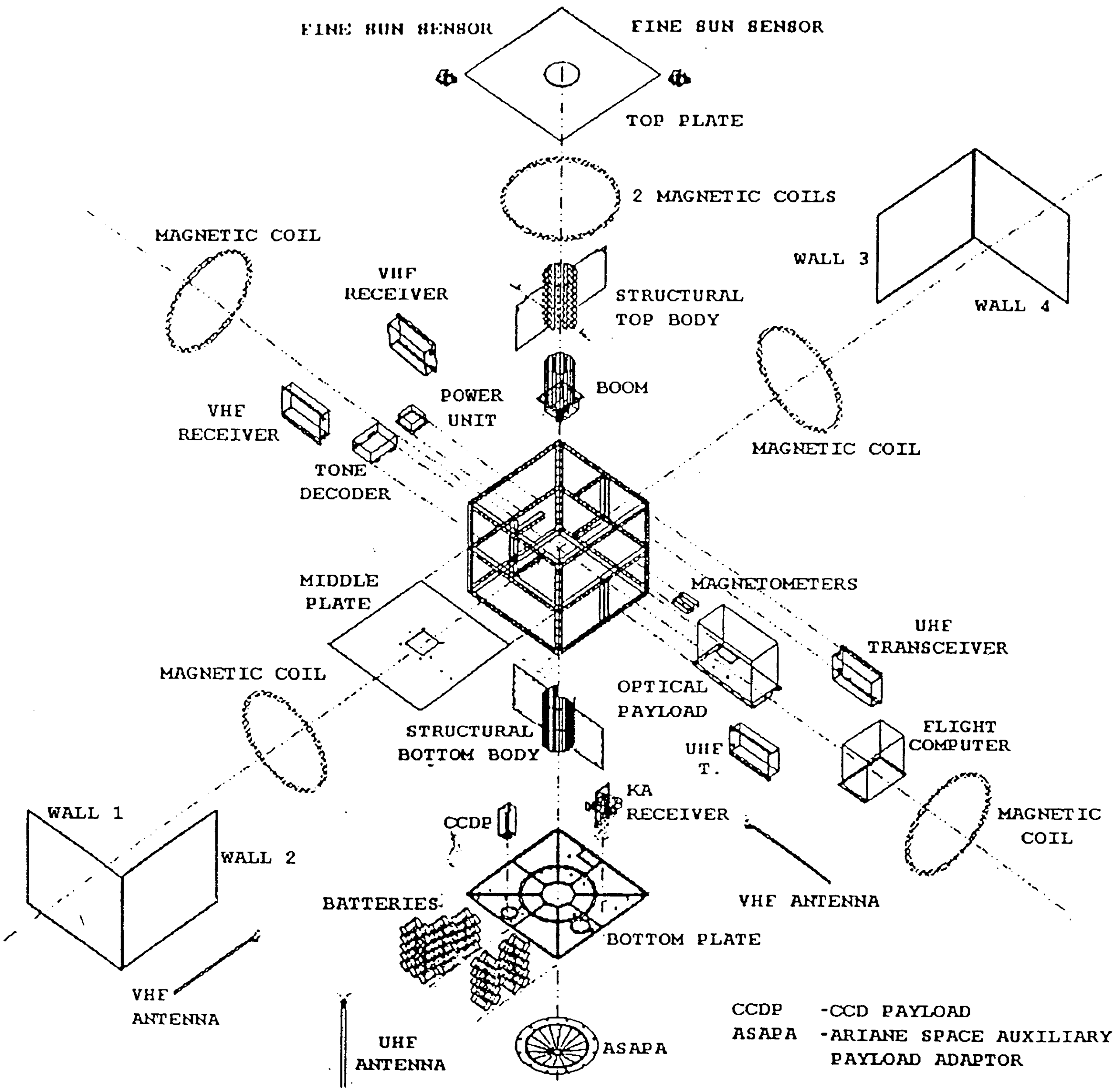

Figure 1: SATEX-1 Exploded Diagram

Specific computer power and control facilities are obtained in the main payloads with the addition of local processors. To enable the communication of all processing elements a redundant ethernet-like on-board network was implemented. Through specially designed protocols, the processing elements are allowed to exchange data and diagnostic results in order to detect failures by comparison. The baseline is the onboard network, which offer every networked node with facilities to talk or to listen any other node.

FAULT TOLERANT HARDWARE

Electronic instrumentation of the vehicle was planned with enough fault-tolerant features both in the hardware and software. A small amount of hardware redundancies were used to avoid the generation of heavy, useless equipment, but still enough to add confidence on the instrumentation. From the hardware view point, a special FμC architecture was proposed. (Figure 2)

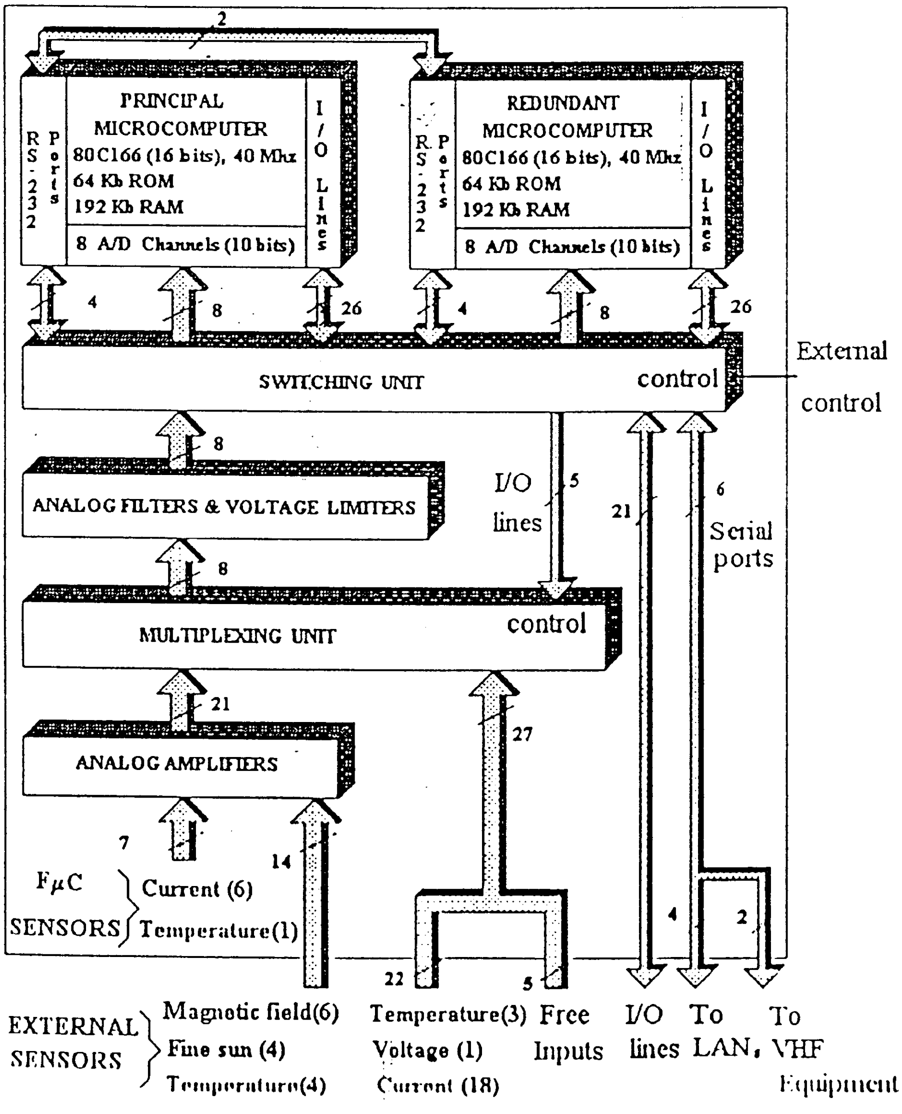

Figure 2: Electronic Architecture for the Flight Microcomputer

In Figure 2, the principal μC (PμC) is backed with a redundant μC (RμC) to provide both fault-tolerance and multiprocessing. The characteristics of the microcomputer characteristics are: 16-bit 80C166 microprocessor operating at 40 MHz, 64 Kb of PROM, 192 Kb of RAM, 26 I/O lines, three serial ports, 8 10-bit A/D channels, timers and an interrupt processor.

The fault-tolerance scheme is utilized when a permanent computer failure is detected in the system. In this case, the RµC is commanded to take control of satellite stabilization, telemetry acquisition and communication with the ground.

The multiprocessing scheme is exploited when both the PµC and the RµC are failure free; in this case, multiprocessing is allowed to execute stabilization algorithms with both main and redundant microcomputers. Taking in to account that power consumption is a main constraint for space applications, the FµC includes switching electronics to control the electrical energization of a few of its electronic submodules and some of its integrated conditioning electronics for vehicle sensors.[3] (Figure 2) With these facilities, the FµC can be operated in various power consumption modes according to the amount of required subsystems to execute a particular command. In this way, energy management can be planned from the GS according to programmed missions.

Another redundancy was introduced to increase communications reliability among networked processors; for this purpose a redundant network link was incorporated. (Figure 3)

FAULT TOLERANT SOFTWARE

Special algorithms software for Satex-1 networked nodes were developed in standard C language to tolerate, isolate and reconfigure the instrumentation in order to overcome some major failures. Among those detected were:

- Local failures in processing nodes with software procedures which interact with installed memory, CPU internal registers, serial ports, 1/0 lines and timers.

- Generation of periodical interrupts in microcomputers to perform diagnose procedures and to exchange results with other networked nodes. In a few cases, when a failure is detected and confirmed, payload microcomputers are allowed to switch from the PµC to the RµC and vice versa. In other cases, the PµC or the RµC is allowed to automatically connect or disconnect payload processors either when failures are confirmed or when current consumption readings overpass established limits.

- Data integrity checking for packet transmission between networked nodes. When errors are detected retransmission requests of particular damaged packets can be commanded from every receptor node.

- Timer procedures are used to avoid infinite loops when communication between nodes cannot be set. If such a condition is found the requesting node stays interactive with a different node. If this new communication trial is unsuccessful the redundant network channel is utilized in next accesses. This process overcomes failures on the primary network channel. (Figure 3)

- Elaboration and integration of failure reports in telemetry data to provide mission control personnel with information on satellite health.

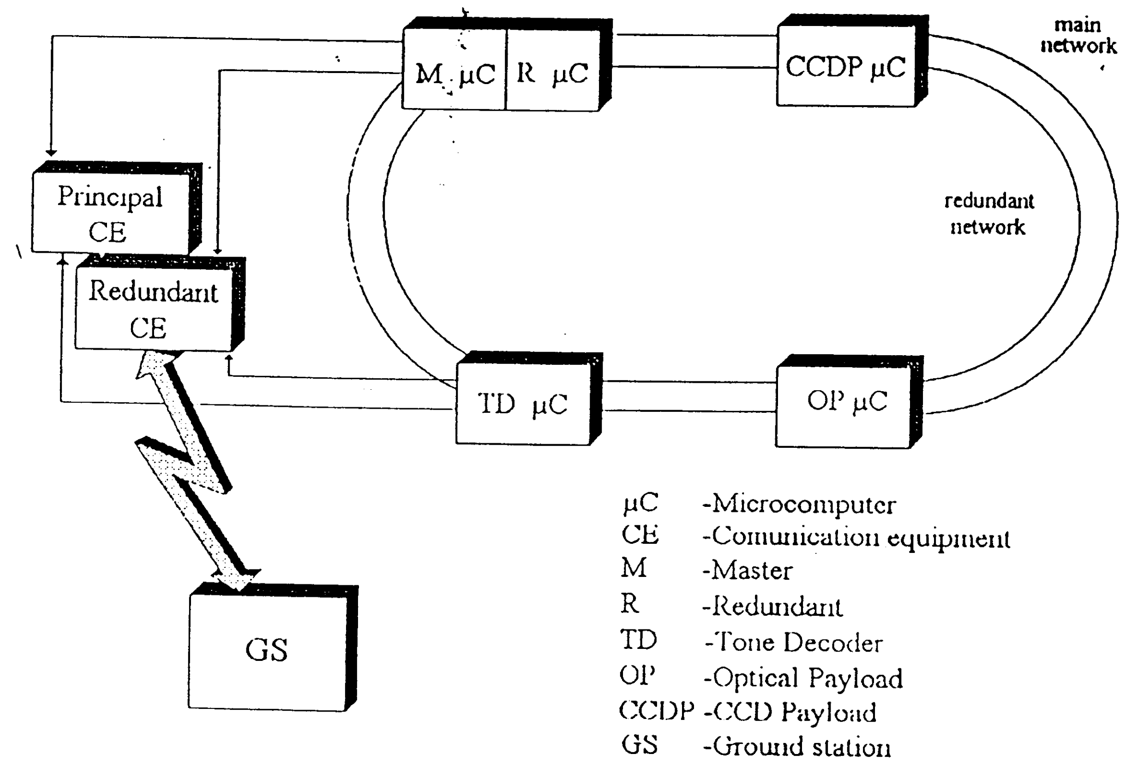

Figure 3: Redundant Communication Network On-Board SATEX-1

- Execution of control commands sent from the GS to reconfigure the satellite instrumentation.

Special protocols were also developed to increase interaction reliability between Satex-1 and the GS basically concern the possibility of transmitting and/or receiving long information packages to the GS in several satellite over-flights. Other important algorithms are related with the detection of data integrity in telemetry packets and with facilities to retransmits one or few of them.

The complement for the above-mentioned algorithms is the ground station software. Programming was done with Borland C++ under Windows. The software includes following facilities telemetry visualization for 45 satellite sensors, visual indicators for alarmed sensors, exhibition of a failure report from satellite equipment, on-line commands, mission programming, program transmission and transmission of second-stage stabilization patterns. The GS software also includes off-line software to solve mathematical models concerning earth magnetic field, orbital dynamics and stabilization.[3] Its results are compared with those obtained by Satex-1 and employed to enhance modeling approaches.

FAULT DETECTION AND RECONFIGURATION

Fault detection in the distributed control system aboard the Satex-1 is accomplished by a distributed intelligent algorithm capable of detecting and deciding when a node in the network has failed. Two of the main goals for detecting failures on the Satex-1 networked microcomputers are the isolation of short circuits and the possibility of transferring control actions to healthy processors. The isolation of short circuits is well understood; it means the possibility to keep a sane power supply.

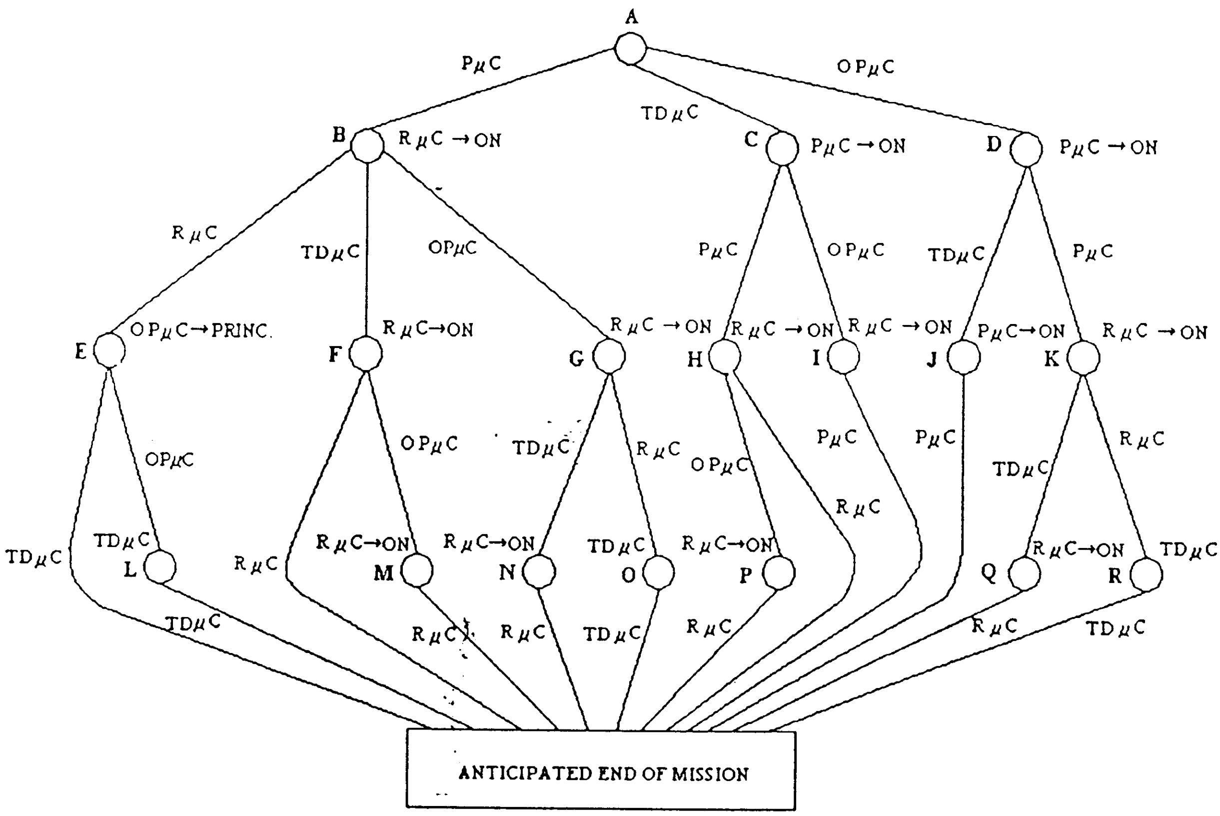

***Figure 4:** Global Decision Tree*

Figure 4 shows the global decision tree which contains the probable failures in the distributed control system onboard the microsatellite. The decision-tree analysis was obtained by assuming different consecutive failures on microcomputers. The fault-tolerant design aims to avoid single points of failure, which also means the possibility of getting access to the satellite even under degraded modes. In Figure 4, every circular node indicates an operative state where at least minimal interaction with the vehicle can be established. State transition occurs when a microcomputer presents a failure. In a few cases the satellite instrumentation tolerates the presence of up to three failed microcomputers. Depending on the appearance order of failures, different degradation mode are presented. For instance, each trajectory defined by nodes ABFM, ABGN, ACHP and ADKQ contain three failed microcomputers and each trajectory still ensures optimal communications between the vehicle and the GS. On the other hand, each trajectory ABEL, ABGO and ADKR also contains three failed microcomputers, but they represent the most degraded operating mode of the Satex-1.

CONCLUSIONS

This paper described the fault-tolerant attributes introduced in the hardware and software development of the Satex-1 microsatellite. Special emphasis was given to the description of redundancies in the flight computer and the network channel, which allows any of the networked nodes to gain attention from any other on-board processor.

Most of the FT facilities in the Satex-1 were integrated into the operative software from the satellite microcomputers. In this case, a distributed fault-detection and reconfiguration algorithm was developed based on decision trees. The distributed algorithm allows in a few cases the presence of up to three failed processors, and depending on the failure sequence, different degraded modes of operation are found. The developed software uses specially designed network protocols to provide each microcomputer with communications facilities to exchange diagnosis results.

ACKNOWLEDGMENTS

The authors would like to acknowledge support provided by the "Instituto Mexicano de Comunicaciones" to the Satex-1 project.

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THE DESIGN CONCEPT OF MULTI-PURPOSE SMALLSAT PLATFORMS IN CHINA*

Zhang Guofu, Li Guo, Zhang Yongwei
Chinese Academy of Space Technology
Beijing, China

INTRODUCTION

Since the 1980s, progress in space technology, especially in the application of advanced microelectronics, micro mechanisms and lightweight materials techniques in spacecraft, has made it possible to reduce satellite size and greatly enhance its functions. It is no exaggeration to say that the characteristics and usage of smallsat will greatly influence the activities of international space circles. Compared with large satellites, smallsats have the advantage of: shorter development periods; lower costs; mature and perfect functions; small development teams, moderate facilities and ripe technologies; and providing more opportunity to demonstrate new technologies

Additionally, smallsats are playing an important role in: testing and verifying new technologies and new materials in orbit prior to practical use; storing and forwarding (S&F) experimental communication; small-scale space science activity; small-scale space remote sensing; and usage of smallsat constellation

The technology bases of the modern smallsat are microelectronics and the computer, especially the widely-used personal computer and local area network (LAN). The practical activities of the smallsat during the 1980s and 1990s also reflect the development and usage in the fields of hardware and software of on-board computers. It simplifies the design, reduces the hardware, improves the reliability and provides a flexible and convenient platform for users.

Smallsats have attracted great interest from a number of developing countries, especially Asian-Pacific countries, looking forward to applying space technology to solve their urgent problems with an acceptable performance-to-price ratio. It is expected that the smallsat may be widely applied by the beginning of the next century.

DEMAND AND ADAPTABILITY OF THE SMALLSAT PLATFORM

China is a country with a large land mass and extensive coastline. It has varied topography and diverse physical features. In west China, it is mountainous and inconvenient, resulting in poor transportation and communication facilities. Mobile communications with smallsats would alleviate this problem. Also, remote sensing has become more important in resource and environmental management, surveillance and disaster monitoring.

This paper, which was presented at the UN/ESA International Conference on "Small Satellite Missions," 9-13 September 1996, in Madrid, Spain, does not necessarily reflect the views of the United Nations.

Experts at the Chinese Academy of Space Technology (CAST) have analyzed the characteristics of the smallsat. In addition to its light weight, small volume, cheap cost and shorter developing period, they noticed that the smallsat is an excellent model of prolonging the life of space instruments simply by using space resources, including:

- gravitational field and gradient of gravity
- geomagnetic field and its magnetic torques
- solar radiation pressure
- using space information, for example GPS orbit and attitude determination
- disposing the satellite system rationally and scientifically, and paying attention to integrating in the system level and multi-path of information

Payload

The platform needed to satisfy domestic requirements of the multipurpose platform include small remote sensors (e.g. ocean color imagers [OCI]), CCD cameras, scientific experimental instruments, S&F experimental communication and new technology test payloads.

Orbit Range

Preliminary analyses of the requirements of a mission indicate that a sun-synchronous near-circular regressive orbit with certain regional coverage and regressive period is needed by most users.

The main characteristics of the orbit are:

- sun-synchronous orbit
- mean altitude of orbit of $H = 600 \sim 900$ km
- dusk-dawn orbit

Operation Mode

In order to meet requirements of different payloads using one platform, the following two operation modes are considered:

- Spin stabilization mode: The spin rate is 10-20 rpm and suitable for space science experimental requirements

- Three-axis stabilization mode: The attitude pointing accuracy is $0.1 \sim 0.5$ °, control stability is ± 0.005 ° and suited for OCI satellites, S&F experimental communication satellites and small-scale remote sensing satellites.

DESIGN CONSIDERATION OF THE SMALLSAT PLATFORM

From previous analyses of multi-purpose and multi-operational modes, the separate module design scheme was chosen for the smallsat platform. The modules include the service system electronic module, payload module and propulsion module.

The shape of the service system electronic module is roughly a cuboid with the size of 100mm x 1200mm x 500mm consisting of the following subsystems: attitude control, integrated housekeeping management (IHM), electrical power and thermal control.

A simple user interface is provided with the platform. It is easily modified, in order to reduce the cost and development period, to suit various mission requirements including new technology demonstration, space science experiments, communication and earth observations.

A stable-state gravity gradient configuration is shown in Figure 1.

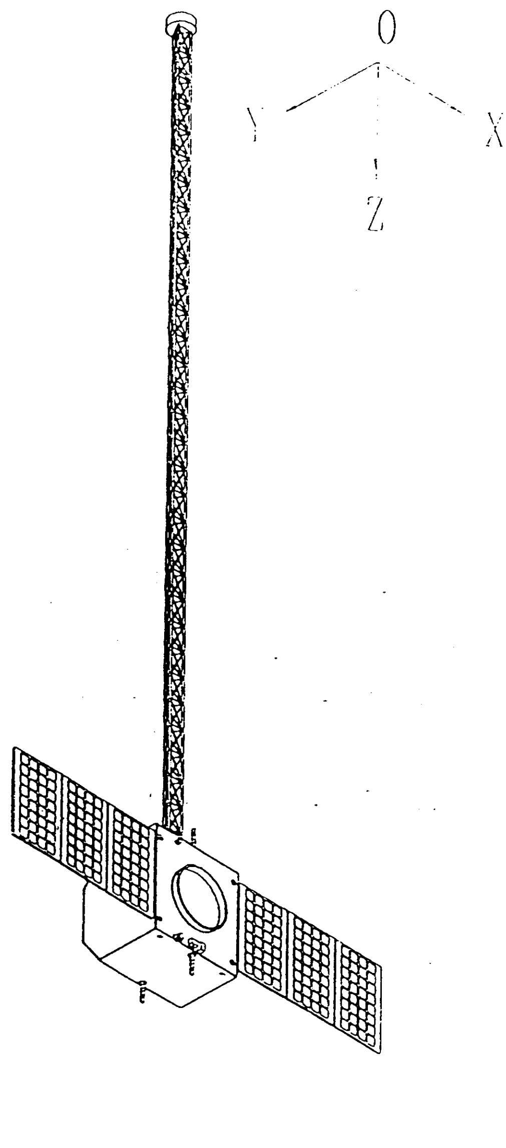

Figure 1: *Stable-State Gravity Gradient Configuration*

Structure Design

For mechanical structure design, a separate module design method is used to give payload independence and simplify the interface. The design scheme means the separate design and installation of the payload and the common platform. The sustaining weight is 250-350 kg, including 100-150 kg for the payload. The structure of the platform should satisfy the adjustable attitude control requirements of minimum-size spin stabilization and three-axis stabilization. Based on the above requirements, a 1200mm x 1100mm x 500mm cuboid structure is selected for the common platform.

Electrical Power

The power is supplied by solar arrays combined with a Cd-Ni storage battery. In the sunlit area, power generated by the solar arrays directly supply the loads as well as charge the battery so that it can supply the loads in the shadow area. For short-term high-power loads, a combined supply scheme is used even in the sunlit area.

The full bus adjustment scheme is considered for primary power sources. The bus voltage is 28±1 V. The power supply to the whole satellite is stabilized with a parallel regulator and a charging/discharging controller.

The dispersing supply mode with a DC/DC converter inside the facilities is used for secondary power sources. Its advantages include a reduction of the residual magnetic field, thus achieving a good electromagnetic environment.

The capacity of the power supply is quite flexible. The numbers of solar arrays and batteries may be increased according to mission demand.

Thermal Control

A passive thermal control scheme is adopted. Proper thermal control coating and multi-layer isolated (MLI) materials are chosen. The working temperature of instruments in the satellite can be controlled in the range of 10±20° C, except for some special devices.

For the thermal design of the internal surface and instruments, it is necessary to consider uniform distribution of thermal flow and to apply radiating and heat-transfer measures with great differences in various facilities and by erect face panels. Embedding heat pipes into part of the facilities' erect face panels, the thermal requirement for multifunction structure can be partly achieved.

In general, since spin satellites have uniform distribution of circumference temperatures and are oriented in inertia space, it is necessary to carefully choose the radiating face.

Attitude Control

In order to meet requirements of the multi-purpose platform, the attitude control subsystem of the satellite has to accomplish two different operation modes, the sun-pointing spin-stabilized mode and the earth-pointing three-axis stabilized mode. The external view of the small satellite with deployment of a gravity gradient boom is shown in Figure 1. The solar arrays are normally along the negative y-axis.

During the initial operation mode, the satellite is required to provide a micro gravity environment. Therefore a magnetorquer is selected as the primary actuator for this mode. The solar arrays facing the sun assure maximum electrical power generation. In the second mode a combination of the gravity gradient boom with active magnetorquing to realize a platform with moderate pointing accuracy is used. Furthermore, the bias momentum wheel is added to improve attitude control accuracy. By using a horizon sensor to provide accurate knowledge of roll and pitch attitude of the satellite, the pointing accuracy is expected to be better than 0.5° rms and meets more stringent attitude requirements of some missions.

1. Subsystem description and configuration

Four different types of sensors, Sun sensor (SS), Earth horizon sensor (ES), gyro and magnetometer (TAM), are used to provide attitude and rate information. Two digital fine sun sensors are mounted on the -y face of the body. Each of them has a field of view of 120° x 128° with a measurement error of about 0.05°. The sensors are the primary components keeping the y-axis pointing to the sun in the sun tracking mode. The installation geometry is shown in Figure 2.

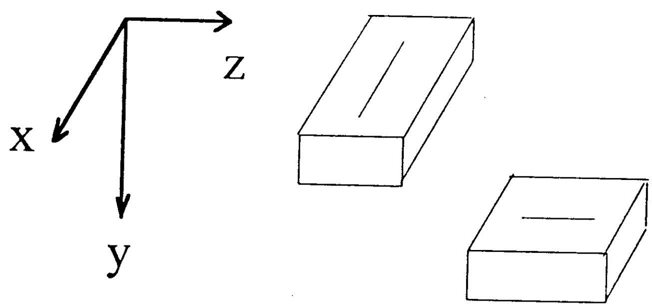

Figure 2: *Schematic Installation of Two Digital Sun Sensors*

The scanning axis of the horizon sensor is parallel to the y-axis of the satellite body. It provides roll (x-axis) and pitch (y-axis) attitude information at the same time. The input axes of two single DOF rate gyros are parallel to the x- and y-axis of the satellite body, respectively.

The actuators of the control subsystem includes three magnetic coils, each aligned with the principal axis of the satellite, a momentum bias wheel and a coal gas propulsion system (PS). The angular acceleration produced by a single thruster is about $0.1°/s^2$ for fast attitude precession control. About 1 kg of gas will be needed to carry out all the necessary attitude adjustments. A simplified block diagram of the attitude control subsystem is in Figure 3.

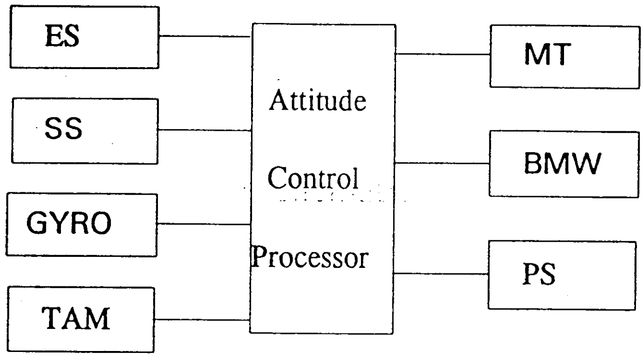

Figure 3: Simplified Function Block Diagram of the Attitude Control System

2. Functions of the subsystem

The smallsat will be immediately spun-up about the y-axis after injection to a designated spin rate. Then the perturbation, due to the deployed motion of solar array, is eliminated. Nutation damping and attitude precession are conducted by the cold gas propulsion system. The correct phase of the jet pulses for the attitude maneuver is provided by the sun sensor. Attitude maneuver from the initial attitude to the sun-pointing attitude can be achieved within several minutes. Once the attitude maneuver is completed and the sun acquisition is achieved, the control mode should be switched to the sun pointing spin-stabilized mode. The magnetic coils work to keep the y-axis to the sun, according to the attitude and rate information provided by the sun sensors and magnetometer, respectively.

When the transition to the Earth pointing three-axis stabilized mode is demanded, the maneuver is performed at a proper position of the orbit where the earth enters the field of view of the horizon sensor. Once the Earth acquisition is completed, the magnetic control can be switched on to establish the condition of deploying the gravity gradient boom. Then normal on-orbit control is started.

For the earth-pointing mode, two control modes can be considered:

Mode A:

- Sensors: infrared earth sensor and magnetometer
- Actuators: gravity gradient boom, magnetic torquers
- Probable attitude pointing accuracy: 5° for three axes

Mode B:

- Sensors: infrared earth sensor, sun sensor and magnetometer
- Actuators: gravity gradient boom, biased momentum wheel, magnetic torquers
- Attitude pointing accuracy: better than 0.5° for three axes
- Control stability: 0.005 °/s

Tracking Telementary and Command (TT&C) and Integrated Housekeeping Management (IHM)

1. TT&C RF Up/Down links

The BUS system is used for TT&C and the corresponding transponder is mounted on the platform. Its basic functions include:

- Providing the satellite up-link, receiving the direct and indirect ground commands, up-link data and job files
- Providing the down-link for the satellite, transmitting the instant and delayed telemetry parameters of subsystems and on-board standard time to ground station, checking and judging system normality

2. Integrated Housekeeping Management (IHM)

The on-board integrated electronics module consists of a central computer, the bus and the local area network connected with management executive units (MEU) embedded in the corresponding on-board equipments. The basic functions are:

- to generate a time base and to broadcast it to the on-board user
- to collect, compress and pick real-time and delay-time telemetry data
- to modulate down-link the telemetry parameters
- to receive, analyze and distribute the data and direct and indirect commands injected from the ground station
- to manage on-board data about the attitude control, thermal control, power supply and distribution, transponder and the parameters of the IHM itself
- to switch over to safe mode, operate and other function management

IHM is the integrated electronics module at the subsystem level based on the microcomputer, the bus and the local area network achieving integration of the control function under the unified topology architecture. The MEU is a small module with simple intelligence and multi-functions. It is embedded in the on-board equipment for monitoring, controlling, supplying and protecting. When connected with the bus and controlled by the central computer, it can make the functions of variable format measures, control, power supply and safeguards.

It is an effective way to increase the intelligence level of the equipment at the present time, the basis of auto management and information multi-path architecture. The IHM overall topology architecture is shown in Figure 4 and the characteristic parameters of the multi-purpose platform are listed in Table 1.

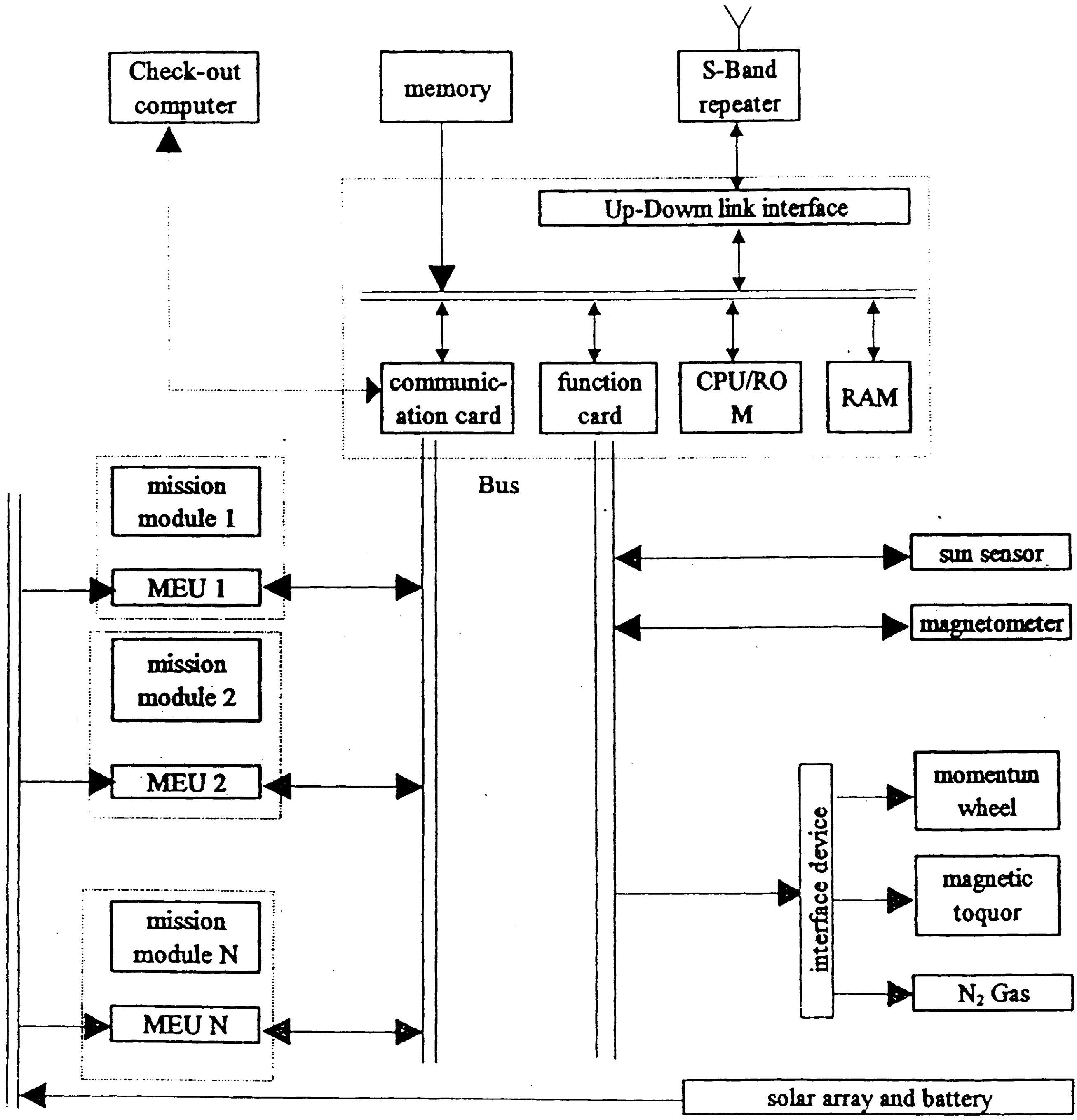

Figure 4: On-Board IHM Block Diagram

TECHNOLOGY ASSURANCE

In order to ensure the proper functions of the technology, it is important to set up a good design environment that includes flexible, convenient, integrated design tools and a special team to practice concurrent engineering. Also, setting up a smallsat test bed for synthetically scheme evaluation and the continuous increase of new technology and maturity can be achieved in the areas of development, scheduling and management. Lastly, active cooperation with international partners for mutual benefit is equally important.

Table 1: Characteristic parameters of a multi-purpose platform

Item	Property Parameter
Orbit	LEO, sun synchronous orbit, altitude is 600-900 km, specified by mission and launch vehicle
Attitude Control	Control modes: spin stabilization earth-pointing three-axis stabilization Attitude pointing accuracy: 0.5°-5° Control stability: 0.005°/s
TT&C	S-band repeater, used as telemetry Up-link data rate: 2Kbps Down-link data rate: 4Kbps omni-directional antenna
IHM	Based on local area network with embedded MEU as terminal
Power Supply	Two solar arrays Capability of electrical power generation: solar array: 350 W (orient to the sun), Battery: 17 Ah, Voltage of bus: 28 V (stable voltage)
Weight	Common platform: 200 kg Payload: 100-150 kg

SMALL SATELLITE PROJECTS IN RUSSIA*

Michael Yu. Ovchinnikov
Keldysh Institute of Applied Mathematics
Russian Academy of Sciences
Moscow, Russia

INTRODUCTION

What is a small satellite? Why is there a marked increase in interest in these instruments? The traditional division of satellites into groups, classes, and families reflects their purpose, mass, orbiting means, life span and other characteristics. Thus, the family of small satellites classically includes satellites up to several hundred kilograms of mass, dimensions under one meter and a simple set of auxiliary and payload (scientific) equipment. The family is further subdivided into mass ranges of exactly small, micro- and nano-satellites. The most important characteristics that distinguish small satellites from all others are their low cost and short term to project realization. These features give rise to a new qualitative effect; this is a classical quantity-to-quality transition. The drop of design and manufacturing costs down to a few million dollars and orbiting costs (in the case of piggyback launch) down to several hundred thousand dollars makes these satellites available to universities and medium-sized companies without financing from national space agencies. A satellite can not only be used for private purposes, but the satellite itself can be personal.

The significance of a reduction in project duration should be specially noted. In the modern economic situation, with the world's space research financing constantly being reduced, no reasonable spacecraft designer would expect long-term investments; therefore, they find themselves faced with either a relatively weak government financing channel or pursuing private investments, which are strictly conditioned on fast realization and whether the project is commercial or scientific.

As a rule, the purposes for small satellites are numerous: solution of scientific, technological, educational questions; carrying out experiments not requiring precise orientation in space over long intervals of time, or large fuel or energy stores; relay connection for financial centers, stock exchanges and other markets, radio-amateurs, expeditions and so forth; receiving and reporting information from automatic measurement stations; ecological monitoring; and environmental diagnosing in the vicinity of larger space vehicles; to name just a few. Small satellites are inexpensive enough to allow back-up in the most vulnerable segments by orbiting several satellites; the reliability of embracing complexes can thus be improved considerably.

Small satellites offer a very good range of solutions as many space enterprises firms are forced to look for new business possibilities because they face various technical, financial, and other challenges that arise from using large orbital stations, freight spacecraft and heavy multi-purpose satellites. Large space companies can cause a further reduction of prices in the

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This paper, which was presented at the UN/ESA International Conference on "Small Satellite Missions," 9-13 September 1996, in Madrid, Spain, does not necessarily reflect the views of the United Nations.

small satellite market by competing using the entire spectrum of the newest achievements in the field. Often, small satellite projects allow companies to make a good profit over a short capital turn-over period; a long-term commitment to the field must also look attractive. Most expert opinions believe that further development of the world's large satellite market will be bound by high costs, large dimensions, and the complexity of modern spacecraft and launchers. To the contrary, small satellites can be conveniently orbited several pieces at a time, or by converted ballistic missiles.

SMALL SATELLITE PROJECTS

The following list is a brief description of past and present small satellite projects developed in Russia, with special attention given to attitude control systems (ACS). In Russia, during the entire period of the development of the space industry, small satellites were regularly orbited and served mainly in experimental capacities to test instrumentation and structure elements for larger spacecraft. Lately, they have become more independent instruments.

- Two Soviet-Czechoslovak MAGION satellites were piggyback launched in 1978 and 1989 with INTERCOSMOS satellites. The ACS was a strong permanent magnet with damping rods made of soft-magnetic material (1978) and two liquid toroidal dampers (1989). Mass of both satellites were about 14 kg.

- A series of small satellites for scientific research and non-professional radio-communication purposes were designed at the Moscow Aviation Institute.[1] One of them, the ISKRA-5 satellite (1981), was equipped with passive GGACS with eddy current damper (ECD) and piggyback launched with the METEOR-PRIRODA satellite. The GGACS with original boom was designed and manufactured by the All-Russia Scientific Research Institute of Electromechanics (VNIIEM). The PION-based MAK-A satellite had a passive aerodynamical ACS with soft-magnetic damping rods.[2] This was for autonomous measurement of atmosphere density in current point locations of the satellite orbit by an on-board accelerometer. The work performed at the MAI, and later in the NIIAME of the MAI, was typical for educational institutes as students took part in the development, design and manufacture of the satellite, as well as processing of the data received from the satellite. The same approach is used at the Samara Avionic-Space University with Central Special Design Bureau (Samara) as six passive non-oriented PION satellites with mass of 50 kg were piggyback launched between 1989 and 1992 with RESURS-F satellites.[3]

- The INFORMATOR-2 communication satellite (1992) was designed by the scientific-industrial enterprise (SIE) POLYOT and equipped with GGACS with ECD. The gravitational boom was fixed in a controllable suspension with two degrees of freedom in order to make attitude control more accurate.

- The SPS-Satellite was developed by the Makeyev Design Bureau Mashinostroyeniya for a low-orbit communication system. With a satellite mass of 280 kg, it had passive GGACS with ECD and preliminary magnetic ACS (PMACS) manufactured by VNIIEM.[4]

  Currently, this Design Bureau develops 350 kg mass satellites for remote monitoring of the Earth's surface by optical means. The combination of sufficiently rough three-axes GGACS with an autonomously oriented small platform on the satellite structure will provide precision orientation of the optic lens to Earth.

  The Makeyev Design Bureau has also ordered the development of the COMPAS experimental satellite. Its mass is about 80 kg. (Figure 1). The combined ACS with gravity-gradient and air-resistance effects is intended to be used for orientation of this satellite. Both satellites will be launched into orbit by converted SHTIL-3N submarine missiles.

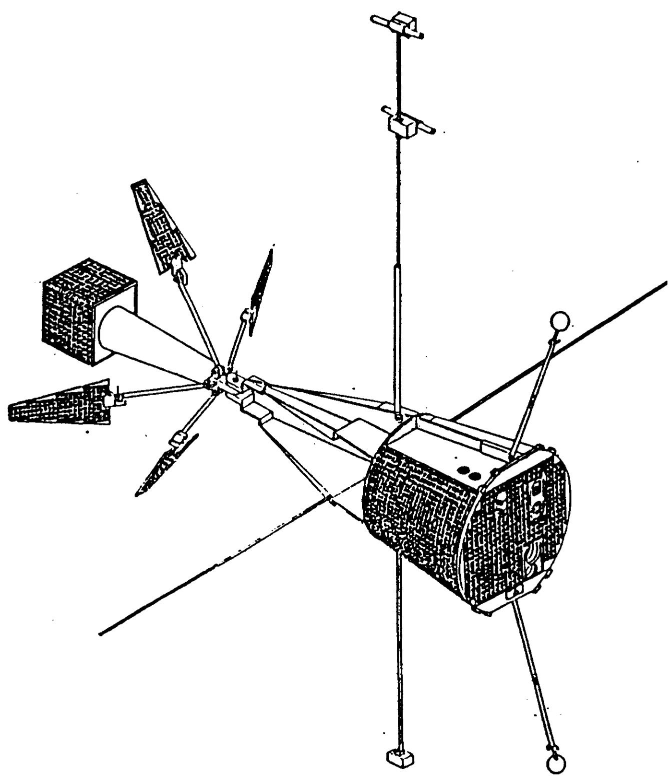

Figure 1: *COMPAS Satellite*

- VNIIEM designed and launched its 60th small satellite, OMEGA, for testing the three-axes flywheel ACS. This ACS is a base for ACS currently used on large satellites METEOR, RESOURSE-O and GOMS. VNIIEM has already carried out the Phase-A stage for Universal Small Space Platform (USSP-1), which is provided by a passive GGACS with ECD and preliminary magnetic ACS (PMACS).[5] The satellite mass is 60 kg and a piggyback launch with a RESOURSE-O satellite was planned.

  Also developed were the Technical Proposals for Universal Small Space Platforms USSP-2 (Figure 2) and USSP-3. The both platforms are provided by active flywheel ACS. The USSP-2 has a mass of about 400 kg with attitude control precision of 6-10'.

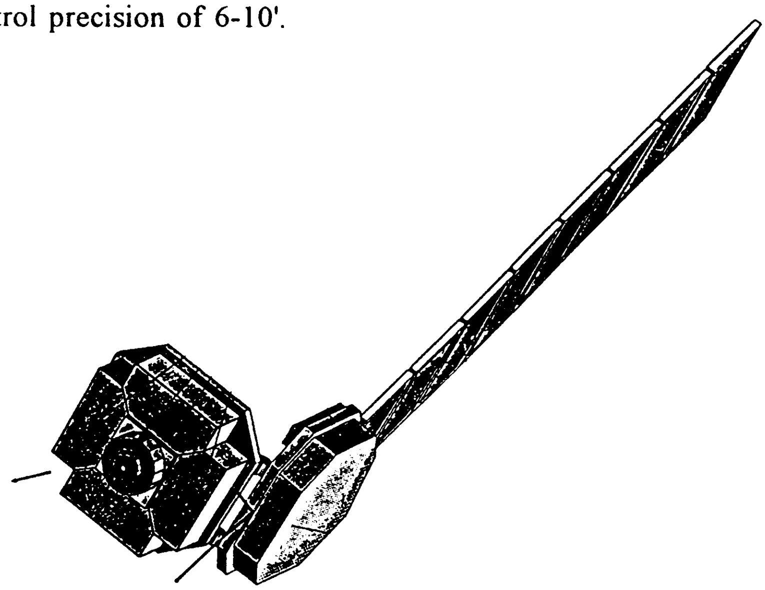

Figure 2: *USSP-2 Satellite*

  The basic payload of the USSP-3 is radio equipment of the COSPAS/SARSAT system. It has a total mass of 140 kg, attitude control precision to Earth of 6-10' and to the Sun of 1°. Launching the USSP-3 into a 900 km circular polar orbit will be performed by a converted START-1 rocket. Increasing the total mass of USSP-3 to 250 kg decreases the orbit height to 600 km.

- The low-orbit communication system GONETS is intended to transmit any information in digital "electronic-mail" mode by the satellites developed by the joint-stock company SmalSat.[6] The satellites will be launched into a 1,500 km circular orbit with inclination of 83°. The total final number of satellites in the system will equal 36 (six satellites placed in six orbital planes) with a lifetime of four years. The first two demonstration GONETS-D satellites were orbited in 1993 by the TSIKLON launcher. It is possible to launch six satellites by this rocket. The satellites will be equipped with passive GGACS and PMACS, have a mass of 250 kg and payload mass of 60 kg and data transmission rates of 2.4 kbps, 4.8 kbps, 9.6 kbps and 64 kbps.[7] A sketch of the satellite is presented in Figure 3.

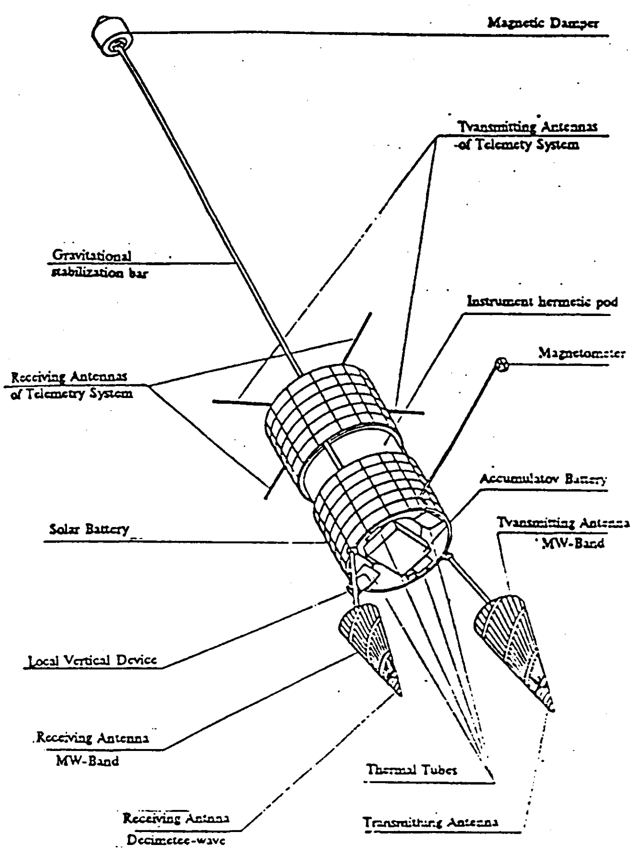

Figure 3: GONETS Satellite

- The low-orbit communication system SIGNAL is developed by the joint-stock company International Concern of Space Communications, under State support.[8] The space segment is designed by Enterprise "Energy." The satellites will be launched into a 1,500 km circular orbit with inclination of 74°. The total number of satellites in the system will equal 48 (12 satellites placed in four orbital planes), with a lifetime of six years. The satellites will have a mass of 300 kg and payload mass of 70 kg and data transmission rate of 2.4 kbps. A sketch of the satellite is presented in Figure 4.

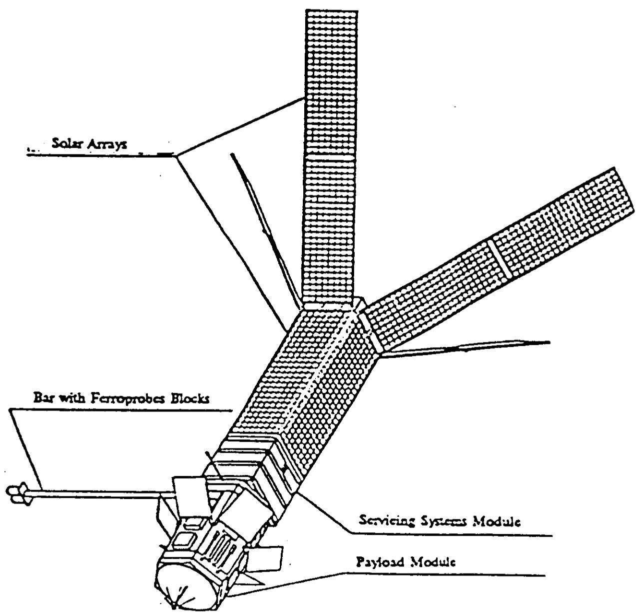

Figure 4: *SIGNAL Satellite*

- The low-orbit communication system COURIER-1 is developed by a group of enterprises headed by Enterprise ELAS and S&RC "Complex," and intended to provide low-cost, reliable, high-quality data communication services to anywhere in the world at any time through small user terminals in "electronic-mail" mode.[9] The system consists of eight to 12 satellites launched into a 700 km circular orbit with inclination of 76°. Each satellite will have eight channels with data transmission rate of 9.6 kbps. The peculiarity of the system lies in its potential to determine the position of a satellite in orbit to within several hundred meters of accuracy. The satellite will have a mass of 250 kg, equipped with GGACS with PMACS. An experimental launch was carried out in 1993 by a START converted rocket.

- The low-orbit communication system GLOBSAT is developed by Khrunichev State Research & Production Space Center.[10] Thirty to 66 satellites might be included in this system, which is intended to provide low-cost digital communication by phone and fax. Passive GGACS is used and launching will be by a converted and modernized ROKOT rocket. A successful experimental launch of the radio-amateur satellite RADIO-M, with a mass of about 120 kg, occurred on 26 December, 1994.

CONCLUSION

The limitations on mass, dimensions and energy consumption of small satellites result in fairly strict requirements for the class of possible control systems. The most desirable ACS should be passive or semi-passive, without energy-consuming final-control elements, orientation sensors and control units. Such a system is based on the principle of creating, restoring and damping torques by shaping the satellite body and tensor of inertia in an appropriate fashion and mounting elements with known physical characteristics on the satellite body. A passive ACS employs the interaction of the satellite, or its elements, with external gravitational or magnetic fields, solar light pressure and aerodynamical drag; it may also use the gyroscopic property of a spinning body to preserve the direction of the axis at the maximal moment of inertia in inertial space. Passive ACS sensors, if any, are used exclusively for monitoring orientation.

Although modern technology, with its efficient computing devices, and the global trend of equipment miniaturization allows the use of active control elements (usually flywheels or ECC interacting with the geomagnetic field), passive and semi-passive systems are still the most common. This is particularly true of Russian small satellites. The data above on ACS for small satellites shows that the most common types are gravity-gradient ACS with passive or active damping elements.

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THE UTILIZATION OF SATELLITE DATA TO SUPPORT FISHERY ACTIVITIES IN AFRICA'S COASTAL WATERS*

M. Gregory Hammann

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)

Ensenada, Mexico

and

Thelina Cárdenas

Asesores en Biología Pesquera (BioPesca™)

Ensenada, Mexico

INTRODUCTION

There is a delicate balance between fishing technology and sustainable yield. Because controlling—or even accurately predicting—biological production of fish populations is nearly impossible, new technology should be carefully used in order not to lead to over exploitation. Nevertheless, the desire in fishery management is to preserve it as a commercial activity and not only for the biological resource it depends on; this means the industry must be economically viable. The difficult task is to link more efficient fishing with more efficient management.

The recent Review of the State of World Fishery Resources[2] published by the United Nations Food and Agriculture Organization (FAO) stated that many of the major fisheries are overexploited because of excess capitalization. Three potential scenarios were described for the future: 1) rebuilding, through fishing-effort reduction, of heavily fished stocks; 2) continued increase in effort, leading to the demise of higher-priced resources and the transition to low-value species; and 3) the use of low-value species as foodstock for coastal aquaculture. Clearly, the most agreeable option is the first, with better utilization of low-value species, such as those used for fish meal and those in the by-catch of higher-value species such as shrimp. In this case, "a wide diversity of fish products will be preserved, and with the reduction of effort, those fishermen still active will be more profitable, and employment can be maximized by the development of small multi-purpose vessels with modern technology."

A FOCUS ON AFRICA

Africa contributes a surprisingly low proportion (only 4 percent) of the world's total marine fish production (1992 data) despite its long coastline and several productive regions (Figure 1). Of the over 30 countries with a marine coastline, few land more than 100,000 metric tons. South Africa, Morocco, Ghana and Senegal are the most important for marine resources (Figure 2), landing mostly species of small pelagics such as sardines, anchovies and mackerel (Figure 3). Other resources such as tuna, billfish and coastal tropical species are also found. An additional characteristic common to many countries is the presence of foreign vessels fishing either inside or beyond their 200 mile zone using modern technologies, including remote sensing. Many African countries (for example Tanzania, Figure 3) have

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important fish resources in lakes and rivers.

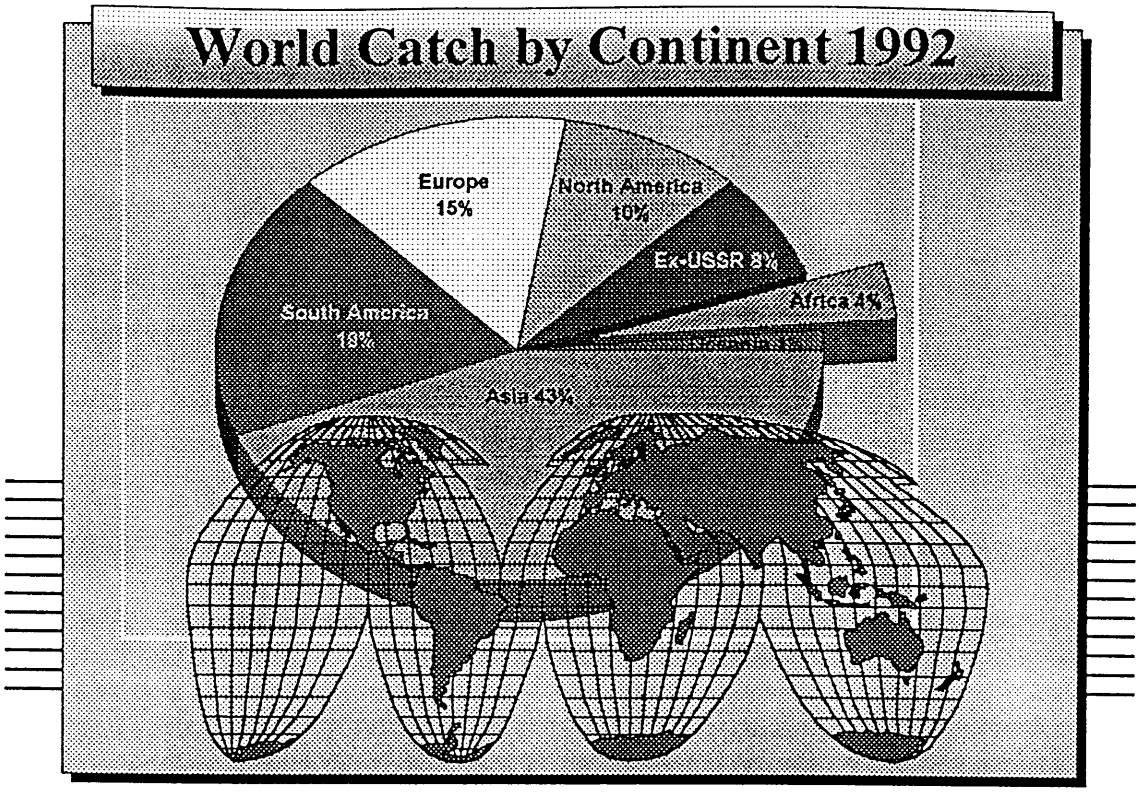

Figure 1: World Marine Fishery Catch by Continent in 1992

Oceanographically, Africa is surrounded by temperate to tropical conditions in both hemispheres, and one must consider both the fisheries and oceanography of two oceans and seas. In west Africa, the presence of two of the world's highly productive Eastern Boundary Currents, the Canary Current in the north and the Benguela Current in the south, bring nutrient-rich polar waters into regions with the abundant light needed for phytoplankton productivity. Also, coastal topography combines with wind patterns to produce important regions of coastal upwelling. In these regions are very abundant small pelagic species such as sardines, anchovies and mackerels. In the tropics, tuna and billfish resources are important, as are slow growing demersal and reef species. There are also tropical small pelagic clupeoid species, which, although not as productive as their upwelling region counterparts, can be important for coastal communities. On the east coast of Africa, local upwelling areas are important, as are the formation of warm core rings and other meso-scale features. Tropical species of small pelagics and tuna and billfish are important resources.

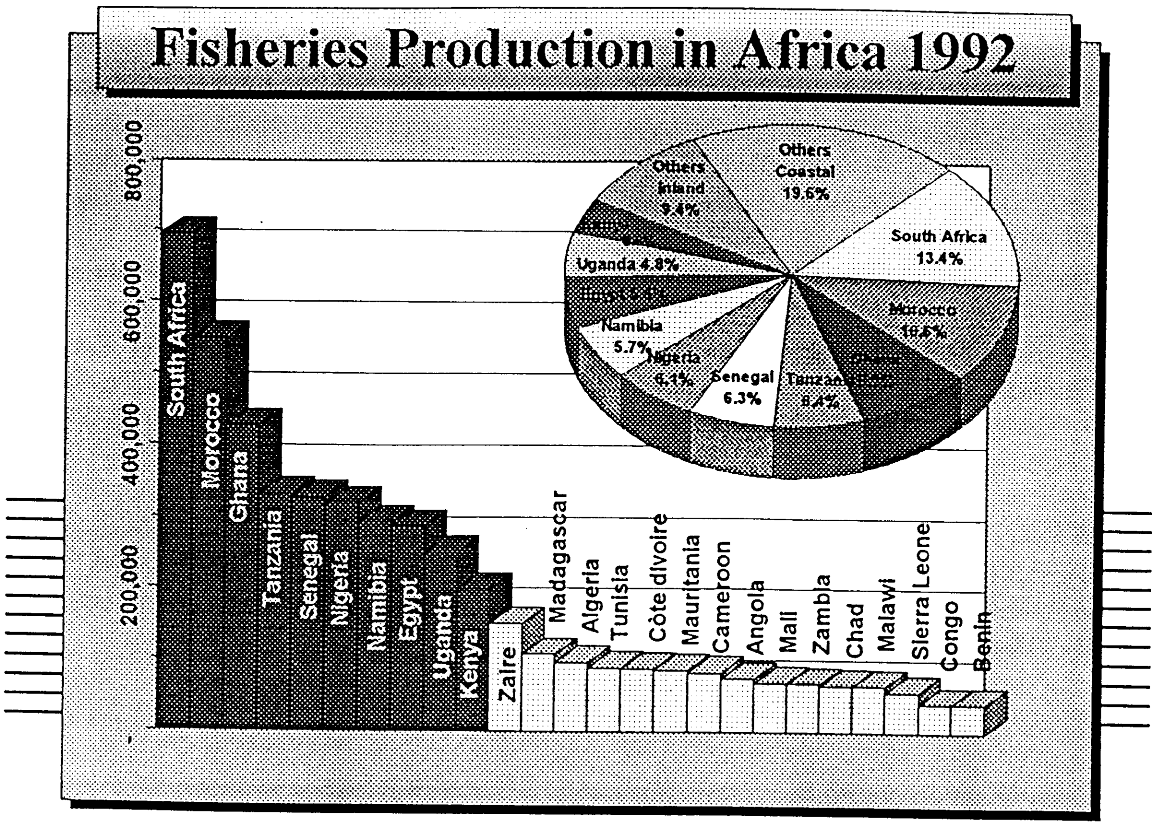

Figure 2: Fisheries Production in Africa during 1992; Principal Countries (Metric Tons)

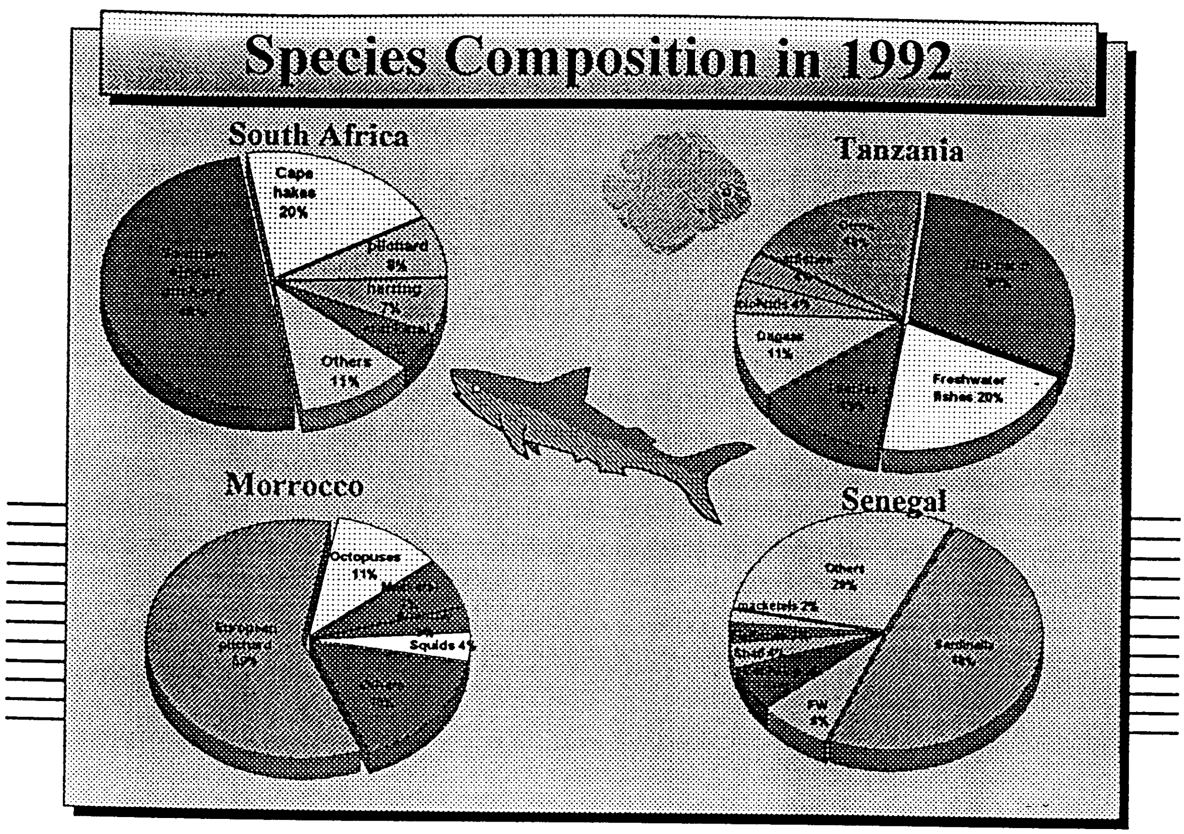

Figure 3: Species Composition in 1992 for South Africa, Morocco, Tanzania and Senegal

Clearly the fisheries of each country and region have their own peculiarities, but in general we can classify them as exploited and under-exploited. Another important division is between the industrialized fisheries and those which sustain coastal communities and thus are socially important for food. One could propose a support scheme for the industrialized private fisheries as a paid service, and perhaps a public subsidized service for the small local communities that depend upon fishing for their existence. Furthermore, in the latter case, this aid could assist those communities in a transition from a sustenance only fishery, to a value added small industry and promote local economic development. Thus the application of technology both to aid in finding fish and in their management will not be the same for all cases.

Remote sensing images reveal important patterns in both Sea Surface Temperature (NOAA/AVHRR/HRPT) and pigment concentration (CZCS). The images show for west South Africa, meso-scale features important for fish distribution that can be observed and followed. It is important to understand both the large-scale and meso-scale variability in surface conditions to be able to relate to resource distribution. The key, then, is to use remote sensing not to see fish, but to describe surface patterns in the ocean, and interpret resource distribution using knowledge of fish behavior.

FISHERIES AND MANAGEMENT

Normal fishing operation depends upon the captain's experience, which usually relates the fishing zone with the time of year. Nevertheless, fish distribution and abundance is more related to surface oceanographic conditions than the calendar date, and such operations are usually very variable, with low catches per effort predominating. Typical search strategies involve the selection of an area and searching with sonar, radar and sight, in a zigzag pattern covering the entire selected area. Normal fisheries management depends on unreliable log books with months to years for data analysis, and often without knowledge of where the fish were really caught, not just landed. Technology allows oceanographic information to be provided to the vessels, and vessel operation data sent back to shore enhancing both the industry and resource management.

The fishermen can benefit from information about Sea Surface Temperature, Surface food availability (pigment concentration or sea surface color), surface currents, winds and waves; weather predictions, reports from other vessels, information on historical performance of the fisheries and the fleet, and market trends. Managers need to understand the search and capture strategies and technologies to describe effort, species composition of the catch, catch per unit effort, catch locality, biological data of the principal species, and economic data. Geographic information systems provide efficient means to store, combine and analysis these data.

With Sea Surface Temperature analyses from satellites fishermen can:

- obtain information about surface temperature distribution, currents, and probable (inferred) productivity, which is important to determine search strategies

- eliminate operation risks and costs for large areas of the sea and only search those areas with high probability of success as judged by observed conditions

Near real-time data acquisition of fisheries operations could allow managers to:

- track real fishing effort by region
- track current population conditions
- compare local stocks with local efforts
- provide faster resource diagnostics
- propose management tools related to actual stock conditions, not past stocks
- provide fleets with operational recommendations

TECHNOLOGIES AVAILABLE

Many new technologies and sensors are soon to become available but selections can be narrowed to those technologies related to Weather and Cloud cover, Sea Surface Conditions, Navigation and Communication technologies, Geographic Information Systems, and data management and modeling.

Weather and Cloud Cover: Analog images are available with low-cost receiving systems from the NOAA polar orbiting satellites and Automatic Picture Transmission (APT) and also the Meteosat geostationary satellite. These images can be useful for monitoring weather conditions and gives some information on winds and possible sea state.

Sea surface conditions: NOAA polar orbiting satellites provide five channels of data from the AVHRR (Advanced Very High Resolution Radiometer) sensor with a resolution of 1.1 km at nadir with High Resolution Picture Transmission (HRPT). This data allows for the calculation of sea surface temperature at scales relevant to fishing operations, and also permits geographic and atmospheric corrections. Although now not operable, the CZCS sensor aboard the experimental NIMBUS 7 satellite showed us the importance of sea surface color to estimate pigment concentration related to primary production. The soon-to-be-launched SEAWIFS sensor aboard an Orbital Sciences Corporation satellite will provide valuable color data. Also, the Japanese have just launched a new satellite with a similar sensor, but operational data availability is still not clear. The new Synthetic Aperture Radar sensor aboard the ERS satellite and Radarsat, provide data which is not effected by weather conditions or clouds, and may provide important products to support fishing operations.

Navigation and Communication: With any given satellite data product, delivery to a vessel at sea requires proper communication technology and once one has the image, it is important to be able to locate interesting characteristics relative to the vessel's position, thus requiring modern navigation instruments. For managers, information on where fish are caught is imperative. The Global Positioning System (GPS) provides good information for using the image to modify the search strategy, and cellular and satellite communications provide digital service allowing image transfer from a computer on land to a computer on the vessel. High Frequency (HF) radio can be used to transmit black and white maps to the vessel, which of course are less desirable than the digital image product.

Depending on the case, output products can be in digital, analog or printed format. It is important to mention that the preferred product can and should vary with the fishery depending on their particular conditions. For example, a vessel that only makes night trips could pick up a color print of the image before the trip. Other considerations in product preparation are algorithm selection, scene size, final resolution, color table selection, frequency of update, annotations and interpretations, all of which can vary with the type of vessel or resource they are looking for.

Geographic Information Systems: Optical and infrared satellite remote sensing are blocked by clouds, and detecting only surface conditions, has not been directly applied to non-surface resources. Geographic Information Systems provide the means of combining other data sources with satellite imagery, and with proper analysis and modeling, can greatly enhance the usefulness of satellite imagery alone.[5] The use of expert system and neural net programming techniques to organize the practical experience of expert fisherman and better understand the relationships between the resource and the environment may prove to be powerful tools in the future.

APPLICATIONS

Fisheries

Satellite data provides fisheries with information on large regions of the sea useful for directing search strategies. This is useful for pelagic resources such as tuna, billfish, shark, squid and small pelagic species such as sardine, anchovy and mackerel. Information on weather conditions and currents relevant to fisheries operations can be interpreted, for example, while setting the fishing gear. The ocean is not homogeneous, and with satellite data one can "map" the ocean city. Because fishing gear is usually selective, to be successful, fish behavior must coincide with the gear design. For example, a purse seine is designed to catch fish in schools. Fish respond to oceanographic conditions and often are concentrated along a thermal front, in a water mass with temperatures within those preferred by the species, in or nearby upwelling areas, or in areas where preferred temperatures, fronts and food supply coincide.

Pelagic fishes concentrate within a preferred temperature interval, typically on a thermal front where their food is also concentrated by upwelling, convergence or other conditions. For each resource, one can describe the temperature interval over which they can be found, and within which optimal fishing occurs. These optimal temperatures are often different for each species, and can vary from one region to the next. Nevertheless, it is more important when optimal conditions occur with surface structure that aids in concentrating the resource. There has been an increasing amount of research describing the relation between surface thermal conditions and fish distribution and behavior.

Aquaculture and Coastal Management

Remote sensing and satellite data can also be very important for the development and planning of land use in the coastal zone. For aquaculture, high-resolution sensors such as Landsat TM, SPOT or ISR (Indian Remote Sensing) multi-spectral data can aid in site selection after an initial exploration with NOAA AVHRR/HRPT. Analyses such as vegetation classification and change detection aid in minimizing environmental impacts and conflicts of land use.

Data from NOAA AVHRR allow risk analysis using several images to determine dynamic weather patterns and oceanography important for operations; for example, questions such as how are temperature extremes likely to affect the input water in an aquaculture project. Ecological regionalization studies that include the relevant parts of the water shed are critical for coastal zone planning, as is habitat identification and vegetation quantification for impact assessment.

Other coastal applications using high-resolution data are coastal zone mapping, bathymetry, and change detection analysis. Project design can be combined with images from satellite data, aerial photographs, field data, and other available data relevant to the site, and analyzed using a Geographic Information System (GIS).

LIMITATIONS

Several limitations for the application of satellite data for Operational Fisheries Oceanography Support must be considered:

- Analog WEFAX HF communications limits ease of use until digital satellite communication becomes commonplace and less costly
- Financial requirements for purchasing new equipment
- Data coverage for NOAA Polar orbiters is limited by antenna foot print
- Until new satellites are operational and data is available, with SST only indirect interpretation of productivity and food availability is possible
- Cloudiness effects imagery (or blocks completely)
- Using only satellite data, only pelagic fisheries can be supported
- Geographic Information Systems are still not commonly applied to fishery oceanography issues
- End users and service providers require training and many aspects are still subject to research and development

NEW TECHNOLOGIES

Technological changes are occurring very rapidly and new technologies will enhance predictive capabilities for resource location and management. Some of these are:

Sea Surface Color: information on pigment concentration and food availability
Problems: costs, only day images are available, and blocked by clouds

SAR: surface structure detail which is not affected by clouds or weather
Problems: processing, interpretation, costs, availability

INMARSAT: satellite communications at lower costs
Problems: requires initial investment by client, operating expenses

GIS/EXPERT SYSTEM: Integrate historical and real-time data into predictive models
Problem: needs development, costs

GENERAL RECOMMENDATIONS FOR AFRICA

Several general recommendations can be made for Africa:

- Enhance Local APT and Meteosat Reception for Weather
- Install Regional HRPT Reception for SST and other Products
- Create Local Training centers
- Develop Weather and ocean product dissemination
- Initiate "Offshore" exploratory fishing programs to search for underutilized species
- Enhance Local fishery data collection and reporting
- Create Joint Industry (fishermen)/Government/Academic advisory committees

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